KEARNEY

Decarbonization of Indian Steel Industry

IndianSteel ASSOCIATION

एच. डी. कुमारस्वामी
H. D. Kumaraswamy

सत्यमेव जयते

मंत्री
भारी उद्योग एवं इस्पात मंत्रालय
भारत सरकार, नई दिल्ली
Minister of
Heavy Industries and Steel
Government of India, New Delhi

Message

India's steel sector is a cornerstone to its development in Amrit Kaal. As world's second largest steel producer and consumer, the industry provides one of the key materials for nation building, and contributes significantly to its GDP. As we forge the growth path, it is critical to harmonize our vision with focus on decarbonization–in line with India's commitment to Net Zero by 2070.

This report on "Decarbonization of Indian Steel Sector" elaborates a well–defined roadmap with a clear emission reduction pathway and focused interventions. It will help in channelizing the effort of all stakeholders towards a common goal to drive innovation and change in the sector. The Ministry of Steel is dedicated to enable this journey by supporting the industry in adopting cleaner technologies along with ensuring its growth and prosperity.

I would like to acknowledge the efforts of Indian Steel Association & its members companies, Kearney as their Knowledge Partner and all the associated stakeholders across value chain involved in the making of this report. This report will serve as a valuable foundation for a sustainable future of the Indian steel sector, and guide all stakeholders in the journey going forward.

(H. D. Kumaraswamy)

Ministry of Steel : Room No. 192, 'G' Wing, 1st Floor, Udyog Bhawan, New Delhi-110011, Tel. : +91-11-23062345, Fax : +91-11-23061395
Ministry of Heavy Industries : Room No. 176, 'E' Wing, 1st Floor, Udyog Bhawan, New Delhi-110011, Tel. : +91-11-23061782, Fax : +91-11-23062552

भूपतिराजु श्रीनिवास वर्मा (बी.जे.पी. वर्मा)
భూపతిరాజు శ్రీనివాసవర్మ (బి.జె.పి. వర్మ)
BHUPATHIRAJU SRINIVASA VARMA (B.J.P. VARMA)

सत्यमेव जयते

ITUWTSA NEW DELHI 2024

इस्पात एवं
भारी उद्योग राज्य मंत्री
भारत सरकार
उद्योग भवन, नई दिल्ली–110011
MINISTER OF STATE FOR STEEL
AND HEAVY INDUSTRIES
GOVERNMENT OF INDIA
UDYOG BHAWAN, NEW DELHI-110011

MESSAGE

The steel industry is the pillar of our nation's industrial strength, supporting millions of jobs and contributing significantly to the country's GDP. India's steel demand is steadily rising, driven by sectors such as construction, infrastructure and manufacturing for which there is a need for additional steel capacity creation at a fast pace. However, this growth has to be sustainable and aligned with global and Indian environmental goals, particularly the 2070 net-zero target of India.

The report on 'Decarbonization of the Indian Steel Sector' presents a clear roadmap for India's steel industry, detailing specific emission reduction targets and interventions. It aims to future-proof the industry and align the efforts of all stakeholders towards the common goal of achieving net-zero by 2070. This document attests to our dedication to sustaining a strong and flexible steel sector in the face of global challenges.

I want to recognize the dedication and expertise of everyone who contributed to this report.

I would like to acknowledge role of Indian Steel Association, its knowledge partner and all the associated stakeholders across value chain whose efforts have been crucial in preparing this report which will help in steering India's steel industry towards a future that harmonizes economic goals with environmental responsibility.

Bhuvan

(Bhupathiraju Srinivasa Varma)

Ministry of Steel : 146, Udyog Bhawan, New Delhi-110011 • Tel. : +91-11-23063810, Fax : +91-11-23062703, Email : mos-steel@gov.in
Ministry of Heavy Industries : 36, Udyog Bhawan, New Delhi-110011 • Tel. : +91-11-23062676/78, +91-11-23061593, Fax : +91-11-23060584
Camp Office : Narasayya Agraharam Bhimavaram, Andhra Pradesh- 534201, Tel. : +91-97010 53445

FOREWORD

Naveen Jindal

Honorable Member of Lok Sabha;
President, Indian Steel Association

Steel industry is an integral contributor to the development of India's economy. Steelmaking capacity in the country is on course to reach 500 MT+ by 2047, and contribute to its industrial and infrastructure development for a Viksit Bharat. This growth needs to be undertaken in a sustainable manner.

Steel production today is an energy intensive process with heavy dependence on carbon–based raw materials. A large part of emissions in this process can only be addressed by breakthrough technologies which are still evolving. In the short–term, there is a well–defined set of efficiency initiatives that can help reduce the energy consumption of steel plants, as well as lead to economic savings. The ongoing development in clean energy is another near–term lever to reduce its carbon footprint.

As the industry adds new capacity, higher investments are needed in cleaner technologies. These investments will need to be supported by adequate availability of required raw materials, such as high–grade iron ore, natural gas, and scrap, coking coal which are in limited supply today in the Country.

Significant efforts in R&D are needed to develop technologies for which pilots for injection of hydrogen in blast furnaces and DRI units will be a crucial bridge in the shift to 100% green hydrogen–based production. Similarly, pilots of carbon capture with utilization in urea and methanol units will be critical, along with ecosystem–wide efforts to plan and develop utilization hubs, storage sites and transport network for captured CO_2.

This transition to near–zero emissions will require significant investments in deploying decarbonization levers which will require strong policy support.

Naveen Jindal
Honorable Member of Lok Sabha;
President, Indian Steel Association

संदीप पौण्डरीक, भा.प्र.से.
सचिव
Sandeep Poundrik, IAS
Secretary

सत्यमेव जयते

भारत सरकार
इस्पात मंत्रालय
GOVERNMENT OF INDIA
MINISTRY OF STEEL

22nd January, 2025

Foreword

India is committed to all around development and growth of its infrastructure, such as highways, railways, airports, metros, ware–housing, cold storage, green power, buildings, and healthcare, for which Steel forms the backbone of all such projects. The Indian steel industry is on track to reach 300+ million tonnes by 2030 to support this growth. However, steel has to be produced through substantially carbon intensive processes. Therefore, there is a need to focus efforts on decarbonizing the sector to ensure a sustainable growth trajectory.

India has a unique position, with a higher starting point of emission intensity on account of higher coal–based production, constrained supply of inputs such as natural gas and scrap. Indian industry therefore, needs to define its own approach to address emissions – one that balances its decarbonization ambitions and practical challenges, with adequate focus on small–small producers. Switching to clean electricity is a viable option to significantly reduce emissions, with India being the third largest global producer of renewable energy. In the coming years, research efforts and investments will be required to scale up usage of hydrogen, biochar and carbon capture for deep decarbonization of the steel sector.

Implementing the above levers will come at a higher cost of production. It will need to be supported by demand for low–carbon emission steel. Globally, this demand is already picking up, with steel consumers looking to reduce their scope 3 emissions and governments looking at sustainable infrastructure projects. A similar story needs to be replicated in India.

This report highlights a balanced trajectory for decarbonization of Indian steel industry, details its techno–economic requirements, and suggests a roadmap to achieve the same.

(Sandeep Poundrik)

Room No. 291, Gate No. 5, Udyog Bhawan, New Delhi-110011
Tel. : +91-11-23063912, 23063489 (Fax); E-mail : secy-steel@nic.in

IndianSteel
ASSOCIATION

FOREWORD

Alok Sahay

Secretary General & Executive Head, Indian Steel Association

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 continue to 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. As Steel makers invest in decarbonization technologies, levelized cost of steel is expected to increase. Hence, it is important to create a market for low emission steel associated with a premium. Government can support this demand generation through public procurement. In addition, the Government can develop policies to promote and mandate use of low emission steel by the private sector. A reduction in GST rate for low emission steel from typical 18% to 5% can push private sector demand. It can also explore mandates for low emission steel purchase by large consumers in auto, appliances, and construction sectors. Meanwhile, Ministry of Consumer Affairs can prioritise the labelling standards for reporting carbon footprints and mandate them for steel product being sold in the country. Government of India has already announced a national carbon market under the Carbon Credit Trading Scheme.

However, if India is to continue to show leadership in climate change and future-proof its steel industry to be net zero, then an ambitious strategy for emission reduction, is required. India will increase its crude steel capacity from current 179.5 MT to 300 million tonne in next 6-7 coming years with BF- BOF for steel manufacturing still remaining the main route for production. As per the National Steel Policy-2017, BF-BOF route will be 60-65% and EAF/IF route: 35-40% by 2030-31. During FY 24, 43% of crude steel production was produced through BF-BOF route, therefore, the capacity expansions by Steel industry will be mainly through BF-BOF route, for which industry has mostly completed forward integration with equipment suppliers. Accordingly, EAF-currently at 22%, route may not be taken as the option for capacity building in India due to low scrap availability.

Therefore, Government of India needs to bring in holistic technology intervention with right policy enablers.

Alok Sahay
Secretary General & Executive Head, Indian Steel Association

FOREWORD

Knowledge Partner

Steel is a cornerstone of India' growth story, supporting the development of its buildings, infrastructure, auto, consumer and capital goods as a key raw material. Indian steel industry is projected to have one of the fastest growth rates in the world, with 8-9% CAGR in this decade, compared to ~2% globally. With an emission intensity of ~25-26 tons of CO_2 per ton of finished steel produced, this growth, if left unchecked, will eventually exceed the sector's share of India's fair carbon budget. Hence, Immediate efforts are required to decarbonize the sector.

Today, steel is produced in India through four different routes, each with its own constraints on availability and quality of raw materials. There are multiple emission reduction levers being deployed in steel production worldwide, which are in various stages of techno-economic maturity. A customized pathway is needed for India, which balances the pace of emission reduction and the investments required in the same while accounting for India-specific nuances.

Indian steel sector can achieve near-zero emissions by 2070, with 10-20% intermediate reduction in emission intensity by 2030, and 75-85% by 2050. This requires immediate focus on fully leveraging energy efficiency opportunities, and ramping up use of high-tCUF hybrid renewabies. In the medium to long term, deployment of green hydrogen and CCUS will be key to fully abate the sector's, emissions. which requires focus on pilot projects for these technologies today. Moreover, higher share of natural-gas based & scrap-based routes in production mix is desirable.

Producers will need to undertake significant investments and major R&D efforts to implement this transition, which will require support through the right set of policy frameworks and fiscal incentives. Small-scale producers will require special handholding to make this transition

Production of low emission steel will lead to a rise in its levelized cost, so its demand from private sector steel consumers is expected to be low in the near term. This initial gap will need to be bridged by public procurement initiatives, supported by a well-defined taxonomy to help in allocation of incentives.

This report describes a detailed approach to arrive at the optimal decarbonization pathway for Indian steel industry. It also discusses generation of demand for low emission steel and a taxonomy for the same. It concludes by describing targeted policy interventions required at each stage and discussing the role of key stakeholders

As knowledge partner for this report, we at Kearney wish to thank Ministry of Steel, Indian Steel Association & its members for providing us this opportunity to chart out the decarbonization roadmap for the steel industry We also thank the broader iron & steel ecosystem-experts, industry bodies, employees of steel organizations-who have contributed significantly to this study through their thoughts and expertise

Saurabh Singh

Partner & APAC Lead, Energy

Nishant Nishchal

Partner & APAC Lead, Metal & Mining

Saurabh Singh
Partner & APAC Lead, Energy

Nishant Nishchal
Partner & APAC Lead, Metal & Mining

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Glossary

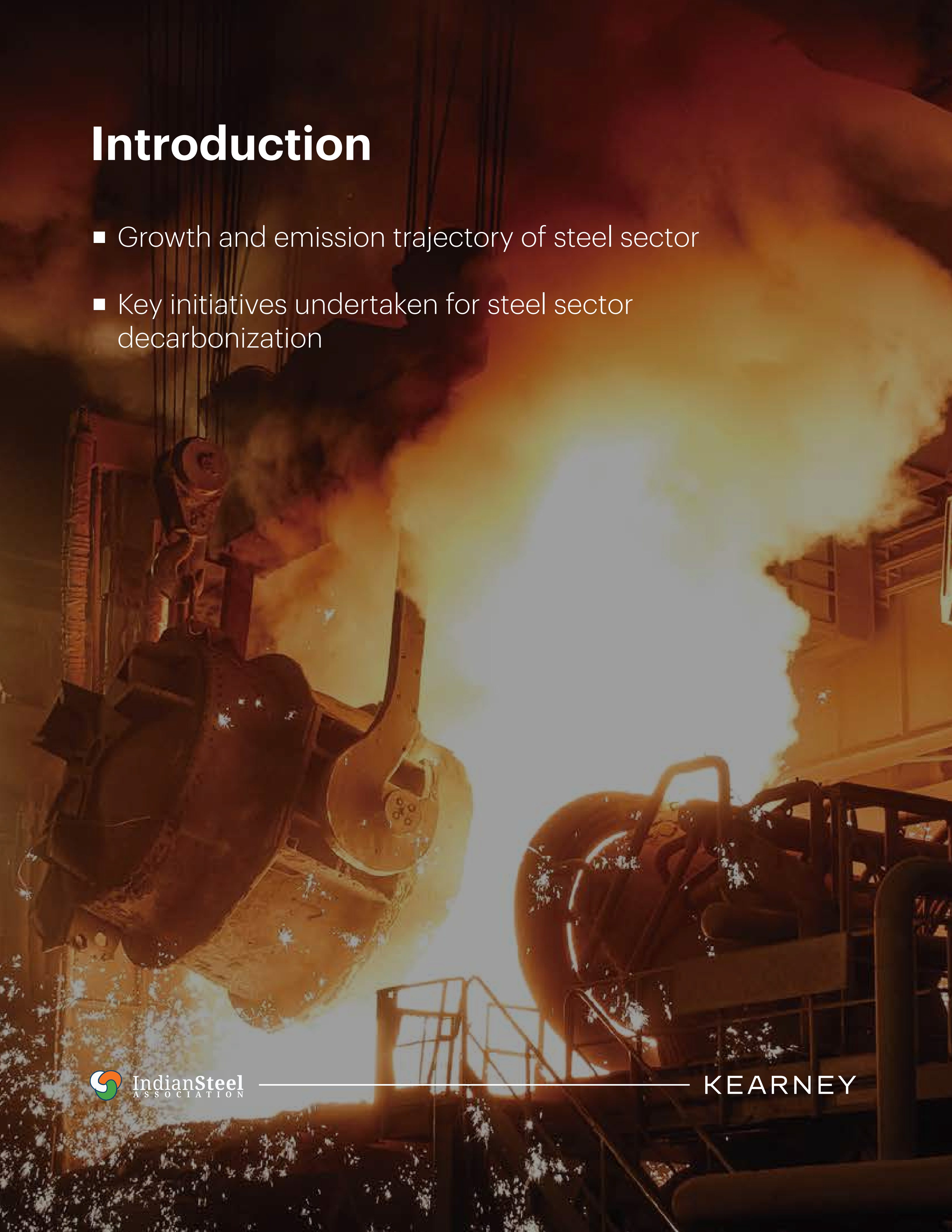
Abbreviation	Expansion
AIIFA	All India Induction Furnaces Association
BAT	Best Available Techniques
BAU	Business-as-Usual
BEE	Bureau of Energy Efficiency
BESS	Battery Energy Storage Systems
BF-BOF	Blast Furnace-Basic Oxygen Furnace
C&D	Construction and Demolition
CBAM	Carbon Border Adjustment Mechanism
CBG	Compressed Biogas
CBM	Coal Bed Methane
CCTS	Carbon Credit Trading Scheme
CCU	Carbon Capture and Utilization
CCS	Carbon Capture and Storage
CCUS	Carbon Capture, Utilization and Storage
CEA	Central Electricity Authority
CSIR	Council of Scientific and Industrial Research
DRI-EAF	Direct Reduced Iron-Electric Arc Furnace
EIF	Electric Induction Furnace
ELV	End Life Vehicles
EOR	Enhanced Oil Recovery
EU-ETS	European Union Emissions Trading System
IEA	International Energy Agency
IIT	Indian Institute of Technology
IPCC	Intergovernmental Panel on Climate Change
ISA	Indian Steel Association
ISP	Integrated Steel Plants
ISTS	Inter State Transmission System
InSTS	Intra State Transmission System
JICA	Japan International Cooperation Agency
LATAM	Latin America
LCOS	Levelized Cost of Steel
LES	Low Emission Steel

Glossary

Abbreviation	Expansion
LESC	Low Emission Steel Certificates
MENA	Middle East and North Africa
MNRE	Ministry of New and Renewable Energy
MoC	Ministry of Coal
MoEFCC	Ministry of Environment, Forest, and Climate Change of India
MoES	Ministry of Earth Sciences
MoHI	Ministry of Heavy Industries
MoPNG	Ministry of Petroleum and Natural Gas
MoS	Ministry of Steel
MRV	Measurement, Reporting and Verification
MTPA	Million Tons Per Annum
NISST	National Institute of Secondary Steel Technology
NPCIL	Nuclear Power Corporation of India Limited
PAT	Perform Achieve Trade
PSP	Pumped hydro Storage Projects
RE	Renewable Energy
RPO	Renewable Purchase Obligation
SBTi	Science Based Targets initiatives
SGE	Specific Greenhouse Emissions
SIDBI	Small Industries Development Bank of India
SIMA	Sponge Iron Manufacturers Association
SOP	Standard Operating Procedures
SRTMI	Steel Research and Technology Mission of India
SSP	Secondary Steel Players
tcs	Ton finished steel
UNIDO	United Nations Industrial Development Organization
WEF	World Economic Forum

Introduction

- Growth and emission trajectory of steel sector
- Key initiatives undertaken for steel sector decarbonization



1.1 Growth and emission trajectory of steel sector

India ranks as world's second–largest steel producer, with current capacity of 150+ MMTPA, and poised for significant growth – ~500 MMTPA by 2050, and further expanding to ~790 MMTPA by 2070. This expansion will be fueled by robust demand across key sectors including infrastructure, construction, automotive, capital goods, etc.

However, this growth will pose significant challenges due to increasing carbon emissions. Currently, steel sector contributes ~12% of total CO_2 emissions in India (~350 Mn tCO_2 emissions annually). This is primarily driven by large share of fossil–fuel based BF – BOF[1] and DRI – EAF[2] production technologies in India leading to high emission intensity of ~2.6 tCO_2/tcs, significantly higher than global average of ~1.9 tCO_2/tcs.

A business–as–usual (BAU) scenario emissions growth with capacity expansion is likely to contribute to 50+ Giga tCO_2 cumulatively up to 2070. Steel sector's fair share of India's carbon budget is 8 – 12 Giga tCO_2 as per below 1.5°C scenario and 25 – 30 Giga tCO_2 as per below 2°C scenario[3] . The BAU scenario will breach steel sector's fair share of India's carbon budget for 1.5°C scenario by 2035 – 2040 and 2°C scenario by 2050 – 2055, challenging India's commitment to Paris Agreement *(see figure 1)*. Therefore, steel sector needs to accelerate its efforts towards decarbonizing while achieving targeted growth.

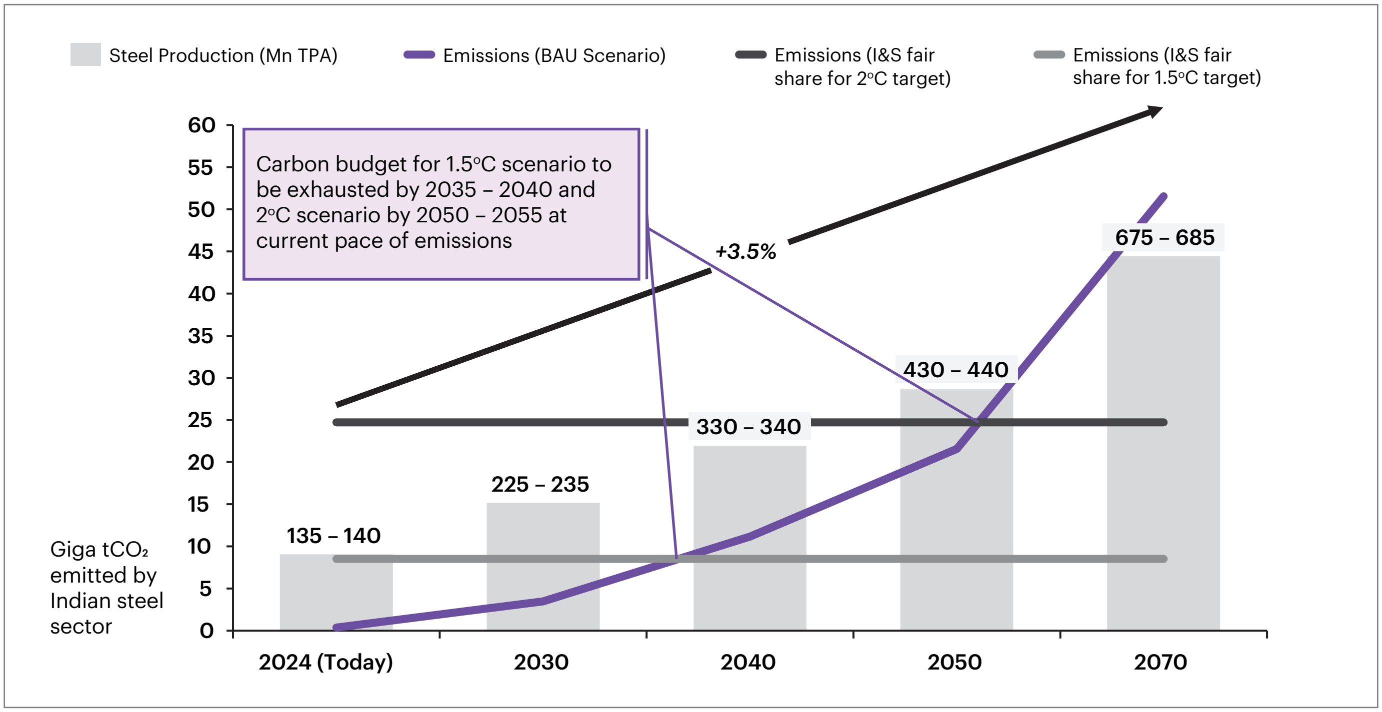


Figure 1: Indian steel production projection and emissions[4,5]

[1] *Blast Furnace and Basic Oxygen Furnace*
[2] *Direct Reduced Iron and Electric Arc Furnace*
[3] *As per IPCC RCP2.6*
[4] *Source: India's long – term low–carbon development strategy, MoEFCC*
[5] *Steel production estimated assuming 85% utilization*

1.2 Key initiatives undertaken for steel sector decarbonization

Steel is a hard-to-abate sector, and decarbonization of this sector is critical for India's 2070 Net Zero ambition. Keeping this in view, Government of India has already undertaken multiple initiatives that directly or indirectly promote decarbonization of the sector, such as:

1. **National Solar Mission (2010):**

   Promote use of solar to replace fossil-based power usage across sectors.

