Green Industrial Policy for India's Iron and Steel Sector Transition

Assessing incentives for low-carbon production pathways

Policy Brief

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CLIMATE POLICY INITIATIVE

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ABOUT CLIMATE POLICY INITIATIVE

CPI is an analysis and advisory organization with deep expertise in finance and policy. Our mission is to help governments, businesses, and financial institutions drive economic growth while addressing climate change. CPI has offices in Brazil, India, Indonesia, South Africa, the United Kingdom, and the United States.

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ABBREVIATIONS

Abbreviation	Definition
BAU	Business As Usual
BESS	Battery Energy Storage System
BF	Blast Furnace
BOF	Basic Oxygen Furnace
CAGR	Compound Annual Growth Rate
Capex	Capital Expenditure
CCS	Carbon Capture and Storage
CCTS	Carbon Credit Trading Scheme
CCUS	Carbon Capture, Utilization, and Storage
CO_2	Carbon Dioxide
DRI	Direct Reduced Iron
DSCR	Debt Service Coverage Ratio
EAF	Electric Arc Furnace
ETC	National Emissions Trading Scheme
EV	Electric Vehicle
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIP	Green Industrial Policy
GPP	Green Public Procurement
H_2	Hydrogen
HBI	Hot Briquetted Iron
HRC	Hot Rolled Coil
I&S	Iron and Steel

Abbreviation	Definition
IF	Induction Furnace
IRR	Internal Rate of Return
LCOS	Levelized Cost of Steel
MoS	Ministry of Steel
MT	Million Tonnes
MTPA	Million Tonnes Per Annum
NSP	National Steel Policy (India)
OECD	Organization for Economic Co-operation and Development
Opex	Operating Expenditure
R&D	Research and Development
RE	Renewable Energy
tfs	Tonne Finished Steel
WPI	Wholesale Price Index

CONTENTS

EXECUTIVE SUMMARY

India's iron and steel (I&S) sector stands at a pivotal moment. As the country expands its manufacturing base to meet rising domestic demand, steel consumption is set to increase substantially over the next two decades. At the same time, the sector must navigate growing pressure to reduce its emissions footprint, with iron and steel currently accounting for roughly 12% of India's total greenhouse gas emissions. India has already laid a strong strategic foundation for addressing this challenge. The Ministry of Steel's recent roadmap and NITI Aayog's work on industrial decarbonization provide a comprehensive and forward-looking vision for the transformation of the sector. These efforts represent a significant step forward in articulating India's long-term ambition for a competitive, resilient, and low-carbon steel industry.

The dual challenge of meeting accelerated demand while aligning with India's 2070 net zero target creates a strategic opportunity for a Green Industrial Policy (GIP) for Steel. To meet the country's developmental needs, a well-designed GIP can guide investment, avoid high-carbon asset lock-ins, and position India competitively in the fast-evolving global market for low-carbon materials. This report is intended to complement and operationalize the strategic direction set out by the Ministry of Steel and NITI Aayog by focusing on the policy and financing frameworks required to translate vision into implementation.

Experience from other sectors demonstrates that effective policy can drive down costs, catalyze private investment, and accelerate the deployment of emerging technologies. India's renewable energy sector illustrates this clearly: targeted incentives, clear long-term signals, and supportive financial structures created one of the world's most competitive solar markets. In the automotive sector, phased policy support and market-creation mechanisms have expanded India's electric vehicle ecosystem, enabling rapid innovation and localization. These transitions show that coordinated policy action, predictable regulation, and catalytic finance can transform industries at scale.

This report draws on modelling and financial analysis to outline a set of strategic policy actions that, when implemented together, can enable India's low-carbon steel transition. Establishing a GIP for Steel would provide long-term clarity on technology pathways, prioritizing cleaner solutions like hydrogen-based DRI–EAF as the anchor for new capacity creation while managing the net zero aligned trajectory of high-emission routes. Targeted, time-bound subsidies—especially for green hydrogen and early demonstration projects—can close the viability gap during the transition phase. Introducing a predictable carbon price trajectory would steer capital towards cleaner technologies, enhance export competitiveness under emerging global norms, and reduce stranded-asset risks. Expanding concessional and blended finance will be essential for lowering the cost of capital, particularly for medium-sized producers. Complementary measures—including green public procurement, strengthening of the scrap ecosystem, support for CCUS in transitional clusters, and the development of industrial hubs with shared infrastructure—will further accelerate technology adoption and deepen supply-chain resilience.

India now has a window of opportunity to shape the future of its steel industry. A GIP for Steel can align economic growth with climate ambition, create high-quality jobs, attract global investment, and secure India's position in the emerging low-carbon economy. The pathway is clear; timely and coordinated action will determine the pace and scale of the transition.

1. CONTEXT

India is one of the world's fastest-growing economies, targeting a GDP of USD 30 trillion by 2047 (Economic Times, 2024). To support this scale of growth, India's manufacturing base and infrastructure systems will need to expand manifold over the coming decades.

Iron and steel are foundational for manufacturing growth, providing upstream inputs to several key industries such as infrastructure, automobiles, defense, and housing. India's iron and steel (I&S) sector had a healthy CAGR of 6% between 2019 and 2023, while China experienced a 1% growth, and a global decline of 1% was noticed (PIB, 2024). However, India's per capita steel consumption stands at 97.7 kg per annum, far below the global average of 233 kg per annum (PIB, 2023). This presents enormous potential for growth.

Additionally, the I&S sector plays a major role in providing employment opportunities, especially beyond metro centers. It contributes 2% to India's GDP and employs 600,000 people directly and 2,000,000 people indirectly (JSW, n.d.).

India has committed to achieving economy-wide net-zero emissions by 2070 (PIB, 2023). As one of India's highest-emitting sectors, I&S accounts for around 12% of the country's total GHG emissions, second only to the power sector (MoS, 2024). The sector will face increasing pressure to reduce its emission footprint even as demand accelerates. Unlike the power sector, where commercially mature low-carbon alternatives already exist, I&S has limited near-term low-carbon commercial technologies. Key options, such as green hydrogen-based reduction and carbon capture, are still early in their cost-competitiveness journeys, making the transition particularly challenging. Balancing rapid capacity addition with decarbonization will be essential to ensure India meets its climate commitments without slowing economic growth.

India's broader push to boost manufacturing through initiatives such as "Make in India" and Production-Linked Incentive (PLI) schemes aims to attract investments and integrate domestic industries into global supply chains. As these programs scale, it becomes imperative to align them with India's long-term net-zero goal. Experiences from other sectors, particularly renewable energy, show that well-designed industrial policies and financial instruments can accelerate technology adoption, reduce costs, and improve global competitiveness. A comparable policy approach tailored to I&S would help guide investment, reduce technology risks, and enable low-carbon production pathways to emerge over time (as illustrated in the figures in Section 2.1).

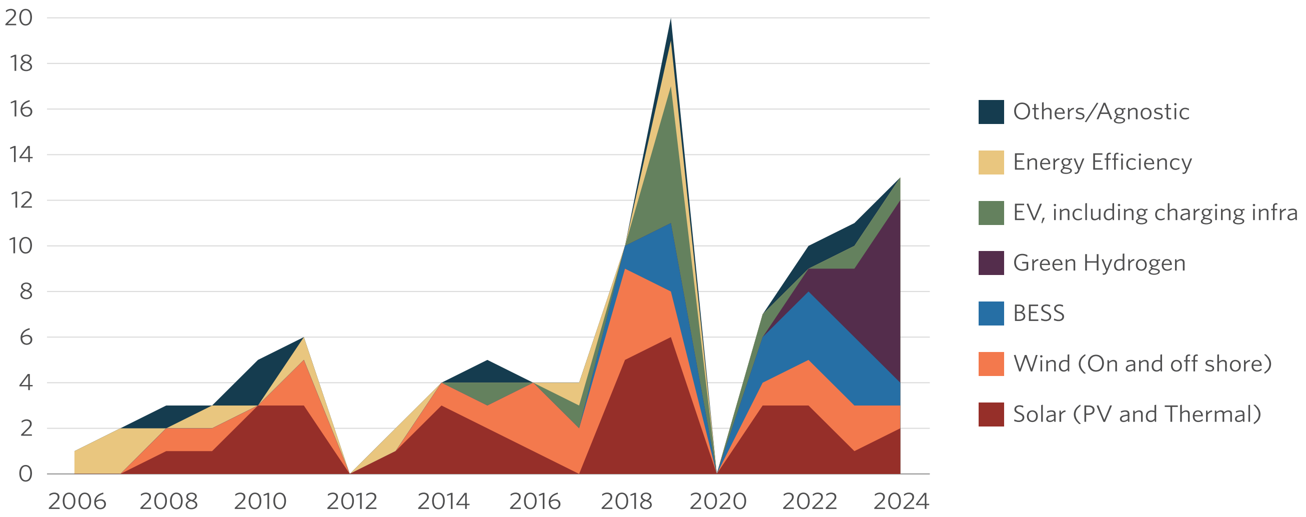
Within the broader sectoral context and the need for policy support discussed above, this technical brief presents a quantitative assessment of the policy levers required for low-carbon steel production, evaluating their impacts on emissions reduction, job creation, and low-carbon project economics. This includes the levelized cost of steel (LCOS), the internal rate of return (IRR), and the payback period.

2. GREEN INDUSTRIAL POLICY

Industrial policy comprises two broad types: 'functional' and 'selective.' Functional policies strengthen the overall framework in which businesses operate, such as improving infrastructure, education, and legal frameworks. In contrast, selective policies focus on specific activities or sectors, using measures such as tax incentives, R&D funding, and subsidies. Functional policies provide overarching support to all the sectors, reducing market risk, while selective policies provide targeted support to strategic sectors.

Green industrial policy (GIP) is more selective than traditional industrial policies, as it supports the establishment of specific industrial value chains and accelerates the introduction of clean technologies to address the climate crisis. Policies referred to as a GIP are those that align with net zero objectives and enable the transition to a low-carbon economy. This involves measures under selective industrial policies, such as targeted subsidies for emerging green industries to offset high initial capex, as well as opex support for emerging feedstocks, such as green hydrogen. The deployment of selective policies under a GIP is expected to allocate resources to the most promising sustainable technologies, ensuring that high-impact industries receive support to scale quickly. To assess the impact, CPI conducted a study of the major GIPs implemented in India targeting low-carbon technologies over the last two decades. Figure 1 highlights the distribution of major GIPs across low-carbon technologies.

Figure 1: Number of major GIPs implemented in India by targeted low-carbon technologies



Source: *CPI analysis*

The data reveals a strong correlation between the deployment of a GIP for a sector and its subsequent growth. As seen in the figure, solar received strong policy support from 2014 onwards, in the form of the Solar Mission, Solar Parks, Green Corridor, etc., resulting in exponential capacity addition in the last decade. Electric vehicles and supporting infrastructure have received increasing policy support in recent years, with schemes such as FAME, FAME-2, PM EDrive, resulting in continued sector growth, which is poised to accelerate in the near future. Similarly, policy support for green hydrogen has grown recently under National Green Hydrogen Mission , pointing to a gradual expansion beyond the power sector.

