POLICY BRIEF #33

Policy Landscape for Transition Towards Carbon Neutral Steel Sector

DECEMBER 2024

Authors:

AMRITA GOLDAR
MD SARWAR ALI
MALAY KOTAL
POULOMI BHATTACHARYA
ISMAIL HAQUE

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Abstract

In 2018, India's iron and steel sector emitted around 270 million tons of carbon, contributing nearly 9% of the nation's total greenhouse gas emissions. To achieve carbon neutrality by 2070, the government has started exploring green steel strategies, though progress remains at an early stage. Key policy frameworks for low-carbon steel, including supply, demand, and export promotion measures, are yet to be implemented.

This study reviews policy initiatives from top steel-producing G20 countries, focusing on supply, demand, and export promotion, to identify best practices for decarbonizing India's steel sector. **It prioritizes policy options based on an Analytical Hierarchy Process (AHP) exercise conducted with stakeholders from industry, government, academia, and civil society.** The research makes a twofold contribution to the current body of knowledge. Firstly, it identifies potential policy choices that the Indian steel industry can implement to reduce carbon emissions promptly. Secondly, it conducts a policy-prioritization exercise involving various stakeholders to unite diverse perspectives on supply, demand, and export promotion strategies. This exercise helps determine the most optimal transition pathway for the sector. Some of the policy levers that were deemed to be crucial for decarbonizing the Indian steel sector are technological innovation/upgradation, improvement in energy efficiency, and green procurement and labelling. Additionally, access to finance is critical to facilitate the adoption of low-carbon technologies for the production of low-carbon or green steel.

Acknowledgement: The authors would like to thank Dr. Deepak Mishra (Director and Chief Executive, of ICRIER)for his constant support and encouragement. We would also like to thank Ms. Esha Agrawal for her contribution in undertaking the AHP analysis.

Keywords: *Low carbon steel, Climate policy, Industrial decarbonization*

JEL Classification: *Q58, L52, L61*

Authors' email: *agoldar@icrier.res.in, mali@icrier.res.in, malaykotal00@gmail.com, Poulomi.ju.eco@gmail.com, ismailhaque140489@gmail.com*

Policy Landscape for Transition Towards Carbon Neutral Steel Sector

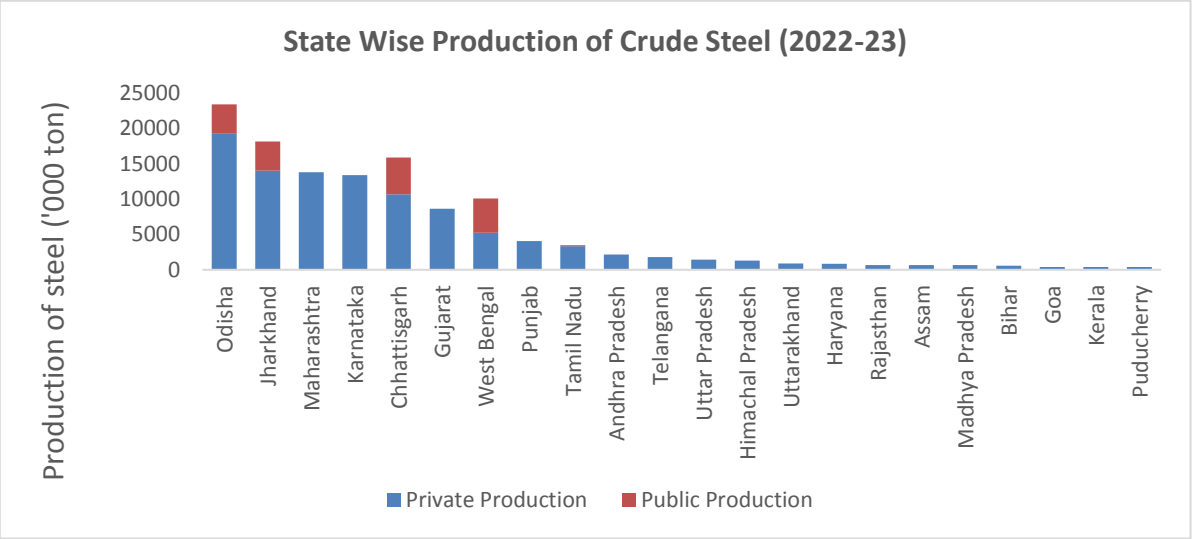
Amrita Goldar, Md Sarwar Ali, Malay Kotal, Poulomi Bhattacharya and Ismail Haque

1. Overview of the Indian Steel Sector

Since India gained independence, the iron and steel industry has been crucial to the country's industrial growth and serves as the backbone of its economy (Mallett and Pal, 2022). Over the years, there has been a steady rise in the demand for steel, but with the liberalization of the Indian economy, this demand has increased significantly, leading to rapid growth in steel production (CCI, 2019; IEA, 2020). Presently, India stands as the world's second-largest producer of crude steel, just behind the People's Republic of China. In 2022, the country's annual steel production reached 125 million tons (MT), accounting for 5.5% of the global crude steel production (Ministry of Steel, 2023). Despite India's impressive steel production, the per capita steel consumption remains relatively low, at only 74 kg, significantly below the global average of 229 kg (Shanmugam et al., 2021). To address this and boost steel production capacity, the Indian government introduced the National Steel Policy 2017, aiming to achieve a steel-making capacity of 300 MT and increase per capita steel consumption to 160 kg by 2030-31 from its current level (GoI, 2017).

The steel industry in India is widely spread across the nation, with a notable concentration in the eastern states of Odisha, Jharkhand, Chhattisgarh, and West Bengal (Figure 1). This concentration is attributed to the region's rich history of industrial development, well-established logistical infrastructure, and abundant mineral resources. However, more recently, states like Gujarat, Karnataka, and Maharashtra have emerged as new steel producers (Figure 1). This shift is due to various factors, including the availability of renewable resources like wind and solar energy, their proximity to ports and markets, and an influx of private investment (Ministry of Steel, 2017; Hall et al., 2022). In India, there is a significant disparity in the amount of steel produced by public and private players. According to the latest data from the Ministry of Steel (2023), the private sector is responsible for a substantial portion of steel production, accounting for nearly 82.28%% of the total crude steel output in the country. Some of the prominent private producers operating in India include Tata Steel (the first integrated steel plant), Vedanta, JSW Steel, and Jindal Steel and Power, among others. On the other hand, public sector plants contribute only 17.72% to the total steel production. Some of the integrated steel plants of the Steel Authority of India (SAIL) include Bhilai Steel Plant, Durgapur Steel Plant, Rourkela Steel Plant, and Bokaro Steel Plant. These public plants were established after India gained independence through collaborations with leading global producers (Ministry of Steel, 2023).

Figure 1: State wise steel production in India (Source: Ministry of Steel, 2023)



In India, steel production follows three primary routes: Blast Furnace-Basic Oxygen Furnace (BF-BOF), Electric Arc Furnace (EAF), and Induction Furnace (IF). Among these, the BF-BOF route has emerged as the dominant mode of production, accounting for 45% of the total steel produced in 2021-22 (Ministry of Steel, 2022). This method is primarily favored by large integrated steel players who utilize iron ore and coking coal to manufacture steel (Climate Group, 2023). In contrast, the other two routes, EAF and IF, are less popular in the country, constituting 28% and 27% of total production, respectively (Ministry of Steel, 2022). These routes are mainly preferred by a mix of large and small steel producers who use sponge iron, melting scrap, and non-coking coal in the steelmaking process (Climate Group, 2023).

Due to the over-reliance on fossil-fuel-based BF-BOF production, the iron and steel sector contributes to higher greenhouse gas (GHG) emissions. According to the latest estimates from 2020, the Indian steel sector is responsible for emitting an average of 2.6 tonnes per tonne of crude steel (T/tcs) in the form of CO_2, making it one of the most polluting industries in the country (Ministry of Steel, 2022).

The Indian government has recently taken significant policy measures to address the challenge of decarbonizing the "hard-to-abate" steel sector, aligning with India's commitment to achieving the Net-zero target by 2070. These initiatives encompass short-term (FY 2030), medium-term (2030-2047), and long-term (2047-2070) strategies. In the short term, the focus is on reducing carbon emissions from the steel industry by promoting energy and resource efficiency, as well as encouraging the use of renewable energy, among other measures. The medium-term strategies involve the adoption of Green Hydrogen and Carbon Capture, Utilization, and Storage (CCUS) technologies. For the longer-term, the emphasis is on exploring disruptive alternative technological innovations that can effectively decrease CO_2 emissions from the steel sector (Ministry of Steel, 2022). However, it's important to note that many of these technical and metallurgic interventions are still in their early stages, and their success in decarbonizing the steel sector will depend on the responsiveness and effective implementation of these policies by various stakeholders.