2. **Perform Achieve Trade (PAT) Scheme (2012):**

   Incentivize and track energy efficiency efforts for various industries; helped reduce emissions in steel sector from ~3.1 tCO_2/tcs to ~2.5 – 2.6 tCO_2/tcs.

3. **Steel Scrap Recycling Policy (2019):**

   Promote decarbonization of transport sector and enhance domestically generated scrap through vehicle scrappage for use in low emission scrap-based steel production.

4. **National Green Hydrogen Mission (2023):**

   Incentivizes substitution of fossil fuels with Green Hydrogen with dedicated investment for steel sector.

5. **14 taskforces by Ministry of Steel (2023):**

   Engagement of diverse stakeholders to discuss, deliberate and recommend upon decarbonization of sector.

6. **Carbon Credit Trading Scheme (2024):**

   Evolution of PAT scheme to incentivize decarbonization manufacturers through development of an Indian Carbon Market.

While these initiatives have helped kickstart the journey, there is a need for dedicated efforts for decarbonization of the steel sector. Therefore, a well-defined roadmap with a clear emission reduction pathway and focused interventions will help in channelizing the effort of all stakeholders towards a common goal–this report aims to define that roadmap and initiatives.

Decarbonization roadmap for Indian steel sector

- Objectives of the roadmap
- Approach and methodology
- Decarbonization pathways
- Production technology mix
- Decarbonization lever mix

IndianSteel Association

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2.1 Objectives of the roadmap

The decarbonization roadmap seeks to answer key questions for major stakeholders in the Indian steel sector, as detailed below:

1. ISPs and smaller players

a. Where to invest?

- *What is the mix of decarbonization levers for each production technology?*
- *What should be the mix of production technologies going forward?*

b. When to invest?

- *What should be the decarbonization pathway for each production technology?*
- *What is the maturity and ease of implementation of decarbonization levers?*

c. How much to invest?

- *What is the Capex and Opex for implementing the decarbonization levers?*
- *What is the corresponding impact on LCOS?*

2. Ministry of Steel

a. What is the roadmap for the Indian steel sector?

- *What should be the emission reduction targets for steel sector?*
- *How can the roadmap be contextualized for India? (Based on production technologies, infrastructure availability, mix of ISPs/SSPs)*

b. What should government do to enable the journey?

- *What are the key policy initiatives required to support steel sector?*
- *How can government help set up the necessary infrastructure and enablers?*

2.2 Approach and methodology

To achieve the objective and address key questions as above, a structured approach has been followed as summarized below:

1. **Interactions with key stakeholders:**

   20+ interactions have been conducted with key stakeholders including industry experts, BEE, sustainability heads of ISPs, SIMA, and NISST, etc. to identify key challenges faced by the sector and contextualize the roadmap.

2. **Analytical modelling:**

   A comprehensive analytical model has been developed using Kearney's decarbonization expertise to identify optimal decarbonization pathway for Indian steel sector (explained in detail below).

3. **Alignment with key stakeholders:**

   Working level interactions with ISA and Sustainability Committee to refine and align on recommendations and way forward.

A comprehensive scientific analytical model has been developed to identify optimal decarbonization pathway for the Indian steel sector. The model considers multiple inputs and constraints to simulate various scenarious (pathway, investment required, total emissions, etc.) to help choose the most optimal pathway that minimizes total investment required for decarbonization, while meeting overall carbon budget. Further, the model incorporates several proprietary engines to estimate demand, supply, and pricing across decarbonization technologies and enablers.

There are three key pillars to the decarbonization roadmap, as detailed below:

1. **Decarbonization pathways:**

   Seven key pathways, including four global and three India-specific views, have been assessed, with baseline emissions and emission reduction targets across milestone years for each production technology.

2. **Production technology mix:**

   Four key production technologies considered for the analysis – BF – BOF, coal-based DRI – EAF, gas-based DRI – EAF, and scrap-based EAF/EIF routes, with evolution of technology mix in line with the projected capacity up to 2070.

3. **Decarbonization lever mix:**

   Seven key levers with applicability across production technologies assessed-Efficiency, RE, biochar, green hydrogen, blue hydrogen, carbon capture and utilization / carbon capture and storage, and carbon offsets.

Further, the model incorporates key constraints relevant to Indian steel sector in terms of iron ore availability, high-Fe content ore, steel scrap availability, carbon storage potential, demand for capture carbon across sectors (e.g., methanol, urea, etc.), biochar availability, and maximum abatement limit across each lever including limits on carbon offsets as per SBTi guidelines.

The three pillars of the decarbonization have been detailed in subsequent sections below:

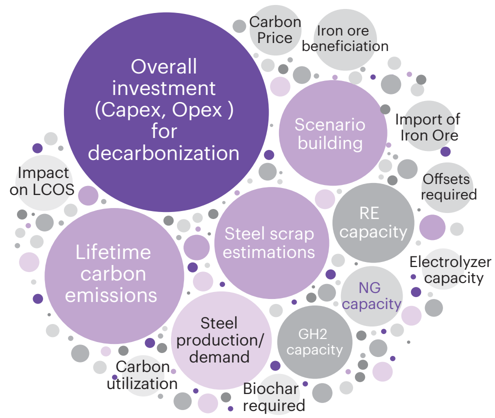
<table>
<tr><th>Key Pillars</th><th>Decarbonization Engine</th><th>Key Constraints</th></tr>
<tr><td rowspan="2">Decarbonization pathways
– 7 key pathways (4 global benchmarks and 3 India specific derived views).
– Emission reduction targets for milestone years for each prod. technology.</td><td rowspan="6">
</td><td>Iron ore availability: Import of ore and beneficiation for high–Fe content to drive cost increase.</td></tr>
<tr><td>Steel scrap availability: Limit dependence on import of scrap beyond 2040.</td></tr>
<tr><td rowspan="2">Production technology mix
– 4 technologies – BF – BOF, DRI – EAF (Coal), DRI – EAF(NG), EIF.
– Projected steel production for India across milestone years up to 2070.</td><td>Carbon utilization / storage: Deploy CCUS in line with storage availabil–ty, utilization demand in methanol, urea, etc.</td></tr>
<tr><td>Maximum abatement limit: Deployed each lever up to technical limits for abatement.</td></tr>
<tr><td rowspan="2">Decarbonization lever mix
– 7 key levers – Efficiency, Biochar, RE, GH2, BH2, CCUS, offsets.
– Capex and Opex evolution up to 2070 across each lever.</td><td>Biochar availability: Constrained basis supply of biomass.</td></tr>
<tr><td>Offsets: Maximum limit of 10% of baselines emissions as per SBTi guidelines.</td></tr>
</table>

Figure 2: Comprehensive scientific model for optimal decarbonization pathway[6]

[6] *No import of scrap beyond 2040 as per Scrap Policy 2019*

2.3 Decarbonization pathways

A well-defined decarbonization pathway with emission reduction targets vis-à-vis current baseline across milestone years for each production technology is a critical step in defining the decarbonization roadmap for the steel sector. This can help identify the optimal mix of production technologies, decarbonization levers, and associated investment required to achieve emission reduction targets.

Seven key decarbonization pathways were assessed, including four globally accepted benchmarks, and three India-specific customized pathways. Salient features of the pathways have been summarized in the table below *(detailed in Appendix 1)*:

		Pathways	Production technology dependent	Net Zero achievement year	Description
Global benchmarks	1	EU-ETS	✓	2050	- Emission reduction targets estimated with respect to 1990 emission intensity, with 55% reduction by 2030, 90% by 2040, and 100% by 2050. - Pathway assumes 30% emission reduction with respect to 1990 emission intensity has been achieved by 2030. - Mandates Net Zero by 2050 making it the most stringent pathway in line with achieving 1.5ºC global warming scenario.
Global benchmarks	2	Science Based Targets initiative	✓	2070 (~90% by 2050)	- For ore-based production, considered emission reduction of 29% in 2030 (from current intensity), 55% by 2040 (from 2030), and 86% by 2050 (from 2040). - For scrap-based production, considered emission reduction of 26% in 2030 (from current intensity), 35% by 2040 (from 2030), and 54% by 2050 (from 2040).
Global benchmarks	3	German Steel derived	✕	2070	- Achieve average of German Steel Performance level 1 band by 2030, level 2 band by 2040, level 3 band by 2050 and Net Zero by 2070. - Considers same step reduction after the first interim target, with similar interim objective across production technologies.
Global benchmarks	4	IEA derived	✕	2070	- Derived pathway considering an industry wide target agnostic of technology. - Interim target for 2030 to achieve 85% of industry average emission intensity (in line with MoS taskforce). - Subsequent targets in line with IEA's pathway to achieve 40% reduction by 2040, 60% by 2050, and Net Zero by 2070.
India-specific pathways	5	FLY	✓	2070	- Pathway derived in line with interim and Net Zero targets committed by leading steel players. - Pathway for DRI – EAF (Coal) and Scrap EAF/EIF predominantly driven by smaller players expected to reduce at a slower rate.
India-specific pathways	6	RUN	✓	2070	- Intermediate pathway derived considering FLY and WALK scenarios contextualized for the Indian steel sector.
India-specific pathways	7	WALK	✓	2070	- Pathway derived basis minimum emission reduction measures (value accretive energy efficiency measures, RE based on RPOs) deployment in short term.

Table 1: Decarbonization pathways

2.4 Production technology mix

Steel in India is produced via four key routes: BF – BOF, coal–based DRI – EAF, natural gas–based DRI - EAF, and scrap–based EAF/EIF. BF – BOF is typically the preferred route by large integrated steel plants while coal-based DRI-EAF and scrap–based EAF/EIF are typically adopted by small scale players. Currently, the production is dominated by fossil-fuel based BF - BOF and coal–based DRI - EAF routes given their economic viability. However, they have high emission intensities compared to the gas-based and scrap-based routes. The current production technology mix, their baseline emission intensities, and key emission drivers have been detailed below:

	Technology	Current share[7] (% of capacity)	Emission intensity[8] (tCO_2/tcs)		Key emission contributors *(non–exhaustive)*	
1	BF – BOF	46 – 48%	2.68	Scope 1 80 – 85% Scope 2 15 – 20%	- BF reducing agents (coke, pulverized coal, natural gas) - Fluxes - Electricity generation - Imported heat (heated blast)	
2	DRI – EAF (Coal)	32 – 34%	2.91	Scope 1 70 – 75% Scope 2 25 – 30%	- DRI reducing agents (coke, pulverized coal) - Direct charge / inject carbon - Fluxes - Electricity generation EAF charge pre–heat (coal / coke)	
3	DRI – EAF (Natural Gas)	7 – 9%	2.13	Scope 1 60 – 65% Scope 2 35 – 40%	- DRI reducing agents (reformed natural gas or syngas) - Direct charge/inject carbon - Fluxes - Electricity generation - EAF charge pre–heat (natural or recycled gas)	**24%** lower emission intensity
4	Scrap–EAF/EIF	10 – 13%	1.60	Scope 1 15 – 20% Scope 2 80 – 85%	- Fluxes - Electricity generation - EAF Charge pre–heat (natural or recycled gas)	**52%** lower emission intensity

Table 2: Baseline production technology mix and emission intensity

[7] *Source: MoS*
[8] *Includes emission up to finished steel production, Source: CEEW*

Decarbonization of Indian steel sector is particularly challenging due to the high dependence on fossil-fuel based technologies. Therefore, there is a need to shift to lower emitting gas-based and scrap-based routes. Additionally, coal gasification + CCU/CCS can be considered as a potential alternative in the interim to NG-based DRI by players, given India's high reserves of coal. There are, however, key bottlenecks pertaining to iron ore availability, high-Fe content ore for DRI, and scrap availability in India that need to be addressed in order to enable to shift. The analysis of iron ore availability and scrap availability have been detailed below:

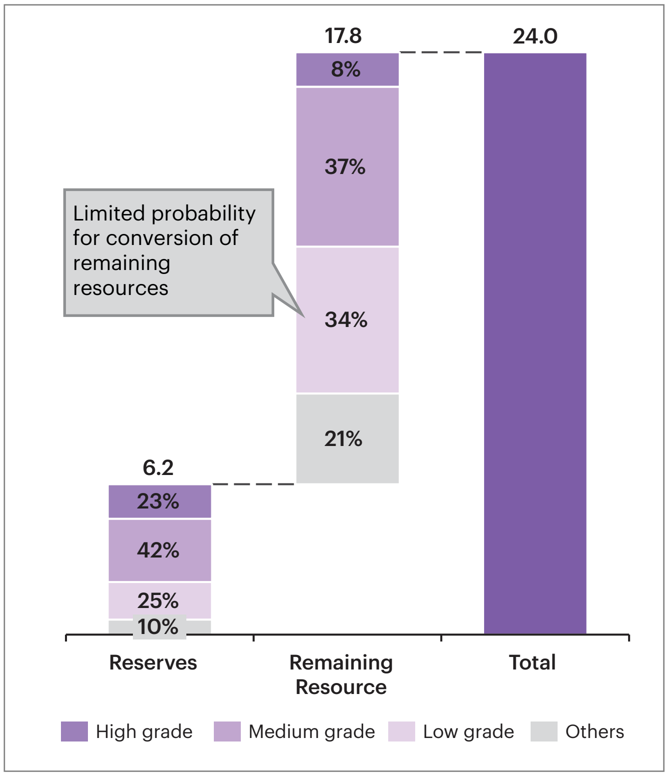


Figure 3: Total hematite iron ore in India (in Bn tons) [9, 10]

Iron ore availability

India predominantly has two types of iron ores– hematite and magnetite. Hematite is typically considered superior because of its relatively higher grade, and therefore, is used in the iron and steel sector. The distribution of the reserves and remaining resources of hematite is shown in the *figure 3*: The available reserves and remaining resources of hematite are expected to be mined over the next 14 – 15 years, increasing India's dependence on import of iron ore in the long term. Further, the total high–Fe content (>65%) iron ore in India is estimated to be around 1.5 – 2 Bn tons, driving the need for beneficiation of low-to-medium grade ores to be utilized for gas-based DRI technology, which is likely to have a potential impact of USD 15 – 20/ton on the cost of ore. Additional magnetite resources of ~11 Bn tons exist, however, their economic feasibility is yet to be proven.

[9] *As per Indian Minerals Yearbook 2021*

[10] *High grade – +65% Fe content; Medium grade – 65 – 62% Fe content; Low grade – below 62% Fe content*

Scrap availability

Currently, there is a supply of 30 – 35 Mn TPA of steel scrap in India, lower than demand of 35 – 40 Mn TPA, leading to import of scrap in India. The steel scrap availability in India is expected to increase to 130 – 140 Mn TPA by 2050, providing an impetus to scrap–based production routes. The projected supply of steel scrap in India across key categories has been illustrated in *figure 4*:

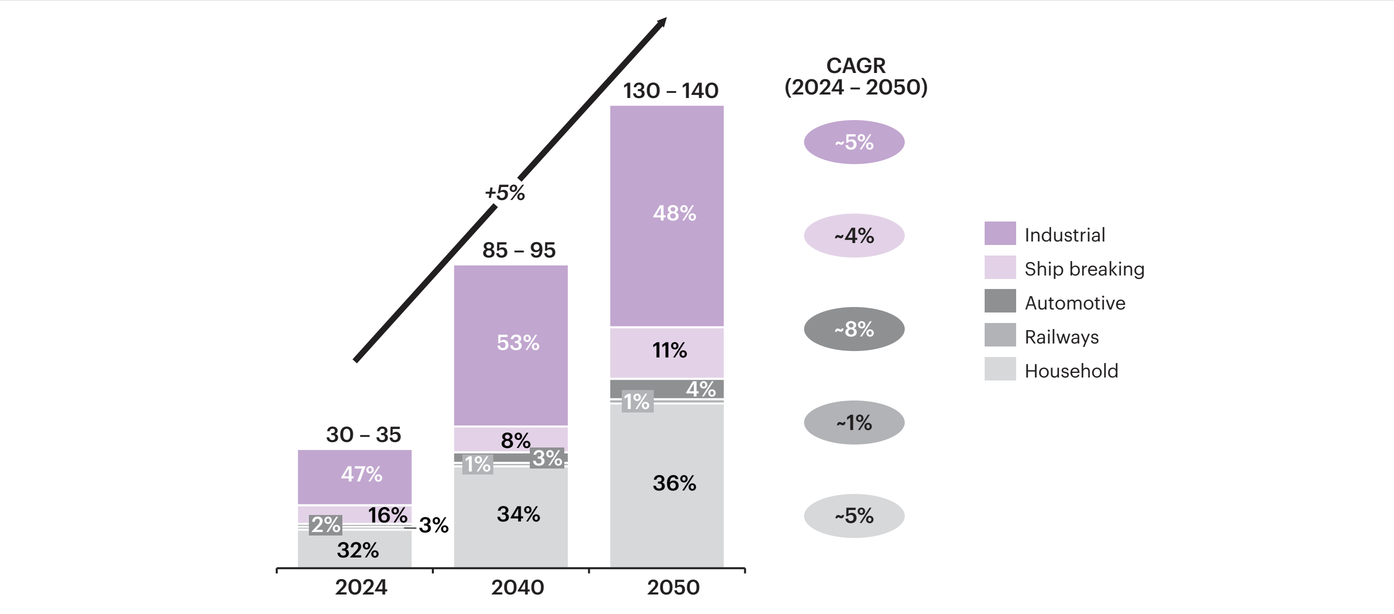


Figure 4: India ferrous scrap supply for steel making (in Mn TPA)[11, 12]

The following key drivers are enabling the increase in availability of steel scrap:

1. **Natural scrapping cycle:**

   Scrap to become available as various segments, based on historical steel usage, reach natural scrapping age.

2. **ELV recycling:**

   Increasing availability of end–of–life vehicles, industrial equipment, white goods, riding on historical growth of the segment.

3. **Infrastructure development:**

   Dedicated investments by steel players to acquire scrap yards and setup processing facilities across India.

4. **Policy support:**

   Policies to drive scrap collection and processing (e.g., VVMP) through setup of scrapping facilities.

[11] *Estimated as per – Industrial: Industrial Production Index for India with lifetime of 30 years, Ship breaking: Number of vessels in India with lifetime of 40 years, Automotive: GDP growth rate for India with average vehicle lifetime of 15 years, Railways: Number of trains in India with lifetime of 30 years, Household: in line with private consumption in India's GDP with lifetime of 10 years*
[12] *Sources: Oxford economics, MOSPI, IBEF, Indian Railways*
[13] *Voluntary Vehicle Fleet Modernization Policy*

2.5 Decarbonization lever mix

Decarbonization of steel sector will require deployment of several key levers for abatement of emissions. Broadly, there are three main decarbonization strategies for steel–A) efficiency, B) substitution with low carbon fuel and feedstock, and C) carbon capture, utilization and/ or storage (CCUS) and offsets. The key levers under each of the above strategy has been shown below:

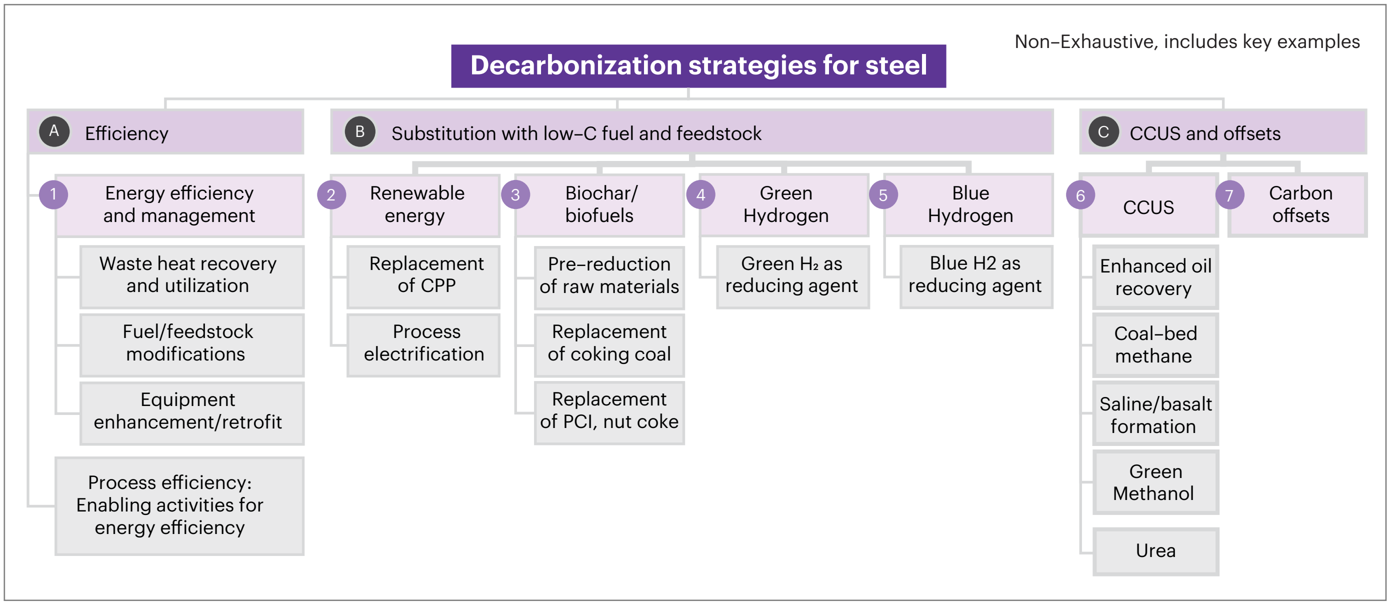


Figure 5: Decarbonization strategies for steel

There are seven key decarbonization levers for steel–efficiency, RE, biochar, green hydrogen, blue hydrogen, CCU/CCS, and carbon offsets. The decarbonization levers can be applied up to possible technical abatement limits for each production technology. The applicability of levers across production technologies and their maximum abatement limits has been summarized below:

Strategy	Lever	BF-BOF	DRI-EAF (Coal)	DRI-EAF (NG)	Scrap-EAF/EIF
Efficiency	Energy and process efficiency	0.25	0.10	0.03	0.07
Substitution	Renewable Energy	0.49	0.74	0.76	1.32
	Biochar / biofuels	1.00	Not Applicable	Not Applicable	Not Applicable
	Blue H_2 + CCUS	0.19	Not Applicable	0.32	Not Applicable
	Green H_2	0.19	Not Applicable	0.32	Not Applicable
CCUS	Carbon Capture, Utilization, Storage	2.41	2.62	1.92	1.44

Figure 6: Maximum abatement limits (in tCO_2/tcs)[14,15]

[14] Carbon capture limit estimated considering an efficiency of 90%
[15] Remaining emissions considered to be abated through offset with a limit of 10% of total emissions as per SBTi guidelines

Energy and process efficiency

Several energy and process efficiency measures can be undertaken across all production technologies, with varying tabatement potential and investments. They key measures and abatement potential have been summarized below:

1. BF – BOF:

Efficiency is key for BF–BOF process, with potential to reduce 8 – 10% emissions from the current baseline. Key measures include coke oven gas recycling, coke dry quenching, top pressure recovery turbine for power generation through waste heat recovery, injection of pulverized coal into the blast furnace, and slag heat recovery among others.