Figure 2a: Number of major GIPs implemented in India by instrument type

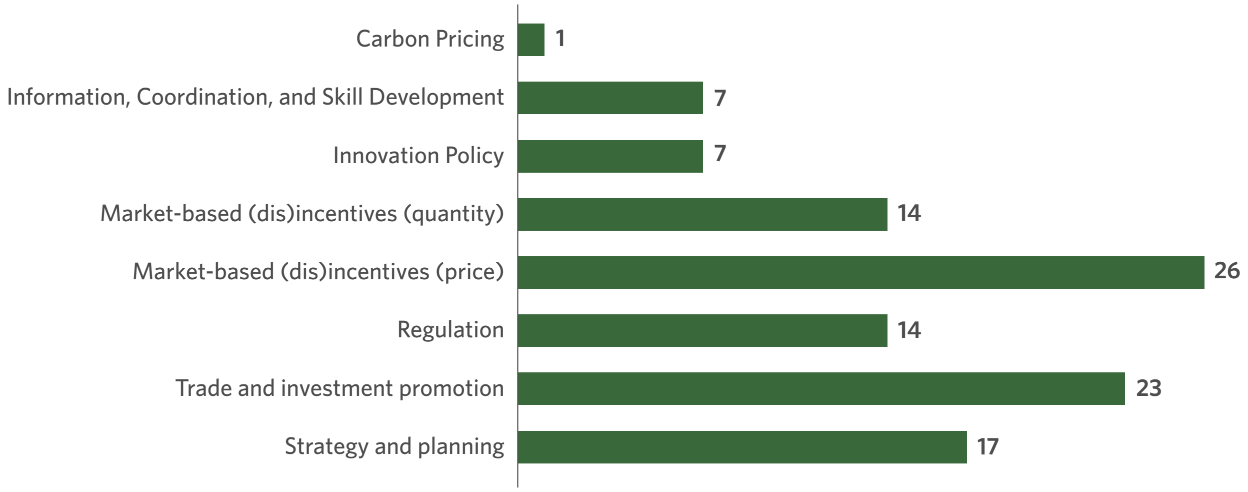
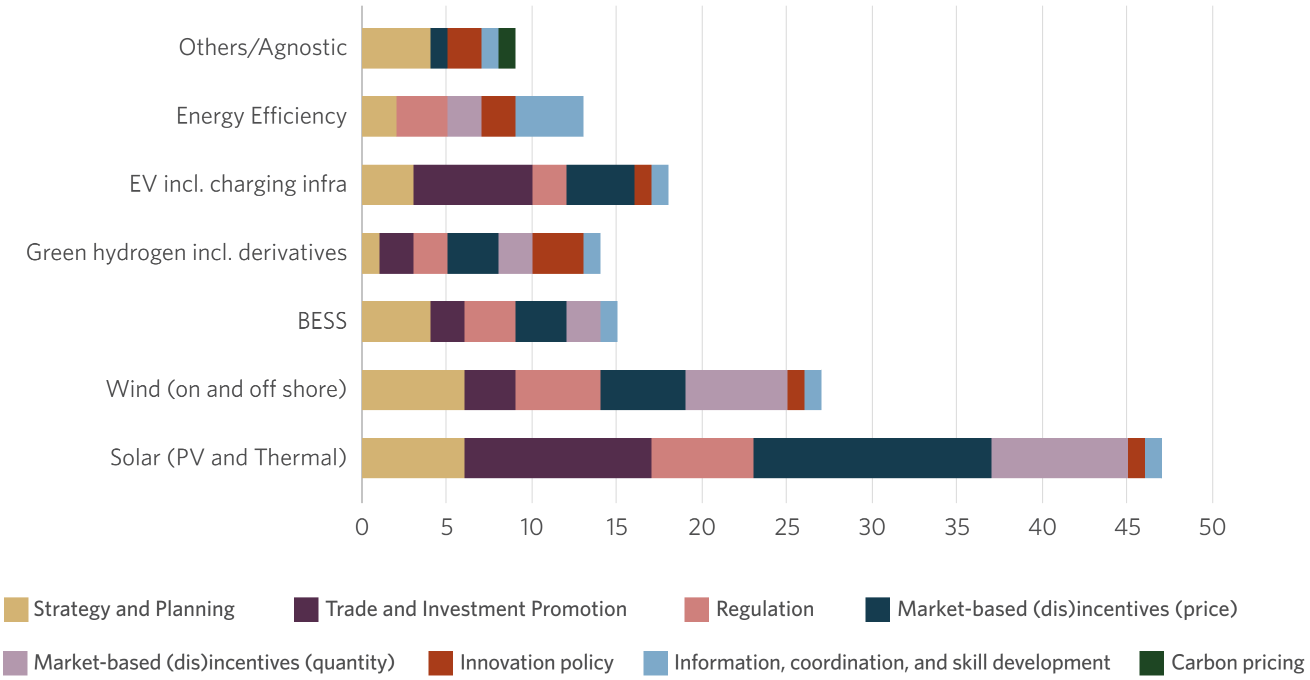


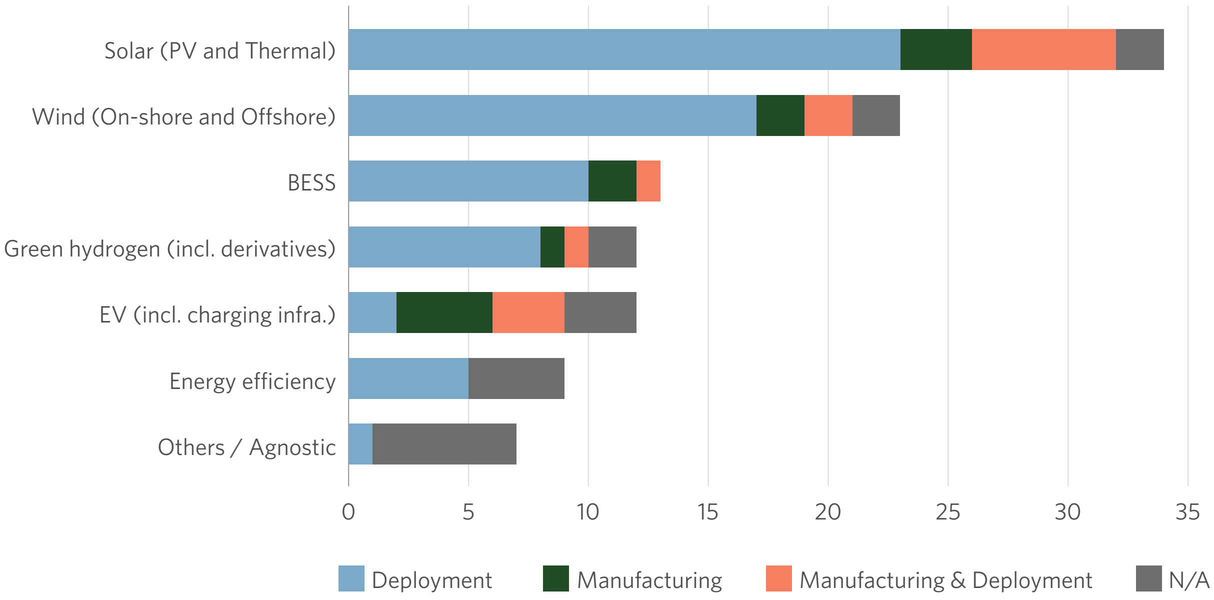
Figure 2b: Number of instruments used by target technology



Source: *CPI analysis*

Figure 2 presents a deeper dive into GIPs deployed across sectors based on instruments employed and their allocation across technologies. The report highlights the critical role of market-based incentives and investment promotions in scaling solar and wind energy in India, with a secondary focus on EV infrastructure, battery energy storage systems (BESS), and green hydrogen. CPI analysis found that carbon pricing has historically been the least used instrument, but is expected to play a larger role as the Carbon Credit Trading Scheme (CCTS) operationalizes in 2026.

Figure 3: Number of major GIPs implemented in India by stated objective - manufacturing, deployment, or both



Source: *CPI analysis*

Beyond the choice of instruments and targeted technologies, the design of GIPs has also evolved in terms of where along the value chain policy support is directed. Figure 3 above categorizes GIPs based on stated objectives. Earlier GIPs primarily emphasized deployment to stimulate demand for green products. In recent years, however, policy focus has shifted toward strengthening domestic manufacturing through incentive mechanisms such as the Production-Linked Incentive (PLI) scheme, aiming to build a more resilient value chain.

2.1 NEED FOR I&S SECTOR GIP

The I&S sector is hard to abate, with limited commercially viable technologies currently available to support deep decarbonization in line with India's Net Zero 2070 target. While direct reduced iron with electric arc furnace (DRI–EAF) is increasingly preferred for new capacity additions globally, India's steel industry has continued to prioritize blast furnace–basic oxygen furnace (BF–BOF) capacity. This preference is driven not only by favorable cost economics, but also by the availability of domestic raw materials such as iron ore and coking coal, established supply chains, and existing infrastructure that support BF–BOF operations at scale. According to the National Steel Policy (NSP, 2017), the BF-BOF pathway is expected to contribute about 60-65% of crude steel capacity and production, with the remaining 35-40% by the EAF & induction furnace (IF) pathway by 2030-31 (MoS, 2017). Structural constraints partly explain this preference: India's iron ore resources are predominantly lower-grade, better suited to blast furnaces, and the domestic scrap supply remains insufficient to meet growing demand. The substantial capital already committed to BF-BOF projects may contribute to a longer tenure of carbon-intensive assets within the sector. While carbon capture offers a potential interim solution, given its early stage of deployment and limited progress beyond pilot projects in India, it should be viewed as a transitional rather than a primary pathway to decarbonization.

Global GIP growth

An OECD study highlights that green industrial policies are on the rise. On average, countries allocate around 1.4% of GDP to industrial policies through grants and tax expenditures, with a marked preference for the latter. Between 2019 and 2021, green instruments increased in most countries, rising from an average of 0.22% to 0.24% of GDP. These instruments are broadly sector or technology-specific. Green grants are predominantly directed toward supporting renewable electricity generation in the energy sector and incentivizing the deployment of specific low-carbon technologies (OCED, 2023).

As per CPI's analysis, the technology readiness gap between BF-BOF and other lower-emission pathways, such as hydrogen-based steelmaking and carbon capture solutions, remains wide. Coupled with the cost barrier posed by the higher price of low-carbon steel, private investment is dampened in the absence of policy-induced demand or carbon pricing mechanisms.

Given the constraints mentioned above, India's I&S sector transition would require targeted policy interventions. The key challenges in the I&S sector transition can be distilled into three main elements for which GIP can play a key role in addressing, as shown in Table 1.

Table 1: Role of GIP in I&S transition

Key challenge	Point of failure	How GIP can help
Scrap deficit	Limited scrap availability reduces EAF viability	National scrap strategy and improved logistics can expand scrap supply
Lack of low-carbon steel demand	Buyers are unwilling to pay a premium without policy support	Green procurement policies and mandates can create potential markets for low-emission steel.
Lock-in of BF-BOF capacity	Conventional BF-BOF is cheaper today, creating a long-term carbon lock-in	GIP can redirect new investments toward low-carbon pathways (H_2-DRI, CCUS)

Source: *CPI analysis*

2.2 POLICY LANDSCAPE AND THE I&S SECTOR

The National Steel Policy (NSP) focuses on economic growth objectives and the high-level vision of a technologically advanced and globally competitive steel sector. The same has been analyzed in detail in annexure 1. There are a few decarbonization goals that guide a transition to lower-emission steel. NITI Aayog's recently published 'Greening the Steel Sector in India,' lays out an action plan for decarbonization. The roadmap lays out India-specific objectives and targets to inform and facilitate the road to net-zero. Table 2 analyzes the planned measures and targets.

Table 2: Greening the steel sector roadmap

Dimension	Planned measures/targets
Green steel emissions threshold	< 2.2 tCO_2/t for three-star rated; < 1.6 tCO_2/t for fivestar rated[1]
Net zero alignment	Steel sector netzero by 2070
Green hydrogen pilots	100% Green–DRI; hydrogen substitution in BF lines
Scrap & EAF transition	Promote heavy scrap use; shift away from BF-BOF pathways in the long term
Procurement mandates	Green steel mandates for government projects from FY 2027–28 onward
Financial incentives	PLI, concessional finance, and carbon credit frameworks

Source: *CPI analysis*

The roadmap is a crucial step toward aligning the steel industry's growth with India's net-zero goals, providing a north star for reducing sector emissions. A GIP combined with the Steel Policy can embed decarbonization objectives directly into the core of industrial strategy.

1 To be revised every three years.

3. APPROACH AND METHODOLOGY

This section outlines the detailed approach and methodology used to develop a comprehensive green industrial policy modelling framework for the iron and steel sector. The modelling framework followed a bottom-up approach, consisting of plant-level models that feed into the sectoral-level model, along with an integrated policy lever and an optimization module.

The plant-level model simulates the production pathways for greenfield steel projects to assess the financial and emission profiles. The modelling framework considered both conventional and transitional low-carbon steelmaking pathways. These include conventional BF-BOF, BF-BOF integrated with carbon capture and storage (BF-BOF + CCS), DRI-EAF using green hydrogen (DRI + EAF with H_2), EAF with outsourced Hot Briquetted Iron (EAF + HBI), and DRI configured for on-site HBI production (DRI for HBI Making).