In this context, reviewing the existing policy initiatives of top steel-producing G20 countries, particularly concerning supply, demand, and export promotion is essential. **By identifying best practices from these countries, India can better navigate its efforts towards decarbonizing the steel sector.**

With the Indian economy transitioning towards a low-carbon pathway, it is widely believed that industries need to be provided with opportunities to become globally competitive, resilient, and carbon neutral. Production of low-carbon steel or carbon-neutral steel can be potentially considered as a multi-billion business opportunity in the coming years. The steady cost reductions in renewable energy generation would likely support the growth of the low-carbon industry.

The global steel industry is one of the largest contributors to carbon dioxide emissions, and the demand for more sustainable and low-carbon steel production methods has been growing steadily. There are several factors that are ideally supporting the prospectus of low-carbon steel as a multi-billion opportunity. This includes market growth, and emission reduction commitments taken up by multiple countries and companies in line with international agreements such as the Paris Agreement, etc.

2. Study Objective

As India gears toward achieving its ambitious net-zero targets, the steel sector forms an indispensable part of the decarbonization storyline. As a result, there is a strong incentive to invest in low-carbon steel technologies to meet these targets. Furthermore, the demand for low-carbon steel is projected to continue growing due to rapid infrastructure development, urbanization, and industrial expansion in various parts of the globe. As the market for steel expands, the demand for sustainable and environmentally friendly steel is likely to increase as well.

The present study discusses the policy landscape of top steel-producing G20 countries and identifies suitable policy options that India can adopt to decarbonize its steel sector. It highlights the prioritized 'fan of policy possibilities' arrived at based on an Analytical Hierarchy Process (AHP) exercise conducted in consultation with key stakeholders from the industry, government, academia, and civil society organizations.

The research makes a twofold contribution to the current body of knowledge. Firstly, it identifies potential policy choices that the Indian steel industry can implement to reduce carbon emissions promptly. Secondly, it conducts a policy-prioritization exercise involving various stakeholders to unite diverse perspectives on supply, demand, and export promotion strategies. This exercise helps determine the most optimal transition pathway for the sector.

The following sections elaborate on some of the policy levels used by G20 countries to support their domestic steel industry. Policy measures related to supply-side, demand-side, and export promotion are examined in depth in the following few sections.

3. Global landscape of steel policy

3.1 Supply side policy levers

Globally, the steel sector is facing a major challenge due to overreliance on the BO-BOF-based production route, which is energy-intensive and emits large volumes of CO_2 into the atmosphere (IEA, 2020). To decarbonize existing steelmaking, countries across the globe have implemented multiple supply-side policy initiatives. The most common supply-side policy intervention among top steel-producing G20 countries is the introduction of new technologies that reduce emissions from existing steelmaking processes or capture and store CO_2 emitted from blast furnaces. Additionally, some countries are focusing on innovative policy instruments that increase production efficiency through restructuring installed capacity, improving energy and material efficiency, and expanding the use of steel scrap. The country-specific details of such supply-side policy levers in top steel-producing G20 countries are explained further, classified into four broad categories.

- **Technological upgradation and innovation:**

Among the different supply-side policy measures, technological upgradation and innovation have emerged as the most preferred policy levers in the top steel-producing G20 countries. In most cases, countries have come up with a "technology roadmap" to decarbonize their steel sector. For instance, in October 2021, Japanese Ministry of Economy, Trade and Industry introduced a technology roadmap for decarbonizing the steel sector. As part of the roadmap, emphasis has been given to the effective use of existing facilities and related equipment; implementation of innovative technologies, such as drastic reduction of CO_2 emissions from blast furnaces through COURSE 50 and ferro-coke technologies; and capture of CO_2 emitted from the blast furnace through CCUS (carbon capture, utilization, and storage) technology. In addition, the roadmap also talks about raising significant funds required for the research and Development and technological transition (JISF, 2021).

Similarly, China introduced a 'Capacity Swap' scheme in 2015, allowing steelmakers to replace old capacity with newer or more efficient facilities. This scheme aimed to upgrade the Chinese steel industry without increasing the country's total production capacity. However, many steelmakers have misused the scheme to increase their installed capacity in the name of quality enhancement. To address the loopholes in the existing scheme, the Chinese government (Ministry of Industry and Information Technology) reintroduced a revised draft in December 2020 (OECG 2021). In the revised draft, the capacity swap ratio for areas vulnerable to air pollution has been increased from 1.25:1 in the current guidance to 1.5:1, which necessitates the elimination of steelmaking capacity more than 1.5 million tons/year for a mill to install a 1 million ton/year converter. Additionally, the ratio in other areas has increased from 1:1 to 1.25:1 (Commodity News, 2020).

In the case of the US, the Department of Energy released a roadmap in 2022 for the decarbonization of the iron and steel sector. The roadmap emphasizes the electrification of the steel industry in two ways: first, by replacing BF-BOF with EAF, and second, by using hydrogen produced from low-carbon energy sources (e.g., renewable or nuclear) instead of natural gas in direct reduced iron (DRI) production and the electrolysis of iron ore. Furthermore, the roadmap also stresses the deployment of Carbon Capture, Utilization, and Storage (CCUS) and other emerging technologies to reuse captured carbon. Since introducing new technologies involves higher capital costs and operational challenges, the roadmap highlights the importance of guiding principles for a research and development action plan, where investment is required to cover both near- and long-term solutions regarding technological maturity and manufacturing scale (DoE, 2022). Additionally, access to finance is critical to facilitate the adoption of low-carbon technologies for the production of low-carbon or green steel. Along with this, the Energy Efficiency Financing Platform (EEFP), the Perform, Achieve, and Trade (PAT), and the carbon credit trading schemes of the Government are anticipated to increase the cost-effectiveness of steel producers adopting energy-saving measures.

Key takeaway for India:

- Most available technological solutions are at a nascent stage and very expensive. Among these, which one will be used by the industry will depend on its cost-effectiveness.
- The future use of the BF-BOF-based production route largely depends on using CCUS technology.
- India needs to encourage the development of the hydrogen economy in the country to replace the BF-BOF production route with EAF in the near future.

- **Achieving materials efficiency:**

The global steelmaking process largely depends on the combustion of carbon-intensive fossil fuels as a primary energy source, which leads to the emission of a large amount of GHGs into the atmosphere. To address this problem, top steel-producing G20 countries are trying to substitute fossil fuels with alternative low-carbon energy sources. In this regard, South Korea made landmark progress by introducing the world's first Hydrogen Act in February 2020. The act was intended to put the Hydrogen Economy Roadmap into practice and advance the security of the country's hydrogen fueling infrastructure and supply. This will help decarbonize the iron and steel sector by reducing the use of fossil fuels. In addition, the act also requires certain electricity providers to supply a portion of their electricity using clean hydrogen (Lee and Ko, 2023).

Similarly, the US Department of Energy also emphasizes adopting low-carbon fuels, feedstocks, and energy sources (LCFFES), like renewable hydrogen, biofuels, bio-feedstocks, and onsite renewable generation for decarbonizing the steelmaking process. The use of these LCFFES, on the one hand, reduces the emission of GHGs from the steel sector, and on the other, helps the steel industry achieve material efficiency (DoE, 2022).

Lately, a number of programs focusing on upgrading and modernizing the steel industry through financial incentives for technology adoption and innovation have been implemented. For example, the US federal government introduced the Inflation Reduction Act (IRA) in late 2021. The act aims to improve the economic competitiveness, innovation, and productivity of industries located in the US while allocating federal spending of nearly USD 400 billion on clean energy. Furthermore, the act also focuses on catalyzing investments in domestic manufacturing capacity, encouraging the procurement of critical supplies domestically or from free-trade partners, and jump-starting R&D and commercialization of clean hydrogen to accelerate the decarbonization of the steel sector (Badlam et al., 2022).

Key takeaway for India:

- The higher cost and storage of hydrogen for industrial use are two main challenges that need to be addressed in the future through technology sharing.
- Replacing the fossil fuel with low-carbon fuels, feedstocks, and energy sources (LCFFES)is the need of the hour. To achieve that goal, the Indian steel sector needs to use clean energy produced from renewable sources.
- Programs focusing on upgrading and modernizing the steel industry through financial incentives for technology adoption and innovation are needed.