2. DRI – EAF (Coal):

Energy efficiency measures such as EAF charge pre–heating, power generation through waste heat recovery from EAF, and process efficiency measures such as oxyfuel burner / lancing in EAF to promote rapid melting in EAF are key measures which can contribute to 3 – 5% emission reduction from the current baseline.

3. DRI – EAF (NG):

While there is limited scope for energy and process efficiency in gas–based DRI – EAF production route, select measures like EAF charge pre–heating, power generation from waste heat recovery, scrap pre–treatment, oxyfuel burner / lancing in EAF, and injection of inert gas (e.g., Argon or Nitrogen) into the EAF for enhanced heat transfer have a potential to reduce 1.5 – 3% emissions from the current baseline.

4. Scrap – based EAF/EIF:

Waste heat recovery from kiln flue gas, char, etc. are select efficiency measures in scrap–based production routes that have a potential to reduce 4 – 6% emissions from the current baseline.

Renewable Energy

Production of steel requires significant amount of electricity. The consumption of electricity across all production technologies, post deployment of energy efficiency measures, are detailed below:

Production technology	Electricity consumption (in kWh/tcs)[16]	Abatement Limit (in tCO_2/tcs)[17,18]	% of baseline emission intensity
BF–BOF	560 – 580	0.49	15 – 20%
DRI–EAF (Coal)	750 – 770	0.74	25 – 30%
DRI–EAF (Natural Gas)	700 – 720	0.76	35 – 40%
Scrap–EAF/EIF	1,230 – 1,250	1.32	80 – 85%

Table 3: Electricity consumption across production technologies

[16] *Source: CEEW*
[17] *Including emissions up to finished steel production*
[18] *Considering a baseline emission from CPP – 0.001 tCO2/kWh*

A significant share of electricity consumption is currently being met by brown power generated by coal–based captive power plants (CPPs), especially in integrated steel plants–the remaining being met through power generated from waste heat recovery units and power procured from grid. Replacement of this brown power is critical for scope 2 emission reduction and aid in decarbonization of the steel sector.

Deployment of the right RE solution is critical for greening of power consumed across steel plants. In the short term (up to 2030) high–CUF (80 – 85%) solar–wind–hybrid solutions can be deployed to initiate replacement of brown power from CPPs. Inter–State (ISTS) solutions can be considered for steel plants in locations with limited RE potential (e.g., Jharkhand, Orissa, Chattisgarh) and, as a way to isolate from regulatory challenges (e.g., banking, deployment of hybrid projects, etc.). Going forward, in the medium–to–long term (beyond 2030), Round–the–Clock (RTC) solutions, including storage (BESS, PSP, etc.) solutions, can be deployed to transition to 100% green power across the steel plants. The landed tariff for the solution is as follows:

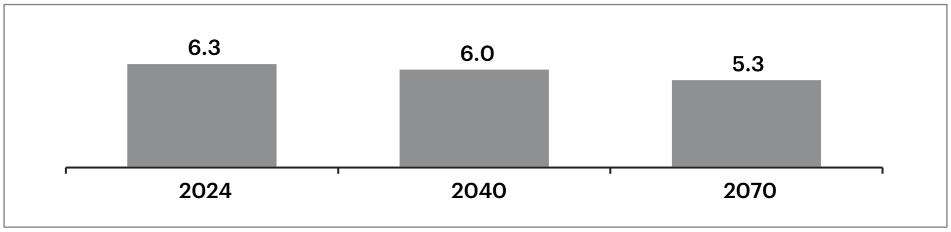


Figure 7: Landed tariff (in INR/kWh)[19]

Reduction in the landed tariff is expected with a declining trend in capex for solar PV modules, wind turbine generators, and EPC services. The expected trend for solar and wind capex is:

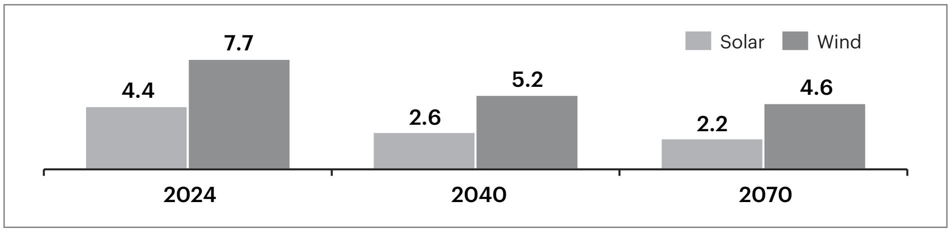


Figure 8: Capex for Solar and Wind (in INR Cr/MW)[20]

The corresponding cost of decarbonization for deploying RE to achieve the emission reduction level detailed *in Table 3* are as below:

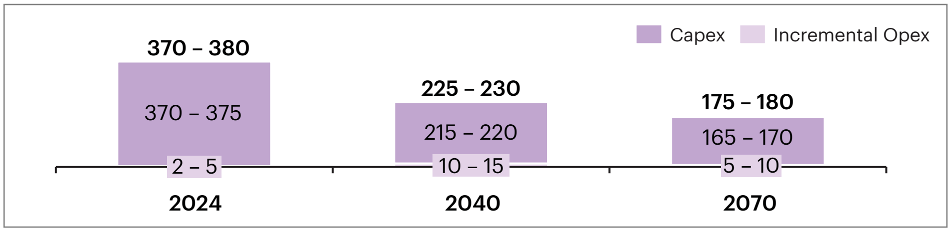


Figure 9: Cost of decarbonization (in USD/tCO_2)

[19] *Open access solution (ISTS) considered for Orissa, with BESS post 2030 for RTC power supply*
[20] *Source: NREL*

Biochar

Biocharcoal (also called Biochar) is an attractive lever for decarbonization of the steel sector. Globally, renewable carbon from biomass has been integrated into the BF–BOF production route. It is expected to cost USD 600 – 650 per ton with an associated cost of decarbonization of USD 160 – 165/tCO² (capex) and USD 170 – 175/tCO² (opex). Below are some key use cases for biochar in BF–BOF route:

Use Case	Biochar consumption (in ton/tcs)	Emission reduction (in tCO_2/tcs)
Sintering solid fuel	0.03 – 0.09	0.12 – 0.32
Coke making blend	0.01 – 0.03	0.02 – 0.11
BF tuyere injection	0.16 – 0.18	0.41 – 0.55
BF nut coke replacement	0.03 – 0.06	0.08 – 0.16
BOF pre–reduction	~0.001	0.08 – 0.15
Steelmaking recarburizer	~0.0003	~0.001
Total	**0.23 – 0.28**	**0.7 – 1.3**

Table 4: Biochar consumption and emission reduction[21]

While, theoretically, the use of biochar seems promising, there are sever supply constraints leading to challenges in availability of biochar to be consumed by the steel sector. India has limited biomass pellet manufacturing facilities leading to an increase in the feedstock cost to USD 85 – 90/ton making the option economically less viable. Technologically, conversion of biomass to biochar requires slow pyrolysis, which is a nascent technology with low conversion efficiencies. Further, increasing mandates for usage of biomass in blending in petrol, and in thermal power plants, is expected to limit the supply for the iron and steel sector.

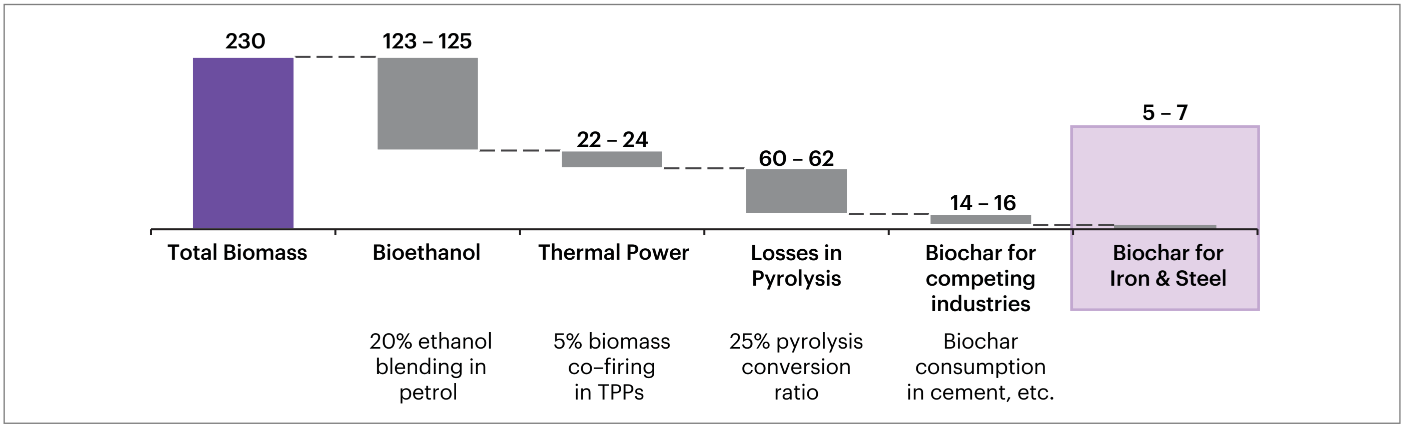


Figure 10: Supply of Biochar in India (2024, in Mn TPA)

[21] Mathieson et. al

Green Hydrogen

Alternative fuels such as green hydrogen have a critical role to play in the decarbonization of the steel sector. While only gas–based shaft furnaces can entirely shift towards green hydrogen, there is a scope for injection into blast furnaces to reduce emissions from coking coal. With high costs of green hydrogen, commercial–scale shifts towards H2–DRI and large–scale injection into blast furnaces are yet to be observed. However, decline in costs are expected with potential reduction in electrolyzer costs, compressor costs, and RE costs, making hydrogen an economically viable lever for decarbonization.

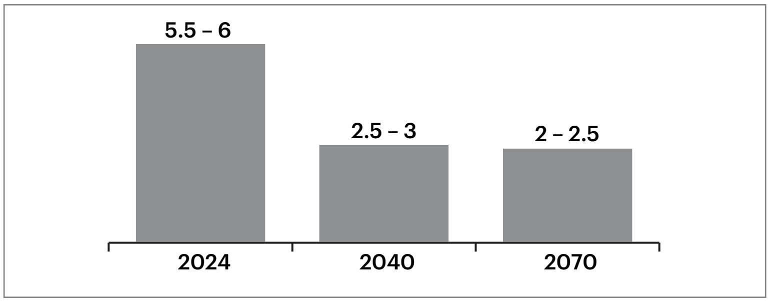


Figure 11: Levelized cost of green hydrogen (in USD/kg)[22]

With capex required in retrofitting of blast furnaces and shaft furnaces for injection of hydrogen, and high incremental opex of replacing coal or natural gas with hydrogen, the cost of decarbonization is expected to be significantly high in the short–to–medium term:

Capex / Incremental Opex

Process	Abatement Limit	Cost of Decarbonization (USD / tCO_2) 2024	2040	2070	Key considerations
BF–BOF	0.19 tCO_2/tcs (~8% of total baseline emissions)	400 – 410 500 – 520 900 – 930	200 – 220 300 – 320 500 – 530	150 – 170 250 – 300 430 – 460	– 15 kg/tcs injection of hydrogen in BF – Incremental capex of USD 40.5/tcs for retrofitting of BF
DRI–EAF (Natural Gas)	0.32 tCO_2/tcs (~17% of total baseline emissions)	350 – 370 520 – 540 520 – 540	100 – 120 220 – 250 220 – 250	70 – 90 210 – 230 210 – 230	– 51 kg/tcs injection of hydrogen in shaft furnace – Incremental capex of USD 118/tcs (2024) reduces to USD 59/tcs (2070) for retrofitting of shaft furnace

Figure 12: Cost of decarbonization for green hydrogen[23]

[22] *Estimated considering landed tariff including STU losses, STU charges, ED, misc. charges, etc. Subject to modifications based on change in law pertaining to regulatory charges*

[23] *Assumes capex–based model, i.e., capex for green hydrogen included as part of total capex, raw material and utilities cost included in opex*

Blue Hydrogen

Currently, with limited availability of green hydrogen in the Indian market, blue hydrogen presents itself as a potential alternative. The hydrogen manufactured through reforming (through steam methane reforming) of natural gas is decarbonized by coupling the reformer with carbon capture and storage / utilization units. While the grey hydrogen formed in the reformer is economical compared to green hydrogen, addition of CCS/CCU makes blue hydrogen more expensive than green hydrogen.

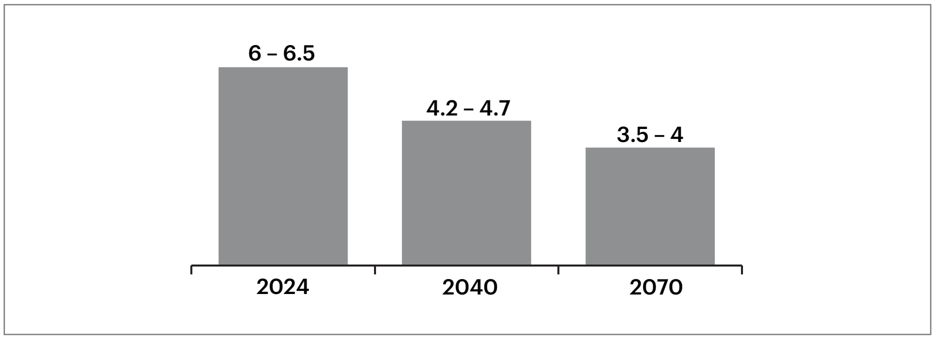


Figure 13: Levelized cost of blue hydrogen including CCS/CCUS (in USD/kg)

Like green hydrogen, additional capex is required for retrofitting of blast furnaces and shaft furnaces for injection of blue hydrogen, and high incremental opex of replacing coal or natural gas with blue hydrogen is expected to make the cost of decarbonization significantly high:

Capex / Incremental Opex

Process	Abatement Limit	Cost of Decarbonization (USD / tCO_2) 2024	2040	2070	Key considerations
BF–BOF	0.19 tCO_2/tcs (~8% of total baseline emissions)	Capex: 210 – 230 Incremental Opex: 480 – 500 Total: 700 – 730	Capex: 200 – 220 Incremental Opex: 350 – 370 Total: 550 – 580	Capex: 200 – 220 Incremental Opex: 280 – 300 Total: 480 – 520	– 15 kg/tcs injection of hydrogen in BF – Incremental capex of USD 40.5/tcs for retrofitting of BF
DRI–EAF (Natural Gas)	0.32 tCO_2/tcs (~17% of total baseline emissions)	Capex: 350 – 370 Incremental Opex: 670 – 690 Total: 1,000 – 1,050	Capex: 170 – 190 Incremental Opex: 400 – 420 Total: 580 – 610	Capex: 150 – 170 Incremental Opex: 240 – 260 Total: 390 – 420	– 51 kg/tcs injection of hydrogen in shaft furnace – Incremental capex of USD 118/tcs (2024) reduces to USD 59/tcs (2070) for retrofitting of shaft furnace

Figure 14: Cost of decarbonization for blue hydrogen[24]

[24] *Assumes opex-based model, i.e., all blue hydrogen capex and opex included as part of total opex*

Carbon Capture, Utilization, and Storage

Decarbonization through efficiency and substitution alone would be insufficient to reach Net Zero emissions, especially in hard–to–abate sectors like steel, with heavy dependence on fossil fuels. Therefore, carbon capture, utilization and / or storage becomes a critical decarbonization lever to achieve Net Zero emissions. There are four key types of carbon streams, as summarized below. Pre–combustion, post–combustion, and oxy–fuel combustion streams are applicable for iron and steel.

1. **Gas sweetening:** *CO_2/CH_4/H_2S separation typically used in extraction of natural gas.*
2. **Pre–combustion:** *Gasification or reformers CO_2/H_2 separation, relevant for SMR operations.*
3. **Post–combustion:** *WCO_2/N_2 separation typically for FCCs, BFs, and other furnaces across industries.*
4. **Oxy–fuel combustion:** *Fuel combusted in pure oxygen, producing a concentrated CO_2 stream.*

There are several types of carbon capture and separation techniques (e.g., solvent based absorption, adsorption, cryogenic separation, etc.). The levelized cost of capture for varying concentration of CO_2 has been summarized below:

Capex Opex

CO_2 concentration	Process	Capture efficiency	Levelized Cost of Capture (USD / tCO_2) 2024	2040	2070
High CO_2 concentration	BF–BOF DRI–EAF (Coal)	90 – 95%	33 – 35 22 – 25 55 – 60	28 – 30 12 – 15 40 – 45	27 – 29 10 – 13 37 – 42
Medium CO_2 concentration	DRI–EAF (Natural Gas) Scrap–EAF/EIF	85 – 90%	110 – 113 15 – 17 115 – 130	60 – 63 10 – 12 70 – 75	45 – 48 8 – 10 53 – 58

Figure 15: Levelized cost of carbon capture

The captured carbon can be stored or utilized. Permanent storage of the captured carbon includes dedicated geological storage sites (e.g., saline aquifers, basalt rock formations, etc.), in enhanced oil recovery (EOR), in enhance coal bed methane recovery (CBM), among others. Utilization can be across various use cases such as biological (e.g., algae growth), chemical (e.g., in green methanol, green urea, bioethanol, sustainable aviation fuel, etc.), mineralization, and food and beverages.

Utilization in Methanol and Urea manufacturing and storage in EOR, CBM are expected to be key levers in the medium term up to 2040, given their technological readiness levels and available ecosystem. Storage in geological sites and other utilization use cases are expected to evolve over the long term beyond 2040 with adequate exploration and enablers to support uptake of captured CO_2.

The comparison across potential use cases of captured CO_2 has been summarized below:

Low | High

Parameter(s)	Storage		Methanol		Urea	
Market potential		150 GT+ potential by 2050 (EOR, CBM, Saline)		Domestic demand expected to be 5 – 6 MTPA by 2040		Domestic demand expected to be 46 – 48 MTPA by 2040
Technological maturity		Evolving, exploration required for Basalt		Expected to achieve maturity over next decade		Mature technology
Cost economics		Cost competitive, subject to transportation costs		Relatively high costs, expected to decline by 2050		Expected to be cost competitive by 2040
Cost of decarbonization (over and above cost of carbon capture)						
Capex (USD / tCO_2 in 2040)	280 – 320		650 – 680		450 – 480	
Opex (USD / tCO_2 in 2040)	5 – 10 (Dependent on proximity of sinks)		100 – 150		30 – 40	

Figure 16: Comparison across potential use cases for captured CO_2

Way forward for Indian steel sector

- Optimal decarbonization roadmap
- Decarbonization lever deployment and investment required
- Production technology shift
- Impact on cost of steel

3.1 Optimal decarbonization roadmap

The seven potential decarbonization pathways *(described in Table 1)* were assessed across key evaluation parameters, as described below:

1. **Carbon emissions:** *Ensure lifetime CO_2 emissions is below India's fair share for 2ºC scenario.*
2. **Cost of Carbon:** *Minimize total investment (Capex and Opex) required for decarbonization.*
3. **Technical feasibility:** *Ensure availability of technologies, and infrastructure to enable commercial scale decarbonization.*

The optimal decarbonization pathway for Indian steel sector will be one that is technically feasible, minimizes lifetime carbon emissions, and achieves decarbonization at the lowest overall cost.

The EU–ETS and SBTi–derived pathways are aggressive for the Indian steel sector requiring significant investment to achieve the emission reduction targets. Further, they require a significant amount of carbon offsets[25] to achieve the emission reduction targets, making it technically infeasible. Whereas the WALK and IEA derived pathways have the potential to breach India's fair share of carbon emissions for the 2ºC scenario.

Historically, targets across sectors (e.g., RPO targets) have seen a compliance of 60 – 70%. Therefore, RUN is the optimal decarbonization pathway for the Indian steel sector with 25 – 30% emissions below the 2ºC scenario, building in adequate buffer to ensure 2ºC scenario is not breached.

