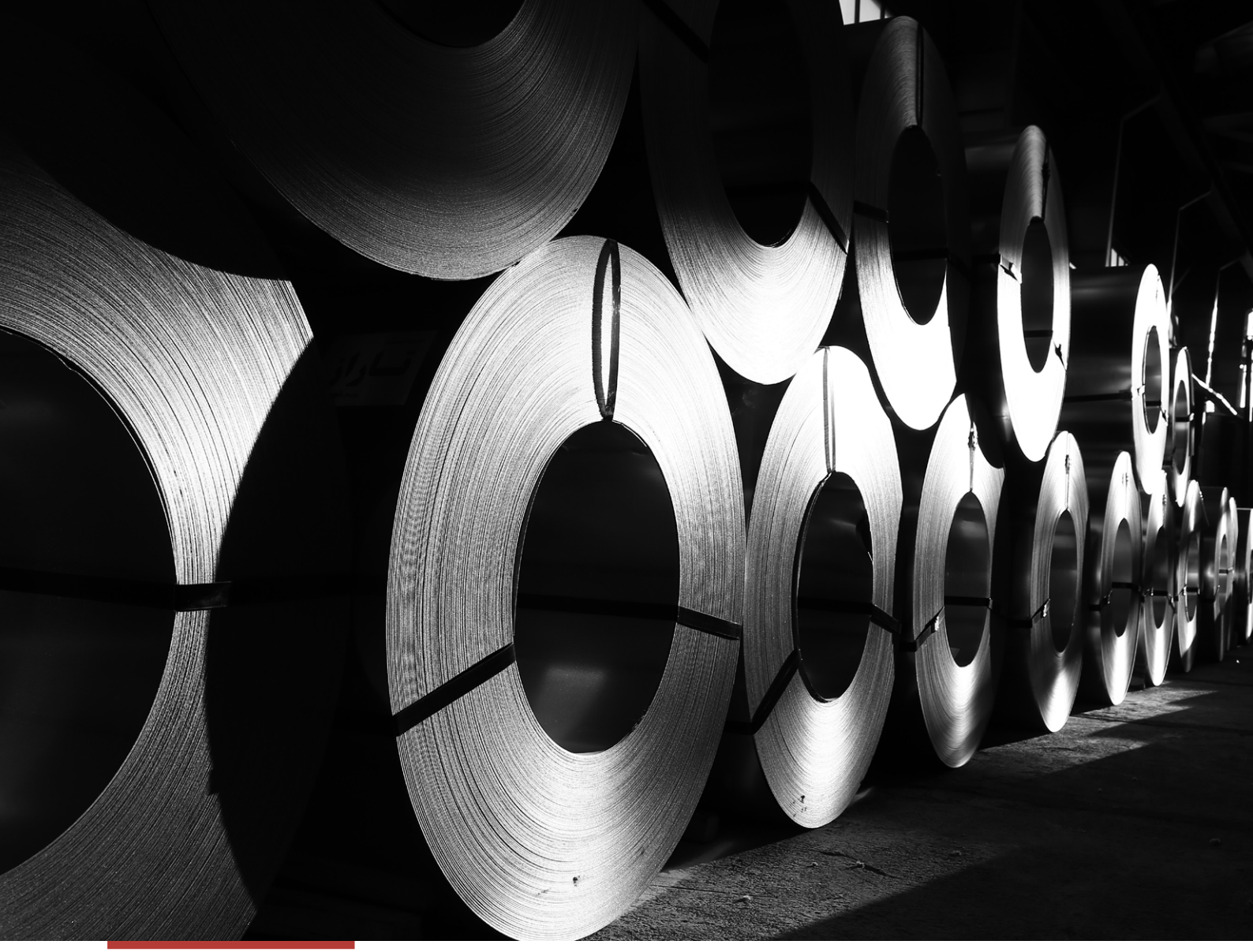


Discussion Paper: Financing Industrial Decarbonization

Challenges and Solutions for India's Iron and Steel Sector

April 2024

CLIMATE POLICY INITIATIVE

AUTHORS

Yash Kashyap
yash.kashyap@cpiglobal.org

Dhruba Purkayastha
dhruba.purkayastha@cpiglobal.org

ACKNOWLEDGEMENTS

The authors would like to acknowledge the contributions of researchers and experts around the globe, who have dedicated their work to sustainable development and helped to further our knowledge and shape our understanding on the topic of industrial decarbonization.

In particular, we would like to thank the Climate Policy Initiative (CPI) team, including Vivek Sen, Saarthak Khurana, and Neha Khanna for their inputs and guidance; Barbara Buchner for her advice and insightful inputs; Arnab Sarkar for his research support; Kirsty Taylor, Rob Kahn and Saumya Tiwari for editing and internal review; Elina Majumdar for editing; and Angela Woodall, Elana Fortin and Alice Moi for layout and design.

Responsibility for the information and views set out in this publication lies with the authors.

ABOUT CPI

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

RELATED CPI WORKS

CPI. 2022. Analysis: Costs and Impacts of Low-Carbon Technologies for Steel and Cement Sectors in India

CPI. 2023. Policy Brief: Policies and Enabling Environment to Drive Private Investments for Industrial Decarbonization in India

CPI. 2023. Taking Stock of Steel: India's Domestic Production Outlook and Global Investments in Green Steel Production

RECOMMENDED CITATION

CPI. 2024. Discussion Paper: Financing Industrial Decarbonization. Challenges and Solutions for the Indian Iron and Steel Sector.

LIST OF FIGURES AND TABLES

FIGURES

TABLES

LIST OF ABBREVIATIONS

BDF	Blended Debt Fund
BF	Blast Furnace
BOF	Basic Oxygen Furnace
CBAM	Carbon Border Adjustment Mechanism
CCfD	Carbon Contract for Difference
CCU/S	Carbon Capture Utilization / Storage
CDM	Clean Development Mechanism
CfD	Contract for Difference
CIF	Climate Investment Funds
DFI	Development Finance Institution
DRI	Direct-Reduced Iron
EAF	Electric Arc Furnace
EBRD	European Bank for Reconstruction and Development
ETS	Emissions Trading Scheme
GCF	Green Climate Fund
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Green House Gases
H-DRI	Hydrogen – Direct-Reduced Iron
IF	Induction Furnace
ITMO	Internationally Transferred Mitigation Outcomes
LCOS	Levelized Cost of Steel
MBM	Market-Based Mechanism
MSME	Micro- Small- and Medium-Sized Enterprises
MTPA	Million Tonnes Per Annum
NDC	Nationally Determined Contributions
NMA	Non-Market Approaches
NZE	Net-Zero Emissions
OECD	Organization for Economic Co-operation and Development

PAT	Perform Achieve and Trade
PCG	Partial Credit Guarantee
R&D	Research and Development
RE	Renewable Energy
SIDBI	Small Industries Development Bank of India
tCO2	Tonnes of Carbon Dioxide
tcs	Tonnes of Crude Steel
TRL	Technology Readiness Level

CONTENTS

PREFACE

The industrial sector is a critical engine of economic growth in emerging and developing economies. Industrial production is highly energy-intensive and fossil-based, making for one of the largest sources of carbon emissions. For instance, the industrial sector is responsible for nearly 30% of India's greenhouse gas (GHG) emissions. The country's high economic growth means that demand for industrial materials such as steel, and their related emissions, are expected to grow rapidly in the coming decades.

Decarbonization of industry is critical to achieving global climate goals and India's target to reach net-zero emissions by 2070. This requires significant additional investment in low-carbon technologies and production assets, supporting infrastructure, and modernization of value chains. However, the country faces significant barriers to the decarbonization of industry. These challenges include the complexity of production processes and value chains, potentially locked-in investments in carbon-intensive assets, internationally competitive markets, the unviability of current low-carbon technologies, and high capital expenditure.

CPI's most recent Global Landscape of Climate Finance shows that in 2021-22 global finance for mitigation activities in industry amounted to just USD 9 billion (CPI, 2023a), and needs to increase dramatically for an industrial transition to net-zero emissions. CPI has also recommended specific policy instruments and enabling conditions required to drive climate-aligned private investment in the heavy-emitting steel and cement sectors in India (CPI, 2023b).