- **Energy consumption efficiency:**

The iron and steel industries are among the most energy-intensive sectors in heavy industry, consuming around 18% of the world's total industrial final energy consumption (He and Wang, 2017; EIA, 2021). The overreliance on the BF-BOF production route leads to higher energy consumption, with significant amounts of energy used in sintering (2–3 GJ/t crude steel), coke making (0.75–2 GJ/t crude steel), and steel rolling (1.5–3 GJ/t crude steel) processes. It is further estimated that the energy used in the BF-BOF production route is around 10–13 GJ/t crude steel, while the EAF-based production route uses 1–1.5 GJ of electricity per ton of crude steel produced (He and Wang, 2017). As a result, to reduce energy consumption in steelmaking, top steel-producing G20 countries are striving to electrify the existing steelmaking process by replacing the BF-BOF production route with the EAF production route (IEA, 2020).

In the case of the US, the ENERGY STAR program was introduced in 1992 by the U.S. Environmental Protection Agency (EPA) as a voluntary, market-based partnership to minimize air pollution and greenhouse gas emissions from the manufacturing sector. It enabled industrial and commercial businesses to make informed choices that save energy, reduce costs, and protect the environment. Later in 2000, the EPA extended the scope of the ENERGY STAR policy to incorporate the iron and steel sector. It developed a plant energy performance indicator (EPI) tool that assesses the energy usage of a mill relative to similar mills in the US and Canada. Mills scoring 75 or higher become eligible to earn ENERGY STAR certification, acknowledging that superior energy performance enables companies to save money by achieving energy efficiency and reducing greenhouse gas emissions (Boyd et al., 2016).

In a similar vein, Russia introduced a draft Energy Efficiency Action Plan in 2020, which outlines numerous national standards and requirements to improve the energy efficiency of the industrial sector, with an emphasis on slightly improving the energy intensity of the cast iron and steel sector (Climate Transparency, 2021).

Key takeaway for India:

- Achieving energy efficiency is low-hanging fruit.
- India can introduce the ENERGY STAR certification as an incentive to promote energy efficiency in the steel sector.

- **Scaling-up of secondary steelmaking:**

The scaling-up of secondary steelmaking has recently been viewed as an emerging strategy to decarbonize the steel sector, where iron and steel scrap is used as a material input to produce steel in EAF and IF-based production routes. This approach reduces emissions from the steelmaking process by decreasing the consumption of raw materials such as iron ore, limestone, and coke, as well as energy. For instance, one estimate shows that using every ton of scrap saves 1.1 tons of iron ore, 630 kg of coking coal, and 55 kg of limestone. Additionally, it reduces energy consumption by 16-17%, water consumption by 40%, and GHG emissions by 58% (Ministry of Steel, 2019). However, the main challenge in using scrap in steelmaking is the availability of high-quality steel scrap in the domestic market and the lack of reverse supply chains to ensure its availability.

To address this issue, top steel-producing G20 countries have introduced several policies that enhance the collection of steel scrap while facilitating the scaling up of secondary steelmaking. For instance, to meet domestic demand for scrap, the People's Republic of China issued a roster in January 2021 allowing the quota-free importation of ferrous scrap grades (plus two stainless steel grades) into the country (Taylor, 2020). In the case of Japan, to ensure a stable supply of iron and steel scrap, the government established the Japan Iron & Steel Recycling Institute (JISRI) in 1991. The main functions of JISRI are to encourage research and educational initiatives in waste treatment, pollution prevention, resource recovery, technology advancement, and management for the iron and steel scrap industry (JISRI, 2018). Additionally, the Japan Iron and Steel Federation's (JISF) basic policies on achieving Carbon Neutrality by 2050 also emphasize expanding the use of iron and steel scrap along with technological innovation, material substitution, and energy efficiency measures to decarbonize steelmaking (JISF, 2018).

Some of the top steel-producing G20 countries, such as Russia, the US, and the European Union, which already have robust domestic iron and steel scrap markets, have restricted the export of scrap outside their countries to boost the growth of secondary steelmaking. For instance, Russia introduced a tariff quota for scrap exports from June 1 to July 31, 2022. This measure restricts the export of ferrous scrap outside the Eurasian Economic Union to spur

domestic consumption. At the end of July 2022, the Russian Federation extended the export restriction timeline to the end of 2022 to encourage secondary steel production within the country (Kolisnichenko, 2022).

Key takeaway for India:

- The availability of the good quality scrap is a major challenge to promote secondary steel production in the country. To address the problem, India needs to set up reverse supply chains such as the establishment of scrap collection centers in the country.
- As countries across the globe are imposing restrictions on the export of iron scrap, it is no longer a viable option to promote domestic steel production. In such a case, effective implementation of the Steel Scrap Recycling Policy will determine the future of the secondary steel sector.

Table 1: Below summarizes some of the supply-side policy interventions implemented by G20 countries.

Sl. No.	Policy	Name of the country	Detail of the policy interventions
1	Technology roadmap	Japan	Effective use of existing facilities and related equipment andimplementation of innovative technologies.
2	'Capacity Swap' scheme	China	Allowing steelmakers to replace old capacity with newer ormore efficient facilities.
3	Road map for steel industry	The US	Electrification of the steel industry and deploying the CarbonCapture, Utilization, and Storage (CCUS) technology.
4	Hydrogen Economy Roadmap	South Korea	Substituting fossil-fuel with the hydrogen.
5	Adopting low-carbon fuels, feedstocks, and energy sources(LCFFES)	The US	Use of renewable hydrogen, biofuels, bio-feedstocks, andonsite renewables, like solar and wind.
6	Inflation Reduction Act (IFA)	The US	Federal spending of nearly USD400 billion on clean energy
7	ENERGY STAR programme	The US	Assesses how efficiently a mill uses energy relative to similarmills
8	Energy EfficiencyAction Plan	Russia	Outlines the numerous national standards and requirements toimprove the energy efficiency
9	Roster on scrap import	China	Quota-free importation of ferrous scrap
10	Japan Iron & Steel Recycling Institute (JISRI)	Japan	Technology advancement, and management for the iron andsteel scrap industry
11	Tariff quota for scrap export	Russia	Restricts the export of ferrous scrap outside the EurasianEconomic Union to spur domestic consumption.

3.2 Demand side policy levers

To drive the decarbonization efforts in the steel sector effectively, it is essential to prioritize demand-side policy frameworks alongside supply-side measures. In recent years, prominent G20 steel-producing countries like Germany, the US, and others have been actively developing demand-side policies to boost the demand for green steel in both domestic and international markets. These nations are taking a comprehensive approach by implementing incentives such as incorporating green procurement practices and setting quotas for low-carbon goods to stimulate the demand for climate-neutral products, including green steel.

Moreover, to further encourage the demand and consumption of low-carbon steel, leading G20 steel-producing countries are considering the establishment of demand-side incentives for this steel. Various key factors have been identified to leverage the global market for green steel, such as emphasizing material efficiency and durability, adopting green procurement and labeling practices, and increasing awareness about the benefits of purchasing green steel.

- **Enhancing Material Efficiency and Durability:**

The enhancements in efficiency and longevity of low-carbon steel or green steel have been seen as a lucrative opportunity to escalate the growth of the low-carbon steel industry among steel manufacturers in G20 countries. Further, the growing demand for steel from various allied industries including automobiles, heavy types of machinery, home appliances, etc., has necessitated steel producers to strategically concentrate on improving their product's efficiency and durability. There are various material efficiency strategies like material recycling, remanufacturing, refurbishment, etc., are given high importance in the form of a demand-side decarbonization strategy for the steel sector. In addition, the demand-side strategies also include prolonging product lifetimes and revitalizing the shared use of steel-based products. Thus, to limit the demand for steel by increasing material efficiency, various leading steel-producing countries such as the US, Russia, South Korea, Japan, etc., have been extensively focusing on upscaling the recycling rates for steel.

Moreover, the steel recycling rates are steadily rising in these nations in the wake of decarbonizing their steel sector. For instance, as per the report of the US Geological Survey, the scrap recycling rate in the country has averaged between 80% to 90% over the last decade (U.S. Geological Survey, 2021). Along with this, the automobile industry remains one of the major primary sources making steel scrap in the country. Additionally, more than 15 million tons of steel are recycled from the automobile industry on average in a year (U.S Geological Survey, 2021). Consequently, the recycling of steel in the US has been considered profitable as per the environmental regulations there as well, hence improving the material efficiency. Thereby, helping to decarbonize the demand side of the steel sector.