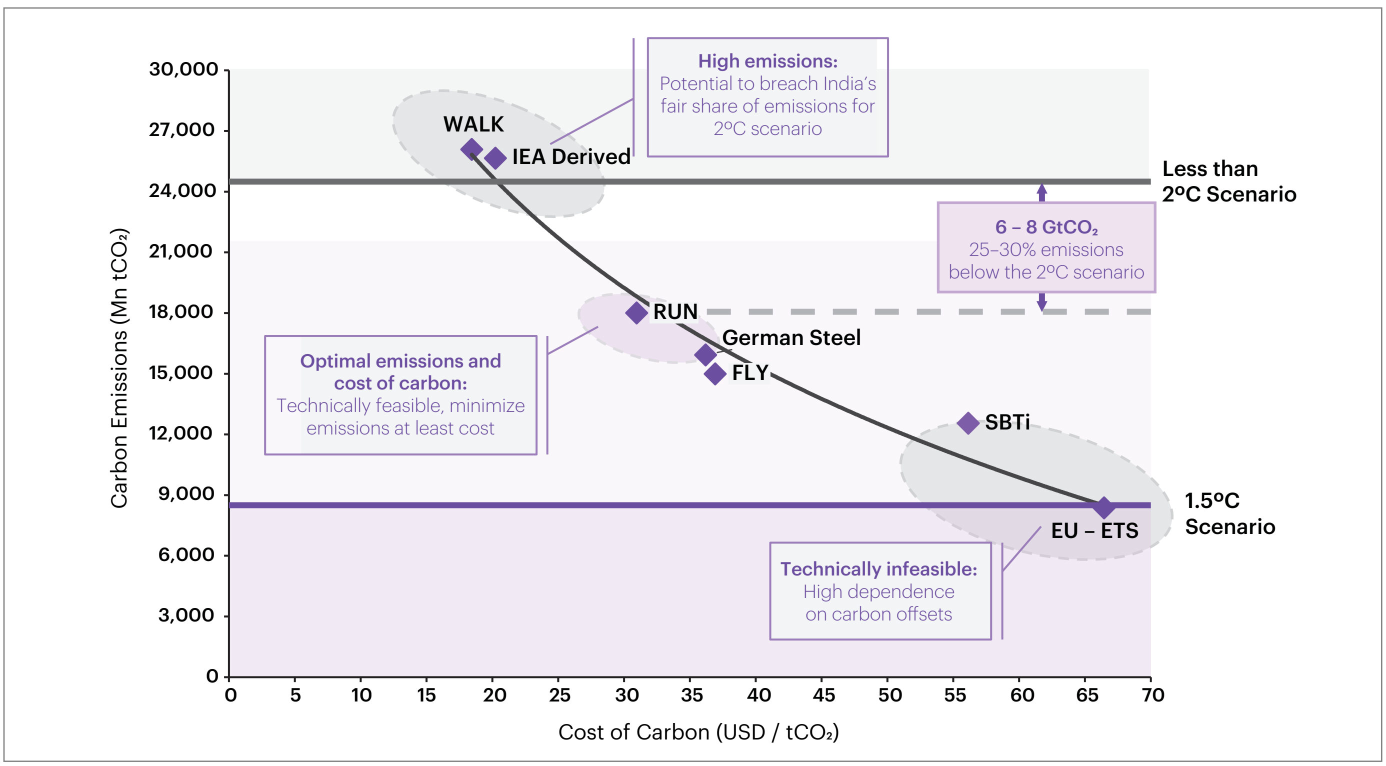


Figure 17: 2024–2070 Indian steel production emission scenarios

[25] *Beyond 10% of baseline emissions as per SBTi guidelines*

3.2 Decarbonization lever deployment and investment required

To achieve the emission reduction targets, set out in the RUN pathway, the steel players will have to invest in decarbonization initiatives in a phased manner and reach Net Zero emissions by 2070. In the short term, up to 2030, efficiency and RE are the key levers contributing to 10 – 15% of emission reduction. Uptake in injection of green hydrogen in BF – BOF and DRI – EAF (NG), initiation of CCU with utilization in methanol and urea production, and CCS with storage in EOR are critical in the medium term up to 2050. Continued focus on CCS technologies beyond 2050 can help achieve near zero emissions by 2070, with the remaining to be offset using carbon credits.

An estimated investment of USD 1,200 – 1,300 Bn including a capex of USD 420 – 470 Bn and annual incremental opex of USD 17 – 19 Bn/year will be required for decarbonization of the Indian steel sector. The optimal mix of decarbonization levers across production technologies have been illustrated below:

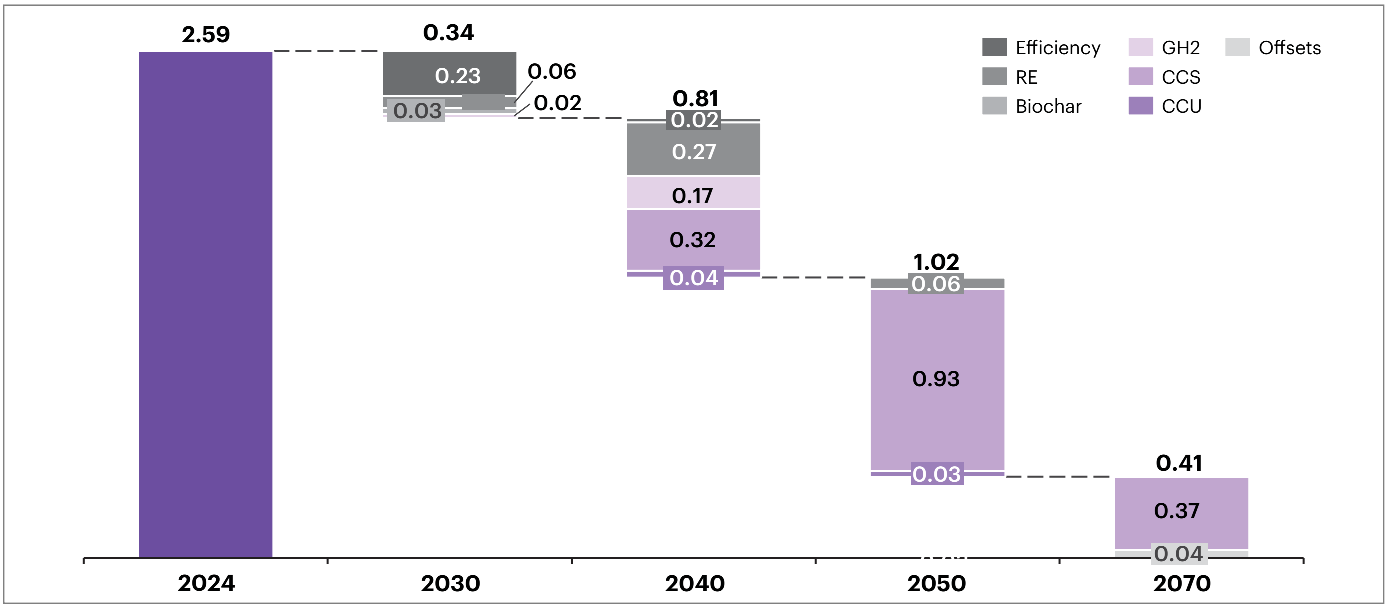


Figure 18: Decarbonization lever mix for BF–BOF (all values in tCO_2/tcs)

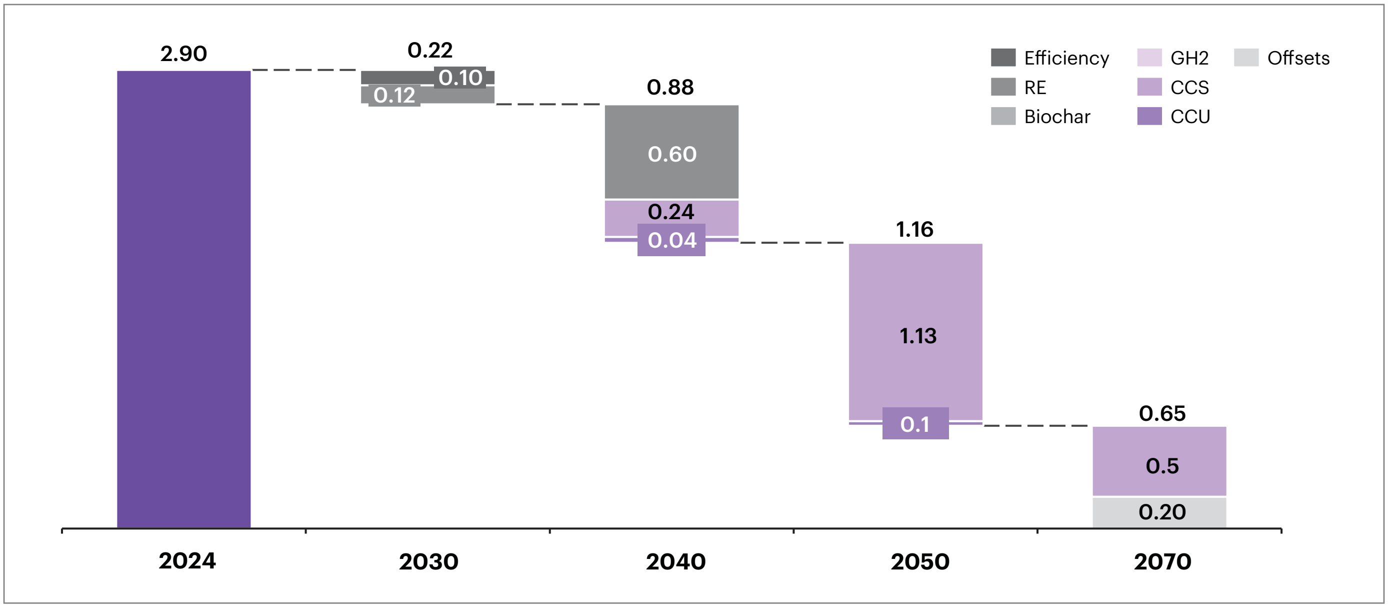


Figure 19: Lever mix for coal-based DRI-EAF (all values in tCO_2/tcs)

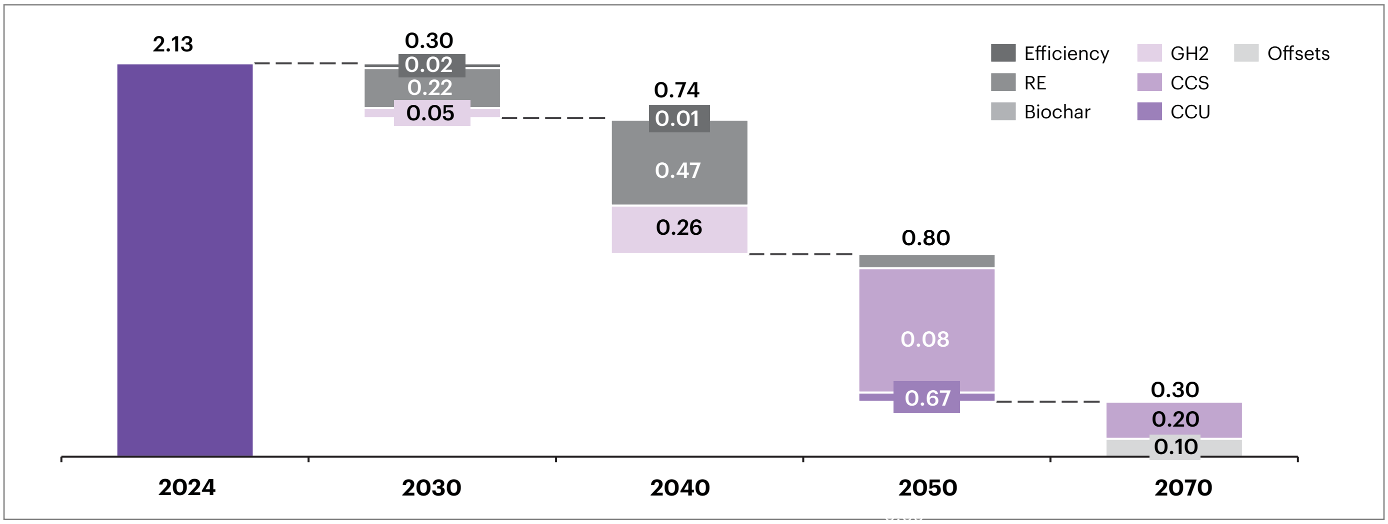


Figure 20: Decarbonization lever mix for gas-based DRI-EAF (all values in tCO_2/tcs)

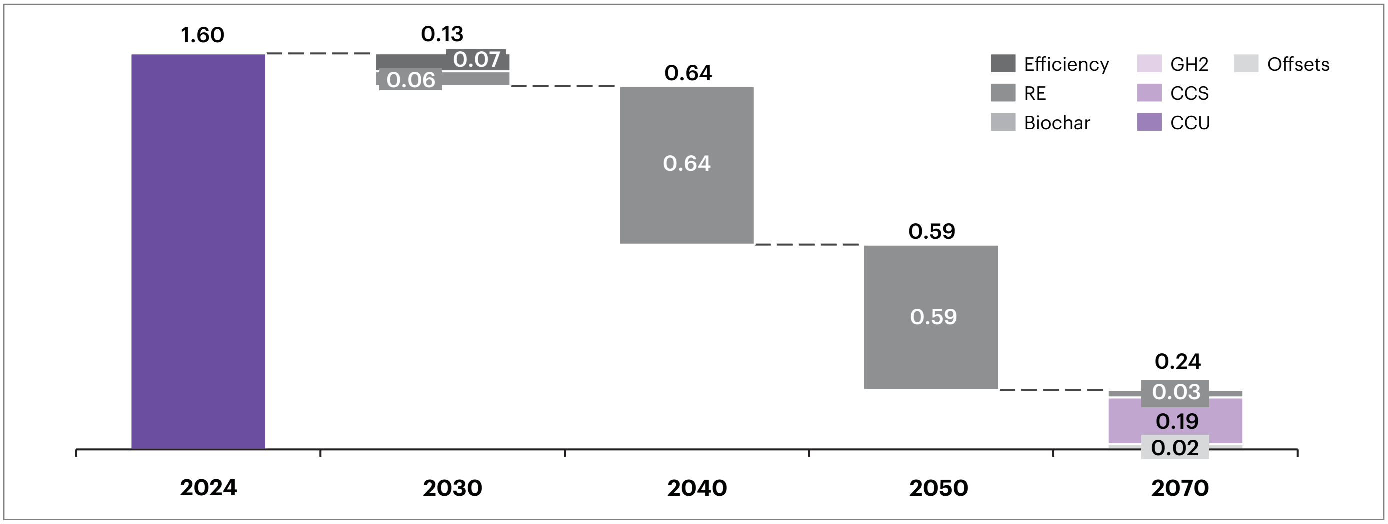


Figure 21: Decarbonization lever mix for scrap based EAF/EIF (all values in tCO_2/tcs)

3.3 Production technology shift

By adopting the RUN pathway, the production technology mix will have to shift towards lower emitting gas-based DRI – EAF and scrap-based EAF/EIF routes. This will require adequate availability of iron ore with high-Fe content *(described in figure 3)* and steel scrap *(described in figure 4)* to enable the shift. The projected production technology mix to achieve the targets set out in the RUN pathway is illustrated below:

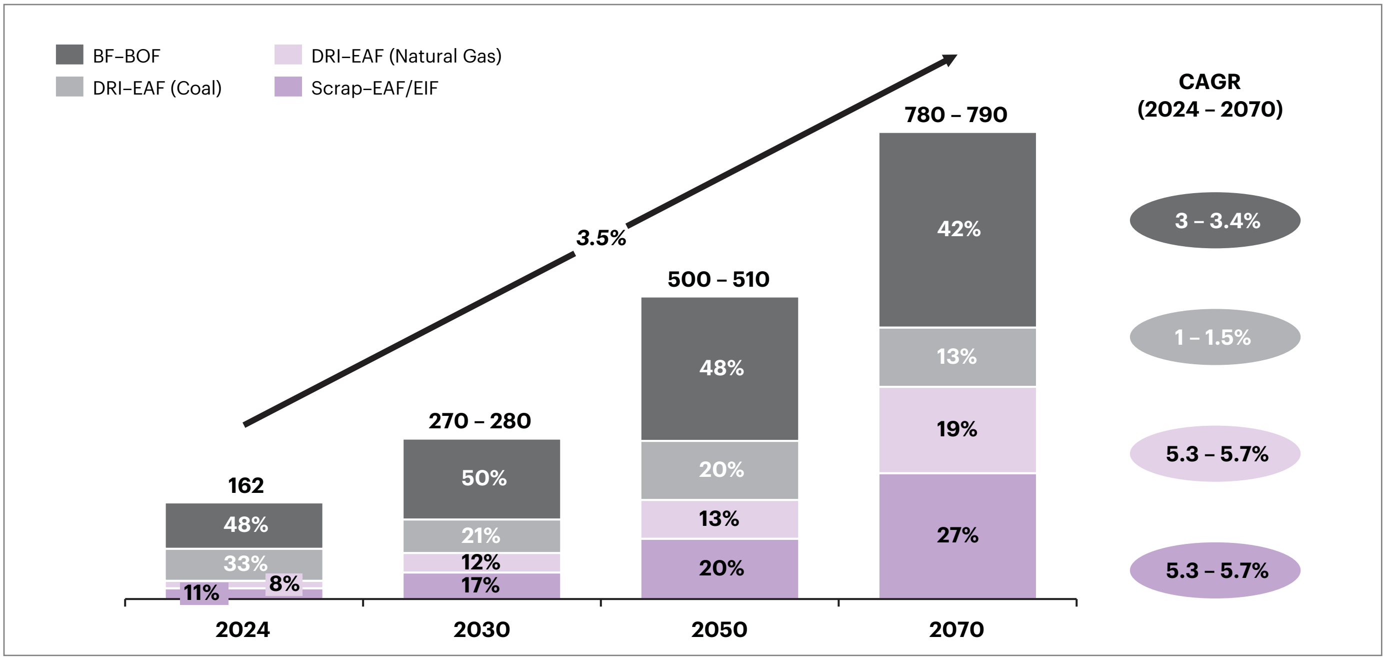


Figure 22: Production technology mix evolution

3.4 Impact on cost of steel

The investment required for decarbonization as per RUN pathway, coupled with shift in production technology mix towards more expensive gas-based DRI-EAF and scrap-based EAF/EIF is expected to have a significant impact on the levelized cost of steel (LCOS). The potential increase in the LCOS has been illustrated below:

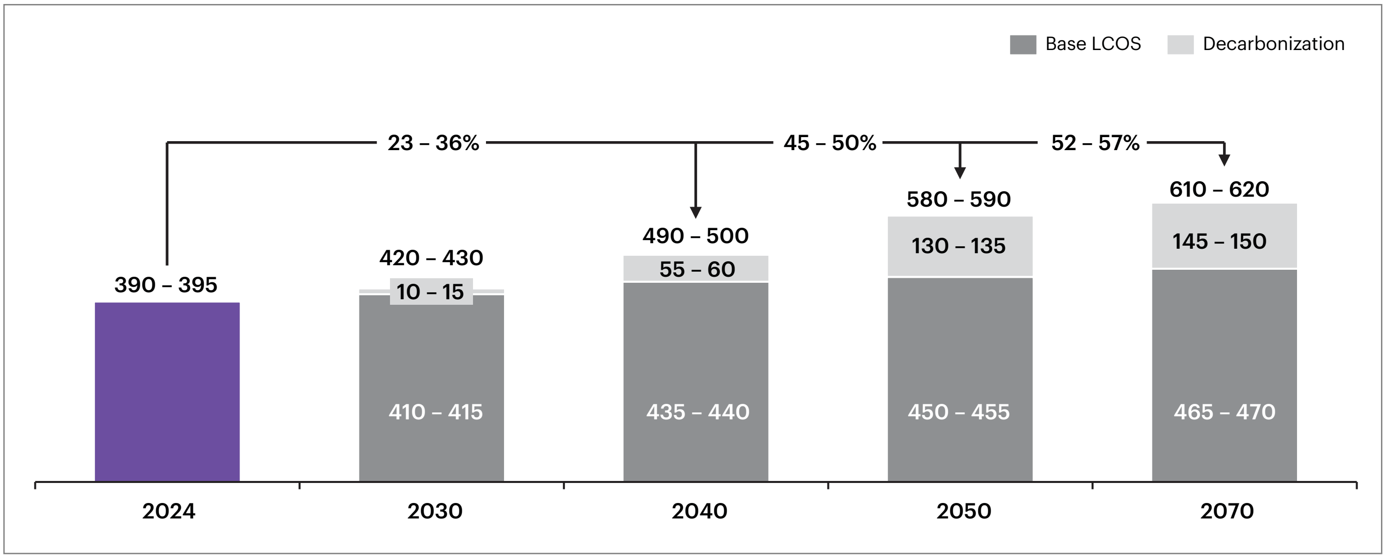


Figure 23: Levelized cost of steel (in USD/tcs)

RUN pathway is expected have varying impact on LCOS across production routes as highlighted below:

1. The BF – BOF production route is expected to witness the highest increase in LCOS with 35 – 40% increase by 2040, and 50 – 55% by 2050 due to the high cost of decarbonization driven by CCU/CCS.

2. The coal-based DRI-EAF and gas-based DRI-EAF routes are expected to increase by 15 – 20% by 2040 and 45 – 55% by 2050 with investments in CCU/CCS and green hydrogen, respectively. However, fluctuations in gas prices can potentially impact the gas based DRI route.

3. The scrap-based production route is expected to have limited impact of 15 – 20% on LCOS with relatively high ease of decarbonization requiring investment predominantly in RE.

With increase in LCOS due to investments in decarbonization, producers will need a market that is willing to absorb higher costs associated with the same. A defined market that is willing to pay a premium for steel produced at lower emissions will be crucial to encourage producers to become early movers in adopting cleaner technologies. Hence, it is important to explore how such a market for 'low emission steel' can be defined, its demand potential, and how it can be shored up, to enable producers to make a business case for investment in decarbonization levers.

Demand generation for low emission steel

- Global demand and supply
- Private sector demand in India
- Public procurement

4.1 Global demand and supply

Global demand for low emission steel today is estimated to be 4 – 8 MT, and it is expected to grow to 40 – 60 MT by 2030, contributing to ~2% of the total steel demand[26].

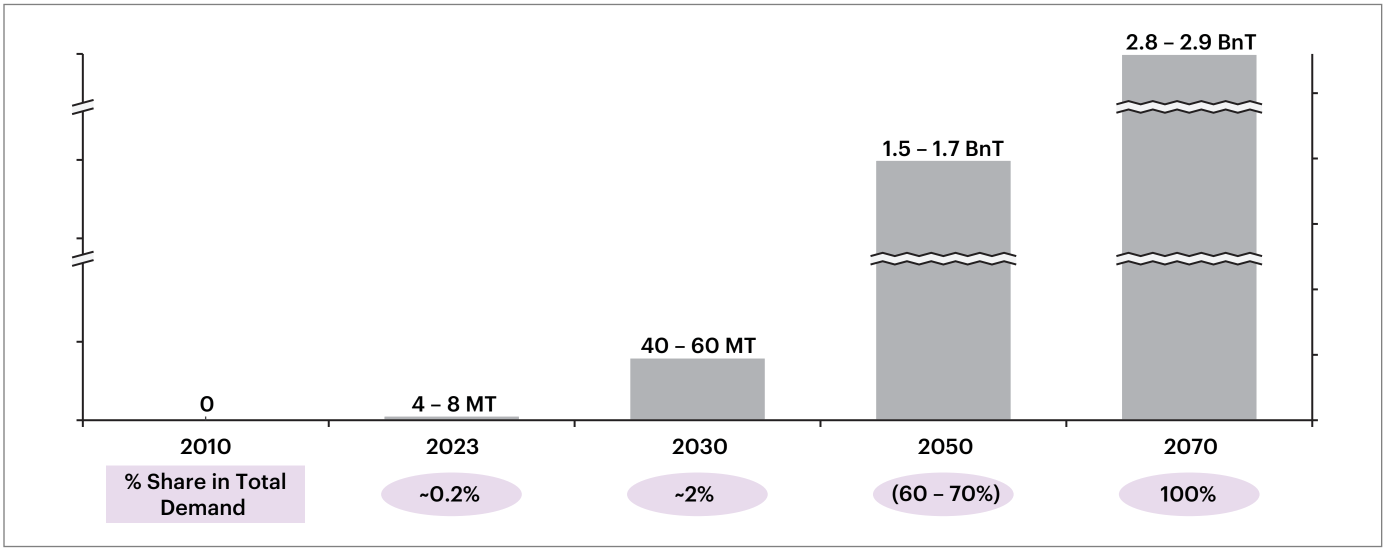


Figure 24: World low emission steel demand

The key drivers for this demand are:

1. **Scope 3 emission reduction:**

   There has been a growing significance of reduction in scope 3 emissions for key steel–using sectors such as auto, construction and consumer goods. Scope 3 emissions include upstream and downstream value chain emissions. In sectors such as auto, as downstream emissions get addressed through increasing electric vehicle penetration, focus is shifting to upstream emissions as well. This shift in focus is driving demand for low carbon materials.