This discussion paper builds on CPI's earlier work, with a focus on the technologies, challenges, and current state of financing for the decarbonization of India's iron and steel sectors, since this is the country's largest GHG-emitting high-growth industrial sector and one of the most challenging to decarbonize. The paper also introduces a conceptual framework for enabling the financing of (sector-agnostic) low-carbon industrial activities at the industry level, as well as measures to stimulate the demand and supply of climate-aligned finance. Finally, it highlights financing and derisking mechanisms that can support low-carbon technologies in the iron and steel sector.

1. INTRODUCTION

The industrial sector is responsible for over one-third of GHG emissions globally, and about 30% of total carbon emissions in India (Gupta et al., 2022). It is on a path to becoming the largest source of carbon emissions in India by 2040 (IEA, 2021) due to increasing demand for industrial materials produced using carbon-intensive conventional processes, and the gradual decarbonization of other major emitting sectors such as power and transport.

The iron and steel sector is India's largest carbon-emitting industrial sector, responsible for about 10-11% of the country's CO2 emissions. While demand for iron and steel has plateaued in most advanced economies, it is one of the fastest-growing sectors in India in terms of both economic output and carbon emissions. India is the world's second-largest producer of crude steel with a total production of about 120 million tonnes per annum (MTPA), contributing about 2% of the country's GDP (MoS, 2021). While India's per capita consumption of steel is just one-fifth of the average for developed countries, domestic demand is expected to increase rapidly as the economy grows. Such growth in production using fossil-intensive means would lead to a tripling of sectoral emissions by 2050 (Hall et al., 2020).

For India to achieve its net-zero emissions target by 2070, and for the world to meet the climate goals under the Paris Agreement, industries must shift to lower-carbon means of production and gradually align to net-zero/carbon-neutral pathways. There is a strong case for the iron and steel sector to lead the path to decarbonization of industries in India, driven by an increasing global impetus for steel decarbonization, presence of large internationally competitive domestic firms, proactive green-growth measures by Indian policymakers, and a growing enabling ecosystem.

1.1 LOW-CARBON SOLUTIONS TO DECARBONIZE IRON AND STEEL SECTOR

Emissions from steel production include direct (scope I) energy-related (20-25%) and process-related emissions (60%), and indirect (scope II) emissions related to the purchase of electricity and materials (15-20%). A range of solutions is required to decarbonize steel production, including energy efficiency, renewable energy (RE), process modifications, alternative fuels and feedstock (e.g., green hydrogen), carbon capture, direct electrification, and material circularity (scrap utilization). Importantly, such solutions are at various stages of development.

Table 1 outlines the characteristics of major technological levers for decarbonizing India's iron and steel sector, including their maturity as indicated by the Technology Readiness Level (TRL). Most technologies required for deep decarbonization of the sector have TRLs of 4–9 (from the prototype to the large-scale demonstration stage).

Table 1: Characteristics of major technological levers to decarbonize the Indian iron and steel sector

Technology Readiness Level	Category	Technologies	Carbon Abatement Potential*	Cost of Carbon Abatement	Increment in LCOS	Importance for NZE
TRL 1 (Initial Idea) to TRL 4 (Early Prototype)	Direct electrification	Low-temperature electrolysis, molten oxide electrolysis	-	-	-	Moderate
TRL 5 (Large Prototype) to TRL 9 (Early Commercial Operations)	Low-carbon fuels and feedstock	(Partial) green H-DRI (30 – 100%)	70 – 95 %	40 – 90 USD/ tCO2	20 – 45 %	High
		Partial injection of green hydrogen in BF (10% injection)	15 %	150 USD/tCO2	5 – 10 %	Low
	Process modification	Top-Gas Recycling-BF (TGR-BF), Smelting Reduction (HIsarna)	20 – 25 %	30 – 50 USD/ tCO2	5 – 10 %	Moderate
	Carbon capture	Carbon capture with BF / TGR-BF / HIsarna	50 – 60 %	50 – 60 USD/ tCO2 (capture only)	10 – 20 %	High
TRL 10 (Commercially Competitive) to TRL 11 (Stable Growth)	Energy efficiency and recovery	TRT, PCI, CDQ, PCG, WHR, and others	2 – 15 %	(-20) – (-5) USD/tCO2	-	Moderate
	Material circularity	Scrap-EAF	80 %	Up to 10 USD/ tCO2	Up to 5 %	High

Source: CPI analysis with TRL classification adopted from IEA (2021a)

Assumptions: Baseline emissions intensity of BF-BOF = 2.5 tCO2/tcs, coal-DRI-EAF/IF = 2.8 tCO2/tcs. Average plant lifetime = 30 years. Capacity utilization = 85%. Weighted average cost of capital (pre-tax) = 11%.

Abbreviations: LCOS = Levelized Cost Of Steel, NZE = Net-Zero Emissions, TRT = Top Pressure Recovery Turbine, PCI = Pulverized Coal Injection, CDQ = Coke Dry Quenching, PCG = Partial Coal Gasification, WHR = Waste Heat Recovery; H-DRI = Hydrogen-Direct Reduced Iron, EAF = Electric Arc Furnace.

**Carbon Abatement Potential calculated against the baseline emission intensity of the alternative conventional route.*

1.2 NEED FOR AND CHALLENGES TO FINANCING IRON AND STEEL DECARBONIZATION

An OECD study highlights that global annual investment in new net-zero-aligned production plants in four key sectors—steel, cement, aluminum, and chemicals—is just USD 15 billion, and needs to increase to at least USD 70 billion by 2030 (OECD, 2023). For the steel sector alone, an additional annual investment of USD 8 billion to USD 11 billion is needed in net-zero compliant technologies to transition the steel asset base alone; while achieving net zero in the sector as a whole by 2050 would require a cumulative investment of USD 5 trillion to

USD 6 trillion, in steel plants, supporting technologies, and infrastructure (Mission Possible Partnership, 2022).

The current level of financing for industrial decarbonization needs to increase by many times to achieve a net-zero transition. Several barriers, often sector and country-specific, can be attributed to this gap, causing certain sectors to be regarded as hard to abate. Here we focus on barriers specific to the iron and steel sector in India.

Several emerging technologies required to achieve a net-zero/climate-neutral iron and steel sector are currently uncompetitive vis-à-vis fossil-based conventional alternatives and are therefore not ready for commercial investments. Technologies that are commercially available in India (mainly RE, energy efficiency, scrap-EAF) and have substantial mitigation potential, remain severely under-used despite having favorable economics. This is especially the case in the small- and medium-sized enterprise (SME) segment, which consists of many small-scale (secondary steel) production units.

Barriers to financing and adoption of low-carbon technologies include technology performance risk, unproven business models, high upfront investment costs, policy and regulatory uncertainty, lack of appropriate incentives, lack of supporting infrastructure, information, and knowledge gaps, limited technical capabilities, limited access to suitable financing and financial services due to lack of tailored solutions. The long lifespan of assets also induces inertia in the industry, hindering the shift away from conventional processes. Indian companies also lack the ability and resources to finance their transition (Singh et al., 2020). Some of these barriers, such as limited technical capabilities and access to finance/financial services, are more pronounced for SMEs than for large companies.

These barriers translate into real and perceived investment risks, causing a mismatch between projects' investment risk-return profiles and the expectations of private investors. This results in a high cost of financing and under-investment in climate-positive activities. Policy, institutional and financial interventions, are therefore needed to address barriers and drive private investment (Polzin, 2017). Historical evidence from the diffusion and commercial deployment of clean technologies globally and in India (e.g., solar PV, wind, electric vehicles, and batteries) shows that this process cannot be left to market forces alone. Targeted interventions focused on both the real and financial sectors, developed through public-private coordination, are required to improve the risk-return profile of investments in low-carbon technology and to create demand for climate-aligned finance in industrial sectors. In particular, the public sector has a key role in correcting multiple market failures (environmental externalities, information asymmetry, coordination failures), and in creating new markets for emerging technologies.

OUTLINE OF THIS PAPER

Having discussed the technological solutions and challenges to steel decarbonization, this paper presents an analysis of the status of India's iron and steel sectors, and what it would take to increase finance for industrial decarbonization in the country.

Section 2 discusses the state of financing for iron and steel decarbonization. Various green steel production technologies are attracting increasing, though still insufficient, investment globally, with hydrogen–direct reduced iron (H-DRI) attracting the largest share of this finance. However, the expected growth in India's steel production capacity is likely to be led

by fossil-based technologies, which would increase the cost and complexity of decarbonizing the sector. Development finance institutions will have a key role in providing technical assistance and catalytic finance to help scale up investment in green steel technologies and avoid locking in emissions in new production infrastructure.