Similarly, governments in South Korea and Japan are also immensely working on improving the steel scrap recycling capabilities in order to fulfill their uprising demand for steel

domestically. In Japan, certain laws have been framed by the Ministry of Economy, Trade, and Industry associated with the recycling of steel such as the Home Appliance Recycling Law, Containers and Packaging Recycling Law, End-of-Life Vehicle Recycling Law, etc. Furthermore, to satisfy the domestic steel demand, the South Korean government is also outlining the ways to manage the steel scrap from different sources like automobiles, abandoned buildings, etc. Accordingly, the rigorous approach related to the recycling of steel by the leading steel manufacturing G20 nations is anticipated to minimize the impact of carbon emissions on the demand side.

Key takeaway for India:

- Despite the implementation of the Steel Scrap Recycling Policy in 2019 by the Government of India, the limited availability of scrap steel impedes the expansion of the secondary steel sector. Thus, to improve this, examining the material flow of scrap steel in India is necessary.
- In addition, the 'Vehicle Scrapping policy' must be taken into account with a lot of seriousness and attention to suffice the increasing demand for steel scrap.
- Further, upscaling the usage of recyclable steel would likely save significant amounts of iron ore, coking coal, lime, etc., hence lowering the considerable amount of carbon emissions. Recycling scrap steel would further limit the demand for new steel, hence minimizing the carbon emissions.

- **Implementation of Green Taxonomy through Green Procurement and Labelling:**

Alongside developing a roadmap for low-carbon steel production in G20 nations, implementing green procurement policies for low-carbon steel demand creation would significantly help reduce emission rates from the steel sector. Furthermore, the enactment of green procurement or purchasing policies for low-carbon steel has been identified as one of the prominent demand drivers in the coming period. In relation to amplifying the demand for low-carbon steel as part of the decarbonization of the steel sector, some G20 nations, such as the US and Germany, have begun implementing green purchasing policies. For instance, in 2022, the Federal Government of the US announced a Buy Clean initiative to prioritize the use of low embodied carbon steel in federally funded projects. The Buy Clean taskforce launched by the Federal Government of the US has also ambitiously targeted the purchase of 98% of low-carbon construction materials, including steel, for federally funded construction projects (U.S. Department of Energy, 2022). The Government of Germany has also envisaged the enforcement of green public procurement policies for low-carbon or carbon-neutral products, including low-carbon steel, to spur the market for low-carbon steel in the upcoming period, thereby reducing GHG emissions.

Hence, given the importance of reducing carbon emissions from the steel sector, the imposition of green procurement policies is projected to play a significant role in upscaling the demand for low embodied carbon steel. In addition, governments in leading steel-

producing countries are increasing their purchasing power for sustainably produced products and materials. The steps taken by the government toward green procurement have encouraged the private sector to opt for low-carbon steel in their final products.

Table 2: Low Carbon Steel Procurement by End Users

Year of Announcement	Country/ Region	Company/Organization Involved	End User	Description
2023	Germany	H2green steel and ZF Friedrichshafen	Automobile	Collaborated to deliver green steel for seven years with an investment of around USD1.64 billion
2023	Germany	Bosch Siemens Hausgeräte and Salzgitter Flachstahl GmbH	FMCG	Signed MoU to source green steel for the production of home appliances like washing machine
2023	Europe and North America	Mercedes-Benz and H2green steel	Automobile	Partnered to deliver green steel for the manufacturing of car

These actions adopted by the public and private steel sectors to reinforce industrial decarbonization are anticipated to create lead markets for green commodities, thereby reducing a considerable amount of GHG emissions.

In addition to implementing green procurement, the execution of green taxonomy for the steel industry has also played a significant role in decarbonizing the sector. The realization of green taxonomy for the steel sector is expected to increase investments by private companies, as it ensures they make environmentally sustainable investment choices. Thus, to boost the demand for low-carbon embodied steel and to encourage private sector investments, several proposals for enacting green taxonomy norms related to the steel sector have been put forward by steel associations in the European Union. For instance, in 2019, the European Steel Association developed a proposal for the 'environmentally sustainable' taxonomy eligibility criteria for the steel production process (EUROFER, 2019). Various amendments were proposed by the European Steel Association to properly assess the performance of steelmaking activities concerning climate mitigation.

Apace with an attempt by the European Steel Association for implementing green taxonomy linked with the sector, the German steel federation Wirtschaftsvereinigung (WV) Stahl also introduced the label system for green steel in 2022. The proposal majorly focuses on establishing the green lead markets by constructively framing the labelling system for green steel. In addition, the proposal classified the green steel labelling into two ways as classification system for green steel and customer-oriented labelling of climate-friendly steel:

- “The classification system is for the steering of green lead markets, i.e. to define requirements and crediting modalities for the use of green steel in different applications and adjusting these over time in line with climate policy ambitions”.

- “The labelling provides steel customers with information on the level of decarbonization of the related production process, supplemented by the product carbon footprint of the respective end- product”.

Therefore, alongside other enabling policies, green procurement and green taxonomy linked with thesteel sector are estimated to facilitate the demand for green or low-carbon steel to the earliest. The norms set by the governments in the leading steel manufacturing nations to procure low-carbon steelfor government-funded construction projects would leverage the purchasing power of the companies.Thereby, decarbonizing the demand side of the steel sector.

Key takeaway for India:

- In India, a substantial amount of steel produced domestically has been utilized in the country itself. Thus, the implementation of green public procurement is essential to decarbonize the Indian steel sector.
- The government of India should set mandate norms to procure low-carbon construction materials including steel for public construction projects.
- Enactment of green taxonomy linked with the steel sector is highly important to encourage investments by the private steel sector.

- **Raising awareness for purchase of low carbon steel:**

Raising public awareness for the adoption of low-carbon steel has been seen as an opportunity area to rapidly flourish the market for low-carbon steel. Furthermore, growing urbanization globally has resulted in the development of infrastructure, and the rising government environmental awareness has been encouraging the usage of low-carbon steel in infrastructure projects. The mounting concerns about climate change have transformed the purchasing behavior of consumers, thus supporting sustainable alternatives. Furthermore, to propel the demand for low-carbon embodied steel, steel producers are also focusing on attaining ‘Environmental Product Declaration’ (EPD) certification to create transparency for the customers regarding the life-cycle environmental consequences of steel or steel-based products. For instance, in 2022, Indonesian steelmaker Gunung Raja Paksi (GRP) successfully gained Environmental Product Declaration (EPD) certification. With this achievement, the GRP can be able to provide transparency about the environmental impact of its steel products. This, in turn, is further expected to build awareness among the customers. Moreover, these sustainable products certifications would likely help in increasing the exports of steel products in the environment-concerned markets.

Additionally, to elevate awareness regarding the purchase and usage of low-carbon steel, steel manufacturers are also engaging themselves in low-carbon steel awareness campaigns. For instance,in 2021, SSAB launched a fossil-free steel awareness campaign in the countries like Finland, Sweden,and the US (SSAB, 2021). Along with this, in 2021, the United States Steel

launched a new Environmental Excellence Campaign in the wake of spreading awareness for the adoption of low carbon steel. Therefore, such type of initiatives by the steel producers would likely assist the growth of sustainable steel consumption patterns. In parallel, steel manufacturers are also immensely focusingon media strategies to disseminate the urgency of utilizing low-carbon steel. The media strategy includes a broader approach by focusing on digital platforms to target audiences extensively engagedin climate change. Thence, in a view of reducing carbon emissions from the steel sector on demand-side, raising awareness for the purchase or consumption of low-carbon steel has been observed as a fundamental pillar.

Key takeaway for India:

- Media activities involving digital platforms must be given importance to increase the engagement of steel end-users focused on reducing environmental impacts.
- India is required to conduct low-carbon steel adoption awareness campaigns to attract climateconscious consumers.

Table 3: Below summarizes some of the demand-side policy interventions implemented by G20 countries.

Sl. No.	Policy	Name of the country	Detail of the policy interventions
1	Federal Buy Clean Initiative	The US	To prioritize the utilization of low embodied carbon steel in federally-funded projects.
2	Green Steel Definition - A Labelling System for Green Lead Markets	Germany	Proposal majorly focuses on establishing the green lead markets by constructively framing the labelling system for green steel
3	Home Appliance Recycling Law, Containers and Packaging Recycling Law, End-of-Life Vehicle Recycling Law, etc.	Japan	To improve the steel scrap recycling capabilitiesin order to fulfil their uprising demand for steel domestically.
4	Environmental Product Declaration (EPD) certification	Indonesia	Product Declaration' (EPD) certification to create transparency for the customers regarding the life-cycle environmental consequences of steel or steel-based products

3.3 Export Promotion Policy levers

As outlined earlier, one critical way to control carbon emissions emanating from the steel productionprocess is energy substitution, which implies that the raw materials or the energy with which the steelis produced is altered. For substituting and consuming finished steel products or raw materials from other countries, trade patterns and its policies become a crucial part of the decarbonization process.