   There are multiple global initiatives encouraging steel consumers to make voluntary commitments on usage of low emission steel. These include initiatives such as the First Movers Coalition backed by WEF, and SteelZero initiative by Climate Group. Multiple private sector consumers have signed up for these initiatives committing to a certain share of low emission steel procurement by 2030.

2. **Carbon based trade policies:**

   Implementation of Carbon Border Adjustment Mechanism (CBAM) in Europe, along with EU–ETS, has given a strong support to carbon pricing. This is expected to minimize the cost advantage for materials with high embedded emissions, in turn promoting demand for low emission materials.

3. **Green public procurement policies:**

   Governments across the world have issued policies for procurement of low emission materials for public projects. This includes including embedded emissions as a decision criterion for public tenders, as well as specifying minimum emission thresholds on procured materials for specific projects. With a large share of global steel demand going into infrastructure activities, such initiatives can significantly boost low emission steel demand.

[26] *Source: GMK, RMI, WSA, IEA, Industry Reports, Kearney*

Majority of low emission steel demand today originates in Europe, with 60+ reported transactions. Europe is expected to continue to have a high share in the near term. Other key geographies which are seeing low emission steel transactions include US, Canada, Japan, and South Korea[27]. Over the next decade, multiple players have announced low emission steel production projects in these regions, supported by government subsidies. Projects have also been announced in other regions such as China, MENA, and LATAM, which are expected to have cheap costs of green technologies such as renewable energy and green hydrogen and/or availability of DR – grade iron ore. Region – wise announced capacity of low emission steel is detailed below[28, 29].

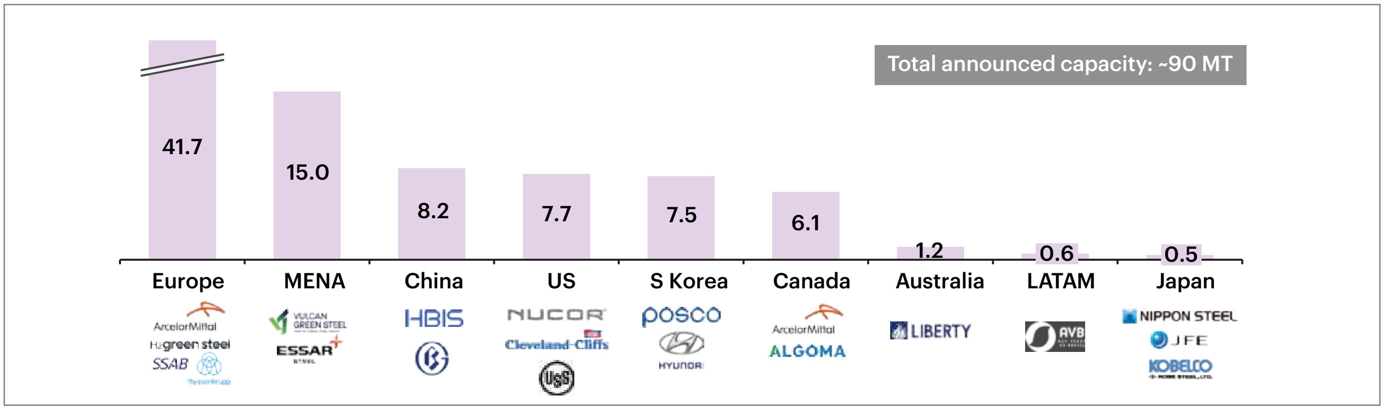


Figure 25: Low Emission Steel announced capacity (MTPA) and major producers

The key trends emerging in global demand and supply of low emission steel are described below:

1. **Regional Demand:**

   Most of the low emission steel transactions so far have been regional in nature. This is in line with the history of inter–regional trade share in global steel market, which has been limited to 10 – 15%[30].

2. **Oversupply in short term:**

   The total announced capacity of global low emission steel projects is 90+ MT, which exceeds the expected demand by 2030.

3. **Limited economic advantage to India:**

   Investments in low emission steel capacities are being made in regions such as MENA and LATAM, which have competitive costs of decarbonization, and are located closer to demand hubs in US and Europe[31].

4. **Restrictive policies:**

   Trade policies such as CBAM in Europe, and the proposed CCA / GASSA in US, are expected to limit imports in these regions from geographies with slower decarbonization pathways[32].

With these factors in play, potential for export of low emission steel from India is expected to be limited in the near term, making it critical to generate domestic demand to absorb the expected rise in LCOS due to focus on decarbonization efforts.

27 *Source: Company announcements, Media reports available in public domain*
28 *Source: LeadIT Green Steel Tracker, SP Global, Company announcements, Industry Reports*
29 *Includes all steel capacities declared as green, low–carbon, low emission, emission–free, zero–emission, carbon neutral, fossil–free, etc. in company reports, including green steel certificates from mass–balance approach, list of producers not exhaustive*
30 *Source: WSA*
31 *Source: IRENA, Statista, Industry Reports*
32 *CBAM: Carbon Border Adjustment Mechanism; CCA: Clean Competition Act; GASSA: Global Agreement on Sustainable Steel and Aluminium*

4.2 Private sector demand in India

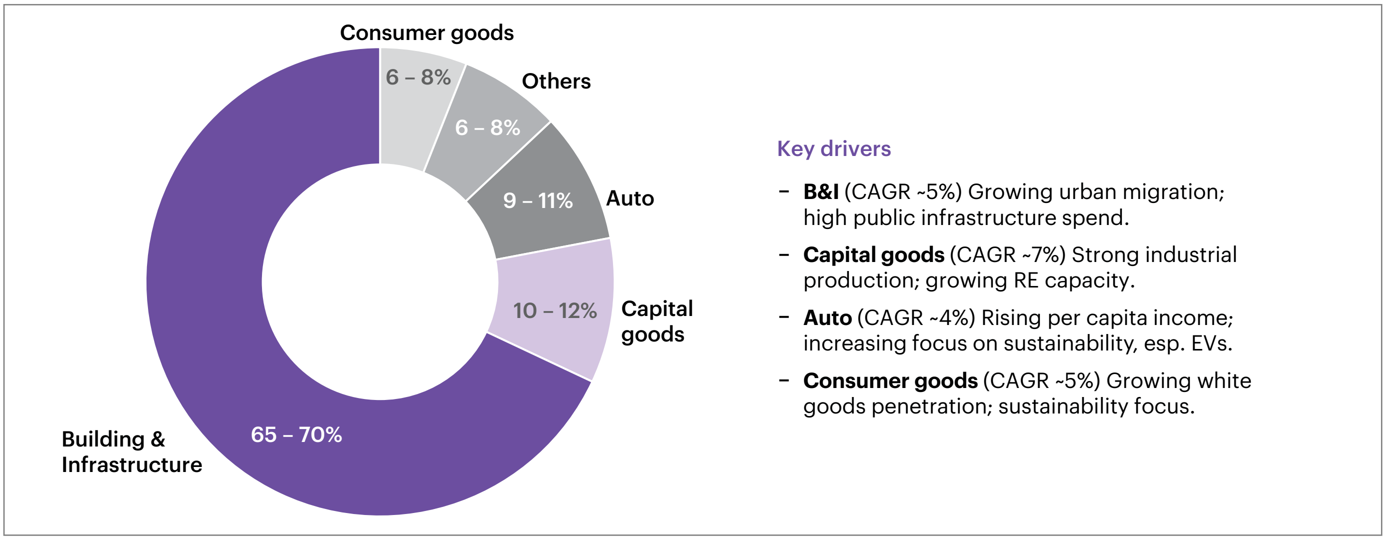


Figure 26: Sectoral split of India's steel demand (2023)

Around two–thirds of steel demand in India comes from construction sector, which includes both public sector infrastructure projects and private sector real estate demand. Majority of the remaining demand comes from capital goods, auto and consumer durables sectors, which are dominated by private players[33]. To understand the appetite for low emission steel in different sectors, discussions were conducted with multiple private players across these end–use sectors.

The discussions indicate that most decarbonization efforts by players across sectors today are focused on value–accretive levers on the cost side (e.g., energy efficiency for scope 1 and 2 emissions) or revenue side (e.g., electric vehicles which is a growing market and impacts scope 3 emissions). With expected higher cost of low emission steel at least in the initial years and limited apparent revenue upside from its use, demand from private sector is expected to be limited to specific applications. The use of low emission steel is expected to be in places where steel is customer–facing ("front end parts"), and too, in premium products (typically higher margin products). Based on primary conversations and benchmarking of global players, use cases for low emission steel in different end–use sectors have been tabulated below. Construction sector, which is the largest consumer of steel, is expected to see the lowest penetration, while auto sector is expected to have the highest adoption. The total low emission steel demand from private sector is expected to be limited to <0.5 MT by 2030.

[33] *Source: Industry Reports, OECD GDP Data, MoS, Kearney*

Sector	Key use cases of 'Low Emission Steel' in short term	2030 expected demand/ penetration[34]
Auto	– Electric four wheelers expected to be the primary use case, given existing sustainability focus in the category. – Within EVs, initial adoption expected to be limited to mid–premium segment (sports/SUV/Sedan models) with typically higher margins.	~0.2 MT (0.6 – 0.8%)
Consumer Goods	– Adoption expected to be limited to premium white goods, with energy efficient ratings (4/5 star) and advanced makes (e.g., front–load washers).	~0.1 MT (0.4 – 0.6%)
Capital Goods	– Offtake expected in specific segments such as wind turbine manufacturing, farm equipment & HEMM equipment. – OEMs with global presence are expected to be first movers.	~0.1 MT (0.3 – 0.4%)
Construction	– Limited adoption across major real estate projects in luxury segment & commercial offices, with high green building ratings.	<0.05 MT (<0.1%)
	Expected total demand	**0.2 – 0.4 MT (0.1% – 0.2%)**

Table 5: Demand for low emission steel in the private sector

[34] *Expected share of low emission steel usage out of total consumption in the sector*

4.3 Public procurement

With demand for low emission steel from private sector players being limited in the shoft term, policy support is critical to kickstart its uptake and support the cost of decarbonization. Globally, governments in US and Europe have introduced green public procurement policies which either mandate purchase of low emission steel in certain projects or make it competitive despite its cost disadvantage. India has also adopted such policies in the past for driving adoption of other green technologies, such as electric vehicles and renewable energy. Details of such policies have been summarized in *Appendix 2*.

Historicaly, public sector has contributed to around one–fourth of steel consumption in India, and it will amount to 50+ MT in 2030[35]. Given this major share, mandates on procurement of low emission steel for public projects can generate significant demand. "Greening" or "Energy Transition" government initiatives in the past, such as RE RPOs, CBG blending, etc., have targeted 5 – 10% adoption (of total public sector procurement) of green technologies in the first 5–7 years. A similar 5 – 10% share of low emission steel in public purchase can create 3 – 5 MT of demand in 2030.

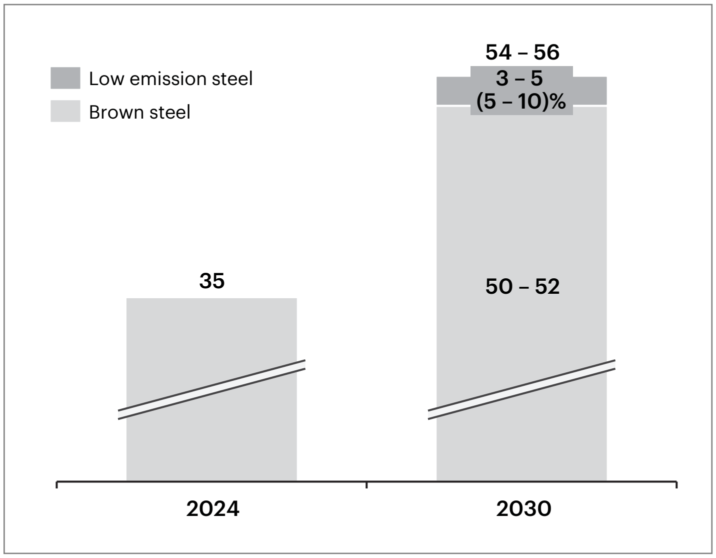


Figure 27: Public sector steel procurement (MTPA)

A premium of \$30/T in initial years, growing to \$50/T+ by 2030, can support the cost of producing low emission steel. At this premium, low emission steel public procurement will require an additional annual outlay INR 2500 – 3000 crores by 2030.

This will result in an annual emissions abatement of 10 – 15 $MtCO_2$, leading to an effective abatement cost of \$20 – 25/tCO_2 for the government, which compares well against other schemes (e.g., ethanol blending GST reduction, FAME subsidy, etc.)[36].

This low emission steel can be used in key infrastructure activities such as construction of highways, metro, etc., basis the total requirement and impact on project cost.

Given that demand for low emission steel will be limited even with public procurement, it is important to define guidelines that can determine the eligibility of producers for calling their steel as "low emission". Therefore, a taxonomy, which proposes a detailed classification mechanism to quantify low emission steel production, is required to be defined in the Indian context.

[35] *Source: Global Efficiency Intelligence*
[36] *Figures estimated basis increase in LCOS across and emission reduction across technologies in RUN pathway*

Taxonomy for low emission steel public procurement

- Review of global taxonomies
- Objective and guiding principles for Indian taxonomy
- Taxonomy for India
- Framework for low emission steel certification and trade
- Roadmap for global alignment

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5.1 Review of global taxonomies

Globally, multiple definitions of green/ low emission steel are in use–there is no universally accepted definition. In select cases, organizations have proposed and adopted their own taxonomy. These taxonomies differ in terms of multiple criteria:

1. Terminology used for low emission / green steel.
2. Methodology to estimate the quantity for such steel.
3. Differentiation of criteria basis product / technology.
4. Emission intensity thresholds for determining quantity of low emission / green steel.
5. Boundary of emissions / scope coverage considered for evaluation.

A summary of global taxonomies is reported below, with select examples detailed in *Appendix 3*.

<table>
<thead>
<tr><th>#</th><th>Organization</th><th>Terminology</th><th>Definition criteria</th><th>Technology/ product differentiation</th><th>Emission intensity threshold</th><th>Scope coverage</th></tr>
</thead>
<tbody>
<tr><td>1</td><td>IEA</td><td>Near zero emissions</td><td rowspan="6">Entire steel production below specified emission intensity threshold</td><td rowspan="4">Sliding scale for scrap mix considered</td><td rowspan="2">Fixed upper limit for given scrap content</td><td rowspan="4">1 & 2 + upstream scope 3</td></tr>
<tr><td>2</td><td>First Movers Coalition</td><td>Near zero emissions</td></tr>
<tr><td>3</td><td>Responsible Steel</td><td>Responsible Steel Performance Level X</td><td rowspan="2">Multiple threshold levels for given scrap content</td></tr>
<tr><td>4</td><td>German Steel</td><td>Low Emission Steel Level X</td></tr>
<tr><td>5</td><td>Global Steel Climate Council</td><td>Lower carbon emissions steel</td><td>Different thresholds for long and flat products</td><td>Declining threshold as per defined trajectories</td><td>1 & 2 + upstream scope 3 + downstream scope 3 (up to hot rolling)</td></tr>
<tr><td>6</td><td>General Services Administration, US Buy Clean Initiative</td><td>Low Embodied Carbon Steel</td><td>Thresholds by finished product type, and differentiated for EAFs vs integrated mills</td><td>Fixed upper limits (basis top 20 %ile emissions) to be revised periodically</td><td>LCA</td></tr>
<tr><td>7</td><td>HYBRIT</td><td>Fossil – free steel</td><td rowspan="2">Entire steel production through proposed route</td><td>NA</td><td>NA</td><td rowspan="2">1 & 2</td></tr>
<tr><td>8</td><td>H2 Green Steel</td><td>Green Steel</td><td>NA</td><td>NA</td></tr>
<tr><td>9</td><td>Multiple steel producers (e.g. Arcelor Mittal, POSCO, Tata Steel, etc.)</td><td>Own branded products (Xcarb, Greenate, Zeremis, etc.)</td><td rowspan="2">Green steel equivalent determined using mass balance approach on verified carbon savings beyond emission intensity threshold</td><td>NA</td><td>Existing respective baseline emissions</td><td rowspan="2">1 & 2</td></tr>
<tr><td>10</td><td>Ministry of Steel Task Force</td><td>Green Steel</td><td>NA</td><td>Declining industry – average threshold derived from CCTS trajectory</td></tr>
</tbody>
</table>

Table 6: Summary of global taxonomies

5.2 Objective and guiding principles for Indian taxonomy

In the Indian context, achieving near–zero emissions in steel production (0.4 tCO_2/tcs for 100% iron ore route and 0.05 tCO_2/tcs for 100% scrap route, as per IEA) is a long–term goal. However, in the short to medium term, consumption of steel produced with lower emissions ('low emission steel') is important to support industry's decarbonization. For private sector players, procurement of steel will be based on audited emission intensities of their suppliers, and alignment of the same with their individual scope 3 emission reduction goals.

Hence, private sector will have limited need for a taxonomy for their procurement. On the other hand, public procurement is expected to be a key driver of low emission steel demand in India. A standardized taxonomy for low emission steel will be critical to enable this and ensure clarity in allocation of associated incentives.

With this objective, Indian taxonomy for low emission steel should abide by four guiding principles:

1. Contextualized for India and its current state of steel production.
2. Provide clear direction on future investments in steel capacity.
3. Ensure ease of adoption by producers and public consumers.
4. Have a well–defined mechanism for MRV.

5.3 Taxonomy for India

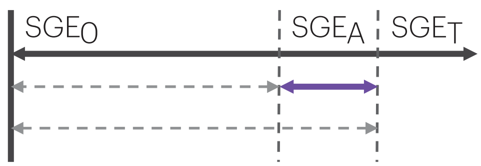
The proposed taxonomy for public procurement of low emission steel in India is as follows:

a. The proportion of low emission steel from a site will be defined as the proportion of overachievement of the actual emission intensity (SGE_A) below the emission intensity target (SGE_T).

b. Here, the actual emission intensity (SGE_A) will be evaluated basis site–level CCTS reporting, and the emission intensity target (SGE_T) will be defined as a uniform sector–level threshold value.

c. The certification for low emission steel will be done based on CCTS MRV, and will be carried out by a national accreditation body appointed by Ministry of Steel[37].

Specific GHG Emissions (SGE) (tCO_2/tcs)



$$Q_{LES} = \left(1 - \frac{SGE_A}{SGE_T}\right) \times Q_{TS}$$

SGE_T – SGE threshold for low emission steel
SGE_A – Actual SGE for the entity
SGE_0 – Zero SGE
Q_{LES} – Quantity of low emission steel production
Q_{TS} – Quantity of total steel production

Figure 28: Illustration of proposed low emission steel taxonomy for India

The proposed taxonomy is aligned to the guiding principles:

a. It is contextualized for India as the emission intensity target will be defined considering the starting point for Indian steel emission intensities.

b. It provides a clear direction on future investments by proposing a uniform sector–level threshold for emission intensity.

c. It ensures ease of adoption by utilizing the already planned CCTS framework.

d. It has a well–defined MRV, in line with that of CCTS, which considers scope 1&2 emissions of a site, and a clear methodology for quantification, with periodically reducing targets.

[37] *MRV: Measurement, Reporting and Verification*

5.4 Framework for low emission steel certification and trade

Framework for certification of low emission steel should be built as an extension to the existing CCTS framework. Eligible producers can file claims for certifying a specified quantum of low emission steel, and carbon credit certificates issued under CCTS should be used to verify and approve such claims. Equivalent low emission steel certificates (LESCs) should be issued via an online registry. The online registry should be linked to a marketplace platform, where producers and consumers are able to trade these certificates in conjunction with an associated physical trade. A detailed visual representation of the framework is presented in *Appendix 4.* In order to enable the same, following enablers are needed:

a. Setup of a national accreditation body, in conjunction with a governance authority, for verification, approval and issuance of LESCs, with development of SOPs to assess claims[38].

a. Establishment of an online registry for issuance and registration of LESCs, and development of a marketplace for LESC trading by producers and consumers.

[38] *SOP: Standard Operating Procedure*

5.5 Roadmap for global alignment

While the proposed taxonomy is contextualized for India, it is important that it evolves with time to enable holistic decarbonization in steel production, as well as ensure export competitiveness in medium to long term. With this view, the proposed taxonomy has been compared with CBAM and Responsible Steel / German Steel taxonomies. The detailed comparison is described below. The major differences which should converge over time are definition of a 'product–level emission footprint' vs the site–level proposed today, as well as expansion of the emission boundary to include upstream scope 3 emissions. A roadmap for the same, along with required enablers has been proposed below.