Section 3 presents a sector-agnostic framework for enabling financing of low-carbon industrial activities and discusses various financing solutions that could support iron and steel decarbonization technologies at different stages of development. Our framework is based on the premise that financing will follow targeted real-sector measures taken to create investment opportunities. Once investment demand has been stimulated, financial sector measures can unlock financing for low-carbon activities from various sources.

Section 4 concludes and presents a way forward for future research and analysis, with a focus on Green Steel Policy, Transition Finance, and CCU/S.

2. CURRENT STATE OF FINANCING IRON AND STEEL DECARBONIZATION

2.1 GLOBAL TRENDS IN GREEN STEEL INVESTMENT

Globally, the following technologies for green steel production are attracting investment: hydrogen-DRI (H-DRI), carbon capture utilization and storage (CCU/S), and scrap-EAF. Our analysis of data provided by LeadIT reveals that **as of November 2023, a cumulative investment of USD 41.7 billion had either been made or announced for low-carbon steel projects.** These investments, expected to be made over the next 10 years, will fund up to 40 MTPA of green steel production capacity; 20 GW of green hydrogen production capacity; and 5 MtCO2 per year of CO2 capture capacity (Vogl et al., 2023). Though significant, this investment falls short of the USD 200 billion needed annually for the commercialization and deployment of technologies to achieve a net-zero steel sector globally by 2050 (Mission Possible Partnership, 2022).

Using publicly available data, we tracked and analyzed the sources of funding for green steel projects. **Figure 1** shows the distribution of investments by technology and project scale, and the share of investments by public and private sources of funding.[1]

Figure 1a: Announced global investment in green steel production by technology and scale of production (investments to be made over 2017-2033)

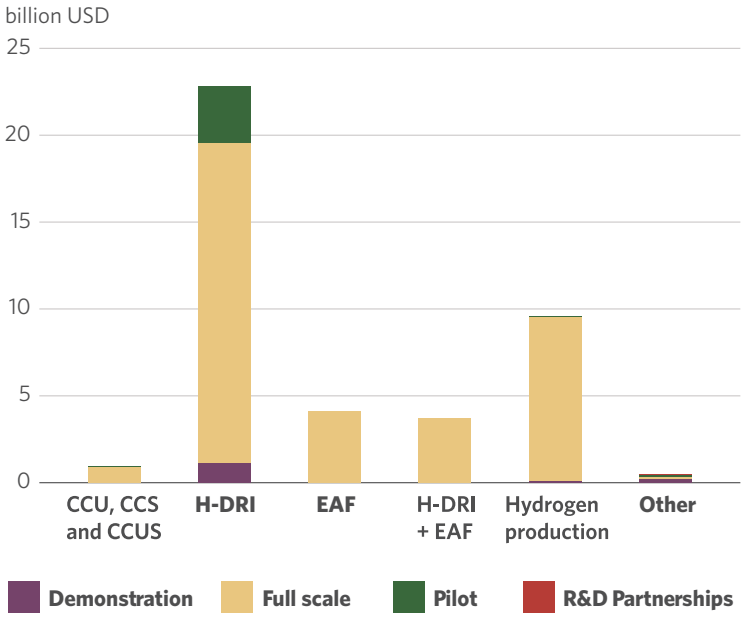
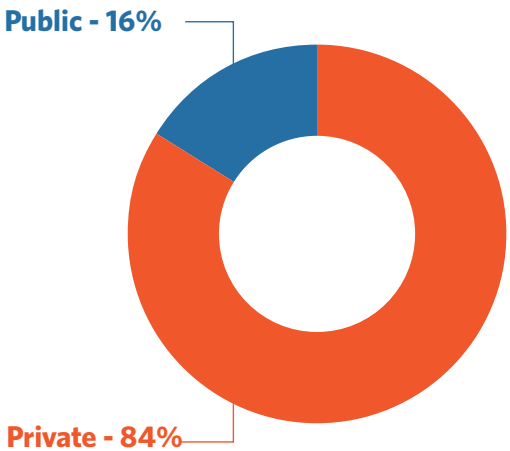


Figure 1b: Share of public and private sources of funding for green steel projects globally (of total USD 25.3 billion)



Source: CPI analysis and Vogl et al. (2023)

1 Based on publicly data available for USD 25.3 billion, about 60% of total tracked investments in green steel production.

H-DRI (and H-DRI + EAF) has emerged as the leading technology for green steel. It accounts for about 87% of planned investment in green steel production (either in steel plants or in hydrogen production for utilization in steel plants), followed by scrap-EAF (10%), CCU/S (2%), and others (1%). H-DRI is likely to undergo high rates of learning and cost decline, increasing competitiveness vis-à-vis conventional routes, which could make it the preferred technology for Indian steel-makers. Other factors such as India's policy push for green hydrogen under the National Green Hydrogen Mission, limited clarity on pathways for deployment of CCU/S technologies, and a lack of scrap steel to meet demand, could further contribute to a shift to H-DRI over the medium-term.

Most of the investments shown in Figure 1 have been announced in the EU (88%), followed by Canada (5%), Australia and Norway (2% each), Russia and South Korea (1% each). Interestingly, nearly 90% of these investments are in full-scale plants, signaling the mitigation of technology risks and the graduation of emerging technologies from the pilot stage to TRL 8-9 (commercial operations) in these geographies. This trend is supported by strong climate policies (e.g., carbon pricing) and large-scale public-funded innovation programs in several countries; increasing cross-border stakeholder collaboration for technology development; and commitments by financial institutions to finance net-zero aligned industrial activities (see the Sustainable STEEL Principles). **Annexes A** and **B** provide an overview of the industrial decarbonization policies and publicly funded programs of several major economies, including India.

Public funds account for a substantial 16% of investment in green steel production, and are a critical source of early-stage risk capital for emerging technologies, thereby catalyzing private investment. Public funds are being deployed as innovation grants, capex subsidies, and equity (as co-investments) for the development of supporting infrastructure (e.g., for hydrogen transportation and storage), and for improving the economic viability of projects. Carbon markets are also an important source of revenue for many projects, especially in the EU, where the carbon price under the EU-Emissions Trading Scheme (ETS) has ranged between 80–100 EUR/tCO2 in recent years.

2.2 IRON AND STEEL INVESTMENT TRENDS IN INDIA

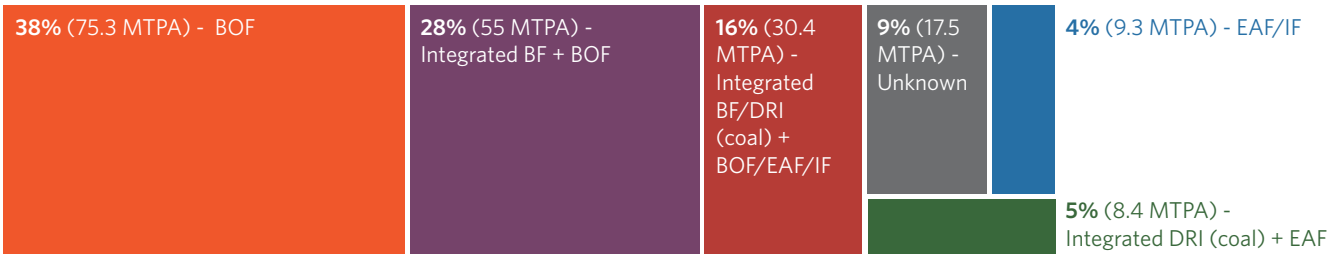
As of March 2023, India's steel sector had about 196 MTPA of fossil-based production capacity in the pipeline (either 'announced' or 'under construction') due to go online over the next 15 years (Global Energy Monitor, 2023). This exceeds the current steel production capacity of the US, UK, Germany, and France combined. **Figure 2** shows our analysis of the distribution of the new production capacity by production route. Nearly all this planned capacity addition is fossil-based (i.e., via. BF – BOF and DRI – EAF/IF routes), with scrap-EAF taking up just under 5% of the share.