The policy levers of most of the major steel producers direct towards focusing on the import side sothat the imported products or raw materials do not add to the carbon emissions level in the economy.India too has its Steel Import Monitoring System (SIMS) that collects granular data like end-use, grade of steel, technical specifications etc., to disseminate information related to steel imports to its domestic industries.

The Carbon Border Adjustment Mechanisms (CBAM) is another such import side policy lever to combat carbon emissions. It is imposed on exports from other countries to developed countries like EU that accounts for carbon leakages that may be arising due to differential emission-based technologies. While some argue that this kind of strategy focusses on taxing the non-green steel products rather than promoting the green steel production and exports, it may induce countries to shifttheir production technologies to utilize energy that emit lower carbon dioxide and develop strict policies to ensure lower carbon emissions during production. Therefore, export promotion strategies and the supply side strategies for decarbonizing the steel sector are inter-linked.

China is an exception amongst the major steel producing economies for not facilitating the exports ofgreen steel, according to China's Trade Policy Review. China increased its export tariffs for high- purity pig iron, and cancelled tax rebates on 23 steel products in 2021 (WTO, 2021; Beroe Inc., 2021). On the other hand, governments such as South Korea provided various tax incentives and financial incentives to the sector as a part of its export promotion strategy. Tax exemptions, preferential export credit schemes, export performance linked schemes are some export promotion strategies adopted bySouth Korea (Ahuja, 2002; Hyun-bin, 2021). As per IEA report, Japan has diversified its energy mix,expanded renewable energy uses and therefore its dependence on imports have reduced. Export tax incentives and government assistance are some export promotion strategies of the country (IEA, 2021). The US too restricts imports of steel by imposing import duties on steel and aluminum. To promote exports, it has adopted various funding initiatives (U.S. Department of Commerce, 2023). Russia's export promotion strategies include preferential export tariffs, export loan arrangement for domestic Russian companies, low tariffs for parts' imports acquired abroad as per steel sector requirements (Berden and Yastrebova, 2011).

In sum, to boost its export sector, major steel producing countries have adopted policies like export tax incentives or relaxing of imports on raw materials utilization for production of green steel. Countries have also focused on preferential export credit schemes that provides insurance to exporters to adopt to green steel production technologies and exports. Globally, major steel producingeconomies have developed bilateral policies to ensure smooth trading of low carbon steel products.

As per India's Ministry of Steel Statistics, India was a net exporter of total finished steel products (both non-alloy and stainless or alloy) as on 2021-22 even though the exports fell by 49%. Therefore,the export promotion strategies for green steel play a crucial role.

- **Export Tax Incentives**

Among the many exports promotion strategies, providing export tax incentives or relaxing export tariffs and duties emerged as the most import policy lever in G20 countries. These incentives lower the amount of money an exporter is liable to pay to the government. Unlike China, countries like South Korea, USA, Japan have stressed on promoting exports of steel products (Table 4). Russia toohas promoted exports of steel but restricted the export of scrap steel with a tariff quota outside the Eurasian Economic Union. India has introduced

such scheme like the Remission of Duties or Taxes on Export Products (RoDTEP) in line with 'Atmanirbhar Bharat' and 'Make in India' initiatives to ensure that exporters are given payments for any embedded levies and taxes or duties that they have suffered during exports. It has planned to include steel under this scheme. The Indian Government had initially in May 2022 imposed export duties on certain steel products to control the rising prices of steel due to Russia-Ukraine invasion and cater to the domestic consumption of steel. However, it was anticipated that such increase in exports duty with relaxed import duties would lead to a fall in domestic demand for steel products thus it cancelled the export duty on steel products in later half of2022, thus encouraging exports and domestic consumption.

Key takeaway for India:

- India has performed quite well in the formulation of export promotion policies of steel productsso far. Its past policies show that waiving of steel export taxes promotes both exports of excess production after catering to the domestic consumption.
- India could see if the exports in certain countries or areas with high geopolitical risks could be restricted with some tariff quotas imposed on the exports of steel products to control aggressiveand unreliable exports.

- **Rationalization of duties for capital imports**

Rationalization of duties for capital imports in the steel sector is a crucial policy approach adopted by various countries to promote technological advancement and enhance competitiveness in their steel industries. By reducing import tariffs and taxes on essential capital goods, these countries aim to facilitate the acquisition of modern machinery, equipment, and technology, which, in turn, boosts production efficiency and drives overall growth in the steel sector.

Some examples of rationalization of duties for capital imports in G20 countries include: India, China,Germany, US and South Korea.

The Indian government has implemented various measures to rationalize duties for capital imports inthe steel sector. For instance, under the "Project Import Regulation," import duties on specific capitalgoods required for setting up or modernizing steel plants were significantly reduced to attract foreigninvestment and promote technological upgradation. China and Germany too have employed a series of policies to incentivize the import of advanced technology and machinery in its steel sector such asimplementing targeted duty exemptions and rebates on capital imports. One notable example in the Chinese case is the establishment of Special Customs Supervision Zones, where certain capital imports are subject to lower or zero tariffs to encourage the adoption of advanced production technologies.

US has used duty drawbacks and tax exemptions to encourage the import of capital goods in the steelsector. Like China, through the Foreign-Trade Zones program, certain imported machinery and equipment used for steel production may be exempt from customs duties. South Korea has strategically lowered import tariffs on essential capital goods in the steel

sector to facilitate technology transfer and promote innovation. This approach has helped domestic steel producers to adopt advanced manufacturing methods and improve overall productivity.

Key takeaway for India:

- Many countries have implemented policies to incentivize the import of advanced technology and machinery in its steel sector such as targeted duty exemptions and rebates on capital imports.
- Special Customs Zones or Foreign Trade Zones to facilitate imports of machinery and equipment have also been established.

- **Preferential Export Credit Schemes**

Preferential export promotion scheme ensures that the exporter of the product is insured against any payments-related default from the importer's side. Such unforeseen events can arise due to various political reasons. Major steel producing economies South Korea, Germany and Russia use preferential export credit schemes to encourage exports of products. Adopting such strategy for exporters of green steel encourages producers to securely export green steel globally. Germany has recently launched a taxonomy- green, white and red, based on which exporters will be guaranteed payments against risks from exports. However, Germany's draft guidelines on export credit guarantees and its taxonomy has garnered much criticisms on the ground that the guideline is exempting and encouraging the use of fossil fuels while nuclear power is excluded from the green category of climate friendly technologies. India needs to plan and follow a taxonomy with slight modifications in defining its categories for delivering an export credit guarantee support to encourageexports of steel thereby promoting exports of low carbon steel.

India's EXIM Bank has implemented various export credit schemes to support the country's steel sector. One of the schemes they have offered in the past is the "National Export Insurance Account (NEIA)" to provide export credit insurance coverage for steel exporters. This scheme helps mitigate the risk of non-payment by overseas buyers and enables exporters to access credit facilities from banks on better terms.

Key takeaway for India:

- Preferential credit schemes for promoting and encouraging exports of low-carbon steel needs have been implemented by many countries, including India. India may follow a taxonomy, slightly modified from Germany, for export guarantees for this particular group of exporters.
- However, the intended preferential segment needs to be targeted, whether it be the MSME sectoror large firms using low-carbon materials to produce steel.