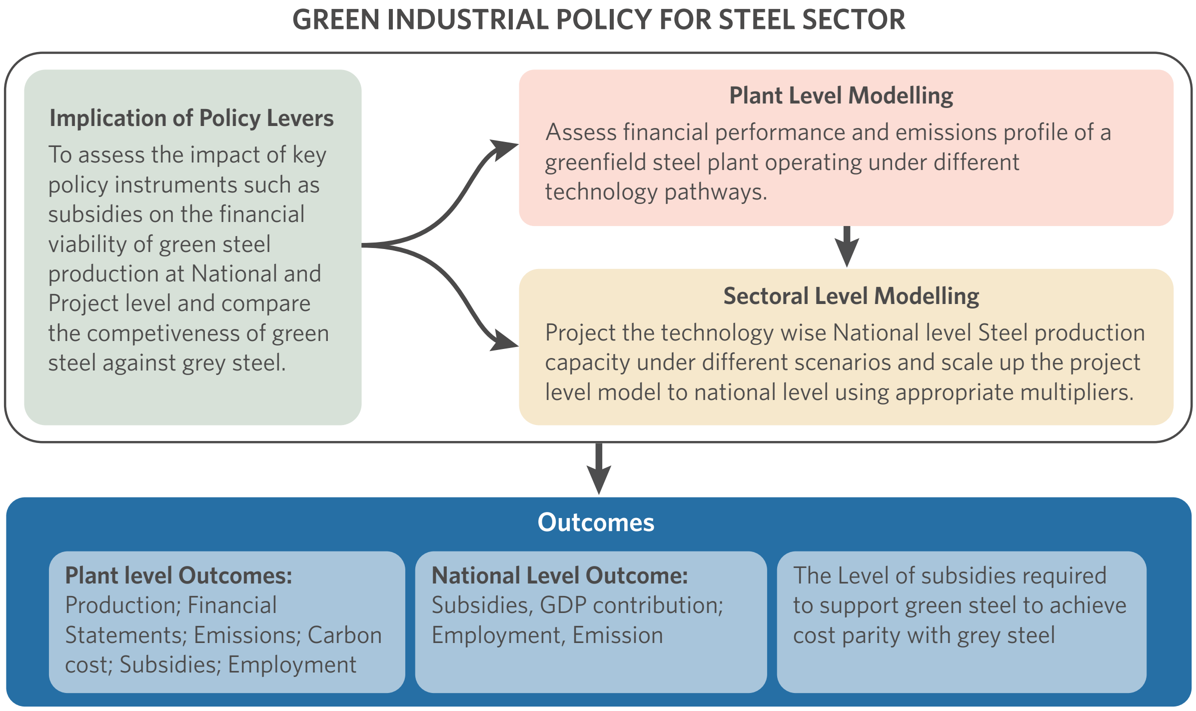
At the sectoral level, the modelling framework incorporates both existing capacities (legacy BF-BOF and Coal-DRIs) and greenfield expansion projects. However, due to data insufficiency and the study's defined scope, brownfield expansions and retrofitting projects have been excluded from both plant- and sector-level modelling frameworks.

Outputs from the individual greenfield plant simulations and existing capacities have been aggregated to the sectoral level, yielding India's projected steel production mix and technology transition pathways. The bottom-up integration ensures that the relationship between steel production and macroeconomics is derived from the plant-level model rather than a typical top-down approach. This bottom-up architecture also allows flexible scenario exploration: modifying assumptions at the plant level automatically recalibrates sector-wide projections, enabling robust testing of alternative technological and cost pathways.

Moreover, the modelling frameworks adopt an iterative approach to capacity expansion spanning 2026 to 2030, in line with the NSP (2017) trajectory, followed by capacity addition in low-carbon steel up to 2050. The technological shift between various gray steel and low-carbon steel technologies is governed by a combination of technical assumptions and Ministry of Steel (MoS) targets, ensuring alignment with national decarbonization goals.

A set of policy levers, such as fiscal incentives, carbon pricing, and financial support mechanisms, has been incorporated to understand the financial performance of different technologies, which has been further optimized to achieve an IRR comparable to that of gray steel production. The optimization module helped in understanding the minimum level of policy instruments required at the sectoral level to make low-carbon steel a viable option. This integrated modelling framework demonstrated how policy, technology, and investment could shape the steel sector's low-carbon transition.

Figure 4: Overall approach of GIP modelling



Source: *CPI analysis*

3.1 OVERVIEW OF PLANT-LEVEL MODELLING FRAMEWORK

The plant-level modelling forms the foundation of the GIP framework. The model captures the financial flows of a greenfield steel plant, modelling the project-level outputs under varying user-defined inputs and assumptions. The plant-level model begins in 2026 and operates iteratively through 2050, projecting year-on-year low-carbon steel production, revenue flows, and emissions.

Plant-Level User Inputs and Project levers: To increase flexibility and accuracy within the modelling framework, a user-driven approach is being adopted for key plant-level parameters, such as plant size, technical lifetime, and financial variables, including the debt–equity ratio, interest rates, debt repayment duration, etc. In addition, multiple project levers are being incorporated to control the feedstock pricing trajectories across minimum, maximum, and baseline price scenarios. These input price scenarios are being projected and primarily being indexed to the wholesale price index (WPI). The source of electricity is being treated as another important lever within the model, which can be drawn from the power grid, the open market, or from captive sources. For instance, most conventional BF-BOF plants rely on captive thermal power plants, which is one of the main reasons for their high emission intensity (Transition Asia, 2024). However, for DRI plants, the model assumes the use of renewable energy-based captive power to reduce the overall emission intensity. Scrap intake is also being treated as a critical lever affecting both cost structures and emissions. A sensitivity analysis is being conducted to quantify its impact on the financial outcomes. Detailed user inputs and assumptions supporting this analysis are provided in Annexure 3.

Technology-specific steel production pathways: Based on these inputs and project levers, the model assess plant performance across a range of greenfield steelmaking pathways, which are mentioned in the above sections.

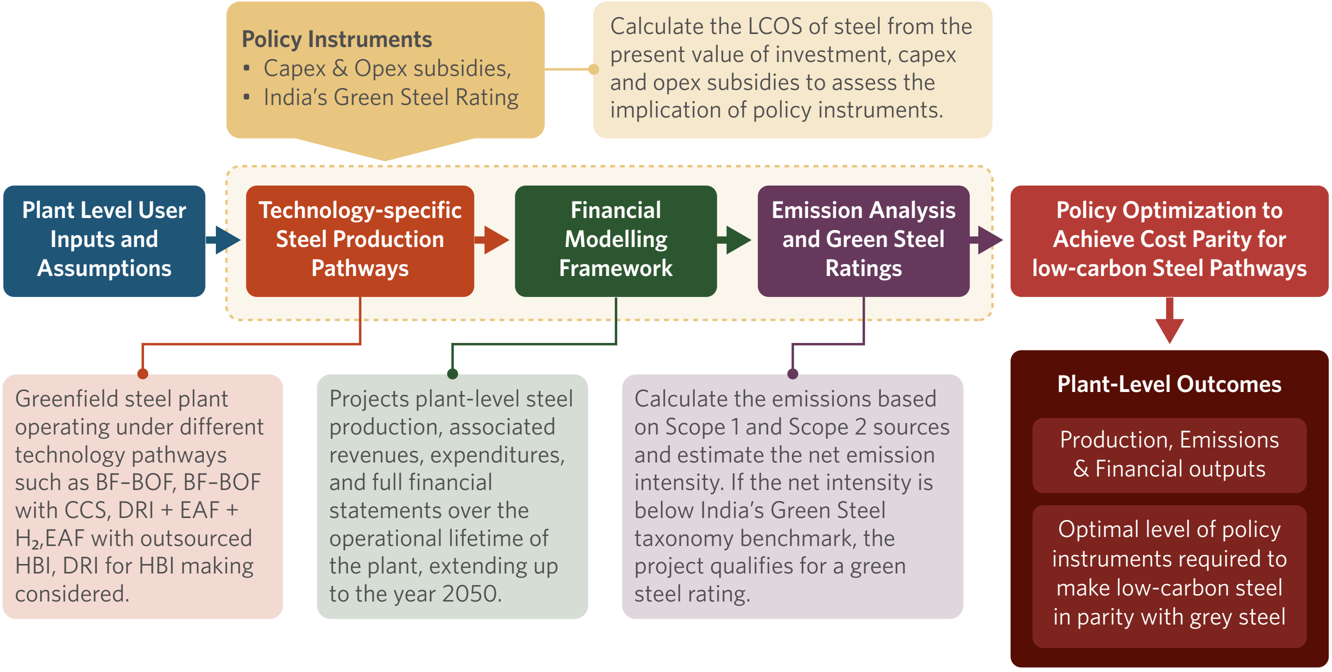
Each of these pathways follows a distinct operational route, with variations in equipment requirements, capital costs, operational expenses, feedstock needs, and emission levels. The feedstock consumption and capital cost for each steelmaking pathway are being calculated based on the midstream processing units involved in production. Correspondingly, emission factors for each feedstock are also being incorporated into the modelling framework. These values, along with the capex data, are summarized in Annexure 4**.**

Table 3: Technology pathways for steelmaking

Technology pathway	Process involved	Feedstock requirements	Energy source
Greenfield BF–BO	Iron ore is reduced using coke in the BF; molten iron is refined in the BOF to produce steel.	Iron ore, coking coal, limestone	Electricity is mainly required for running the plant equipment Sources: Grid, Market, or Thermal Captive
Greenfield BF-BOF + CCS	Same as BF-BOF but includes a CO_2 capture system.	Iron ore, coking coal.	Electricity is required for running the plant Sources: Grid, Market, or Thermal Captive
Greenfield DRI + EAF with H_2	Iron ore is reduced using green hydrogen and processed in an EAF to form steel.	Iron ore, green hydrogen	Electricity is used to operate plant equipment and to drive energy-intensive processes such as electric arc furnaces and electrolysers for hydrogen production. Sources: Grid, Market, or RE Captive
Greenfield EAF with Outsourced HBI	HBI melted in EAF; no DRI or hydrogen production	Outsourced HBI	Electricity is used to operate plant equipment and to drive energy-intensive processes such as electric arc furnaces and electrolysers for hydrogen production. Sources: Grid, Market, or RE Captive
Greenfield DRI for HBI Making	Iron ore is reduced by using hydrogen-based DRI	Iron ore, Hydrogen	Electricity is used to operate plant equipment and to drive energy-intensive processes such as electric arc furnaces and electrolysers for hydrogen production. Sources: Grid, Market, or RE Captive

BF-BOF technology, which currently dominates steel production, is one of the most carbon-intensive pathways, relying heavily on coal both as a reducing agent and a primary energy source. In this study, greenfield BF-BOF is being adopted as the baseline steelmaking pathway to benchmark the gray steel production pathways. All other transitional pathways, including BF-BOF+CCS, DRI + EAF, are comparatively less carbon-intensive. In the model, the BF-BOF+CCS configuration is assumed to abate approximately 80% of process emissions through single-point carbon capture applied to the blast furnace gas stream (CPI, 2025). Coupling these processes with cleaner energy sources could significantly reduce emissions from these pathways.

Figure 5: Plant-level modelling framework



Source: *CPI analysis*

Financial Modelling Framework: For each steelmaking pathway, based on plant-level user inputs and financial and technological assumptions, the module enables a comparative assessment of investment attractiveness. This is being done through cash flow analysis and the calculation of key financial indicators, including the IRR, payback period, and debt service coverage ratio (DSCR). The model estimates the levelized cost of steel production using discounted cash flow analysis, which helped benchmark different technologies against the market price. Details are given in **Annexure 4.**

Emission Analysis and Green Steel Ratings: Emissions from the steel plant were estimated by accounting for Scope 1 (direct) and Scope 2 (indirect: electricity) emissions. Scope 3 emissions (indirect: outside the plant location) are being excluded from the analysis. India's Green Steel Taxonomy identifies steel produced with an emission intensity of 1.6-2.2 tCO_2/tfs as "Green Steel" (Press Information Bureau, 2024b). However, the emission intensity for green steel is expected to reduce over time. This analysis considers that the emission threshold will be revised during the initial four cycles of three years from 2024 to 2035 and will subsequently shift to stricter annual reduction targets, ultimately reaching 0.9 tCO_2/tfs in alignment with international standards presented by the Joint Research Centre (JRC, 2025). This evolving Green Steel Taxonomy could serve as a guiding principle for determining the trajectory of India's carbon price. The plant-level emission intensity was then benchmarked against the projected emission threshold trajectory. Based on the corresponding emission allowances, carbon credits to be purchased or generated were estimated. The resulting cost/revenue was added to the operational revenue/expenditure stream to determine the plant's overall financial performance.