About 90% of this capacity is expected to go online by 2030. While this is needed to meet domestic demand, it has major implications for the sector's emissions trajectory. According to our analysis, the average emissions intensity of the sector (considering all production routes and accounting for the best available energy efficiency technologies) could rise from 2.18 tCO2/tonne of crude steel (tcs) to 2.27 tCO2/tcs (ignoring any further efficiency improvements). Consequently, sectoral emissions could increase at a faster rate in the

coming years and could double from the current 260 MtCO2 per annum to 560 MtCO2 per annum by 2030. This presents a massive decarbonization challenge for the sector.

An increasing share of BF–BOF is likely to add to the overall cost and increase the complexity of decarbonizing the Indian steel sector. The data reveals that the share of BF – BOF in the overall capacity mix is expected to increase dramatically. This trend may be partly driven by concerns over the availability and quality of minerals (lower-grade iron ore available in India is primarily suited for utilization in the BF), and the limited availability of scrap to meet growing domestic demand. However, the BF – BOF route is much harder to decarbonize than the DRI – EAF route, as achievement of near-zero emissions depends on carbon capture technologies, which have high technological complexity and high related costs of CO2 abatement (especially when CO2 storage is included).

Figure 2: Distribution of new crude steel production capacity in India expected to come online between 2021-2038, by production route (Total capacity = 196 MTPA)



Source: CPI analysis based on data from Global Energy Monitor (2023)

While there has been no investment in commercial-scale green steel production to date, the Indian government and industry are taking steps to pilot hydrogen-based steelmaking. Under the National Green Hydrogen Mission, which has a total capital outlay of USD 2.3 billion (INR 19,744 Crore), the government has recently announced the allocation of about USD 55 million (INR 455 Crore) to support pilot projects substituting fossil fuels with green hydrogen in steelmaking until 2029-30 (MNRE, 2024). Two large private players, Jindal Stainless Ltd., and TATA Steel are piloting the use of hydrogen as a substitute for fossil fuels in the annealing process of stainless steel and for injection in the blast furnace, respectively. While encouraging, these steps are not sufficient to decarbonize the Indian steel sector. Comprehensive sectoral policies, appropriate financial solutions, and strengthened stakeholder coordination are also needed.

2.3 DEVELOPMENT FINANCE INSTITUTIONS FOCUSING ON INDUSTRIAL DECARBONIZATION

Development finance institutions (DFIs) can provide financial and non-financial assistance to stakeholders, including advisory for the formulation of policies and an enabling environment at the government level; development of low-carbon pathways at the sectoral level; transition plans at the corporate level; support for implementation of projects through technical assistance; and use of direct financing and risk mitigation instruments.

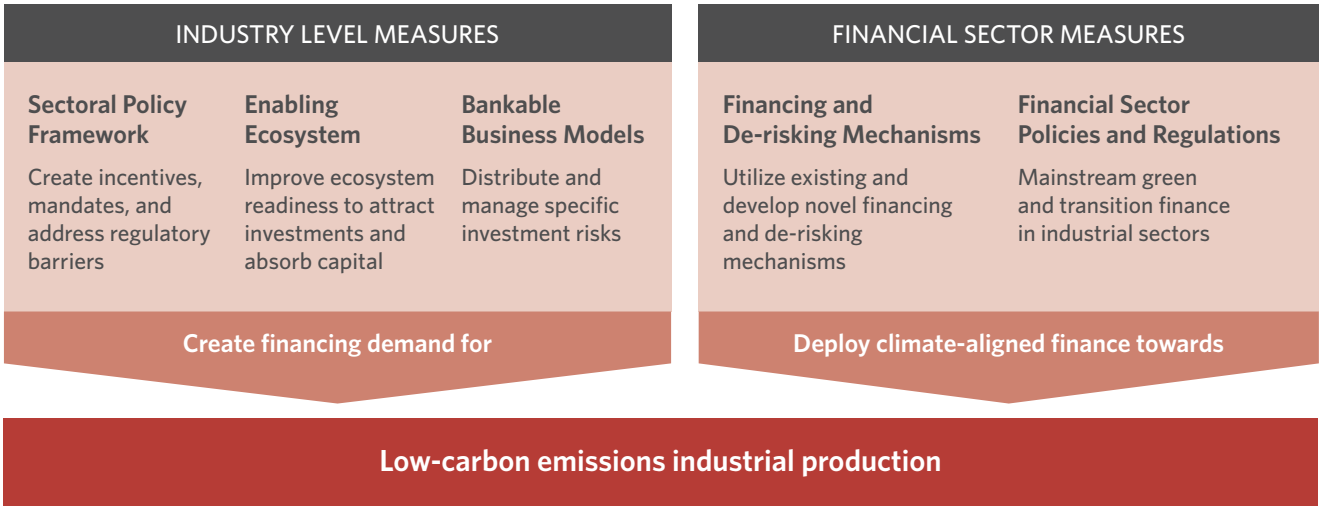
DFIs must prioritize industrial decarbonization. New programs that are dedicated to heavy industries and provide technical and financial assistance to governments, corporations, and projects should be implemented, and existing programs need to be scaled up. Industrial decarbonization is a nascent space for DFIs, and most are in the early stages of developing industrial sector strategies (Maltais et al., 2022). To date, only the Climate Investment Funds have a dedicated program on industries, and few have broader programs that include heavy industries as a focus area (e.g., the World Bank, European Bank for Reconstruction and Development, Global Environment Facility, and Green Climate Fund) (Mondini et al., 2023). The Small Industries Development Bank of India (SIDBI) is the only DFI in India that assists industries on decarbonization, through the Partial Risk Sharing Facility. This facility is a broad credit guarantee scheme that provides technical assistance and loan guarantees to energy efficiency projects of MSMEs. With support from the World Bank, SIDBI has also recently launched the Decarbonization Challenge Fund to provide grant support to innovative green solutions in carbon-emitting sectors, including industries.

3. FRAMEWORK FOR ENABLING FINANCING FOR INDUSTRIAL DECARBONIZATION AND SOLUTIONS FOR THE INDIAN IRON AND STEEL SECTOR

3.1 FINANCING FRAMEWORK

Figure 3 shows CPI's proposed framework for enabling the financing of low-carbon industrial production, developed through an extensive analysis of global investment trends, lessons learned from the diffusion of clean technologies, stakeholder consultations, and review of relevant literature (CPI, 2023a; Mission Possible Partnership, 2022; OECD, 2022, 2023; Polzin et al., 2019; Waissbein et al., 2013; World Economic Forum and Oliver Wyman, 2021). This framework can be applied to any industrial sector and is based on the premise that financing follows targeted real-sector measures, which are needed to create investment opportunities. Once investment demand has been stimulated, financial sector measures are required to unlock financing for low-carbon activities from various sources. We briefly discuss the five pillars forming the basis of this financing framework below.

Figure 3: Conceptual framework for financing low-carbon industrial production.



SECTORAL POLICIES

Well-designed sectoral policies are essential to level the playing field between low-carbon and conventional technologies. Various policy instruments can be used to incentivize early adopters of low-carbon solutions, reduce investment risks (reducing cost of capital) unique to these solutions, penalize carbon-intensive activities, and create markets for green products. Historically, India's policies for heavy industries, particularly for the steel sector, have prioritized rapid growth, energy security, and competitiveness. Until recently, only a few instruments have supported decarbonization (e.g., the Perform Achieve and Trade scheme is a market-based mechanism promoting energy efficiency). Those that do exist focus on low-

hanging fruits and are insufficient for promoting emerging technologies and demand-side measures such as material efficiency.

The last decade or so has seen the launch of the National Solar Mission in 2010, the Indian Carbon Market in 2022, and the National Green Hydrogen Mission in 2023, along with numerous policies to promote RE technologies. This demonstrates the use of certain industrial policy tools (primarily regulations and subsidies) to support the localization and deployment of specific low-carbon technologies and for the creation of new markets. These initiatives demonstrate the government's central role in coordinating stakeholder action to achieve targeted outcomes. Perhaps India has entered a new era of (green) industrial policy, in which the state and market must work together to achieve technology-led green growth. This aligns with global trends of increasing implementation of climate-friendly industrial policies by large economies (particularly the US, the EU, and China). Such international climate policies are also likely to have repercussions for Indian producers. We discuss the implications of the EU's Carbon Border Adjustment Mechanism (CBAM) in the box below.