Table 4: Steel Export Promotion Policies for Select G20 Countries

COUNTRY	STEEL EXPORT PROMOTION POLICIES
INDIA	1. The Indian Trade Ministry seeks to include steel in the RoDTEP scheme. (Reuters,2022b) 2. The Indian government, in November 2022, has revoked the export duty which waslevied on iron ore and certain steel products in May 2022. (PIB Delhi, 2022)
CHINA	1. China increases export tariffs for pig iron and ferrochrome and annuls tax rebates for 23steel products. (Reuters,2021) 2. China cancels VAT rebates on exports of 146 steel products. It also cuts the import taxon "ferrous scrap" entirely. (S&P Global Commodity Insights, 2021)
JAPAN	1. Japan and the United States agree to revoke the 25% tax rate on the Japanese steel imports into the US. A quota is agreed upon (1.25 mmt.) and any amount exceeding the quota will face the import tax rate in US. (Swanson, 2022- The New York Times) 2. India and Japan sign a MoC "to secure sustainable growth" in the respective steel industries. (Indian Ministry of Steel & Japanese Ministry of Economy, Trade and Industry,2020)
SOUTH KOREA	1. The United States will not reconsider the import quota imposed on Korean steel duringthe Trump administration. (Reuters,2022a) 2. South Korea has announced its objective to grow its exports in 2023 with the aid of pertinent strategies to be incorporated by all of its governmental ministries. (The South Korean Ministry of Trade, Industry and Energy,2023)
RUSSIA	1. Russia has announced tariff quota on the export of iron scrap outside the Eurasian Economic Union (EAEU). (Interfax, 2022) 2. The Russian government aims to provide subsidies to the export of steel, announced bythe Russian Deputy Minister of Industry and Trade. (Eurometal, 2022)
The US	1. The U.S. Department of Commerce has launched a programme to provide funds for projects related to export promotion. (U.S. Department of Commerce, 2023) 2. U.S. is proposing to impose steel and aluminum tariffs on the basis of the amount ofcarbon emissions. (Reuters, 2022c) 3. US and the EU entered into a temporary agreement on 2021 on steel tariffs. 4. US agreed on allowing for imports of steel from UK with an annual tariff rate quota of 0.5 mmt.
GERMANY	1. Germany launches its own green taxonomy for promoting export credits (Reuters, 2023)

4. Analytic Hierarchy Process for Policy-Prioritisation

Analytical Hierarchy Process (AHP), first introduced by Thomas Saaty in 1980, captures both subjective and objective aspects of decision-making processes as it helps reduce a complex issue intoa series of pairwise comparisons, enabling the users of the process to reach the best outcome. It helpssolve the quandary of working with many criteria of different units to derive at the best solution possible for a pertinent problem. The hierarchical process involves identifying attributes that contribute to the solution, key players associated with the problem, and the ambient setting of the problem (Saaty, How to make a decision: The Analytic Hierarchy Process, 1990). AHP is a promising mathematical tool that can be used in the fields of management and operations, as it removes bias byintroducing consistency in decisions made by the decision-makers.

- **Application of AHP**

AHP works on the sets of criteria and alternatives. It is important to remember that this process doesnot optimize each criterion, but rather singles out the best option based on the trade-off among the choices available. The approach of forming pairwise comparisons has

garnered much interest from the researchers, particularly in determining the relevance of each alternative compared against other alternatives (Triantaphyllou & Mann, 1995). It assigns weight to each choice that has to be evaluated; the pairwise comparisons are presented in the form of matrix which is further used to obtain weightsusing eigenvectors. Eigenvectors, in turn, produces ranks for each criterion and alternative based on a specific criterion that can help us deduce the best option (Taylor, Managing transportation infrastructure and assets, 2021).

Intensity of importance	Definition
1	Equal importance
3	Weak importance of one over the other
5	Essential or strong importance
7	Demonstrated importance
9	Absolute importance
2, 4, 6, 8	Intermediate values between the two adjacent judgements

Ranging of scores from 1 to 9, a value of 9 is assigned using the scale to reflect the absolute importance (Saaty, 2008). Further, a pairwise matrix is formed after quantifying the relative importance of each criterion to determine the ranking of the priorities. To do so, eigenvectors are calculated by squaring the matrix and computing the sum of each row, which is then divided by totalof the sum of each row. Continue with this step until the eigenvectors does not vary from the previousiterations. The eigenvectors are nothing but the weights we assign to each criterion. Same procedureis applied to compute the weights of combination of each alternative based on specific sub-criteria. After computing the weights of each combination of alternatives, the product of weights of criteria and combination of each alternative, appropriated against sub-criteria, presents us with the final solution (Haas & Meixner). The alternative with highest ranking i.e., highest value, is deemed to be the best option.

- **Super Decisions™**

To run the AHP model, one has to feed in the objective, criteria that may influence the solution, andrelevant alternatives pertaining to the problem. The process itself can be a daunting task, demanding considerable time and efforts. However, use of software can streamline the process, making the tasksimpler and time efficient. Super Decisions is an analytical software used for implementing Analytic Hierarchical Process (AHP) (SuperDecisions, n.d.). It is a software used for managing the propertiesof the model and obtaining results by the way of inputting criteria evaluated based on self-judgement. The software is also useful for performing sensitivity analysis.

The software considers the goal, criteria, and alternatives as nodes in the model where each alternativeis connected to a sub-criterion, and each sub criterion is connected to the goal, resulting in a hierarchalmodel as represented in figure 2. In the software, each level of hierarchy comprising alternatives, criteria, or goal represents clusters which are connected through arrows flowing in a single directionfrom top-to-bottom.

Super Decisions can be used to determine pair-wise comparisons based on each criterion, where the nodes that have to be pairwise compared are always present in the same cluster and are compared against the node from which they are connected. This leads to 'local priorities' of child node in relation to the parent node, which is the previous node in the analysis (Super Decisions). After the comparisons are assessed and presented in the matrix form, inconsistency of the hierarchal model is estimated. Ideally, the inconsistency should lie below 10 percent (Super Decisions), however, if thisthreshold is breeched, the software allows adjustments to the initial inputs to address the problem of inconsistency. Finally, the decision maker can draw conclusion by applying bottom-up or top-down approach based on the importance of the criteria and alternatives. The final results can be accessed through the synthesis command, that reflects the judgment made by the decision maker while selecting criteria and adjusting the objective. Figure 2 depicts the objective and criteria chosen in this particular case.

- **Prioritizing the Fan of Policy Possibilities: AHP Exercise**

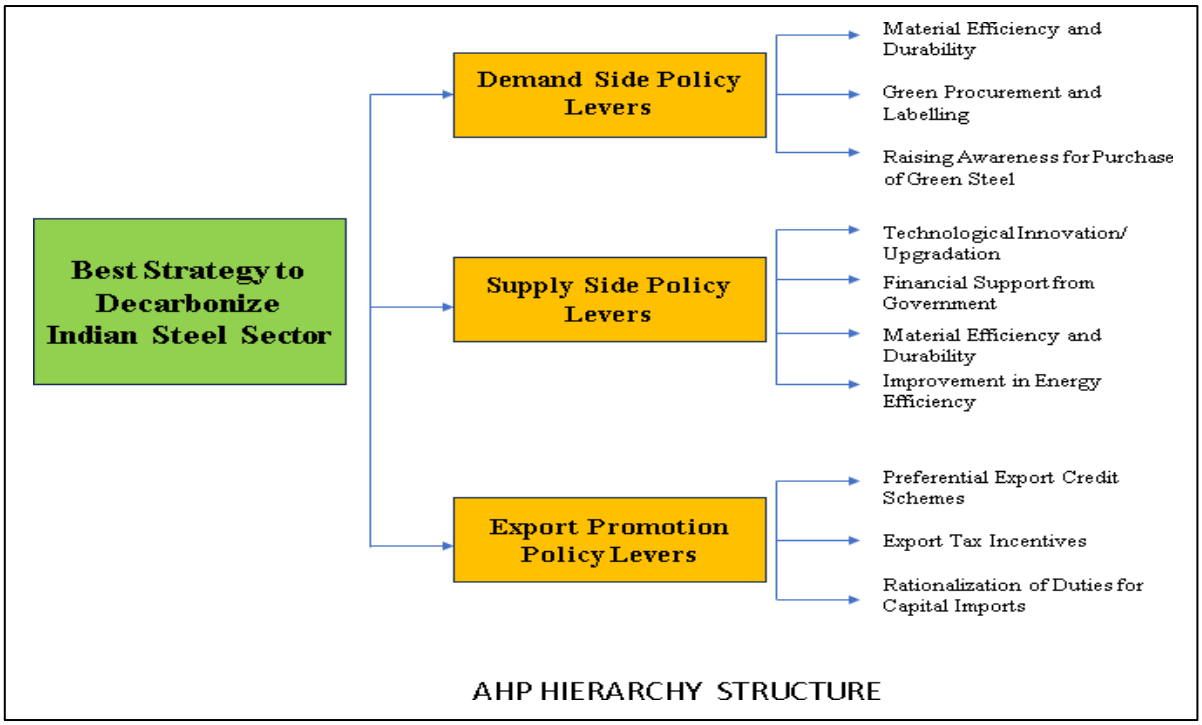
The policy discussion in earlier sections highlights the existence of a 'fan of policy possibilities' thatexist for the low-carbon steel sector. However, as a developing country, India would need to select aset of strategies that would best serve its purpose and be conducive to national circumstances.