Parameter	CCTS	CBAM	Responsible Steel & German Steel	Recommendation
Emissions boundary	Scope – 1 & 2 only	Scope – 1,2 & specific upstream scope–3[39]	Scope – 1,2 & upstream scope–3	Scope – 1,2 with upstream scope–3 reporting
Process details	Site level gate–to–gate emissions captured	Product wise emissions intensity segregation based on production routes & emission streams	Site level emissions performance monitoring	Report product footprint for export competitiveness
Emission details	Biofuels emission not reported under overall emissions	Biofuels emission included in overall emissions	Biofuels should meet recognized sustainability std. for reduction	Biofuel emission not to be reported under overall
Monitoring methodology	- Accredited Laboratory analysis for calorific values - EF[40] selection & calculations - Methodology adopted	- Data quality & methods of determining emissions - EF used for indirect energy consumption - Methodology & Calculations	- Emissions measured using recognized regional / international std. - Measuring techniques & quality assurance (ISO14064)[41]	Follow CCTS monitoring guidelines

Table 7: Comparison of low emission steel taxonomy proposed for India with global standards

[39] *Excludes mining, coke ovens, lime kilns & logistics*
[40] *EF: Emissions Factor*
[41] *ISO 14064: verification and validation of GHG statements*

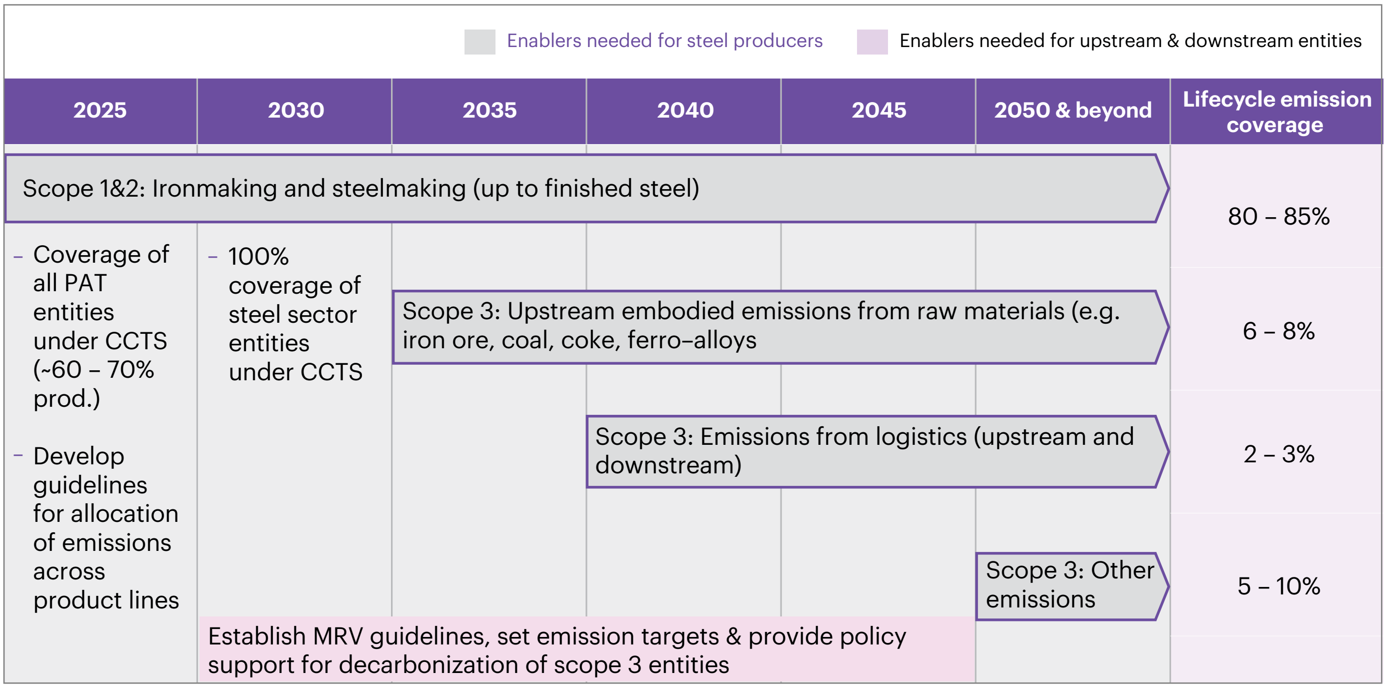


Figure 29: Roadmap for global alignment of low emission steel taxonomy for India[42]

[42] *Source for emissions coverage: EUROFER, WEF, CDP*

Policy Recommendations

IndianSteel ASSOCIATION

KEARNEY

The RUN pathway requires large investments in decarbonization levers, and significant efforts in setting up the enabling ecosystem. This will require support from the government in the form of financial incentives, as well as non–financial assistance to enable adoption of low carbon technologies. The key policy recommendations required are summarized below:

a. Enable adoption of energy efficient technologies:

Investments in BATs and initiatives to improve the thermal and electrical efficiency of existing plants will play a key role in the near term, with potential of being value accretive. While larger steelmakers have made significant progress in this area, smaller players are lagging due to challenges in financing. Government can launch focused schemes to extend loans with preferential interest rates of 6 – 7% for smaller players for deploying energy efficiency measures. The total capex required for such players, which includes coal based DRI producers and induction furnaces, will be ~USD 2 Bn. Multi–stakeholder partnerships can help raise and deploy funds for such schemes, through collaborations between international agencies (e.g., World Bank, UNIDO, etc.) and implementing bodies (e.g., BEE, SIDBI[43], etc.)

b. Incentivize switch to clean and renewable energy:

Growth in steel capacity & associated requirement of energy for captive usage, green hydrogen production and carbon capture projects will lead to an additional load of 80 – 100 BUs by 2040 and 100 – 130 BUs by 2050. While bodies like CEA and PGCIL need to work on strengthening the grid infrastructure to support this load, there is a need for government incentives to ensure continued adoption of clean and renewable power[44]. Waiver of ISTS charges, which contributes to 5 – 10% of landed power tariff has helped in incentivizing RE adoption, especially in states with low RE potential. Extension of this waiver for projects commissioned till 2030 (from existing 2025 deadline), along with additional waivers on electricity duty (another 10 – 15% of tariff), will further enable installation of 25 – 30 GW of RE capacity required by the steel sector in this period.

Further, MNRE can develop centralized regulations for promoting RE installations. A centralized policy is needed on hybrid projects to promote and incentivize high – CUF hybrid capacity. Centralized banking regulations are needed for InSTS open access, which provide higher flexibility on banking duration and optimal banking charges within 2 – 5%. In order to address the intermittency challenges posed by renewables, government should also consider promoting nuclear power as a clean energy source and explore potential for its expansion through NPCIL or public–private partnerships[45].

c. Develop infrastructure for natural gas:

The RUN pathway requires an increase in share of gas based DRI production. Setting up this capacity will require natural gas to be available near key steel producing regions. MoPNG, through its implementing agencies, should commission development of pipeline network in the eastern region to enable supply of 10 – 12 MMTPA natural gas for the steel sector by 2050. An estimated 1500 – 2500 km of pipelines will need to be setup, requiring a total capex of INR 6000 – 9000 crores.

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43 BAT: Best Available Technology; BEE: Bureau of Energy Efficiency; SIDBI: Small Industries Development Bank of India; UNIDO: United Nations Industrial Development Organization
44 CEA: Central Electricity Authority; PGCIL: Power Grid Corporation of India Limited
45 NPCIL: Nuclear Power Corporation of India Limited

d. Support R&D and technology indigenization:

A significant share of decarbonization for steel is dependent on emerging technologies such as hydrogen–based reduction and carbon capture, utilization, and storage. These technologies require scaling up of pilots before they can be deployed at a commercial scale. Currently, India is dependent primarily on import of direct reduction technology for steelmaking. To ensure that hydrogen based direct reduction is successful in the Indian context and is available at commercially feasible rates to be adopted by smaller players, R&D efforts are needed to indigenize the technology. Government can set up a multi – stakeholder consortium for innovation on these topics, comprising of industry bodies (e.g., ISA, SIMA, AIIFA) and their members, research organizations (e.g., NISST, SRTMI) and academia (e.g., CSIR, IITs)[46]. Funding such projects will require mobilization an estimated sum of INR 3000 – 3500 crores over the next 10 years, where INR 1800 – 2000 crores can come in through government grants, and the remaining can be jointly funded by members[47].

e. Set up ecosystem for biochar:

Use of biochar can serve as an additional lever for decarbonization of steelmaking through the traditional blast furnace route. However, supply of biomass today is limited. Government should enable development of ecosystem for collection and processing of biomass to produce biochar. Once the ecosystem is in place, it can explore mandates for 2 – 5% injection of biochar in BF–BOF process.

f. Support adoption of green hydrogen:

Application of green hydrogen to substitute carbon–based reduction will be the primary driver of steel decarbonization in the medium term. However, given the technology is nascent, adequate policy support is required to ensure its adoption while the technology and cost curves evolve. Government can provide production–linked incentives of INR 130 – 150/kg of green hydrogen to the steel sector in initial years to make it commercially viable. The incentives can be reduced over time to INR 80 – 100/kg by 2040 as production costs go down. Mandates for green hydrogen blending of 5 – 10% across production routes should also be issued from 2030 onwards, to accelerate adoption and development of the technology.

Meanwhile, MNRE (in collaboration with other relevant ministries) can ensure that a robust transportation network is setup for green hydrogen through dedicated pipelines as well as retrofitting of existing gas pipelines to supply steel producing regions. Government can also appoint nodal agencies to enable demand aggregation and set up of green hydrogen production hubs near steel belts, to ensure ease of access for smaller producers.

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[46] *ISA: Indian Steel Association; SIMA: Sponge Iron Manufacturers Associations; AIIFA: All India Induction Furnaces Association; NISST: National Institute of Secondary Steel Technology; SRTMI: Steel Research and Technology Mission of India; CSIR: Council of Scientific and Industrial Research*

[47] *Figures based on typical spend and government contribution for decarbonization related R&D in Europe, Japan, US, etc., indexed for Indian steel sector; includes existing allocation under schemes such as National Green Hydrogen Mission*

g. Develop ecosystem for carbon capture, utilization, and storage:

CCUS will be a critical lever in the long term to abate all remaining emissions once other levers reach their limits. However, significant efforts are required in developing the technology as well as planning for its deployment. Government can support depoyment through viability gap funding of 20%+ for carbon capture projects in the steel sector. It can also engage national think tanks (e.g., NITI Aayog) to develop a comprehensive national policy for CCU / CCS. Such framework can include potential mandates on utilization of captured carbon across industries such as urea, methanol, a robust framework for setup of dedicated CCU clusters with long–term offtake agreements, and policies for allocation of storage sites. It can also explore performance–based tax credits carbon capture projects with annual carbon capture thresholds and compliance with storage / utilization requirements.

While utilization of captured carbon has established applications, there is limited knowledge on potential of carbon storage sites in India. Government should assemble a taskforce / committee on CvCS comprising of MoS, MoHI, MoPNG, MoC, MoES, MoEFCC, etc. to explore carbon storage sites and plan networks for CO_2 transportation[48]. This taskforce should guide commissioning of projects for exploration of storage sites through ONGC, OIL, CIL, etc., and initiate phase–wise development of CO_2 pipeline network through GAIL, IOCL, etc.

h. Support growth of scrap ecosystem:

According to the RUN pathway, 130 – 140 MTPA of scrap–based steel production will be required in the country by 2050. As generation of domestic scrap grows and imports become difficult, domestic capacity will be needed for scrap collection and recycling, with ~2400 collection and dismantling centers, and ~1100 shredders. The government can facilitate this setup through capital subsidies of 10 – 20%, and create favorable environment for investment in such facilities through other measures such as assistance in land acquisition and development of common infrastructure for utilities, waste disposal, etc. In addition, it can consider simplification of taxation regime and compliance for scrap ecosystem with consideration of formal and informal players present in the value chain. It can also ensure strict compliance with existing / proposed policies such as E–Waste Management Rules, ELV Management Rules, C&D Waste Management Rules; and introduce end of life waste management compliance for other sectors such as solar/wind power equipment[49].

i. Establish a strong carbon market:

Reaching near–zero emissions in the steel sector by 2070 will require significant investments. Materializing these investments will require imposition of an equivalent carbon price on the sector. Government of India has announced a national carbon market under the Carbon Credit Trading Scheme. While the actual carbon price will be market determined, BEE must ensure the market is well–regulated to ensure the RUN pathway is achieved in a sustainable manner. It should also ensure that coverage of the carbon market expands to all producers and there is strict compliance and active participation by players.

j. Enable transition for smaller producers:

While all players will require support for transitioning to near–zero emission steel production, smaller producers face unique challenges. They have limited access to capital through market sources and have limited resources to develop awareness and technical expertise for adopting new technologies. In this context, government can help set up energy transition funds through collaborations between international agencies (e.g., World Bank, UNIDO, JICA, etc.) and implementing bodies (e.g., BEE, SIDBI, etc.), to support investments by smaller players through direct funding for RE, green hydrogen, etc.,[50]. It should also develop ups killing and knowledge transfer programs for these players on emerging technologies, CCTS mechanism, financial assistance schemes, etc.

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[48] *MoS: Ministry of Steel; MoHI: Ministry of Heavy Industries; MoPNG: Ministry of Petroleum and Natural Gas; MoC: Ministry of Coal; MoES: Ministry of Earth Sciences; MoCF: Ministry of Chemicals and Fertilizers; MoEFCC: Ministry of Environment, Forestry and Climate Change*

[49] *ELV: End of Life Vehicles; C&D: Construction and Demolition*

[50] *UNIDO: United Nations Industrial Development Organization; JICA: Japan International Cooperation Agency*

k. Incentivize demand generation for low emission steel:

As producers invest in decarbonization technologies, levelized cost of steel is expected to increase. Hence, it is important to create a market for low emission steel associated with a premium. Government can support this demand generation through public procurement of 3 – 5 MTPA of low emission steel over the next decade, accounting for 5 – 10% of public procurement, at a potential premium of $30 – 50/T. In addition, the government can develop policies to promote offtake of low emission steel in the private sector.

A reduction in GST rate for low emission steel from typical 18% to 5% can push private sector demand. Government can also impose mandates on reporting of scope 3 emissions, starting with top 1000 listed companies, to drive focus of steel consumers on reducing upstream emissions. It can also explore mandates on low emission steel purchase for large consumers in auto, appliances, and construction sectors. Meanwhile, Ministry of Consumer Affairs should issue BIS – equivalent standards on reporting of CCTS – compliant emissions and mandate them for all steel sales in the country, to establish relevance of embedded emissions in the steel value chain. Additionally, to ensure that high emission steel imports do not impede adoption of low emission steel, an Indian carbon border tax can be explored in the medium term, basis learnings from implementation of CBAM in Europe.

In the recommendations, select policies have been defined specifically for high–emitting, smaller players to ensure they are able to follow the decarbonization pathway. These include low–interest loans for energy efficiency, transition funding for low carbon technologies, setup of green hydrogen hubs, upskilling and knowledge transfer programs, and R&D for technology indigenization.

The policy interventions will require implementation over a phased manner in the future, with dedicated outlay from the government, as described below:

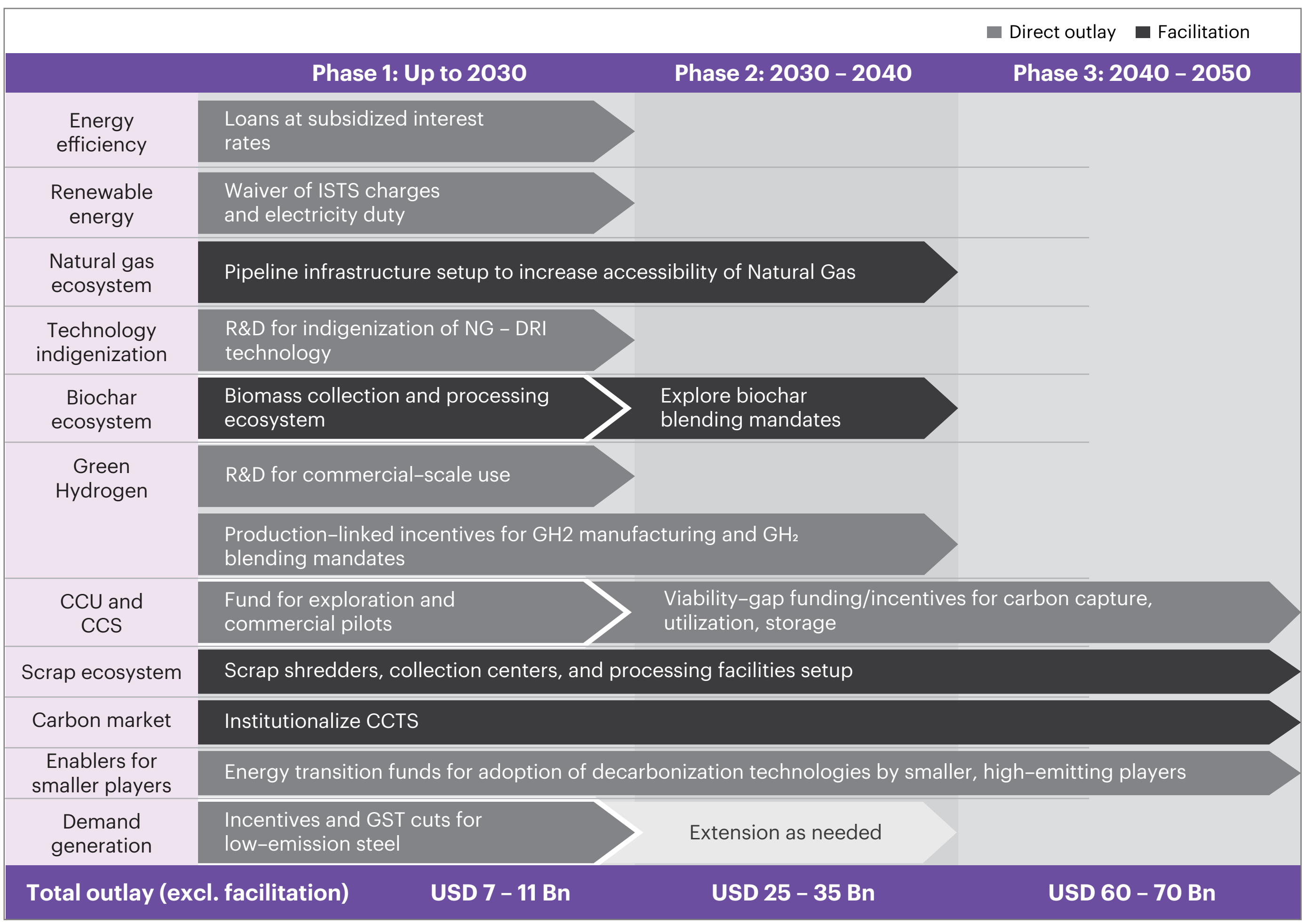


Figure 30: Timeline and outlay for key policy interventions

Role of stakeholders

IndianSteel Association

KEARNEY

While policy support from government can help create a favorable environment for decarbonization, it will be equally important for producers to play an active part in managing their own decarbonization efforts. Steel producers need to act across six key areas to enable the transition to near–zero emissions production:

1. **Measurement:**

   Producers should set up systems for measuring emissions and define a baseline. This should be followed by continuous monitoring & reporting of emissions.

2. **Target setting:**

   Once an emission baseline is established, producers should set ambitious goals on their decarbonization path, with clear targets set for near and medium term.

3. **Investment:**

   Intelligent capex planning will be critical for both new capacity and modification of existing plants. This requires careful evaluation of commercial factors, carbon impact and techno–economic feasibility of various options, to make the right investments.

4. **Innovation:**

   Emerging technologies such as hydrogen and CCUS require significant research and pilots to reach commercially viability. ISPs should lead the effort through in–house R&D and global technology transfer agreements.

5. **Collaboration:**

   ISPs should transfer knowledge on energy efficiency initiatives with smaller players. Steel producers and developers should come together to build high–capex shared assets such as RE farms and Green H2 hubs.

6. **Market development:**

   Producers should actively engage with consumers to develop the market for low emission steel. In the near term, it should involve engaging with public sector on enabling public procurement of low emission steel. In the medium term, producers need to engage with private sector customers to develop low emission steel as a lever for scope 3 emission reduction.

Meanwhile, industry bodies such as ISA, SIMA and AIIFA should actively engage with stakeholders across the spectrum to enable a smooth transition for the industry[51]. They should actively participate in discussions with government authorities to finalize a sectoral decarbonization roadmap for the industry, and advocate for policy interventions required to support the same. They should promote knowledge sharing amongst members, as well as leverage connects to enable technology transfer from global players. They should support smaller producers in creating awareness around decarbonization, help them set up emission monitoring systems, and educate them on government policies and best production practices in the industry. They should also engage with end–consumer industry bodies and global forums to promote adoption of low emission steel produced in India.

[51] *ISA: Indian Steel Association; SIMA: Sponge Iron Manufacturers Association; AIIFA: All India Induction Furnaces Association*

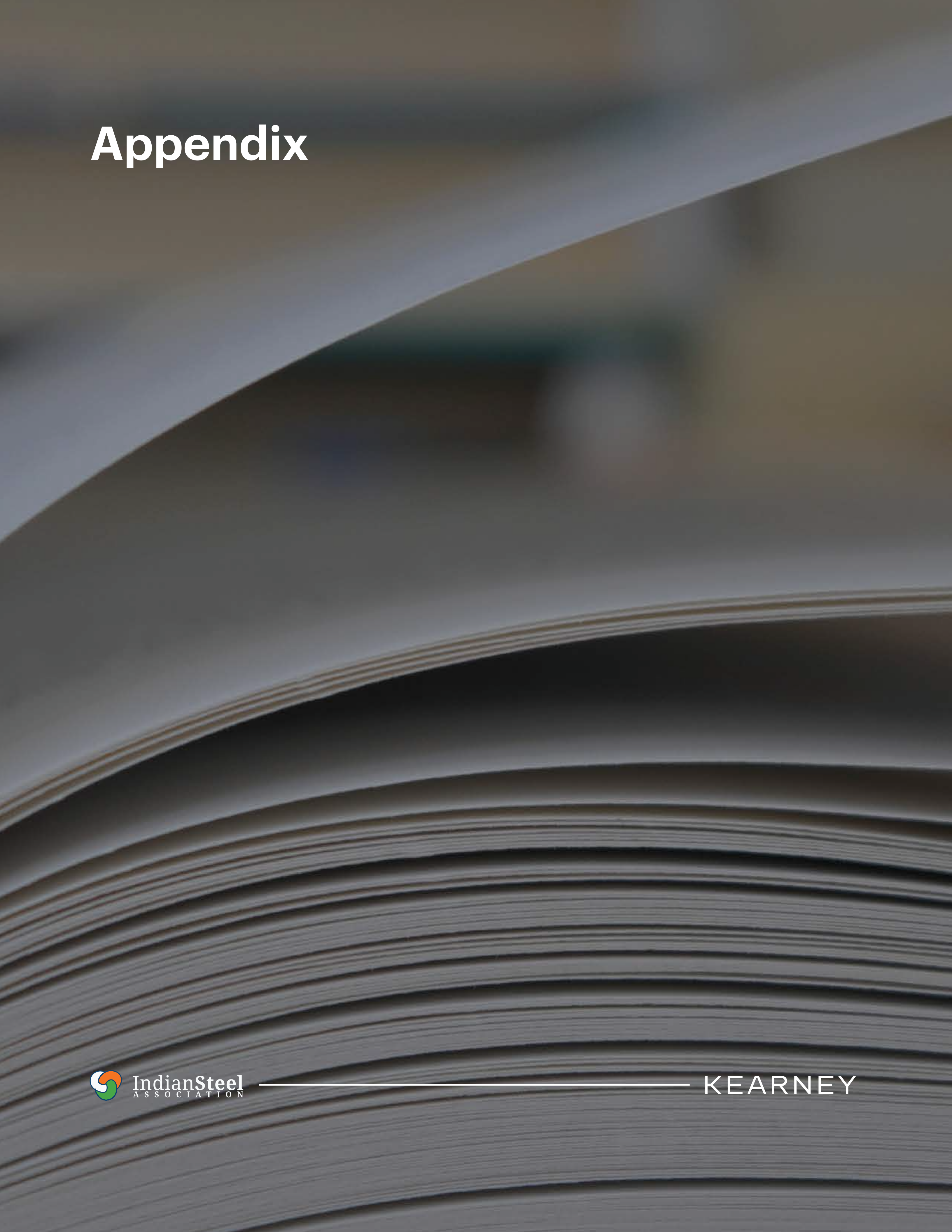
Conclusion

With Indian steel sector poised for a strong growth over the upcoming decades, curbing emission is imperative to ensure India achieves its 2070 Net Zero.