For the iron and steel sector, green industrial policies are required that target (and balance) multiple outcomes – output, competitiveness, and decarbonization – while complementing the existing initiatives. A well-designed green steel policy could include a mix of financial, market-based, and regulatory instruments to move the supply side (e.g., via subsidies, technology mandates, and tax credits) and the demand side (e.g., via green public procurement, product carbon standards). Such a policy must also foster innovation, which is critical for sustainable green growth. CPI has given an in-depth assessment of various policy instruments, in earlier work (CPI, 2023b).

ENABLING ECOSYSTEM

An enabling ecosystem consists of laws, regulations, directed use of public finance, natural and human capital, and voluntary actions to facilitate private investment. Here, we differentiate between an industry-wide enabling environment (i.e., regulations applying to all businesses that improve ease of doing business, such as accessing electricity, dealing with permits, etc.), and an industry-specific ecosystem that involves different stakeholders implementing measures that address barriers to investment. While both are crucial, we focus on the latter. For the steel sector, an enabling ecosystem could consist of the following: Formulation of sectoral transition pathways (governments, industry associations), public investments in shared infrastructure for hydrogen and CO2 (by governments), voluntary commitments to pay a premium for green steel (by steel buyers), facilitating access to emerging technologies (by international technology providers), increasing allocation of risk capital and concessional finance to heavy industrial sectors (by DFIs), voluntary net-zero aligned financing and tailored financial products (by private financial institutions), building steel R&D partnerships (amongst government, companies, and academic institutions), and skilling of workers (by governments, industry associations), etc.

BANKABLE BUSINESS MODELS

Ideally, industry and financial sector players should coordinate to establish new business models that have bankable cashflows, achieved through appropriate allocation and effective management of investment risks. For the steel sector, specifically in the context of emerging

technologies, companies can adopt measures that either reduce risks across the board or transfer specific risks to those best suited to handle them. Deconsolidated financial structuring (project financing) and co-financing of projects by multiple sponsors (steel and energy companies, technology providers, etc.) allow for ring-fencing and sharing of risks among parties, improving the overall risk profiles of investments. Other measures that target specific risks include long-term agreements for the supply of inputs (e.g., green hydrogen) and offtake of green steel to address demand and revenue risk; technology verification, construction guarantees, and technology risk insurance to address technology and construction risk; local currency financing and foreign exchange hedging to address currency risk, political risk insurance; and entering into contracts with strong counterparties to address performance risk. **Annex C** provides contextual information on risk categories and measures for derisking for an H-DRI project.

Box 1: Implications of International Climate Policies on India's Iron and Steel Sector – Carbon Border Adjustment Mechanisms

The EU's Carbon Border Adjustment Mechanism (CBAM) is a tool to put a price on carbon emitted during the production of carbon-intensive goods entering the EU, thereby encouraging cleaner industrial production in non-EU countries. Exporters to the EU will be subject to a border adjustment 'tariff' based on the embedded emissions of their products. The tariff equates to the difference in the carbon price in the EU (under the ETS) and the price that has already been paid in the country of origin. The CBAM will initially apply to cement, iron and steel, aluminum, fertilizers, electricity, and hydrogen. The mechanism is likely to reduce carbon leakage from the EU; reduce the competitiveness of producers in countries with higher emissions intensity of production and/or a lower price on carbon than the EU; enhance the competitiveness of EU's domestic producers against importers; and result in flow of funds from trading partner countries to the EU (it is estimated that CBAM will generate EUR 1.5 billion per year as of 2028 (European Commission, 2023)).

Iron and steel are the most exposed sectors for India. Around 23.5% of the country's steel exports (which have ranged between 6 – 12 MTPA in recent years) go to the EU. This is relatively small compared to total steel production. Moreover, over the next few decades, exports to the EU will make up an increasingly smaller share of India's total exports, as the bulk of national production capacity will be needed to meet domestic demand. The CBAM may therefore have a marginal effect, especially if appropriate policy measures are adopted.

Indian steel producers have options available. In the early stages of CBAM implementation, higher prices in the EU will enable some competitive producers with low-emission intensity to maintain exports to Europe, while others can divert higher-emission steel to alternative markets. Over time, the implementation of climate policies around the globe, and the increasing costs of carbon will pressure producers to shift to cleaner production, creating opportunities for those who are able to decarbonize to capture higher margins in the EU market.

FINANCING AND DERISKING MECHANISMS

Several financing and derisking solutions exist for supporting low-carbon technologies at different stages of the innovation cycle-from basic scientific research to development, demonstration, and deployment. As technology progresses up the TRL ladder, its risk-return profile changes, as do the types of financial instruments and funding sources (investor profile).

Mapping of suitable mechanisms for industrial technologies, TRL, financing instruments, and sources of finance are shown in **Figure 4**.

It is important to highlight the catalytic role of the state and other public finance providers. At the early stage (TRL 1 – 4), high-risk funding — usually in the form of grants and equity — is needed from public and private sources for R&D. The state, instead of just providing the conditions for innovation (skilling, patent laws, etc.), should proactively direct innovation in areas of high potential and importance to the economy, with the long-term goal of building domestic technological advantage and driving sustainable growth. Through effective innovation policy, the state can play an entrepreneurial role by funding the most uncertain phase of innovation, which is too risky for the private sector, and then continue to oversee the commercialization process as a network coordinator (Mazzucato, 2011). In the case of industrial sectors where India's current innovation capabilities are limited and there is a need for accelerated technological change, the state can negotiate low-cost (royalty-free) international technology transfer. Additionally, incentives for private sector R&D are also important; however, this may result in incremental rather than radical innovation, the latter of which is required for an industrial transition to low-carbon emissions.

As the technology moves into the demonstration stage (TRL 5 – 8), investment risks—particularly technology risks—remain high. Funding requirements are also large, often beyond the scope of private investment. At this stage, public sources can provide critical zero/low-cost finance to increase returns, reduce risks, or both, thereby crowding in private investment. A mix of instruments such as equity, subsidies, carbon credits, concessional debt, and guarantees, from various domestic and international sources can be used to structure innovative mechanisms to undertake pilot, demonstration, and first-of-a-kind commercial-scale projects. The substantial share of public finance in global investments in green steel (discussed in Section 2) highlights its catalytic role. **Annex B** provides information on major public-funded programs for industrial sectors implemented globally.

Upon successful demonstration, as the technology reaches the market-entry and deployment phases (TRL 9 – 11), equity, debt, and structured blended mechanisms can deploy capital at scale, increasingly from the private sector. Derisking instruments such as guarantees and insurance from public and private sources, can help address remaining specific investment risks, such as currency risk. A crucial role of the state at this stage is to bridge the information asymmetry that is likely to exist between the finance demand and supply sides, owing to financiers' lack of experience and the lack of technology's performance track record. Dedicated public-funded credit guarantees can help address this by reducing credit risks for lenders, especially those who are early movers, and by supporting the building of internal capacity, knowledge, and confidence in the market. Governments and state DFIs can also help to create and directly participate in the markets for instruments such as sustainability-linked and transition bonds.