3.2 OVERVIEW OF SECTORAL-LEVEL MODELLING

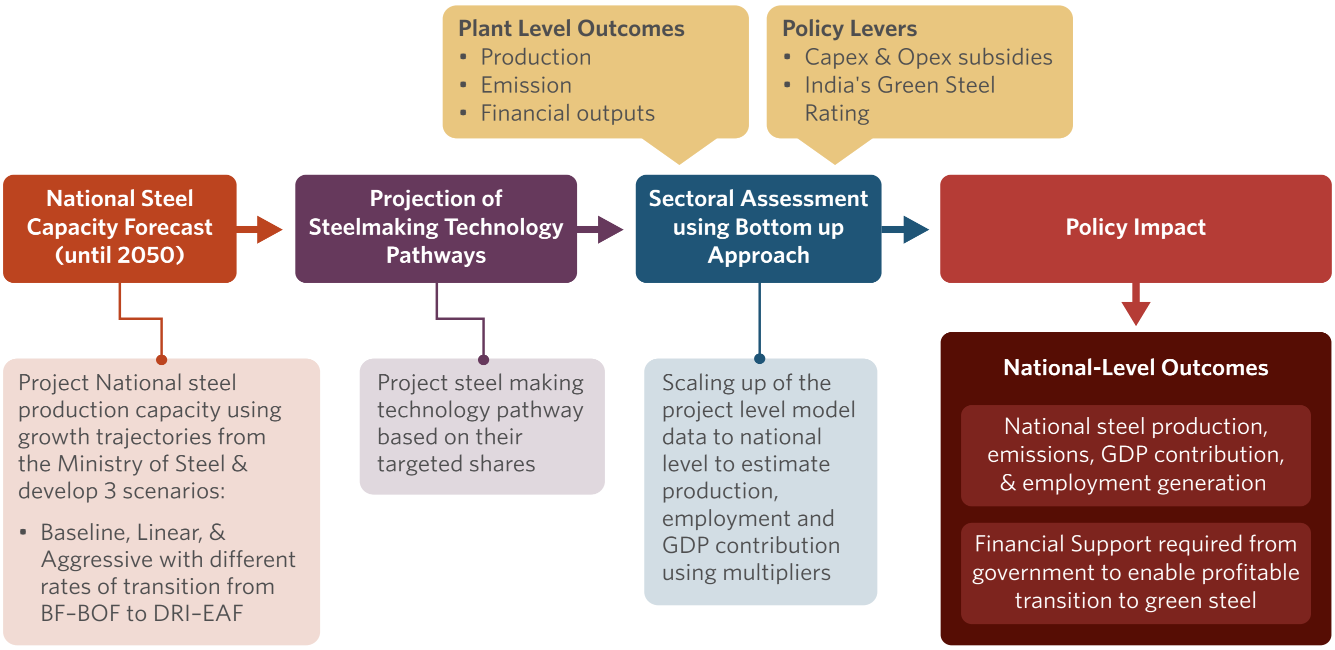
The sector-level modelling framework integrates the plant-level output to project the national-level steel production capacity and technology mix, in line with national steel production targets. Under the MoS trajectory, steel production capacity is expected to reach around 300 MT by 2030 and 500 MT by 2047. Additionally, as per this trajectory, BF-BOF is projected to account for around 60% of the capacity share, with DRI reaching around 40% by 2030 (Ministry of Steel, 2017).

To align future capacity additions with a low-carbon transition pathway, BF-BOF technology is being held constant after 2030, with no further expansion. Moreover, the framework considers CCS as an interim decarbonization measure. Accordingly, CCS deployment is assumed for the short term until hydrogen-based DRI-EAF technology matures. Thus, the future demand in the sector is considered to be mainly driven by DRI-EAF technology pathways.

Using a scaling-up factor of plant-level outcomes, the sector-level production, employment generation, and GDP contribution were estimated. Multipliers are given in the Annexure 3.

Figure 6 illustrates the sector-level modelling framework used to develop a green industrial policy for the Indian iron and steel sector.

Figure 6: Sector-level modelling framework

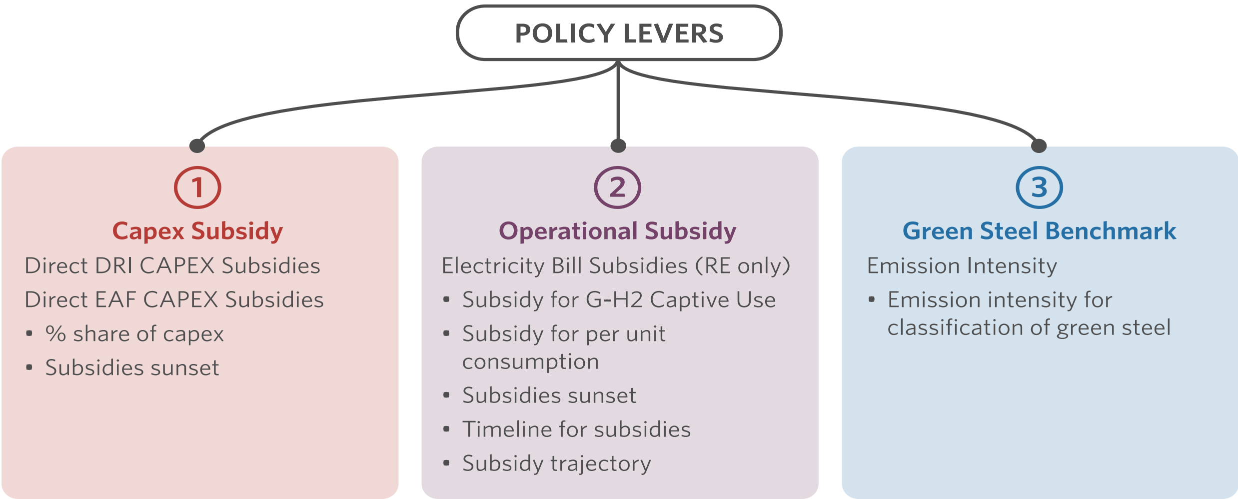


Source: *CPI analysis*

3.3 POLICY-LEVEL OPTIMIZATION

At the policy level, there are already some policies in place, such as the National Green Hydrogen Mission and the Green Steel Taxonomy. Future measures may include green public procurement (GPP), interest subvention schemes, production-linked incentives, viability gap funding, or targeted subsidies.

Figure 7: Policy Levers



Source: *CPI analysis*

Given the scope of this study and uncertainties regarding the nature of future policies and timelines, a representative set of policy levers has been selected to analyze their implications for low-carbon steel production. These include direct subsidies, green steel benchmarking, and carbon price trajectory. Within direct subsidies, both capex subsidies for DRI and EAF technologies and opex subsidies for hydrogen and electricity were considered.

The primary objective of the optimization module was to minimize the subsidy requirements while maintaining a market-competitive IRR for the DRI-EAF pathway. Simultaneously, the framework maintained viable returns for BF, the BF-BOF, and BF the BF-BOF + CCS pathway through the transition years, ensuring these pathways remain financially viable until the EAF pathway becomes fully competitive. The variables include:

I. The percentage share of DRI and EAF subsidies based on their respective capital costs.

II. Electricity subsidies (renewable energy-only) and hydrogen subsidies for captive use.

III. The trajectories for opex subsidies.

IV. Timelines for capex and opex subsidy implementation.

V. Emission intensity targets for green steel for the years 2026 and 2050.

The optimization problem can be formulated as:

$$Minimize{:}\ Z = \sum_{t=0}^{T} (Capex\ subsidy + Opex\ Subsidy)$$

$$Subject\ to{:}\ \ IRR_{DRI\text{-}EAF}(13 \pm 2\ \%)\ \&\ IRR_{BF\text{-}BOF}\ (min\ Profitable\ IRR)\ \forall\ t \leq 2030$$

The study estimated the required levels of these policy instruments to ensure the profitability of low-carbon steel production in India. Key insights and results of the modelling exercise are provided in the next chapter.

4. KEY INSIGHTS

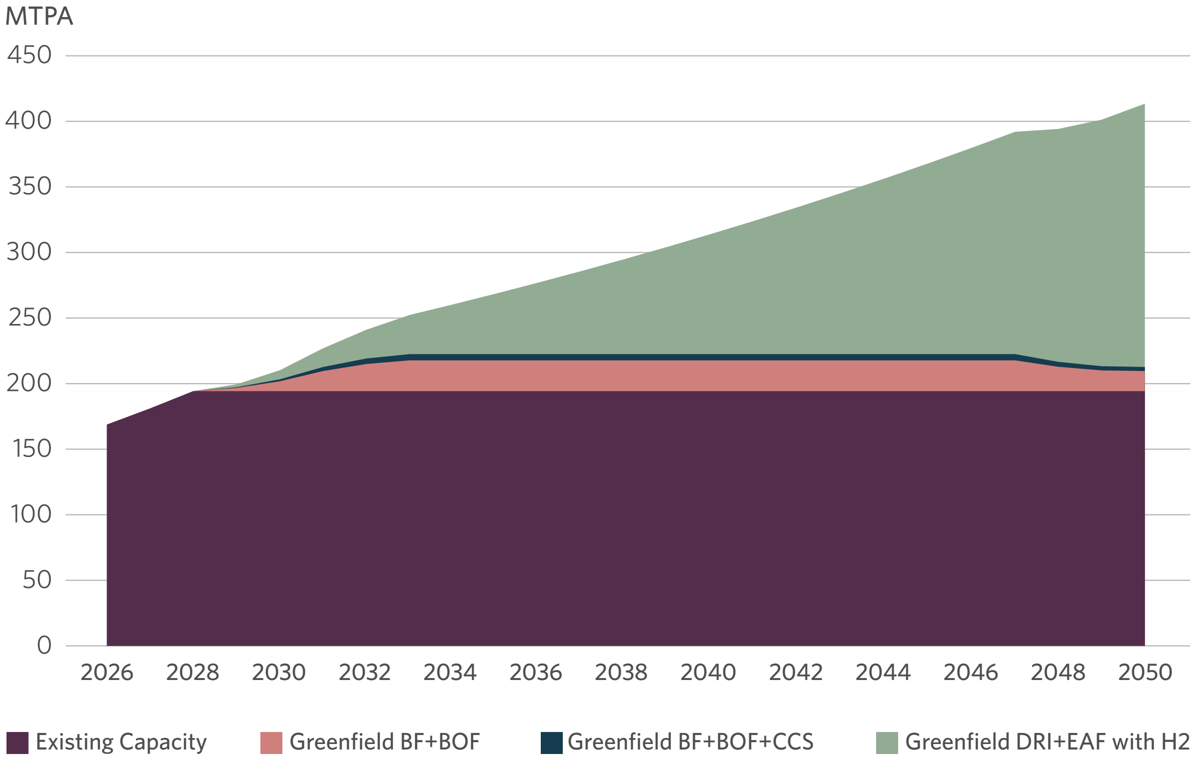
This chapter summarizes the key insights emerging from the modelling undertaken to evaluate the conditions under which low-carbon steel production in India can achieve financial viability. Building on the contextual and methodological framework outlined earlier, the analysis quantifies how combinations of capital and operational support, together with carbon pricing, shape the uptake of low-carbon steelmaking pathways.

The results are organized into thematic subsections, including the projected evolution of competing production pathways, the scale and design of required subsidy support, the carbon price necessary to close the cost gap, and the corresponding effects on project-level economics. The section also assesses the pathway's emission-reduction potential. It concludes with an examination of the wider macroeconomic implications, highlighting how a transition to low-carbon steelmaking can contribute to employment creation, industrial competitiveness, and long-term GDP growth.

4.1 PRODUCTION PATHWAY TRAJECTORY

India's steel production landscape is projected to undergo a sharp transformation over the next two decades. As per our analysis, Steel production in 2050 is expected to be dominated by yet-to-be-commissioned hydrogen-based DRI-EAFs and legacy unretired capacity,[2] as shown in Figure 8.[3]

Figure 8: Technology-wise steel production distribution (MTPA)



Source: *CPI analysis*

2 The existing capacity in this figure consists of legacy blast furnaces and coal DRIs.
3 In our analysis, we have assumed the capacity utilization factor of 80% based on inputs from industry experts.

The legacy blast furnace and coal-DRI capacity is projected to plateau after 2028, representing existing production capacity that will gradually retire beyond the modelling horizon. The greenfield addition of blast furnaces could taper down by 2030, owing to carbon pricing mechanisms being developed under CCTS in India. The potential of CCS to decarbonize could remain limited due to technological and economic challenges associated with carbon capture. By 2030, only 4 million tonnes per annum (MTPA) of production capacity may consist of carbon-capture-based BF-BOFs, with profitability sustained solely by capacity commissioned by 2033/34, throughout their 40-year operation. This could primarily serve as a transitional solution until DRI-EAF deployment is ramped up.