The existing policy frameworks should be further strengthened, by coupling with additional policies with robust governance to ensure the emission reduction targets defined in the pathway are being met by the producers. Further, setting up of adequate enabling infrastructure to help producers deploy relevant decarbonization levers is critical.

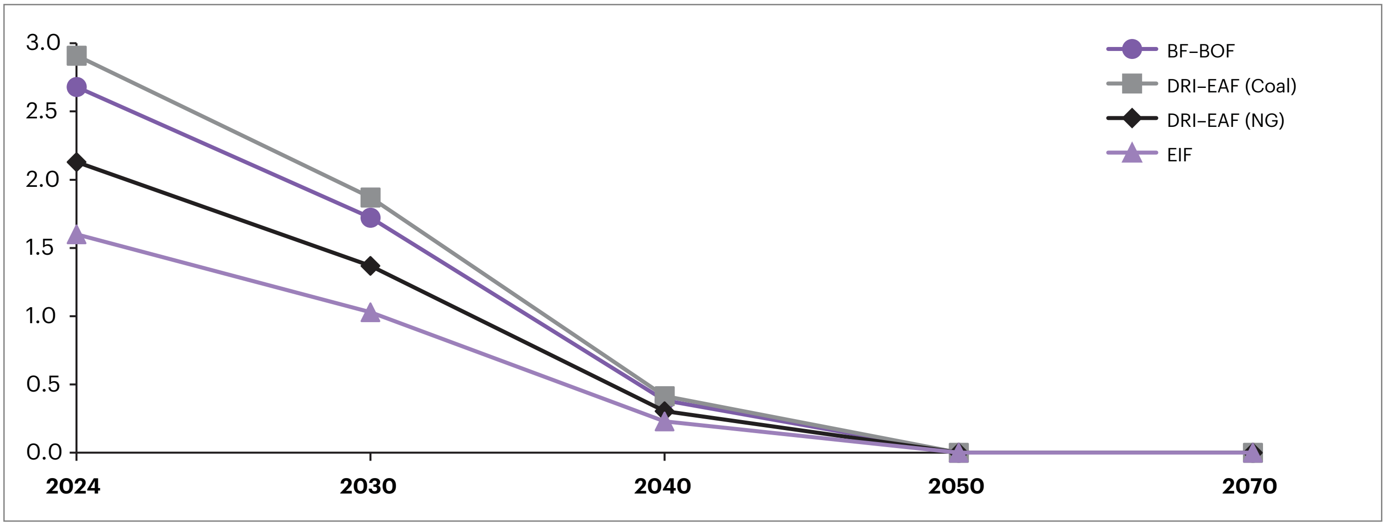
Decarbonization of steel sector would require combined effort across all stakeholders including steel producers, policy makers, academia, and associations to enable the successful implementation of the roadmap.

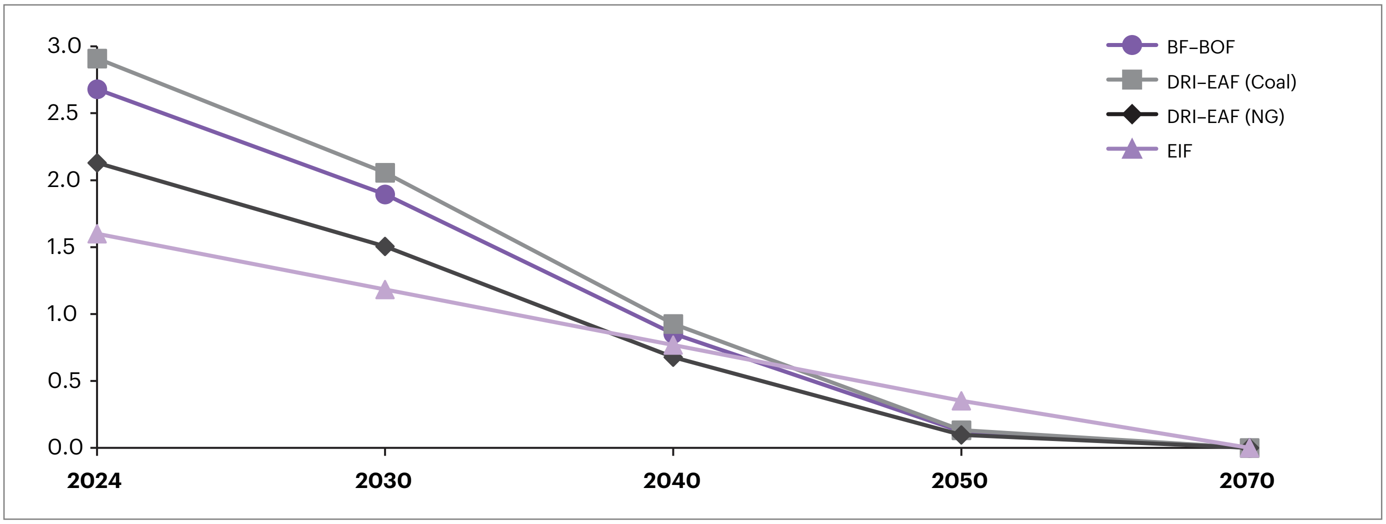
Appendix



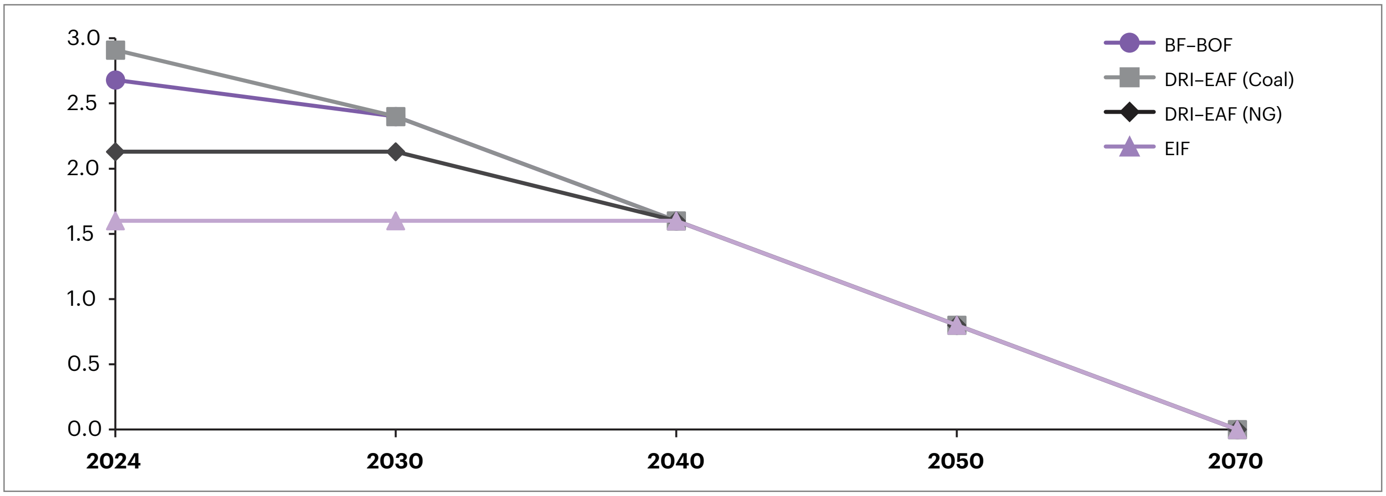
Appendix 1: Details on decarbonization pathways

EU–ETS pathway:

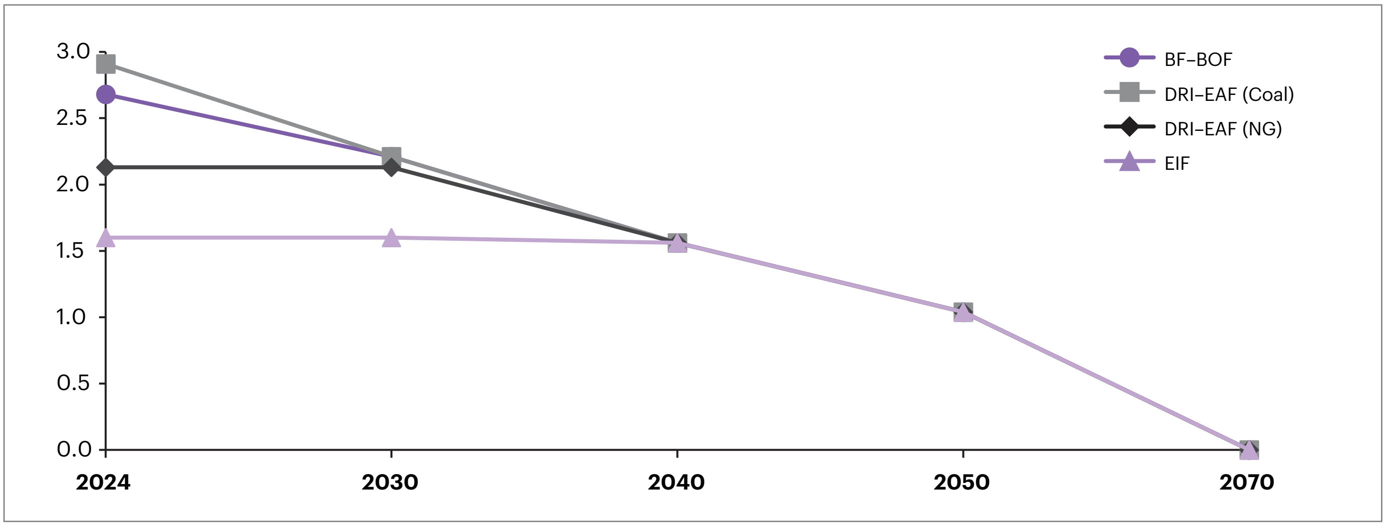




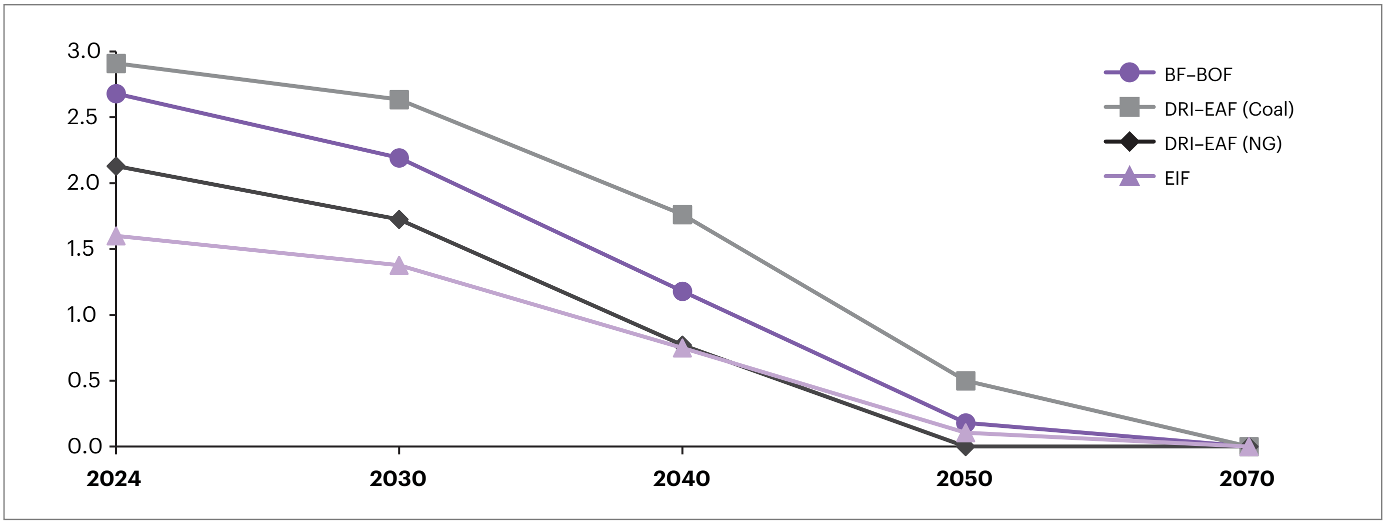
German Steel derived pathway:



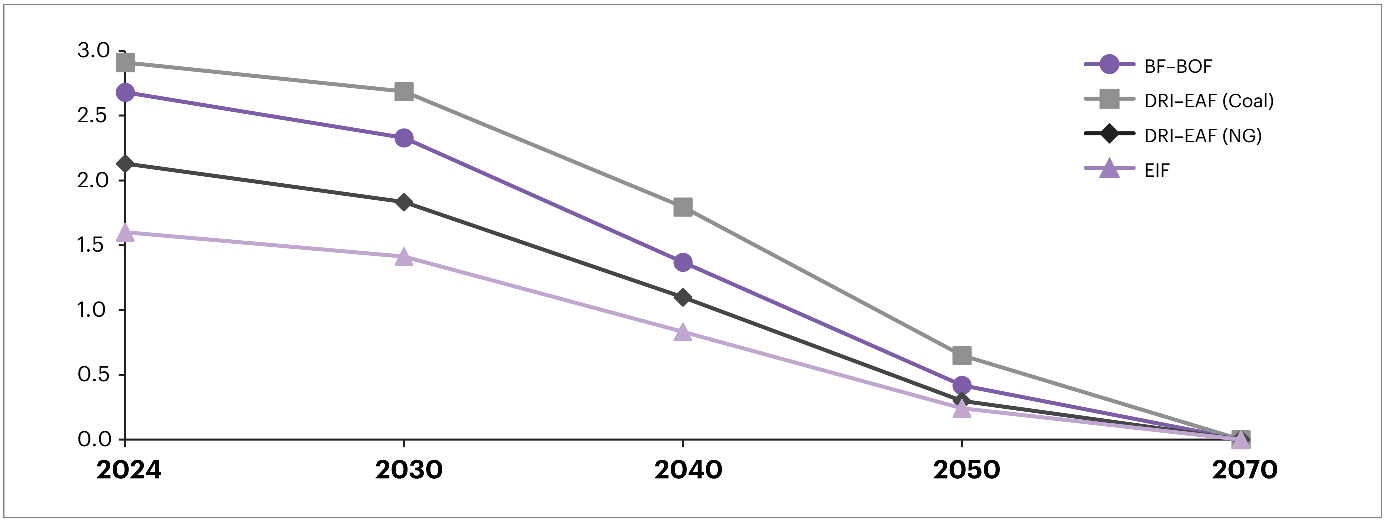
IEA derived pathway:



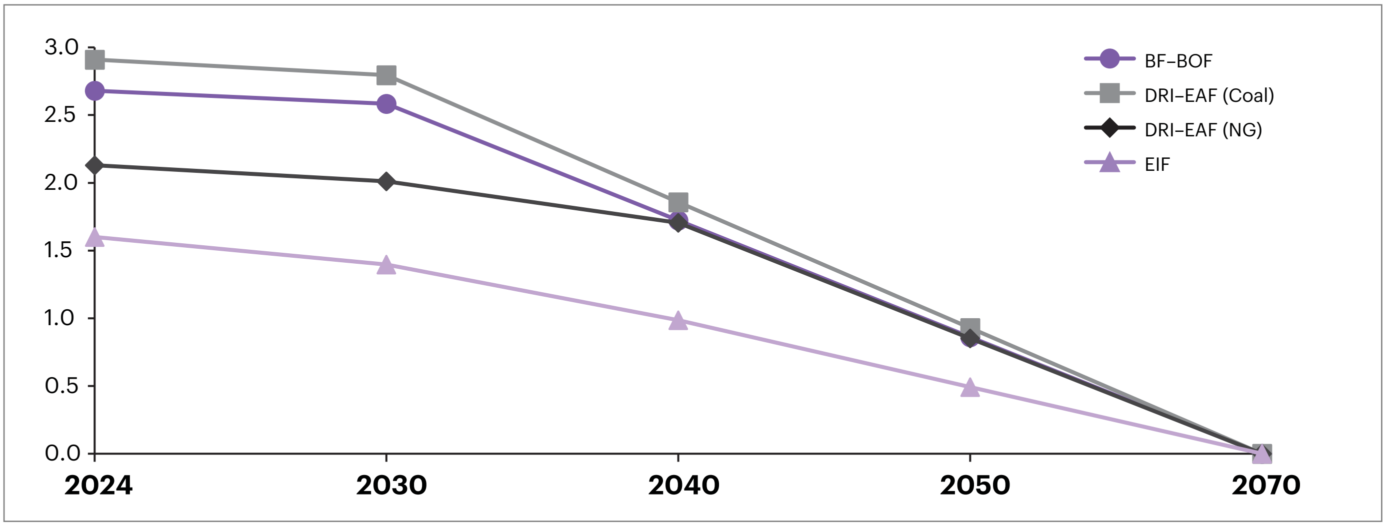
FLY pathway:



RUN pathway:



WALK pathway:



Appendix 2: Key enablers for decarbonization of steel sector

KPI	Units	2030	2040	2050	2070
RE capacity[52]	GW	20 – 25	35 – 40	50 – 55	90 – 95
GH_2 requirement	Mn TPA	0.1 – 0.3	1 – 1.5	1.5 – 2	3 – 3.5
Electrolyzer capacity for GH_2	GW	0.5 – 1	7 – 9	10 – 13	18 – 20
Natural Gas requirement	Mn TPA	6 – 8	9 – 11	11 – 13	27 – 30
Carbon storage/ utilization requirement	$GtCO_2$	–	0 – 0.2	1.5 – 2	10 – 12
Iron ore consumption	Mn TPA	335 – 345	490 – 500	620 – 640	890 – 910
Scrap consumption	Mn TPA	55 – 60	75 – 80	130 – 140	260 – 270

[52] *Includes RE for Green H_2 production and carbon capture*

Appendix 3: Benchmarking of proposed policy recommendations through select global and Indian examples[53]

The decarbonization roadmap seeks to answer key questions for major stakeholders in the Indian steel sector, as detailed below:

1. Low – interest loans for energy efficiency measures for smaller players

a. India: Assistance to Develop Energy Efficiency and Technology in India (ADEETIE)

- *The ADEETIE Scheme, overseen by the Bureau of Energy Efficiency, is an online platform designed to encourage and scale up energy efficiency financing for MSMEs and other industries.*
- *It aims to offer interest subvention of 4 – 8"% on energy efficiency projects.*

b. China: Carbon Emission Reduction Facility (CERF)

- *Under this facility, the People's Bank of China provides low–cost funding for green and low–carbon projects.*
- *60 percent of the principal for such projects is funded through central bank lending for a certain period of time at an interest rate of 1.75 percent.*
- *The facility has motivated financial institutions to issue over RMB670 billion in loans and facilitated carbon emission cut in the amount of 150 million tons from Nov 2021–Apr 2023.*

c. India: Interest Subvention Scheme for MSMEs

- *MSMEs were provided interested subvention of 2% on incremental credit under this scheme.*
- *The scheme ran from FY19 – FY21 with a total allocation of INR 975 Crores.*

2. Incentives on deployment of renewable energy projects

a. India: ISTS Waivers

- *Inter–state transmission charges are fully waived for 25 years for new renewable energy projects completed by June 2025, to promote renewable capacity addition.*

b. US: Inflation Reduction Act (IRA)

- *Production tax credits up to 3.05 ¢/kWh (~INR 2.55/kWh) are provided under IRA, for energy generated in the first 10 years of new renewable energy projects.*

3. Enabling supply of natural gas

a. Europe: Projects of Common Interest (PCI)

- *PCIs are key infrastructure projects aimed at completing the European internal energy market and help the EU to achieve its energy and climate objectives.*
- *Projects in the PCI list get fast–tracked planning permissions and are eligible for EU funding under the Connecting Europe Facility.*
- *Major gas pipeline projects such as IGB Pipeline, Baltic Pipe, EastMed Pipeline, etc. have been / are being supported as PCIs.*

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53 *Source: Respective government department websites and publications*

b. Nigeria: Ajaokuta – Kaduna – Kano (AKK) Project

- *The AKK project is a $2.8 Bn natural gas pipeline under construction in Nigeria, with the government providing a sovereign debt guarantee for financing the same.*
- *The pipeline is expected to be operational in 2025 and improve power availability in country's northern region through addition of 3,600 MW power to national grid.*

4. Support for R&D in low emission steelmaking technologies

a. Europe: Clean Steel Partnership (CSP)

- *The CSP is a European co-programmed public-private partnership established between European Commission and European Steel Technology Platform, an association constituting of steel producers and academic institutions as members.*
- *It aims to develop technologies at a high readiness level (TRL8) to reduce the CO_2 emissions stemming from EU steel production.*
- *The funding for CSP is provided through public pillars of Horizon Europe (HEU) and Research Fund for Coal and Steel (RFCS), totaling EUR 700 Mn (~INR 6,500 Cr) over 2021-2027, with matched contribution from the private sector.*

b. Japan: Hydrogen Steelmaking Consortium

- *The consortium comprises of major Japanese steel producers along with Japan Research and Development Center for Metals, with support from universities and research institutes.*
- *It aims to develop technologies for use of hydrogen for carbon-neutral steelmaking process across blast furnaces and DRI.*
- *The research is fully funded through Japan's Green Innovation Fund, with JPY 193.5 Bn (~INR 11,000 Cr) allocated for steel sector.*

5. Support for establishing ecosystem for biochar

a. US: Policies for biomass collection and utilization

- *Biomass Crop Assistance Program provides financial assistance to landowners and operators for up to 50% of the cost of establishing a biomass feedstock crop, annual payments for 5 – 15 years for feedstock and payments of up to $20/DMT for sales to advanced biofuel production facilities.*
- *Biomass Thermal Energy Bioincentive Program by Minnesota Department of Agriculture provides incentives of up to $5 /MMBtu of power production.*

b. Indonesia: Policies for biomass collection and utilization

- *PLN, the state-owned power company, and the Ministry of Energy and Mineral Resources, have announced plans to implement biomass co-firing at 52 coal units, leading to 10% contribution in generation mix by 2050, equal to ~19 GW of capacity.*
- *Indonesia has affirmed the plan by including biomass co-firing in its 2022 enhanced Nationally Determined Contribution (NDC), targeting 9 MT biomass utilization by 2030.*

c. India: Policies for biomass collection and utilization

- *Biomass Programme by MNRE provides central financial assistance of up to INR 45 Lakhs for set up of biomass briquette / pellet plants and up to INR 5 Crores for biomass co-generation projects.*
- *Revised Biomass Policy by Ministry of Power mandates 5% co-firing of biomass in all coal-based thermal power utilities.*