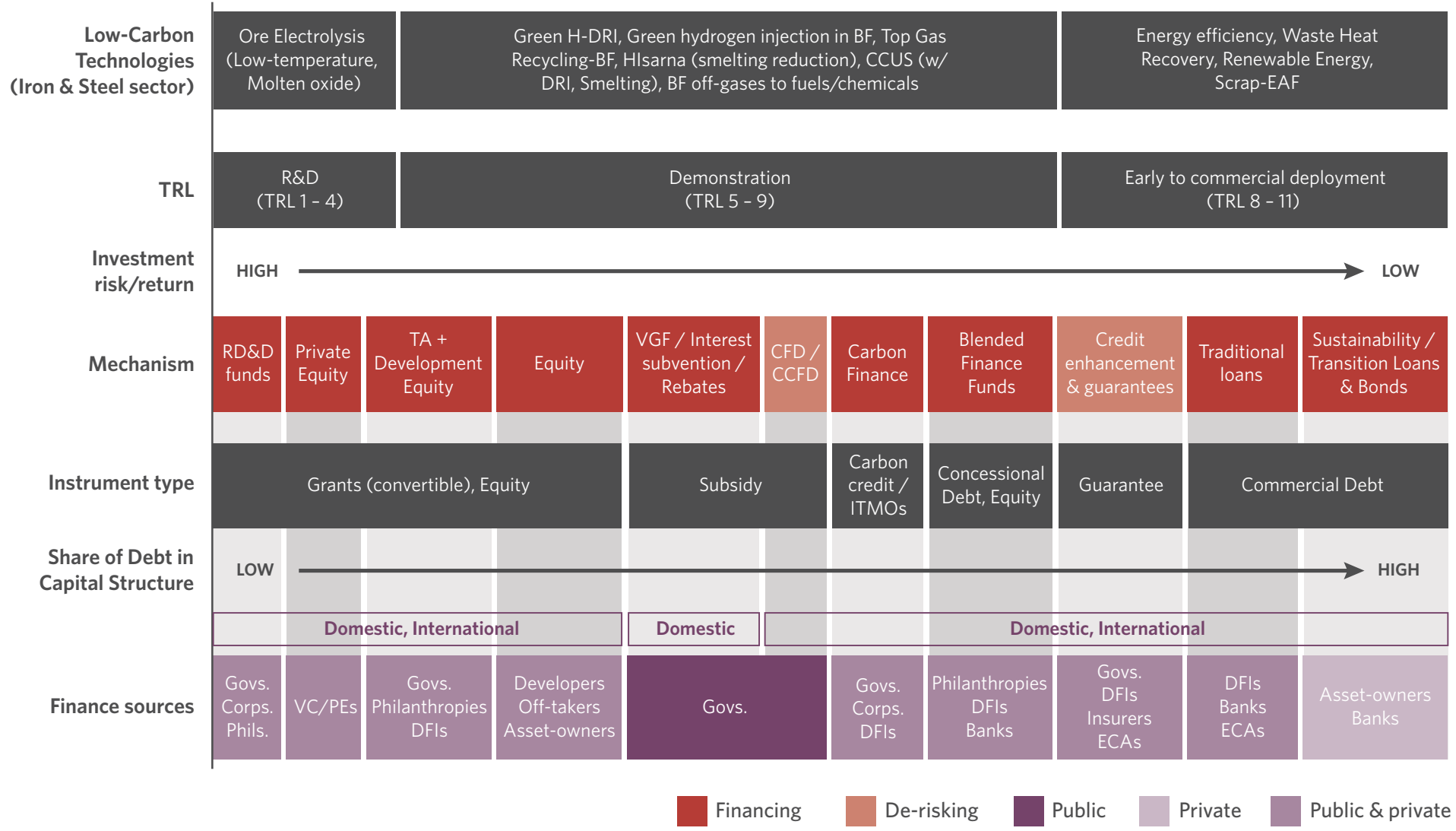
FINANCIAL SECTOR POLICIES AND REGULATIONS

Financial sector regulations play a crucial role in directing financial flows to underserved but important economic sectors. Numerous tools that can be used by policymakers and regulators include:

- Guidelines and disclosures that facilitate investment decision-making; build market confidence; and prevent greenwashing; including taxonomies on sustainable, green and transition finance, sectoral technology-specific benchmarks, mandates for FIs to measure and report financed emissions, etc.
- Mandates and incentives that can help direct financial flows towards desired sectors/ activities – expanding the Priority Sector Lending scheme, mandating corporate issuance of use-of-proceeds (green/transition) and KPI (sustainability)-linked bonds, and incentivizing banks to lend to specific activities.

In addition, regulations are required to enable the implementation of innovative financing mechanisms. Government and state DFIs can also use risk mitigation and financing instruments such as credit guarantees and bond issuances, as discussed above.

Figure 4: Mapping of low-carbon technologies, technology maturity levels, applicable financing mechanisms, instruments, and sources



Abbreviations: RD&D = Research Development and Demonstration, TA = Technical Assistance, VGF = Viability Gap Funding, CFD = Contract for Difference, CCFD = Carbon Contract for Difference, ITMO = Internationally Transferred Mitigation Outcome, VC/PE = Venture Capital/Private Equity, DFI = Development Finance Institution, ECA = Export Credit Agency.

Source: CPI analysis

3.2 DEEP-DIVE INTO SELECTED FINANCING AND DERISKING MECHANISMS FOR THE IRON AND STEEL SECTOR

Financing mechanisms can be structured in effective and innovative ways to better suit the financing needs of technologies at different stages of development. Such mechanisms often combine capital from a variety of sources and make strategic use of scarce public capital to catalyze private capital. As we have seen, technologies for decarbonizing the iron and steel sector are at various TRLs, and will therefore require a host of different mechanisms to support them. Of the various mechanisms presented earlier, we discuss a selected few that could support steel decarbonization in India.

TECHNICAL ASSISTANCE FACILITY AND DEVELOPMENT EQUITY FUND

Stage of Intervention: TRL 4 - 7

Instruments: Grants, equity

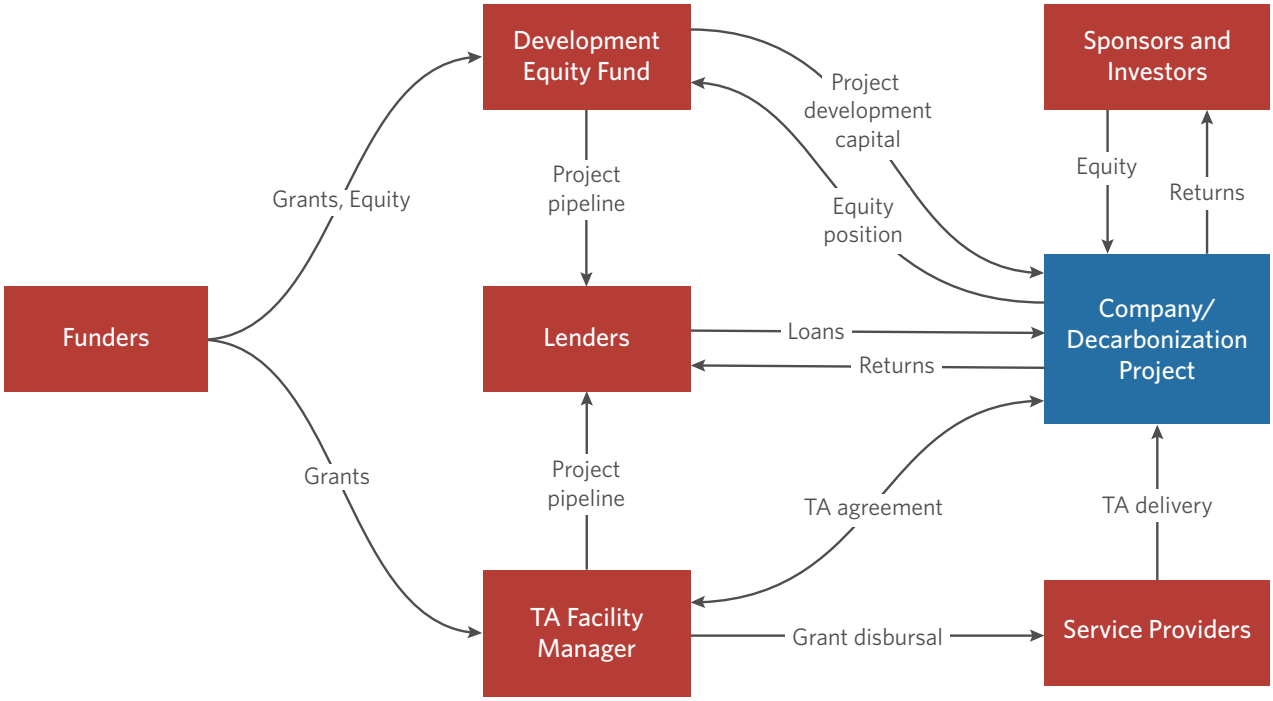
Source of Funds: Governments, philanthropies, DFIs, multilateral funds

Rationale for intervention: Early-stage projects deploying breakthrough technologies lack commercial viability and have high project development costs, especially in capital-intensive sectors. Moreover, projects based on innovative/unproven business models face information asymmetry, lack of track record, unmitigated business model risks, etc., that limit their access to debt. These barriers need to be addressed through technical assistance and risk capital at an early stage to create a pipeline of bankable projects, improve investor confidence in the technology, and mobilize debt for the commercialization phase.

A dedicated technical assistance facility, combined with a development equity fund, can assist early-stage projects/ventures by offering them development support to establish commercial feasibility and improve investability. These facilities can also contribute to reducing information asymmetry by improving the quality of information available for debt appraisal.