By the early 2030s, greenfield investments could begin to favor the DRI-EAF pathway using hydrogen as the primary reducing agent. The transition would accelerate even further in the 2040s as the low-carbon steel production pathway and renewable energy costs fall with economies of scale.

The emergence of DRI-EAF as the preferred pathway indicates a structural shift toward electrification and hydrogen use, aligning with India's objective of deep decarbonization. This change could be driven by hydrogen subsidies, as discussed in the following subsection.

4.2 SUBSIDY DESIGN

Low-carbon steelmaking continues to face a significant cost differential relative to the conventional BF-BOF pathway. Capital expenditure for hydrogen-based DRI-EAF configurations is currently approximately 1.5 times higher than that of traditional pathways, and operating costs rise substantially as production shifts from coal to inputs such as green hydrogen and renewable electricity. As per our analysis, the elevated cost of clean hydrogen is the dominant contributor to the overall cost premium in the early stages of transition.

In the absence of targeted support, early low-carbon steel projects cannot meet commercial investment thresholds. Modelled project-level returns range between 4–6%, well below the 10–12% internal rate of return typically required to attract long-tenure industrial capital from investors and lenders. This underlines the need for calibrated fiscal intervention to bridge the viability gap during the technology's initial deployment phase.

Our analysis highlights that rather than sustained, large-scale subsidies, the transition requires lean, time-bound, and viability-gap-oriented support to catalyze early investments, reduce supply-chain risk, and enable cost declines over time. A well-structured subsidy package can narrow the cost gap between conventional and low-carbon pathways while maintaining fiscal prudence. The analysis, therefore, proposes a phased subsidy roadmap and evaluates two direct policy instruments (Table 4) that could influence investment decisions and operating costs for low-carbon steelmaking projects.

Table 4: Optimized subsidy instruments

Category	Applicability	Details
Capex subsidy	For DRI	1% of capex cost
	For EAF	4% of capex cost
Opex subsidy	Green hydrogen subsidy	INR 50/kg in year 1, tapering to INR 30/kg by year 3
	Electricity subsidy	Not required

Source: *CPI analysis*

This combination could enable the deployment of commercially viable DRI-EAF in the early years while allowing the sector to transition toward long-term self-sufficiency. Capex support could ease upfront financing barriers for initial projects, but its effect on long-term competitiveness is limited. Opex support for green hydrogen remains the key lever, as it could directly lower production costs and enable medium-term cost parity with BF-BOF.

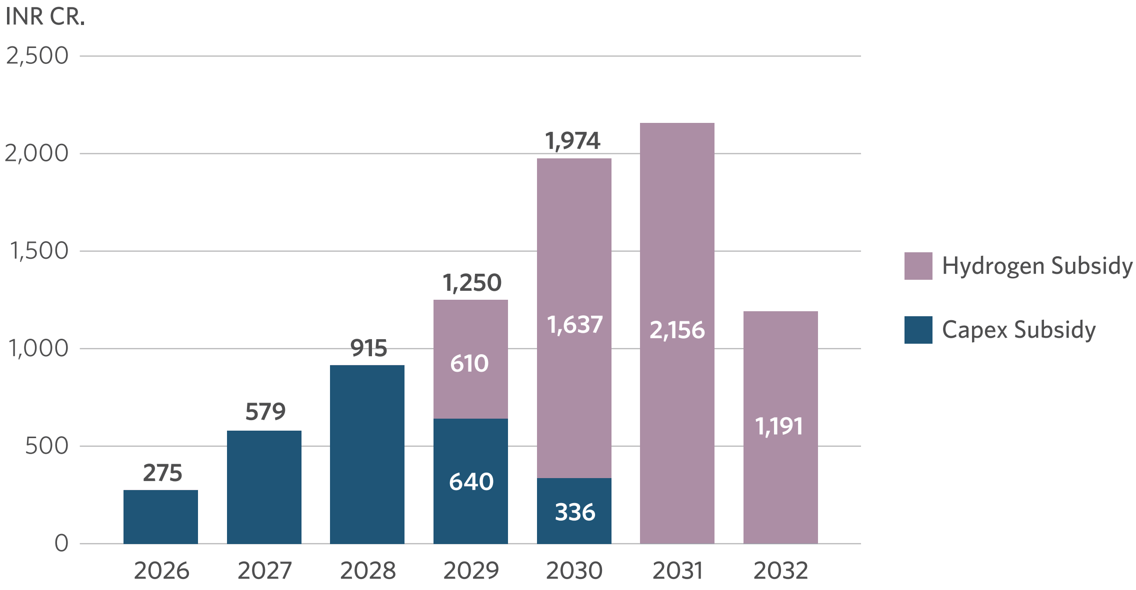
The optimized subsidy pathway excludes electricity subsidies, as renewable power has already achieved cost parity with grid electricity. Most producers can further stabilize costs through the procurement of renewable energy in-house. **Including electricity subsidies would therefore raise the fiscal burden without improving adoption outcomes.**

As per CPI analysis, the subsidy requirement could peak at INR 2,156 crore in 2031 and declines as hydrogen prices fall with technological learning and domestic supply-chain expansion.

The subsidy package supports 39 MTPA of low-carbon steel capacity by 2032 in line with India's long-term production trajectory. The cumulative subsidy outlay between 2026 and 2032 is INR 8,340 crore, of which:

- 67% is for hydrogen operating cost reduction.
- 33% is capital cost relief for technology adoption.

Figure 9: Subsidy expenditure (INR Cr.)



Source: *CPI analysis*

The subsidy framework is modelled to be fiscally efficient and strategically targeted. Its overall budgetary footprint remains small relative to the sector's scale, ensuring that public support is catalytic rather than distortionary. As green hydrogen costs decline and electrolyzer performance improves, subsidy needs fall proportionally, creating a naturally self-tapering structure. The framework also maintains operational flexibility by allowing producers to source hydrogen through either captive or merchant routes, enabling alignment with changing cost and supply conditions. All instruments are time-bound, with clear sunset clauses, thereby limiting long-term fiscal exposure while encouraging innovation, accelerating technology learning, and improving cost competitiveness.

In parallel, carbon pricing could be essential in strengthening the business case for low-carbon steel. The following section outlines how carbon pricing interacts with subsidies to create a balanced, mutually reinforcing policy framework.

4.3 CARBON PRICING

Carbon pricing could be a critical policy lever for narrowing the competitiveness gap between conventional and low-carbon steelmaking. While subsidies help manage the near-term costs of technology transition, a credible and predictable carbon price could establish a long-term economic signal by internalizing emissions costs and directing investment toward low-carbon steel production pathways.

The analysis indicates an upward carbon price trajectory, beginning at USD 10 per tCO_2 in 2025 (S&P Global, 2024) and reaching USD 50 per tCO_2 by 2050.[4]

4 1 USD = 85 INR

Table 5: Projected for carbon price for this analysis

Year	2025	2030 (P)	2035 (P)	2040 (P)	2045 (P)	2050 (P)
Projected carbon price (USD/tCO_2)	10	30	35	40	45	50

Source: *CPI analysis*

Carbon pricing could be critical for closing the competitiveness gap between conventional and low-carbon steelmaking. While subsidies address near-term transition costs, a credible and predictable carbon price provides the long-term market signal needed to internalize emissions costs and steer capital toward cleaner production pathways. Together, these may instruments create a balanced financial architecture that strengthens the business case for low-carbon steel over time.

A rising carbon price progressively erodes the profit margins of BF-BOF plants by increasing the cost of high-emission operations, creating clear financial risk for carbon-intensive assets. For low-carbon producers such as green hydrogen–DRI, it could potentially enhance financial resilience by improving project returns, narrowing the cost gap with BF-BOF, and attracting investment.

As per our analysis, BF-BOF with CCS remains a transitional option only for plants commissioned before 2033/34, as these facilities can absorb carbon costs across their operating lifetimes. Beyond this window, new CCS-based projects become uneconomical due to residual emissions that require credit purchases and the inherent limits of capture efficiency, which limit compliance with emerging green standards. Carbon pricing, therefore, may function as both a risk-management instrument for legacy technologies and an opportunity driver for low-carbon pathways in India's decarbonization architecture.

India currently lacks an explicit economy-wide carbon price. Existing mechanisms—such as Perform, Achieve, and Trade and Renewable Energy Certificates—offer partial signals but are shaped by sector-specific market conditions. The ongoing development of the National ETS and Carbon Credit Trading Scheme (CCTS) is expected to introduce a unified, market-based price that better aligns domestic carbon costs with global trends.

Predictable carbon pricing can also deepen financial markets by creating sustained demand for carbon credits and supporting the growth of green ratings, carbon-linked financial instruments, and results-based finance structures that reward verified emission reductions.

4.4 FINANCIAL VIABILITY OF LOW-CARBON STEEL PATHWAYS

The financial analysis evaluates the performance of different steel production pathways across policy and market scenarios. The results indicate a clear, investable transition pathway in which hydrogen-based DRI-EAF emerges as the most future-ready option. When paired with transitional subsidies and a moderate carbon price, the pathway could achieve acceptable returns without compromising financial viability.

INVESTMENT RATIONALE FOR TRANSITION

By 2026, low-carbon steel technologies would be technically mature but commercially constrained. Conventional BF-BOF continues to deliver strong short-term returns, driven by lower input costs and established supply chains. Still, its cost structure is increasingly vulnerable to future carbon pricing, fuel price volatility, and potential border adjustment measures. In contrast, H_2-based DRI-EAF offers long-term cost stability and near-zero emissions but requires initial support to compete during the transition phase. Financial indicators—including Internal rate of return (IRR), payback period, and levelized cost of steel (LCOS)—provide a comprehensive view of how project viability evolves under different policy and market conditions.

2026: SUBSIDIES UNLOCK EARLY ADOPTION

Hydrogen-based DRI-EAF is not yet investment-ready at only 4% equity IRR, constrained by high capital intensity and operational costs. Capital subsidies alone are insufficient to shift this scenario. In our model, the breakthrough emerges when the hydrogen operational subsidy is combined with the carbon price, lifting H_2-DRI + EAF equity returns to 13%, reducing the payback period to six years, and significantly narrowing the LCOS gap with BF-BOF.

Under the business-as-usual (BAU) scenario in 2026, the economics of low-carbon steelmaking remain fundamentally unbalanced. Conventional BF-BOF assets dominate with a 22% equity IRR, and even BF-BOF + CCS delivers a competitive 15%, highlighting the continued financial strength of coal-based pathways.

This demonstrates that no single instrument, but rather a coordinated mix of capital support, operating incentives, and carbon pricing, can bring the first generation of low-carbon steel plants into the investable zone, laying the groundwork for scale-up in the next decade.

Table 6: Comparative financial performance of steelmaking pathway under different policy scenarios (2026)

Pathway	Equity IRR (BAU)	IRR with capex subsidy	IRR with capex + opex subsidy	IRR with subsidy + carbon price	Payback (years)	LCOS (INR/t)
BF-BOF	22%	22%	22%	19%	4	95,550
BF-BOF + CCS	15%	15%	15%	18%	5	96,449
H_2-DRI + EAF	4%	7%	9%	13%	6	98,044

Source: *CPI analysis*

2030: COMPETITIVENESS SHIFT WITH CARBON PRICING

By 2030, policy signals will begin to reshape market behavior more visibly. In the absence of any support, BF-BOF still yields the highest returns (26%), with BF-BOF + CCS at 14% and H_2-DRI + EAF at just 5%. Capex subsidies offer incremental improvement, but the combination of capex and opex support will meaningfully increase the hydrogen-based DRI-EAF IRR to 12%.

When carbon pricing is layered in, the competitive landscape changes sharply: conventional BF-BOF profitability declines to 9% due to rising carbon liabilities, while BF-BOF + CCS improves to 17% and H_2-DRI + EAF achieves a 15% IRR with a stable five-year payback.

Crucially, hydrogen-based steel becomes the lowest-LCOS option at INR 1,05,985/t—undercutting BF-BOF and BF-BOF + CCS for the first time. This turning point underscores how the combined effect of targeted subsidies and carbon pricing shifts incentives away from unabated coal technologies and toward future-ready hydrogen pathways.

Table 7: Comparative financial performance of steelmaking pathways under different policy scenarios (2030)

Pathway	Equity IRR (BAU)	IRR with CAPEX Subsidy	IRR with CAPEX + OPEX Subsidy	IRR with Subsidy + Carbon Price	Payback (Years)	LCOS (INR/t)
BF-BOF	26%	26%	26%	18%	4	1,08,429
BF-BOF + CCS	14%	14%	14%	17%	4	1,07,729
H_2-DRI + EAF	5%	9%	12%	15%	5	1,05,985

Source: *CPI analysis*

2050: HYDROGEN-BASED STEEL MAKING ACHIEVES COST LEADERSHIP

By 2050, the cumulative effect of earlier policy support, cost learning, and carbon constraints will entirely reshape the sector. Both BF-BOF and BF-BOF + CCS become financially unviable under stringent carbon regimes and volatile fossil-fuel economics, resulting in negative returns.