- *Ethanol Blended Programme by MoPNG targets 20% ethanol blending in petrol by FY26 and provides support through measures such as interest subvention up to 6% on to establish or expand distilleries, incentives of INR 6–7/L on ethanol produced from C–heavy molasses, reduced GST (18% to 5%) on ethanol, etc.*

6. Incentives for green hydrogen production

a. US: Inflation Reduction Act (IRA)

- *Production tax credits up to $ 3/kg (~INR 250/kg) are provided under IRA for clean hydrogen production.*

b. Europe: European Hydrogen Bank (EHB)

- *EHB provides subsidies for renewable hydrogen production, allocated via auctions, with a ceiling price of EUR 4.5/kg (~INR 415/kg).*

c. India: National Green Hydrogen Mission

- *MNRE is providing subsidies of up to INR 50/kg, allocated via tenders, with 2 rounds of tendering already completed.*

7. Viability Gap Funding for CCUS

a. US: Inflation Reduction Act (IRA)

- *Tax credits up to $85/tCO_2$ for CCS projects and $60/tCO_2$ for CCU projects are provided under IRA.*

b. UK: Carbon Capture Storage and Infrastructure Fund

- *An amount of GBP 1 Bn has been pledged for this fund, with the aim of establishing four CCUS clusters in the country by 2030, leading to capture of 20 – 30 MtCO2 per annum.*

c. India: Viability Gap Funding schemes

- *Various VGF schemes are in place to provide support for 20 – 40% of project costs to clean technologies such as offshore wind projects, battery energy storage systems, etc.*

8. Support for growth of scrap ecosystem

a. Germany: E LV Ordinance

- *Scrapping is permitted only by authorized collection and dismantling facilities, who can further transfer shells (bales) only to authorized shredding facilities, post issuing Certificate of Destruction.*
- *OEMs are obligated to take back ELVs free of charge via a comprehensive network.*
- *Recovery rates for ELVs by net weight of vehicle are clearly defined (85% must be reused/recycled and 95% must be reused/recovered).*

b. India: State–wise schemes

- *Various states such as Odisha, Telangana, etc. provide capital subsidies of 10 – 20% for set up of Registered Vehicle Scrappage Facilities.*
- *Government of Maharashtra plans to set up four circular economy parks, including shipbreaking, e–waste, auto parts and steel scrappage, with incentives for first comers such as lower utility tariffs, cheap land access, etc.*

9. Establish a strong carbon market

a. Europe: EU – Emissions Trading System (ETS)

- *EU – ETS has led to a strong carbon market in Europe, with current price of ~$75/tCO2, and has helped bring down power and industry emissions by 47% vs 2005 levels.*
- *It has raised over EUR 175 Bn since 2013, which has supported investments in RE, energy efficiency and low carbon technologies across EU member states.*

b. China: National Emissions Trading System (ETS)

- *China's ETS, established in 2021 is the largest in the world, covering 5 Bn tCO_2, accounting for 40% of country's emissions.*
- *It registered a compliance rate of 99.5%, with trade volume growing 316% and price rising by 23% in 2023.*

10. Energy transition funds for small producers

a. India: GEF – UNIDO – BEE Project

- *The project, running from 2011 to 2022, offered grants for promoting energy efficiency and renewable energy across select MSME clusters, supported by GEF grant of $7 Mn.*

b. Japan: Green Transformation (GX) Plan

- *The plan aims to implement supportive measures amounting to JPY 700 Bn (~INR 40,000 Cr) to assist the low carbon transition of SMEs, particularly to improve energy efficiency and achieve zero emissions for buildings.*

c. Bosnia and Herzegovina: Inclusive Decarbonization Activity (IDA) Project

- *The IDA project, financed by Government of Japan and backed by UNDP, is supporting 20 SMEs across three sectors–power, steel and cement, through technical and financial assistance for implementation of energy efficiency measures and renewable energy.*

11. Green public procurement initiatives and incentives for low emission steel

a. US: Federal Buy Clean Initiative

- *US General Services Administration received $2 Bn (~INR 16,500 Cr) under IRA in 2022 for funding for low–carbon materials.*
- *The funding will be used across 150 federal construction projects over 2 – 3 years to procure low–carbon steel, concrete, asphalt, and glass.*
- *Materials purchased for these projects should have GWP within top 20%ile of the industry.*
- *Similar initiatives will be undertaken by Department of Transportation for highway projects.*

b. Japan: Green Transformation (GX) Plan

- *The plan aims to provide tax credits up to JPY 20,000 /T (~INR 11,500/T) for production of green steel up to 10 years.*

c. Netherlands: CO_2 Performance Ladder

- *Organizations are evaluated on their CO_2 management practices (including scope 3 emissions) and their performance is certified across 5 levels.*
- *These certificates are used in public tenders to award 'fictitious discounts' on the price quoted by organizations, providing advantage to organizations with higher levels.*
- *The CO_2 Performance Ladder is also being rolled out across other European countries.*

d. Germany: Assessment System for Sustainable Building

- *German federal government has devised a comprehensive system to evaluate all federal building projects.*
- *The criteria include ~3% weightage for total GWP during the lifecycle of the project.*
- *The program is being extended to include additional emission limits for specific materials such as green steel and cement.*

e. India: EESL EV Tender

- *EESL conducted a competitive bidding process for procurement of 10,000 electric vehicles.*
- *The cars were to be used for replacement of existing petrol/diesel vehicles used by government agencies.*
- *The objective of the initiative was to create the market for electric vehicles through initial aggregation of demand and bulk procurement.*

Appendix 4: Select deep dive on global taxonomy examples

A. ResponsibleSteel[54]

Responsible Steel is an international, non–profit multi–stakeholder membership organization.

Standard with 12 principles defined to certify a site as a producer of Responsible Steel.

Governance Principles
1. Corporate leadership
2. Social, Environmental, Governance management systems
3. NEW: Responsible Sourcing
4. Decommissioning and Closure

Social Principles
5. Occupational health and safety
6. Labor Rights
7. Human Rights
8. Local Communities
9. Stakeholder engagement and communication

Environment Principles
10. Climate change and greenhouse gas emissions
11. Noise, emissions, effluents, and waste
12. Water stewardships
13. Biodiversity

Select prominent members of Responsible Steel

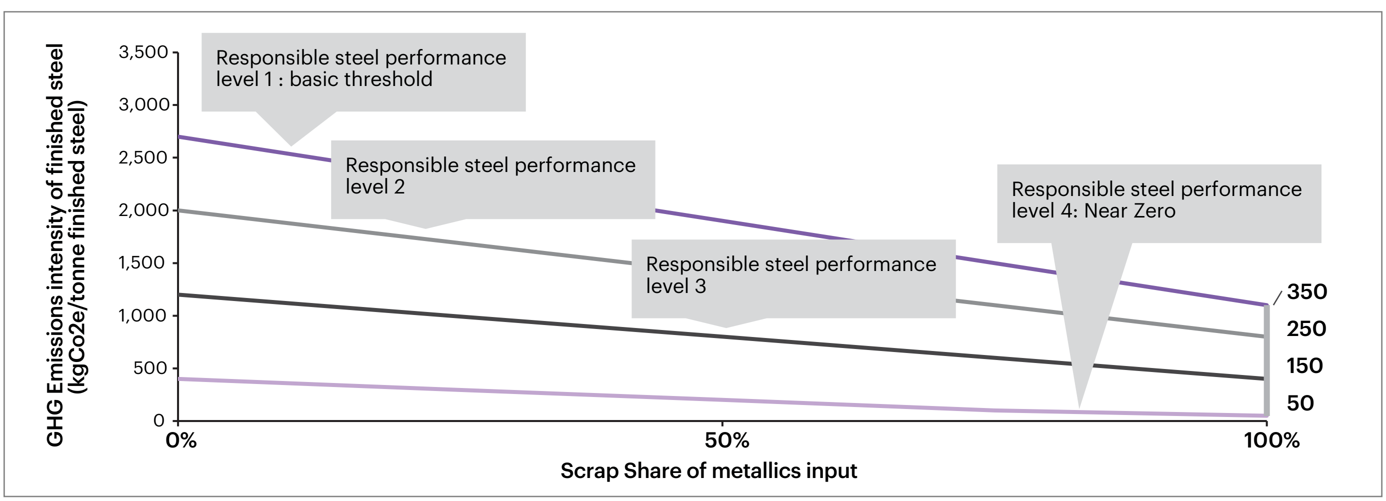


Figure 31: Performance levels for GHG emission intensity under ResponsibleSteel

[54] https://www.responsiblesteel.org/

B. GermanSteel[55]

Wirtschaftsvereinigung Stahl

Categorization of visual reference plants into the classification system for green steel production

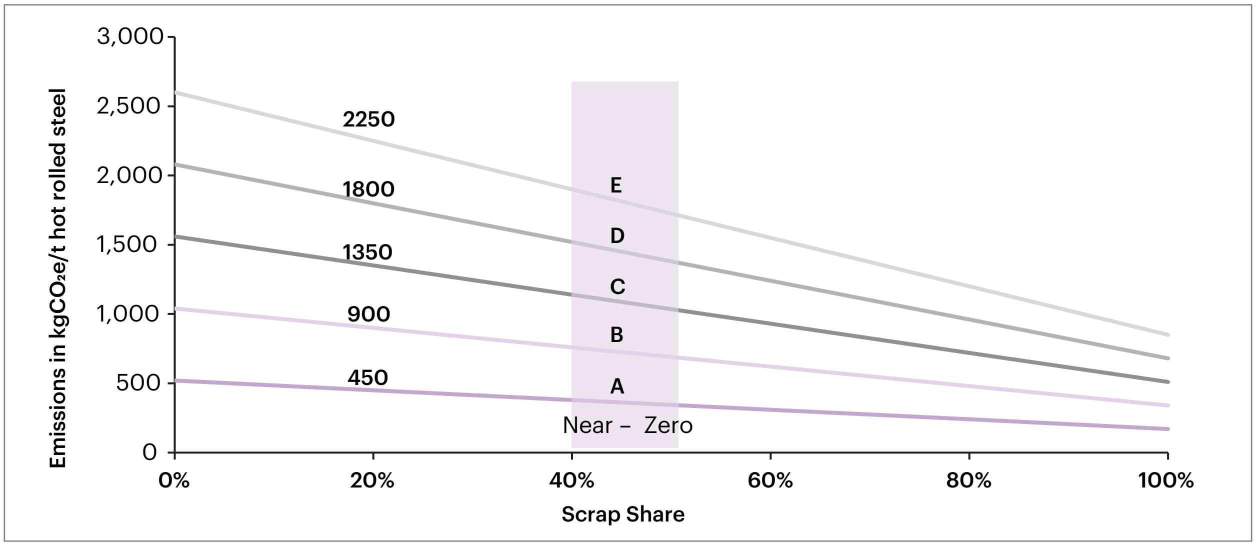


Figure 32: Performance levels for GHG emission intensity under German Steel

Select prominent members of German Steel

thyssenkrupp, MAX AICHER, SALZGITTER AG Stahl und Technologie, Georgsmarienhütte GmbH · seit 1856 · Edelstahl, ArcelorMittal

[55] https://www.stahl-online.de/

C. Taskforce by Ministry of Steel

इस्पात मंत्रालय
MINISTRY OF
STEEL
सत्यमेव जयते

The taskforce is taking a fixed intensity route for defining green steel

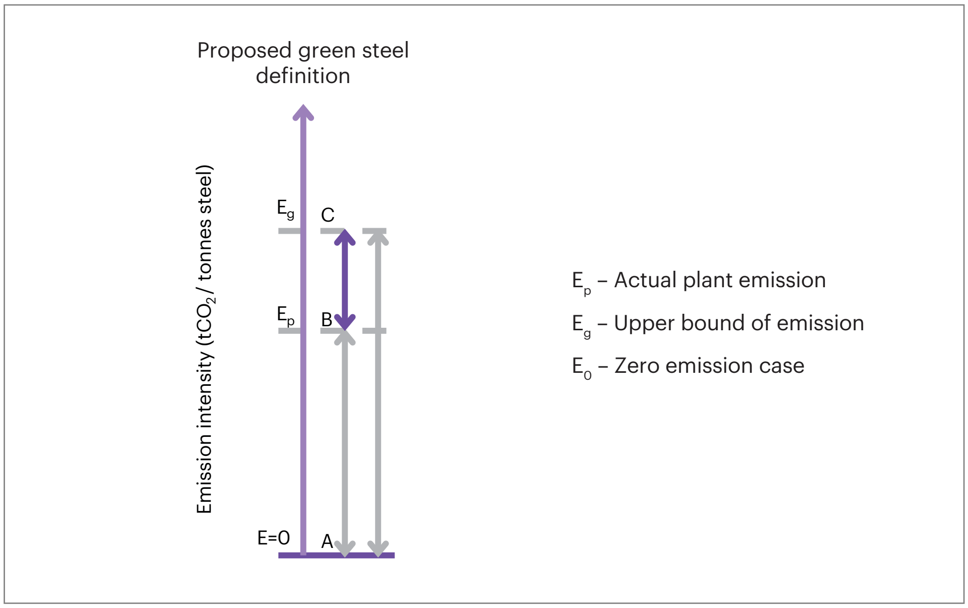
Based on emission accounting methodology, average emission of Indian Steel makers (E_a)

Through CCTS, BEE to measure E_p for all obligated entities under the PAT/CCTS scheme.

Upper bound of emission (E_g) calculated basis 85% of Ea

$$P_{GS} = \left(1 - \frac{E_p}{E_g}\right) \times P_{TS}$$

Green steel proportion shall be defined by above equation, whereby manufacturers will be incentivized to move towards Net Zero emissions.



Salient points

1. Emission boundary: scope 1 & scope 2 emission included.
2. Benchmark: Upper threshold based on 15% lower than industry average.
3. Process / production: No dynamic guideline based on technology / scale.
4. MRV: Based on CCTS MRV framework in line with past PAT scheme's MRV.

Appendix 5: Framework for LES Certification and Trading[56,57]

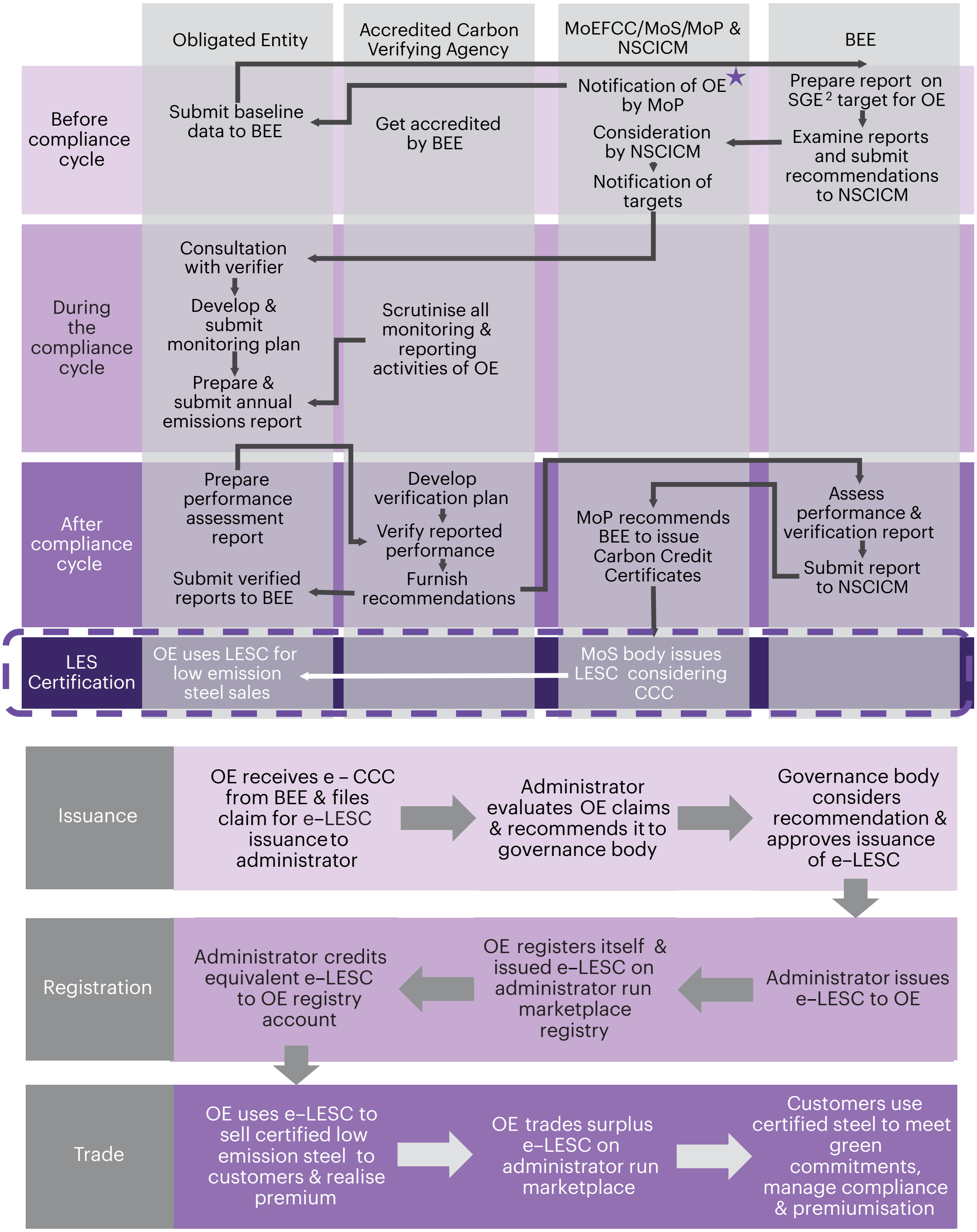
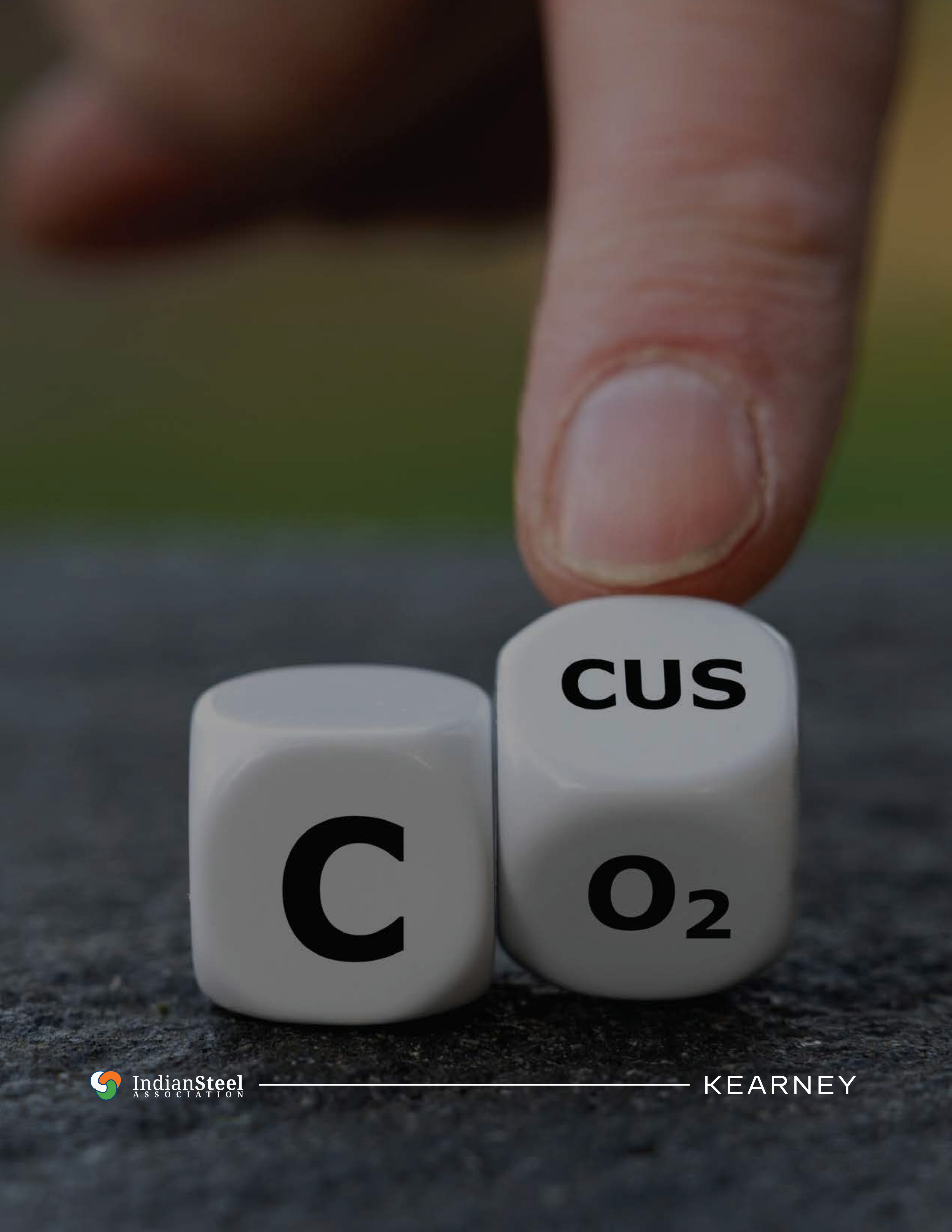


Figure 33: Framework for issuance and trading of low emission steel certificates

[56] *LES: Low Emission Steel; NSCIM: National Steering Committee of Indian Carbon Market; SGE: Specific GHG Emissions; LESC: Low–carbon steel Certificates; BEE: Bureau of Energy Efficiency; CCC: Carbon Credit certificates; OE: Obligated Entity*

[57] *Trading of LESCs to be limited to downstream value chain; re – trading to be not allowed for end consumers*



IndianSteel ASSOCIATION

KEARNEY

About the 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.

www.indsteel.org

Upper Ground Floor No. 4, Kanchenjunga Building, 18, Barakhamba Road, New Delhi, India-110001

011- 42668800 media.isa@indsteel.org www.indsteel.org

@IndianSteelAssociation @Indian-Steel-Association @IndianSteelAssociation @IndianSteelAssociation Indian Steel Association

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