Mechanics: The technical assistance facility would provide grants to industrial decarbonization projects to defray part of the costs of project preparation, including but not limited to technical feasibility studies; market assessments; impact assessment; legal advisory services; permitting costs; investment banking; etc., and enable the projects to become investment-ready. These services can be provided by specialized service providers impanelled by the facility. The facility could be set up to mobilize debt financing by linking with lending institutions to facilitate discussions with beneficiaries upon completion of project preparatory activities.

Figure 5: Technical assistance facility and development equity fund



The development equity fund would support projects by providing early-stage risk capital, helping to reduce the risk associated with the project development stage. Once the projects raise debt financing, the capital would be converted into an equity position in the project. The fund has the potential to direct private sector investments in need of initial project development support, in the form of concessional capital. The fund could also tie up with lending institutions to facilitate discussions with beneficiaries.

Example: IFC InfraVentures is a USD 150 million global infrastructure project development fund created by the World Bank Group to support early-stage private and public-private partnership infrastructure projects. Its objective is to enhance the pipeline of projects in developing countries by offering early-stage risk capital and experienced project development support to address the key constraints to private investment.

CONTRACT FOR DIFFERENCE / CARBON CONTRACT FOR DIFFERENCE

Stage of Intervention: TRL 6 – 9

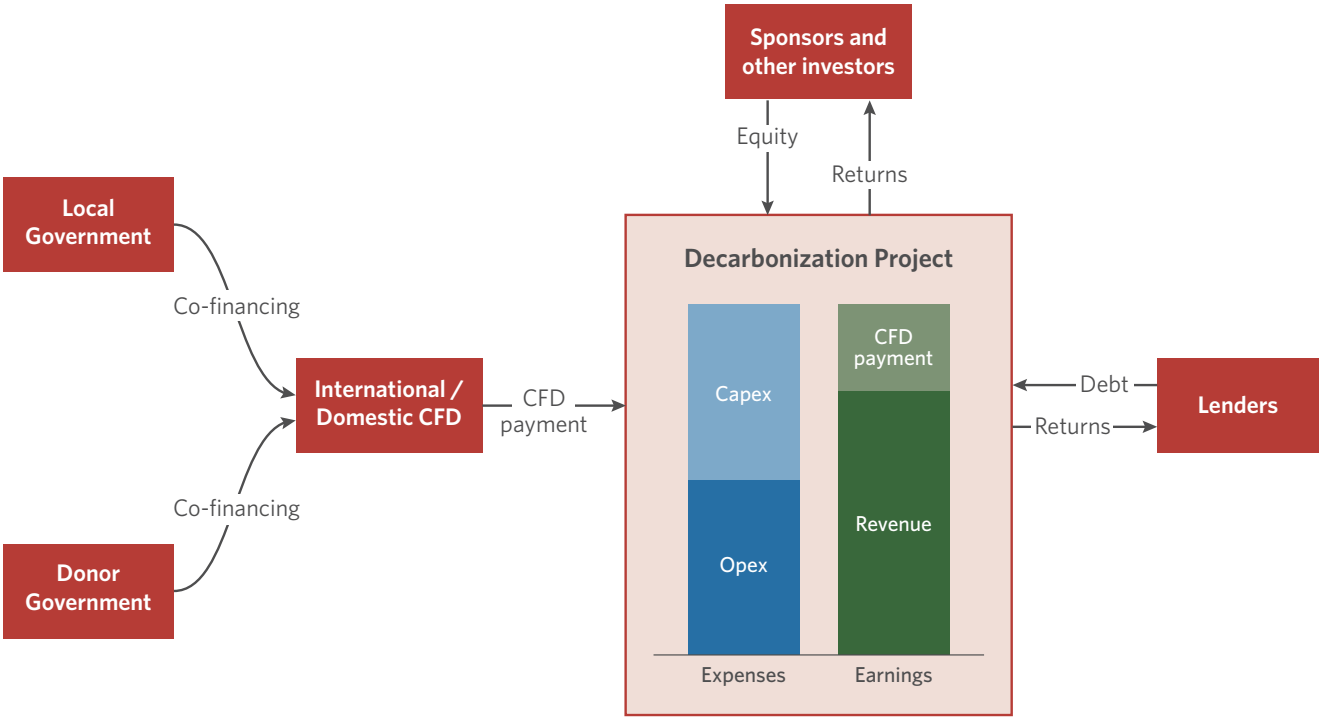
Instrument: Subsidy

Source of Funds: National and donor governments

Rationale for intervention: Breakthrough technologies can have substantial incremental production costs compared with conventional technologies, a significant barrier to adoption. This can be due to higher capex or opex. Moreover, market uncertainties can lead to revenue uncertainty, directly impacting a project's access to finance (e.g., debt); financing structure (e.g., debt-to-equity ratio); financing costs; cost of CO2 mitigation; and ultimately, financial viability.

Mechanics: In the context of heavy industries and breakthrough technologies, a project-based Contract for Difference (CfD) is a bilateral contract between the government/government-owned entity and a low-carbon project, that financially covers the incremental cost of production compared with conventional technology. The low-carbon project would receive payments equal to the difference in the levelized cost of production using a low-carbon technology—the strike price versus the market price of steel produced using conventional technologies. A CfD is therefore both a policy and a financial instrument that de-risks investments by addressing market uncertainties. A key benefit of a CfD is the stabilization of revenues, which improves bankability and financing conditions while lowering carbon mitigation costs (Richstein and Neuhoff, 2022).

Figure 6: Contract for difference mechanism



Source: Adapted from Richstein and Neuhoff (2022)

Alternative mechanism based on carbon price: Carbon revenues obtained from the trading of credits in carbon markets can be an important source of cash flow for producers of low-carbon materials. Carbon-price-based CfD (or CCfD) can act as a hedging mechanism wherein the contract is structured around an agreed carbon price required to make the project viable, or strike price (rather than net production costs), and the price of carbon in the market. This mechanism closely resembles CfDs traditionally used in the financial and RE sectors and adopted by countries including the UK, Germany, Australia, France, Italy, and Portugal. CCfDs could be viable in India post-2030, once the Indian Carbon Market is fully functional, has demonstrated credibility, and has attained predictable carbon prices to effectively minimize the government's liability over the long term.

The economic efficiency of CCfD schemes can be maximized through careful design such as having project-based CCfDs to limit exposure of the state to specific projects; structuring long-term contracts for 10 years or more to sufficiently hedge against long-term carbon and energy price risk; and accounting for all expenditure and revenue streams (such as green premiums) when evaluating the strike price.

ARTICLE 6 OF THE PARIS AGREEMENT

Stage of Intervention: TRL 6 – 10

Instrument: Carbon credits, ITMOs, grants, equity, debt, guarantees

Source of Funds: Governments, DFIs, multilateral funds

Rationale for intervention: Several barriers to industrial decarbonization in emerging markets and developing economies, such as the limited supply of public finance, a lack of low-cost capital and tailored financing solutions, and limited institutional and technological capacity, may be difficult to overcome using domestic resources within a timeframe compatible with global climate ambitions. In this context, trans-national solutions can be developed to address these barriers and expedite technological change. Cross-border collaboration can also be more cost-effective since the cost of carbon abatement is lower in developing than developed economies. The Paris Agreement provides an international architecture for countries to autonomously take up climate targets via Nationally Determined Contributions (NDCs), and to collaborate to achieve these NDCs through various market-based mechanisms (MBMs) and non-market approaches (NMAs).

Mechanics: Article 6 of the Agreement enables voluntary international cooperation among countries for the implementation of NDCs via both MBMs (paragraphs 6.2-6.3 and 6.4-6.7) and NMAs (paragraphs 6.8-6.9). Through Article 6, developed countries can provide developing countries with low-cost finance and non-financial assistance for decarbonization, in exchange for a claim on the resulting mitigation outcomes (and potential financial returns). Relevant paragraphs under Article 6 cover the following (ADB, 2018):

- **Article 6.2-6.3** establishes cooperative approaches, which involve the use of internationally transferred mitigation outcomes (ITMOs) towards NDCs. Both the scope and approaches for the generation of ITMOs are currently broad, to be agreed bilaterally between Parties. These paragraphs provide a guidance framework for the transfer of ITMOs between Parties.
- **Article 6.4-6.7**, which is closely related to the Clean Development Mechanism (CDM) under the Kyoto Protocol, provides the basis for a centralized international market mechanism for trading carbon credits under the supervision of the Conference of Parties.
- **Article 6.8-6.9** provides the basis for NMAs to achieve NDCs through mitigation, adaptation, finance, technology transfer, capacity building, etc.