Hydrogen-based DRI-EAF attains long-term cost leadership, delivering a 13.3% IRR and the lowest LCOS at INR 1,69,375/t. This outcome reflects the compounded benefits of early policy intervention—CAPEX incentives to reduce entry barriers, OPEX support during market formation, and a predictable carbon price trajectory.

Together, these levers establish hydrogen steelmaking as the most resilient and competitive production pathway by mid-century.

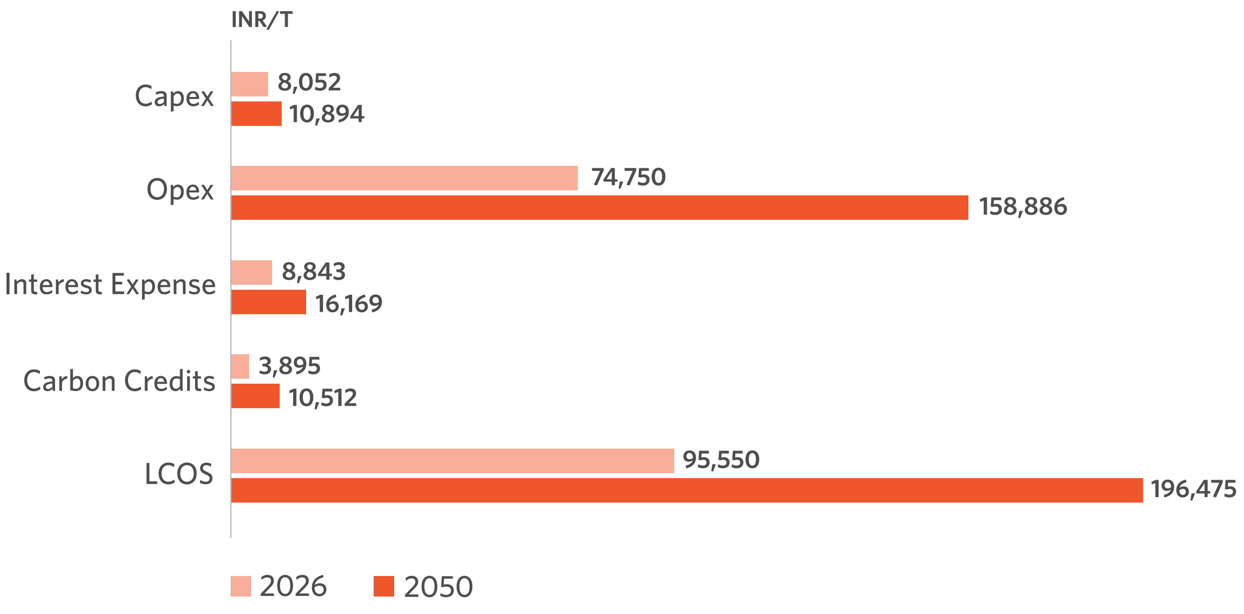
Table 8: Comparative financial performance of steelmaking pathways under different policy scenarios (2050)

Pathways	Equity IRR (BAU)	IRR with capex subsidy	IRR with capex + opex subsidy	IRR with subsidy + carbon price	Payback (years)	LCOS (INR/t)
BF-BOF	22%	22%	22%	-ve return	23	1,96,475
BF-BOF + CCS	11%	11%	11%	−ve return	23	1,89,785
H_2-DRI + EAF	9%	9%	9%	13.3%	5	1,69,375

Source: *CPI analysis*

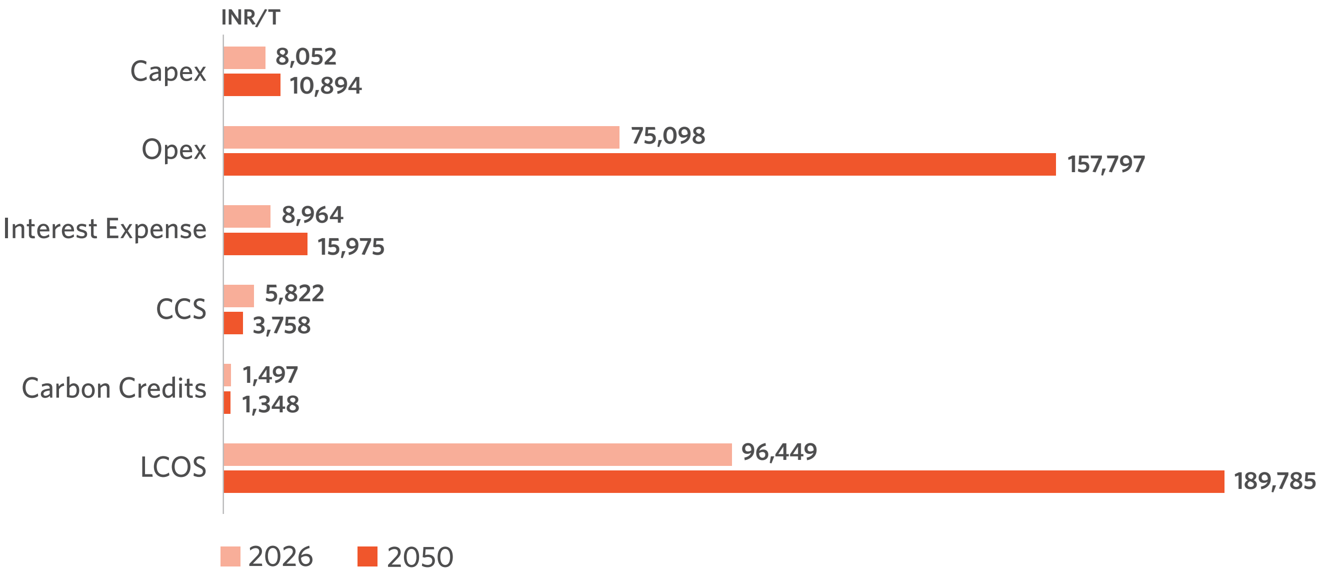
In terms of LCOS, the analysis shows that operating costs dominate total production costs. The graphics below highlight the cost component of LCOS over time for BF-BOF, BF-BOF +CCS, and the H_2 DRI-EAF pathway.

Figure 10: BF-BOF LCOS cost component (INR/T)



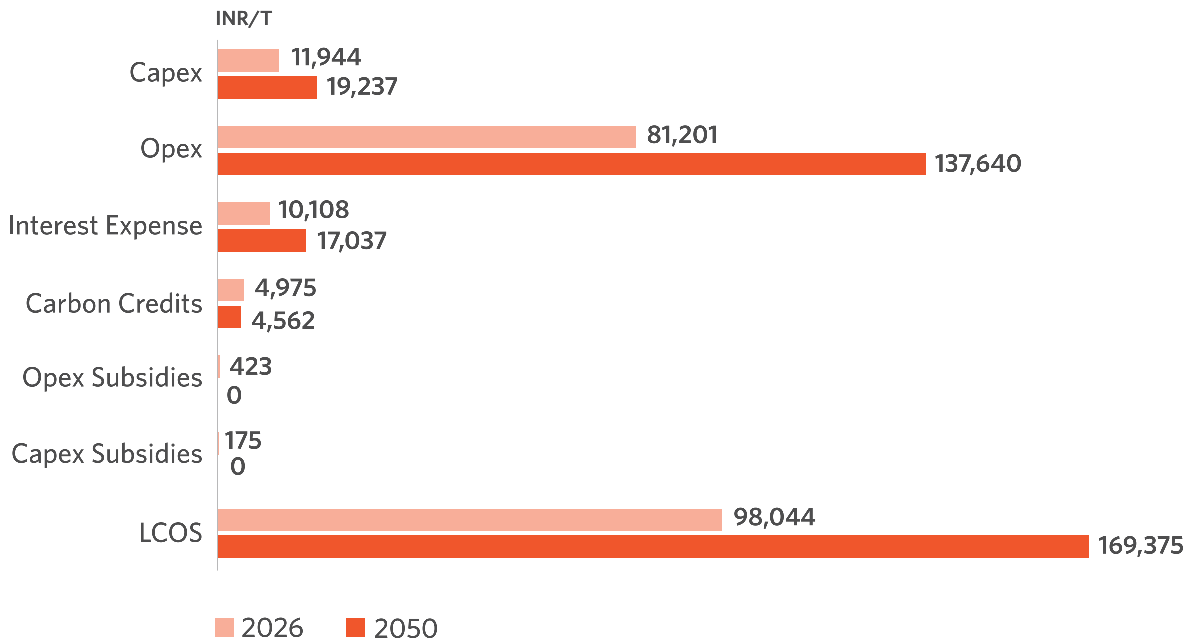
Source: *CPI analysis*

Figure 11: BF-BOF+CCS LCOS cost component (INR/T)



Source: *CPI analysis*

Figure 12: H_2 DRI-EAF LCOS cost component (INR/T)



Source: *CPI analysis*

In 2026, green hydrogen accounts for nearly 40% of H_2-DRI + EAF operating cost. Hydrogen subsidy reduces LCOS by almost INR 4,300 per tonne. By 2030, improving electrolyzer efficiency and renewable energy availability will reduce hydrogen costs, bringing LCOS to near parity with BF-BOF. By 2050, green hydrogen cost projections place LCOS below those of coal-based pathways, eliminating the need for further policy support.

Scrap intake sensitivity and impact

Beyond policy instruments, plant-level levers such as scrap utilization further shape financial returns and emission outcomes. Higher scrap use significantly enhances both cost efficiency and emissions performance across steelmaking pathways. Increasing scrap reduces dependence on iron ore and coal, cutting energy use and improving returns.

In BF–BOF, the LCOS decreases from INR 98,610 per tonne at 0% scrap to INR 93,471 per tonne at 40%, while IRR rises from 21% to 24% and emissions fall from 2.82 to 1.85 tCO_2 per tonne.

For BF–BOF + CCS, the LCOS falls from INR 99,085 per tonne to INR 94,179 per tonne, with IRR improving from 18% to 22%, highlighting a strong synergy between scrap use and carbon capture.

In H_2–DRI + EAF, where hydrogen dominates operating costs, scrap still lowers LCOS from INR 99,729 per tonne to INR 98,047 per tonne and slightly raises IRR from 14% to 15%.

Scrap availability and recycling infrastructure are crucial to India's low-carbon steel transition. Strengthening national systems for scrap collection, processing, and logistics can enhance financial viability while accelerating decarbonization.

FINANCIAL TRANSITION SIGNALS

The financial analysis yields three clear signals. First, hydrogen-based steel becomes investable between 2026 and 2030 under moderate policy support. Second, BF-BOF remains viable only for plants commissioned before 2030, while BF-BOF with CCS serves as a transitional option for projects entering operation by 2033/34, with viability maintained over their full operating life. Third, after 2033, green hydrogen becomes the lowest-risk and highest-return pathway, emerging as the natural anchor for future capacity addition.

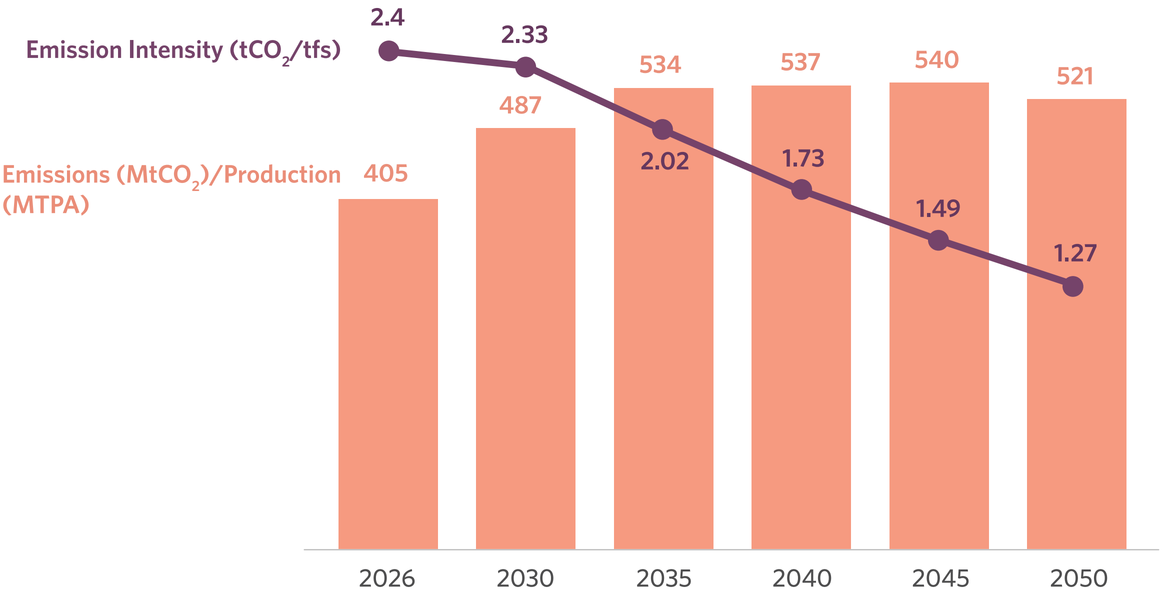
With the commercial feasibility of low-carbon pathways established, the next section examines how these pathway choices and policy instruments reshape the sector's emissions trajectory, quantifying the scale and pace of decarbonization achievable by 2050.