To identify the optimal portfolio of strategies that India can adopt to decarbonized the 'hard to abate' steel sector, the aforementioned AHP exercise was conducted with array of stakeholders belonging to diverse sectors. In total, sixteen stakeholders were requested to provide inputs on the best possiblepolicy intervention to be deployed to decarbonize the industry. Stakeholders from diverse background, such as academia, government, steel industry, and civil society organizations (CSOs), were consulted to understand the possible demand side, supply side, and export promotion strategies that India can adopt. Representatives from the official ministries, such as Steel Users Federation of India (SUFI), Federation of Indian Chambers of Commerce and Industry (FICCI) and Ministry of Steel, among others, were engaged in the consultations, to understand their perspectives and approaches towards decarbonization of the sector. Stakeholders hailing from steel industries were reached out to seek an in depth understanding of the challenges the industry faces, particularly the financial constraints involved in technological upgradation within the industry. Steel producers such as Vardham Steel, JSW Steel, Kalyani Steel, among others were approached to get a nuanced perspective of the challenges observed by the producers

scattered all over India. Consequently, expertise from stakeholders from non-governmental backgrounds such as academician and CSOs, was sought after to understand the opportunities and challenges involved in the decarbonization of the hard-to-abate sector. These included representatives from IITs, National Council of Applied Economic Research, Institute of Economic Growth, along with other research think tanks like Council on Energy, Environment and Water (CEEW), to incorporate diverse perspectives into the study. The stakeholder consultations were conducted in the months of May, June and August, following which they were asked to rank different policy levers from a scale of 1 to 9. These ranks were further used to conduct AHP analysis to analyse which policy lever, according to the stakeholders, can best optimize the decarbonization path. Their preferences are reflected in the final values derived.

As mentioned earlier, the AHP hierarchy structure is depicted in figure 2. The first level addressed the objective of the exercise, which is to identify the best strategy to decarbonize Indian steel sector.The next level discussed the policy levers namely demand side, supply side, and export promotion. The third level involved the strategies under each side. These policy levers and strategies served as the criteria in the software which were compared against each other to determine the best possible strategy.

Figure 2: AHP Hierarchy Structure



The supply side intervention strategies involved technological innovation and upgradation, financialsupport from government, material efficiency and durability, and improvement in energy efficiency.On the demand side, strategies such as material efficiency and durability, green procurement and labelling, and raising awareness for purchase of green steel were considered. Meanwhile, preferential export credit schemes, export tax incentives, and

rationalization of duties for capital imports were some of the export side strategies that were surveyed. These options were derived from the detailed analysis of policy levers done earlier. The following table provides a brief snapshot of what each of the policy strategies entail.

Policy Levers	Description
Technological innovation / upgradation	Technological roadmap by implementing innovative technologies such as CCUS, replacing BF-BOF with EAF, use of greenhydrogen, etc., for decarbonizing the steel sector
Financial support from government	Funding from the government to decarbonize the steel-making process
Material efficiency and durability (Supply Side)	Inclusion of low-carbon fuels, feedstocks, and energy sources
Improvement in energy efficiency	To reduce the energy consumption in the steel production process
Material efficiency and durability (Demand Side)	To increase the recycling rate of scrap steel to limit the demand for raw materials
Green Procurement and labelling	To encourage the procurement of low-carbon steel in public construction projects, and also to enforce green taxonomy in the steel sector
Raising awareness for purchaseof green steel	Awareness campaign to flourish low-carbon steel market
Preferential Export Credit Schemes	Exporters in the steel sector are offered export credit at a lower interest rate than the prevailing market rates
Export Tax Incentives	Export tax incentive is to impose zero or reduced export dutyon low-carbon steel products
Rationalization of duties for capital imports	Refers to the process of reducing or streamlining import duties on machinery, equipment, and other capital goods used in the steel industry.

The Super Decisions™ software calculated the weighted importance of each criterion or strategy by comparing it to other criteria. These weights were then further utilized to determine the rank of eachcriterion. The ranks were calculated using the arithmetic mean, which reflected the strategy most preferred by each stakeholder. Finally, the criterion with the highest value or rank was deemed to be the most preferred strategy that the country can adopt to accelerate the efforts of decarbonizing the steel industry.

Table 5: Aggregate Ranking of Policy Strategies

Criteria	Priorities	Rank
Technological innovation/upgradation	0.18	1
Improvement in energy efficiency	0.17	2
Green Procurement and labelling	0.11	3
Export Tax Incentives	0.10	4
Financial support from government	0.10	4
Material efficiency and durability	0.10	4
Material efficiency and durability	0.09	5
Raising awareness for purchase of green steel	0.06	6
Preferential Export Credit Schemes	0.05	7
Rationalization of duties for capital imports	0.05	7

The results suggested technological innovation and upgradation to be the most preferred and importantintervention to realize the objective. This was followed by improvement in energy efficiency,highlighted as the second potential strategy. Green procurement and labeling third

highest-rankedstrategy, was the most preferred demand-side policy intervention. Export tax incentives, financial support from the government, and material efficiency and durability trailed closely behind, ranking as the fourth most preferred policy interventions.

Parsing the data further based on the domains the stakeholders represented provides further insights into the variations in preferences. The stakeholders from the government ranked technological innovation and improvement in energy efficiency as the most important supply-side interventions. Raising awareness for the purchase of green steel, a demand-side strategy, was ranked the second most preferred intervention. The private sector representatives chose technological innovation as themost preferred strategy, along with financial support from the government, green procurement and labelling, and export tax incentives as the second most preferred strategies to meet the objective. CSO stakeholders, however, chose improvement in energy efficiency as their most favored strategy, closely followed by technological innovation as their second most preferred intervention. Lastly, thestakeholders from academia selected energy efficiency improvement as the most preferred. The second most preferred strategy were the demand side approaches, namely material efficiency and durability, and green procurement and labelling.

Table 6: Disaggregated Ratings from Stakeholders

Criteria	Government	Private	Academia	CSO
Technological innovation/upgradation	0.25	0.22	0.12	0.17
Financial support from government	0.04	0.13	0.05	0.14
Material efficiency and durability	0.10	0.08	0.08	0.15
Improvement in energy efficiency	0.25	0.10	0.22	0.20
Material efficiency and durability	0.07	0.05	0.13	0.07
Green Procurement and labelling	0.03	0.13	0.13	0.08
Raising awareness for purchase of green steel	0.16	0.06	0.05	0.05
Preferential Export Credit Schemes	0.01	0.05	0.06	0.06
Export Tax Incentives	0.03	0.13	0.09	0.07
Rationalization of duties for capital imports	0.07	0.05	0.06	0.02

As per the observations, expert opinions and preferences of the stakeholders from diverse backgrounds emphasize technological innovation and energy efficiency improvement as the two mostimportant strategies. Additionally, green procurement and labelling, export tax incentives, material efficiency, and durability were also considered significant measures. The sector-wise analysis perfectly aligns with the aggregate results of the survey.

5. Way Forward

Many low-carbon steel production technologies are in its embryonic phase in India. Thus, BF-BOF based production route along with its integration with CCUS technology needs to be an initial pathway for the decarbonization of the steel industry in the country. Furthermore, the progression of a hydrogen-based economy must be encouraged to leverage the EAF-based steel-making process. The hydrogen storage issues for industrial usage as well as its high cost

need to be resolved in the coming years, through technology sharing. The Indian steel sector should facilitate onsite clean energy production from renewable energy resources for the steel-making process. In addition, programs focusing on upgrading and modernizing the steel industry through financial incentives for technology adoption and innovation are needed. India needs to focus on introducing the ENERGY STAR certification as an incentive to promote energy efficiency in the steel sector. As achieving energy efficiency is a low-hanging fruit.

Alongside this, the availability of better-quality scrap is a major challenge to promote secondary steel production in the country. To address the problem, India needs to set up reverse supply chains such as the establishment of more efficient scrap collection centres in the country. Moreover, regardless of the enactment of the Steel Scrap Recycling Policy in 2019 by the Government of India, the scarce supply of scrap steel impedes the expansion of the secondary steel sector. Thus, to improve this, examining the material flow of scrap steel in India is necessary. For leveraging the market of low-carbon steel or green steel, the implementation of green taxonomy through green procurement and labeling is required. India itself utilizes a significant amount of steel produced domestically, thus the implementation of green public procurement would be pivotal in enhancing the demand for low-carbon steel or green steel. Additionally, India is required to conduct low-carbon steel adoption awareness campaigns to attract climate-conscious consumers.