4.5 IMPACT OF GIP ON SECTORAL EMISSIONS

India's steel industry has an emission intensity of 2.54 tCO_2 per tonne of crude steel, which is higher than the global benchmark of 1.91 tCO_2/tcs (worldsteel, 2025). To align with India's 2070 net-zero commitment and its Nationally Determined Contribution target of reducing emission intensity by 45% from 2005 levels by 2030, the sector must accelerate its transition toward low-carbon steel production (UNFCCC, 2022).

In FY2024, India's steel sector emitted 367 $MtCO_2$, corresponding to a finished steel production capacity of 139.2 MTPA (MoS, 2024). It is anticipated that there will be a substantial reduction in emissions from the steel sector through the implementation of several levers, including transitional subsidies, policy measures, increased scrap utilization, and carbon pricing. The analysis estimates that emissions would reach 521 $MtCO_2$ by 2050, as shown in the figure.

Figure 13: Projected emissions and emission intensity of India's steel sector



Source: *CPI analysis*

Transitional subsidies and policy measures will facilitate the large-scale adoption of H_2-DRI-EAF pathways. At the same time, enhanced scrap utilization will reduce the reliance on conventional feedstock, further contributing to emission reduction.

In addition to emissions reduction and technological transformation, the low-carbon steel transition could yield substantial economic co-benefits, such as employment creation and increased contributions to the country's GDP. By 2050, the sector could generate approximately 540,000 additional employment, of which around 70,000 could be direct and 470,000 indirect jobs.

5. RECOMMENDATIONS

India's steel sector can accelerate its transition to low-carbon pathways by aligning financial incentives, carbon regulation, and market-creation measures. The modelling results demonstrate that when transitional subsidies, carbon pricing, and concessional capital operate together, low-carbon steel becomes commercially investable within this decade. Delivering this outcome will require coordinated action across ministries, regulators, financial institutions, and industry. The key recommendations are:

- **Establish a Green Industrial Policy for Steel:** A dedicated GIP can provide long-term investment certainty and align new capacity with India's net-zero trajectory. Prioritizing DRI-EAF for future expansion in place of greenfield bf-bof capacity after 2030 will help avoid high-carbon lock-ins that risk becoming uncompetitive under tightening global climate norms. This approach reduces future compliance costs—including those associated with CBAM—safeguards export competitiveness, and positions India to tap rapidly growing global demand for low-carbon materials.
- **Implement Targeted, Time-Bound, and Viability-Gap-Based Support:** Short-duration subsidies for green hydrogen and enabling technologies can reduce early-stage costs, improve bankability, and catalyze private investment. Time-bound support with sunset clauses ensures fiscal discipline, accelerates technology learning, and facilitates cost declines similar to the trajectories observed in solar and electrolyzers. Well-structured support packages can unlock early deployment while ensuring long-term competitiveness.
- **Introduce Predictable, Phased Carbon Pricing:** A stable and predictable carbon price—anchored to the emerging Carbon Credit Trading Scheme—can close the competitiveness gap by rewarding efficiency and penalizing high-emission operations. A phased price path, starting with a modest signal and rising over time, reduces regulatory uncertainty, lowers investor risk, and mitigates the risk of stranded assets. Predictable carbon pricing also improves capital allocation by enabling banks and investors to better assess long-term operational risks.
- **Expand Concessional and Blended Finance for Industrial Decarbonization:** Scaling dedicated green-finance windows in key financial institutions lending to the sector can lower financing costs for low-carbon steelmaking, particularly for micro, small, and medium-sized enterprises facing high capital costs for technology upgrades. Blended finance tools—guarantees, first-loss capital, subordinated debt, and results-based finance—can crowd in private capital, reduce Weighted average cost of capital (WACC), and accelerate deployment of clean steel technologies. This strengthens industrial competitiveness and drives regionally balanced economic growth.
- **Create Domestic Demand Through Green Public Procurement:** GPP can provide long-term demand certainty for low-carbon steel by leveraging the government's role as India's largest buyer across transport, infrastructure, defense, and public housing. Anchoring offtake commitments reduces investor risk, creates visibility of cashflows, speeds up learning curves, and could support the creation of globally recognized Indian low-carbon steel brands. GPP can serve as a major market-shaping tool, accelerating domestic investment and enhancing export competitiveness.

Complementary measures could reinforce the above core pillars. Strengthening scrap availability through a national circular-economy and scrap-management mission can reduce import dependence, lower production costs, and enhance resource security. Supporting early CCUS utilization markets—such as methanol, synthetic fuels, and low-carbon materials—can serve as a transitional buffer for existing BF-BOF assets while creating new industrial value chains. Finally, developing integrated industrial clusters with shared hydrogen, renewable power, water, and storage infrastructure, alongside robust monitoring, reporting, and verification systems aligned with global standards, could help reduce costs, attract investment, and enable India's deeper participation in emerging green value chains.

India's low-carbon steel transition now hinges on shifting from high-level policy design to coordinated, project-level implementation. While the modelling results demonstrate that transitional subsidies, predictable carbon pricing, and concessional finance together unlock commercial viability, the next phase would require translating these signals into a steady pipeline of finance-ready low-carbon steel projects—particularly for medium-sized producers that face higher abatement costs and limited access to affordable capital.

A systematic approach is needed to guide the development of targeted subsidy schemes, operationalize carbon market frameworks, and scale blended finance instruments that can reduce early-stage risks for emerging technologies. Strengthening project preparation capacity will be central. The sector requires structured tools for assessing the techno-economic feasibility of the best-available technologies across different production pathways, supported by plant-level transition planning and clear investment documentation.

The creation of standardized project investment notes, aligned with the due diligence processes of banks, development finance institutions, and other financial intermediaries, will help accelerate capital mobilization. Integrating these project-level analytics with national green industrial policy would be essential to enable technology adoption at scale, attract long-term investment, and position India's steel sector to remain competitive and resilient as global markets tighten carbon-related trade and performance standards.

ANNEXURES

ANNEXURE 1: NSP 2017

The following table highlights the major objectives, performance targets, and policy priorities set out under the National Steel Policy (2017).

Table A 1: Key takeaways - National Steel Policy 2017

Element	NSP (2017)
Competitiveness	Build a globally competitive steel industry.
Demand generation	Increase per capita steel consumption to 160kg by 2030.
Build domestic capacity	To domestically meet the entire demand of high-grade automotive steel, electrical steel, special steels, and alloys for strategic applications by 2030. Projection: 300 MTPA output by 2030.
Energy security	Increase domestic availability of washed coking coal to reduce import dependence on coking coal from around 85% to 65% by 2030.
Trade promotion	To have a wider presence globally in value-added/high-grade steel.
Energy efficiency	Encourage industry to be a world leader in energy-efficient steel production in an environmentally sustainable manner. Targets: Techno-economic performance roadmap covering coke rate, CDI rate, BF productivity, and specific energy consumption, until 2030.[5]
Cost effectiveness	Establish a domestic industry as a cost-effective and quality steel producer.
Health and safety	Attain global standards in industrial safety and health.

Source: *Ministry of Steel*

5 Details in the Annexure 2

ANNEXURE 2: ENERGY EFFICIENCY UNDER NSP 2017

The table illustrates the current industry performance relative to international benchmarks and NSP's 2030–31 energy-efficiency goals.

Table A 2: Energy efficiency under NSP 2017

Parameter	Units	International Best Practices	Current Value	Target for 2030-31
Coke Rate	Kg/thm	275 - 350	400 - 600	300 - 350
CDI Rate	Kg/thm	200 - 225	50 - 200	180 - 200
BF Productivity	tonnes/m^3/day	2.5 - 3.5	1.3 - 2.2	2.5 - 3.0
Specific Energy Consumption	Gcal/tcs	4.5 - 5.0	6.2 - 6.7	5.0 - 5.5

Source: *Ministry of Steel*

ANNEXURE 3: MODELLING FRAMEWORK

This Annexure presents the complete modelling framework used to evaluate low-carbon steel pathways and design optimal policy support. The framework integrates three components: (i) a plant-level techno-economic model, (ii) a sector-level aggregation module, and (iii) a policy optimization engine. Together, these modules assess how technology choices, market conditions, and policy interventions influence the financial and emissions performance of India's steel sector.

PLANT-LEVEL USER INPUTS

The plant-level model begins with a set of user-defined parameters. These determine the configuration, financing structure, operating profile, and scrap usage of a given greenfield steel plant.

Table A 3: User inputs required for plant simulations

Category	Parameter	Unit
Plant-level inputs	Plant size	Mtpa of HRC
	Target utilization rate	%
	Start date	Year
	Plant lifetime	Years
	Scrap intake	%
	Salvage value	%

Category	Parameter	Unit
Financial inputs	Debt-to-equity ratio	Ratio
	Equity IRR	%
	Average interest rate	%
	Debt repayment period	Years
	Working capital interest rate	%

These inputs determine the fundamental project profile and form the basis for generating annual production, capex, opex, financial flows, and emissions.

PROJECT LEVERS (USER-DRIVEN SCENARIO INPUTS)

Project levers capture uncertainties in market conditions. They are not optimized; instead, the user selects Baseline / Min / Max scenarios. The model then computes corresponding trajectories for prices, resource needs, financial performance, and LCOS.

Table A 4: Project levers

Project levers	Scenarios options
Scrap price	Baseline, Max, Min
Iron ore	Baseline, Max, Min
Dri	Baseline, Max, Min
Electricity source	Grid, Market, Captive
Electricity price	Baseline, Max, Min
Hydrogen source	CaRCptive, Market
Hydrogen price	Baseline, Max, Min
H price	Baseline, Max, Min
Coke price	Baseline, Max, Min
Manpower requirement	Baseline, Max, Min
Labor cost	Baseline, Max, Min
CCS cost	Baseline, Max, Min

These inputs determine yearly cost flows and enable sensitivity analyses across multiple market conditions.

POLICY LEVERS (OPTIMIZATION VARIABLES)

Policy levers represent the instruments whose values the model can adjust to identify the minimum support required to make low-carbon steel financially viable. Unlike project levers, these variables are part of the optimization module.

PREDEFINED VS. OPTIMIZED TRAJECTORIES

For the three core instruments, carbon price, hydrogen subsidy, and electricity subsidy, the model includes:

- Three predefined trajectories, representing alternative policy pathways
- One optimized trajectory, which the model derives to minimize subsidy expenditure

Table A 5: Policy levers (Inputs to optimization engine)

Policy lever	Description
Carbon price trajectory	Three predefined trajectories + one optimized curve (2025–2050)
DRI capex subsidy (%)	Optimization variable within upper bounds
DRI capex subsidy deadline	Upper limit year for applicability
EAF capex subsidy (%)	Optimization variable
EAF capex subsidy deadline	Upper limit year
Electricity Subsidy (RE-only)	Optimization variable; optional lever
Electricity subsidy trajectory	Three predefined pathways + one optimized
Hydrogen Subsidy (INR/kg)	Optimization variable within bounds
Hydrogen subsidy duration	Optimization variable
Hydrogen subsidy trajectory	Three predefined pathways + one optimized
Green steel benchmark	Exogenous intensity thresholds for 2026 and 2050

These policy levers are central to the modelling exercise and determine how much fiscal support is needed to make DRI-EAF financially competitive while maintaining viable returns for BF-BOF and BF-BOF+CCS during the transition.