India has performed quite well in the formulation of export promotion policies for steel products so far. Its past policies show that waiving steel export taxes promotes both exports of excess production after catering to domestic consumption. Preferential credit schemes for promoting and encouraging exports of low-carbon steel needs have been implemented by many countries, including India. India may follow a taxonomy, slightly modified from Germany, for export guarantees for this particular group of exporters. However, the intended preferential segment needs to be targeted, whether it be the MSME sector or large firms using low-carbon materials to produce steel.

6. Conclusion

In conclusion, green steel policies hold immense potential for transforming the steel industry and fostering sustainable development. The study outlined a range of policy possibilities available to countries like India to spur their domestic steel sector while moving towards greener practices. Emphasizing environmentally-friendly approaches in the industry brings dual benefits of emission reduction and gaining a competitive advantage in the rapidly-expanding green market.

The analysis highlighted the importance of expert opinions in shaping policy preferences. Among thevarious strategies considered, technological innovation and upgradation emerged as the top choices for promoting low-carbon steel production. Additionally, improving energy efficiency and implementing green procurement and labelling were recognized as essential

steps to further the industry's environmental goals. Some of the other transition pathways for decarbonizing India’s steel sector encompass increasing availability of scrap steel for secondary steel making process, and the adoption of innovative technologies like the integration of green hydrogen and electric arc furnaces (EAF). In parallel, the integration of CCUS into the BF-BOF route can notably reduce the direct carbon emissions. Hence, decarbonization Indian steel industry requires holistic approach.

These findings underscore the need for governments, industries, and stakeholders to collaborate and invest in innovative technologies and sustainable practices to achieve a low-carbon and eco-friendlysteel sector. While challenges may exist in the implementation and transition towards green steel, thelong-term benefits in terms of reduced environmental impact and increased competitiveness are wellworth the efforts.

By adopting and effectively implementing green steel policies, nations can position themselves as leaders in sustainable industrial practices, fostering economic growth, mitigating climate change, and preserving the planet's natural resources for future generations. The journey towards greening the steel industry is not only an environmental imperative, but also a promising economic opportunity, and concerted efforts in this direction will play a crucial role in shaping a greener and more prosperousfuture.

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Annexure

Table A.N.1: Country Wise Policy Review

Country	Policies	Regulations enacted/ amended	Financial/fiscal measures							
			Carbon pricingwith border adjustment	Tax incentives/ state subsidy	Mandatory/ Voluntary labelling	Carbon emission trading system	RD & D	Data discloser and ESG	Green procurement	Green taxonomy
China	▪ Started National trading system for carbon emissions for steel sector ▪ Removed tax rebateon export and put cap on steel production ▪ National Development and Reform Commission (NDRC) plan of 300-320 Mtpa for domestic steel scrapsupply by 2025	NA	Not implemented : China considered CBAM to be a protectionist measure and have repeatedly spoken out against it	Removed tax rebate on steel export	Taiwan is the first place to implement carbon label system in China, however this scheme has not been fully popularized in mainland China (Xu & Lin, 2022)	Introduced a draft national carbon emission trading scheme, 2020 Propose d a cap- and-trade system for the steel sector in the 14th 5-yr plan	Initiatives taken for Rd & D support	Carbon reporting made mandatory	In 2006, China has introduced this policy (Denjean, et al., 2015)	China's green taxonomy, known as the “Green Bond Endorsed Project Catalogue” was first released in 2015
India	▪ Short term (FY 2030) target to reduce carbon emissions through promotion of material efficiency ▪ Steel scrap recycling policy, 2019	Motor Vehicles (Registration and Functions of Vehicles Scrapping Facility) Rules 2021, seeking to increase availability of scrap in the steelsector	India does not levy an explicit carbon price	Scrapped the 15% export tax on severalsteel productsto improve its availability inthe domestic market and tame prices.	A task force for ‘monitoring of carbon emission of steel plant’ has been set up that will work on formulating	Took several short-term initiative s to promote energy and material	Facilitator ’s task force has been set up to prepare a research road map for the green	This provision does not exist in India	Does exist (Hasanbeigi & Bhadbhade, 2023)	A task force has been set up for developing green steel taxonomy
	▪ National Solar Mission, 2010 ▪ Perform, Achieve				standards for CO2 emission monitoring and	efficiency and renewable	transition of the steel sector			

	and Trade (PAT) scheme ▪ Demand-side task force, 2023 for creating demand forgreen steel across key end use sectors				developing of methodology and institutional mechanisms for monitoring.	energy				
Japan	▪ R & D fund- design and development ofa promotion systemand institutional design to encouragethe spirit of challenges in companies in the operation of the green innovation fund	NA	Does exist	Tax incentives to stimulate 1.7 trillion-yen worth of private investment over 10 years	Japan has adopted such policy tool to monitor the life cycle environmental impact of product or services (Zhao et al., 2021)	Does exist	Initiatives are in place for RD & D support	Introduce d mandatory ESG discloser	Japan's act on promoting green purchasing, 2001 (Hasanbeigi & Bhadbhade, 2023)	NA
Russia	▪ Carbon trading under Article 6 of the Kyoto Protocol framework ▪ Voluntary carbon market ▪ Tax incentives for producing electricity using renewable sources of energy ▪ Green certificates issued to owners of the qualified facilities producing electricity using atomic or renewable energy sources	▪ **Environmental Laws** Industrial emissions are regulated in government decrees and federal authorities' orders. ▪ **Enforcement of environmental regulations** Civil, administrative andCriminal penalties for environmental damages ▪ **Environmental permit** Integrated environmental permit (for 7 yrs.) must be obtainedfor high emitting facility like steel ▪ Law on limiting GHG	Russia does notlevy an explicit carbon price	▪ Provided tax incentivesand price stimuli forenhanced use of renewable energy ▪ State subsidies for partial cost reimburseme nt of facilities' cost associated with the purchase and maintenance of energy efficient equipment and initiatives	Apartment buildings, lift and domestic appliances must have energy efficiency labelling	Implemented carbon trading scheme for investment projects to reduce GHG emission s	NA	High emitting facilities like steel must disclose data on GHG emissions over one year reporting periods through CPD	Introduced a draft amendment bills for low-carbon certifications (Green Certification s) to be issued to industrial facilities generating electricity using atomic or renewable energy sources	'Permitting regime'- similar to green taxonomy exists where all emitting facilities are classified into four categories (I-IV) from highest to lowest environmen tal impact

		emissions2021 ▪ National regulatory framework for monitoring GHG emissions is underdevelopment		▪ Three-year property tax rebate for energy efficient housing						
South Korea	▪ Emission trading scheme- major emitters of GHG (e.g., iron and steel)are required to put a limit on their CO_2 emission with average annual cap of 610mt CO_2 emissions set for initially 6 sectors including steel from 2021-2025	NA	Does exist	Provided R&D tax incentives for manufacturing industries including Steel	Implemented carbon labelling scheme (Liu et al., 2016)	Introduce d emission trading scheme (ETS) in 2015	Lot of investment has been done in RD & D towards developing high-value steel products	Republic of Korea introduced the environmental information disclosure system in 2013	Does exit (Hasanbeigi & Bhadbhade, 2023)	The Korean Green Taxonomy
USA	▪ Focus on energy efficiency- more than 2/3 of total GHG emissions reduction to near zero in 2050 comes from improvement in energy efficiency and switching low/no-carbon fuelsand electrification	Imposed 25% tariff on imported steel in 2018 under section 232 of the Trade Expansion Act of 1962	US does not have a federal carbon tax; however, many state and federal programs to reduce carbon emissions effectively price carbon—for example, through cap-and-trade systems or regulations	NA	Implemented carbon labelling scheme (Zhao et al., 2021)	Unveiled a new voluntary carbon trading market scheme	Initiatives are place for RD & D support	Us has mandated carbon reporting through CPD's supply chain program	Buy Clean California Act	NA

Indian Council for Research on International Economic Relations (ICRIER)

Our Offices:

4th Floor, Core 6A, India Habitat Centre, Lodhi Road, New Delhi-110003

The Isher Building, Plot No. 16-17, Pushp Vihar, Institutional Area, Sector 6, New Delhi-110017

O: +91 11 43112400, **F**: +91 11 24620180 | **W:** www.icrier.org | **E:** info@icrier.res.in