TECHNOLOGY ASSUMPTIONS

Technology-specific engineering assumptions, capital needs, feedstock requirements, and energy sources define each steelmaking pathway. These parameters remain fixed across scenarios.

Table A 6: Core technology characteristics

Implementation data	Greenfield BF+BOF	Greenfield BF+BOF+CCS	Greenfield DRI+EAF with H_2	Greenfield EAF with outsourced HBI	Greenfield DRI for HBI making
Gestation period (yrs)	3	3	3	3	3
Ramp-up time (yrs)	2	2	2	2	2
Plant life (yrs)	40	40	40	40	40
Iron reaction feedstock	Coke	Coke	Hydrogen	Hydrogen	Hydrogen

FINANCIAL MODELLING MODULE

The plant-level financial modelling involves the following key steps:

I. **Capital Structure Formation:** The model first calculates total project capex based on plant size, technology configuration, and construction period. This capex is then split into debt and equity using the user-defined debt–equity ratio. Capex subsidies directly reduce upfront equity and debt requirements, shaping the initial financial structure.

II. **Production Ramp-Up and Throughput:** Annual production is derived from installed capacity, ramp-up schedule, and target utilization rate. The model accounts for lower output in early years before stabilizing at the steady-state utilization. This determines the revenue base and influences unit-level financial metrics.

III. **Revenue Projections:** HRC price trajectories follow WPI-indexed escalation based on historical wholesale price trends. Annual revenue is computed by multiplying output by the projected HRC price. This ensures that revenue forecasts reflect realistic macroeconomic inflation patterns.

IV. **Operational Costing:** Feedstock prices (ore, coke, hydrogen, power) are selected from Baseline/Min/Max scenarios and projected annually. OPEX subsidies for hydrogen and electricity are subtracted after price trajectories are generated, reducing the net operating cost. These computations drive yearly EBITDA levels and cash flows.

V. **Debt Repayment and Interest During Construction:** Loan disbursements are scheduled across gestation years, and Interest During Construction (IDC) is calculated on cumulative outstanding debt using the interest rate defined by the user. Post-commissioning, the model switches to a structured repayment schedule with annual interest and principal deductions. This determines the project's debt service profile.

VI. **Depreciation (Book and Tax):** Book depreciation uses a straight-line method over plant life, considering salvage value. Tax depreciation follows a written-down value approach aligned with allowable tax norms. Both affect taxable income and net profit projections.

VII. **Working Capital Requirement:** Working capital is estimated as a 90-day operating cycle based on yearly opex. Interest on working capital is then added as a financing cost. This helps capture liquidity needs and impacts annual cash flows.

VIII. **Financial Statements:** The model compiles a full set of Income Statements, Cash Flow Statements, and Balance Sheets for each year. These statements form the basis for computing IRR, NPV, and DSCR. This enables a consistent comparison of technology pathways on a like-for-like basis.

IX. **LCOS Computation:** LCOS is calculated by discounting net project cash flows and dividing by total lifetime steel output. This creates a technology-neutral cost metric comparable across BF-BOF, CCS, EAF, and hydrogen-based DRI pathways.

EMISSION ANALYSIS AND GREEN STEEL RATINGS

The following are the steps involved in the calculation of emissions and green steel ratings

I. **Scope 1 and Scope 2 Estimation:** The model calculates direct emissions from fuel use and process chemistry (Scope 1) and indirect emissions from electricity consumption (Scope 2). Emission factors are applied to each feedstock and electricity source. The resulting annual emissions form the basis for intensity calculations.

II. **Emission Intensity Calculation:** Emission intensity is obtained by dividing annual emissions by total steel output in that year. Technologies with higher electricity usage or fuel switching reflect corresponding intensity shifts. This enables direct comparison with green steel benchmarks.

III. **Abatement from CCS**: For BF-BOF + CCS, abated emissions are deducted based on single-point capture rates applied to blast furnace gas. This reduces net emissions and modifies the project's carbon exposure. The model assumes abatement occurs only within process emissions and not in upstream activities.

IV. **Benchmarking Against Thresholds:** Emission intensity is compared with India's evolving Green Steel Taxonomy thresholds. Benchmarks tighten over time, reflecting future policy expectations. If emissions fall below the allowance, the plant earns surplus credits; if they exceed, the plant incurs carbon costs.

V. **Carbon Cost or Revenue:** Based on the carbon price trajectory selected (predefined or optimized), the model calculates annual credit revenue or certificate purchase obligations. This amount is then added to or subtracted from operating cash flows. Carbon price signals, therefore, directly influence profitability across all pathways.

SECTORAL-LEVEL MODELLING FRAMEWORK

The sector-level modelling framework scales the plant-level techno-economic outputs to a national steel outlook by applying growth trajectories, technology shares, and macroeconomic multipliers. Three scenarios—Baseline, Linear, and Aggressive—are used to evaluate how different combinations of demand growth and technology adoption influence India's long-term production mix, emissions, employment, and GDP contribution. These trajectories ensure that sector-level insights remain grounded in bottom-up financial and production performance rather than top-down assumptions.

ECONOMIC MULTIPLIERS USED IN THE MODEL

The following multipliers convert incremental steel output into economy-wide indicators:

Table A 7: Economic multipliers

Economic multipliers	Values
Output multiplier	1.40
Employment multiplier	6.80
Steel emission intensity (t CO_2/t HRC)	2.40

SECTOR TRAJECTORIES USED IN THE MODEL

I. The primary trajectory used in the model follows the MoS growth outlook. Under this pathway, national steelmaking capacity grows from 197 MTPA in 2025 to 300 MTPA by 2030–31 and further to 500 MTPA by 2047, consistent with NSP 2017 and MoS's long-term vision. BF-BOF remains the dominant production pathway through 2030, after which its share stabilizes, while DRI-EAF gradually expands its role as the key low-carbon growth pathway. Although the MoS trajectory does not include carbon capture, the modelling incorporates an additional assumption that 20 percent of new BF-BOF capacity additions adopt CCS, resulting in approximately 10.88 MTPA of CCS-enabled capacity by 2031. This MoS-aligned trajectory serves as the core reference case for evaluating technology shifts, carbon impacts, and policy requirements.

In addition to the MoS-aligned baseline, the model examines two supplementary scenarios to stress-test long-term capacity and technology shifts:

II. **Linear Growth Trajectory:** A steady growth path from 197 MTPA in 2025 to 600 MTPA by 2050, implying a CAGR of approximately 5%. Technology shares converge to 50% BF-BOF and 50% DRI-EAF by mid-century.

III. **Aggressive Front-Loaded Trajectory:** Rapid early expansion to 439 MTPA by 2038, followed by a gradual rise to 600 MTPA by 2050, representing a front-loaded investment cycle. This scenario captures an accelerated transition with earlier penetration of hydrogen-based DRI-EAF.

SECTOR-LEVEL OUTPUTS

Sector-level outputs are generated by scaling plant-level financial and technical results to the national context. Annual capacity additions are first determined from each scenario's growth trajectory, after which national production is calculated by applying a scaling factor that links sectoral capacity to a representative plant size. Employment and GDP contributions are then derived using fixed economic multipliers. Finally, sectoral emissions are estimated by combining projected technology shares with plant-level emission intensities. Together, these steps provide a coherent bottom-up view of how different technology pathways and policy choices shape India's steel sector transition through 2050.

POLICY-LEVEL OPTIMIZATION

At the policy layer, the modelling framework integrates a dedicated optimization engine that determines the minimum set of fiscal instruments required to make greenfield DRI-EAF projects financially viable, while ensuring that BF-BOF and BF-BOF + CCS remain economically operable through the transition years. Instead of prescribing fixed subsidy levels or arbitrary policy choices, the optimizer systematically explores combinations of capex support, hydrogen and electricity opex subsidies, and carbon price trajectories to identify the lowest-cost intervention pathway that still meets financial and emission benchmarks.

The optimization problem is structured as a cost-minimizing function:

$$\text{Minimize: } Z = \sum_{t=0}^{T} (\text{Capex subsidy} + \text{Opex Subsidy})$$

$$\text{Subject to: } IRR_{DRI\text{-}EAF}(13 \pm 2\ \%)\ \&\ IRR_{BF\text{-}BOF}\ (\text{min Profitable IRR})\ \forall\ t \leq 2030$$

Subject to three key constraints:

I. IRR bankability for low-carbon steel: The returns for hydrogen-based DRI-EAF must remain within a viable band (approximately 11–15%) to qualify as investable for long-tenure industrial assets.

II. Transitional viability for BF-BOF pathways: Unabated BF-BOF and BF-BOF + CCS must remain above a minimum viable IRR until 2030, preserving system stability as low-carbon technologies mature.

III. Alignment with green steel benchmarks: Plant-level emission intensities must stay within the green steel thresholds defined for each compliance cycle, ensuring consistency with India's evolving taxonomy.

The optimization engine adjusts several policy levers simultaneously: the percentage of CAPEX support for DRI and EAF, hydrogen OPEX support levels (and their tapering), electricity subsidy design for RE-based captive power, and the timelines over which each support mechanism is applied. It also optimizes trajectories for carbon pricing, hydrogen subsidies, and electricity subsidies. These trajectories represent plausible policy futures ranging from conservative to ambitious, with the "optimized" option activated only when it lowers overall fiscal cost while maintaining financial viability.

By integrating these elements, the optimization framework not only identifies the cost-efficient mix of policy levers but also maps how these choices influence year-wise IRRs, LCOS, subsidy outlay, the pace of technology shift, and progress against national emission benchmarks. This ensures that the final policy package is both fiscally prudent and strategically aligned with India's long-term steel sector decarbonization pathway.

ANNEXURE 4

This annexure outlines the key techno-economic assumptions used in the modelling exercise. Table A9 summarizes the unit CAPEX estimates for core iron and steel production equipment, while Table A10 provides the feedstock price assumptions applied across scenarios.

Table A 9: Equipment CAPEX Assumptions (2026)

Equipment capex	Unit	2026	Rationale
Pelletizer	INR Cr./MTPA of Pellets	400	CAPEX values are compiled from multiple validated sources including Energy Transitions Commission (ETC) reports, Environmental Clearance (EC) submissions, industry-expert interviews, and established sectoral benchmarks. Where costs were originally reported in USD, a conversion rate of USD 1 = INR 85 has been applied. Capital costs for 2026 and beyond incorporate an annual 2% escalation, reflecting typical trends in technology maturation, learning effects, sectoral inflation, and cost-normalization as projects scale.
DR	INR Cr./MTPA of sponge iron	2,250	
EAF	INR Cr./MTPA of liquid steel	1,600	
Continuous Casting	INR Cr./MTPA of crude steel	425	
Hot Strip Mill	INR Cr./MTPA of HRC	1,000	
Coke Oven	INR Cr./MTPA of coke	1,533	
BF	INR Cr./MTPA of liquid sponge iron	153	
BOF	INR Cr./MTPA of liquid steel	255	
BOF (Relining)	INR Cr./MTPA of liquid steel	128	
Briquetting	INR Cr./MTPA of HBI	270	

Table A 10: Equipment CAPEX Assumptions (2026)

Feedstock Price	Unit	2026	Revised Rationale
HRC Price	INR/t	67,658	Estimated using PIB-published 2013 price data, indexed to the Wholesale Price Index (WPI), and escalated in line with long-term historical price growth trends.
Iron Ore	INR/t	9,723	Calculated from 2013 PIB benchmark values and updated using WPI-linked escalation consistent with historical price trajectories.
DRI	INR/t	26,517	Derived using PIB 2013 baseline data and escalated through WPI adjustments to reflect observed market price evolution.

Feedstock Price	Unit	2026	Revised Rationale
Coal	INR/t	15,466	Based on 2013 PIB reference data and escalated using WPI movements aligned with historical coal price dynamics.
Electricity Price	INR/ MWh	3,927 – 7,753	Reflects tariffs for multiple electricity sources (renewable captive, thermal captive, grid supply, and green market). Prices are benchmarked to discovered tariffs, state DISCOM tariffs, and IEX market data.
Hydrogen Price	INR/kg	200 – 450	Reflects a range of costs for captive and market-based hydrogen supply, benchmarked against discovered tariffs, corporate announcements, and declared national targets.
Manpower Requirement	Nos/t	0.003	Based on standard industry manpower benchmarks for integrated steel operations.
Labor Cost	INR/t	7,397	Derived from prevailing industry labor-cost benchmarks for steel manufacturing.
CCS Cost	INR/ TPA	4,790	Sourced from CPI–Dastur analytical studies and aligned with published CCS techno-economic assessments for the Indian steel sector.

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