Article 6 allows the structuring of mechanisms to facilitate financing linked to carbon emissions reductions, technology transfer, and capacity building for industrial decarbonization projects. Carbon revenues from direct sales of certified emissions reduction/ITMOs can help reduce the viability gap of projects, but may not completely cover the gap

(GIZ, 2021). Therefore, other low-cost financing instruments and revenue sources (such as green premiums) may be required. Moreover, developed (financing) countries may not find it desirable to directly purchase credits, and developing (host) countries may not have the infrastructure to sell the credits. Alternatives to direct purchase could be devised to overcome these issues. One study suggests a 'project investment' approach, where financing states make low-cost investments in projects (using a variety of instruments from grants to debt) and receive credits for a proportion of the associated emissions reductions, alongside a financial return (Sandler and Schrag, 2022). In addition, NMAs could be used to complement and increase the effectiveness of MBMs. While the scope of NMAs is still rather unclear, among other things this may include coordination in setting regulations (e.g., technological standards); joint research and development programs; low-cost technology transfer, and use of economic and fiscal instruments (Anderson, 2022).

Historically, MBMs have attracted criticism in relation to the calculation of accurate baselines, additionality, double counting, and carbon leakage. Article 6 aims to address several of these concerns. Given its complex transnational nature, the operationalization of this article is still at an early stage – issues related to the scope of activities, transparency, governance, accounting methodology, monitoring, and reporting need to be addressed. Nevertheless, progress is being made. As of March 2024, 81 bilateral agreements had been signed under Article 6.2, covering up to 141 mitigation projects in various sectors, with the largest number in industrial energy efficiency (47). Hundreds of existing CDM projects are being processed for transition to Article 6.4. While MBMs have received the most attention over the years, capacity-building and technical support programs are now being developed, with implementation support from DFIs and multilateral agencies (UNEPCCC, 2024). India's participation in Article 6 mechanisms has been limited so far and mainly includes CDM projects. India needs to consider and take strategic actions to utilize the potential of Article 6, especially in the context of hard-to-abate sectors.

BLENDED DEBT FUND AND PARTIAL CREDIT GUARANTEE MECHANISM

Stage of Intervention: TRL 8 – 10

Instrument: Grants, concessional debt, guarantees

Source of Funds: Governments, DFIs, multilateral funds, commercial lenders

Rationale for intervention: High perceived credit risk remains a key constraint in accessing debt finance to scale up near-commercial and commercially available technologies. This issue is particularly pronounced for SMEs and early-stage projects, which may lack/have low credit ratings due to unproven business models and/or repayment records. Strategic use of public capital in structured blended finance instruments can help address these issues.

A blended debt fund (BDF) blends capital from multiple sources, usually with the aim of utilizing public capital for derisking to mobilize private capital. By blending funds from different sources, each with a different risk appetite, a BDF can make lower-cost and longer-term investments in companies/projects that would otherwise be deemed too risky and are underserved by traditional commercial sources of debt.

Commercial lenders in the market can be supported by a partial credit guarantee mechanism, which covers the risk of borrower default on the guaranteed portion of the loan amount.

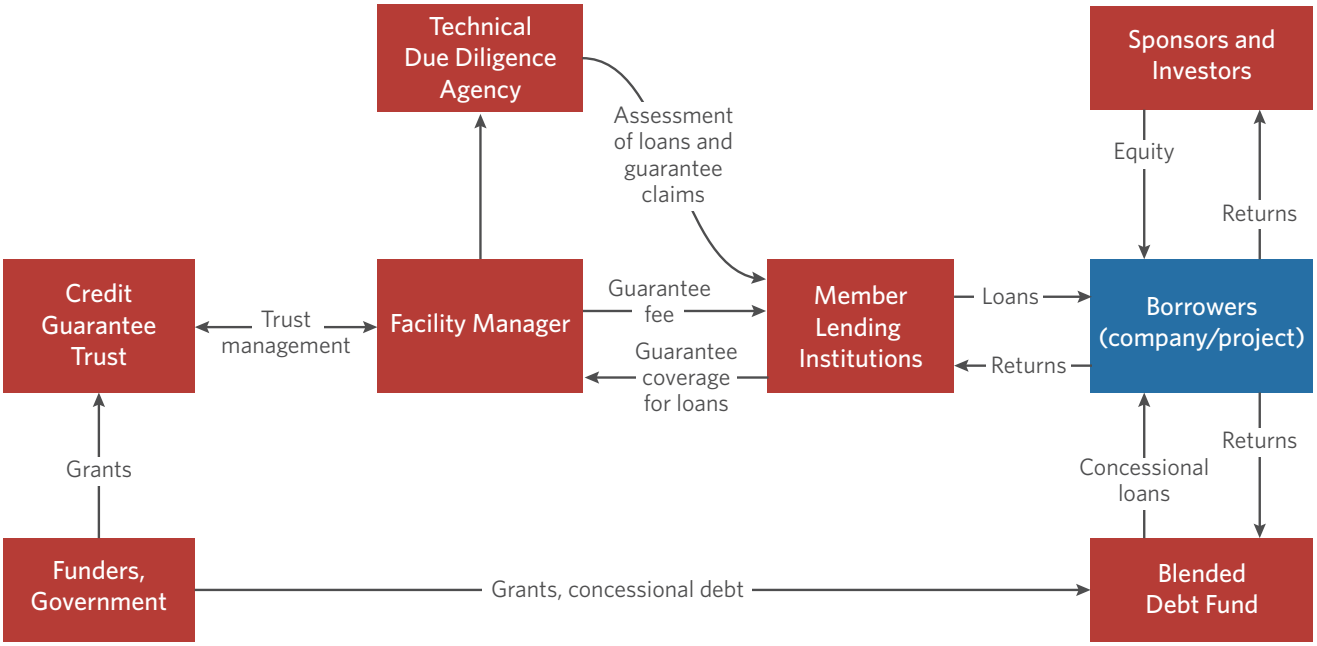
Risk-sharing between the guarantor and the lender helps mobilize debt financing for bankable projects, reduces information asymmetry, encourages lenders' participation in target sectors, and supports the expansion of the credit market. Partial credit guarantee mechanisms can also help to improve lending terms (e.g., cost of capital and tenure).

Mechanics: A simplistic BDF can be structured as an alternative investment fund consisting of at least two capital tranches: a concessional tranche funded by public sources (governments, DFIs, multilateral funds) that is subordinate to the senior commercial tranche funded by commercial sources (banks, institutional investors). By taking on higher risk and demanding lower returns, the concessional tranche enables the participation of more risk-averse commercial lenders. Additional risk capital, in the form of a first-loss tranche, may be included in the structure to further increase the fund's risk appetite. A donor-funded technical assistance facility can be included as part of the mechanism to provide grants for project development activities and to support the development of a pipeline of projects for the BDF.

Alternatively, concessional lenders can directly provide lines of credit to local financial institutions, which can then blend the concessional funds with their own to provide lower-than-market rate debt to industrial sectors.

Since the availability of concessional funds is limited, these must be used for maximum catalytic effect. This may be achieved by linking concessional finance to specific climate performance and corporate governance standards, and by directing investments towards the incremental 'risky' portions of projects (i.e., low-carbon technology) and meeting the remaining financial needs with traditional sources of capital.

Figure 7: Blended debt fund and a partial credit guarantee mechanism



The most plausible partial credit guarantee structure is a trust fund that is capitalized by domestic and international funders, and managed by a facility manager. Commercial lenders can become members of the scheme and apply for partial guarantee coverage for loans, in exchange for a fee. The guaranteed loans are technically assessed by an independent third-

party agency to ensure proper risk management and increase lenders' knowledge. In case of default, the fund pays lenders for the covered portion of the loan.

Certain design considerations can improve the efficacy of a partial credit guarantee mechanism: partial loan coverage (~50% - 70% of loan principal) to ensure sufficient incentive for lenders to participate, while limiting the moral hazard of improper risk management; affordable pricing of the guarantee fee (low enough so as not to offset the positive effect on reduction in debt financing costs); and long-term guarantee coverage (15 years or above) to match the long lifetime of industrial projects.

Examples:

GCF and EBRD High Impact Programme (HIP): The HIP is an industry-focused technical assistance and investment program co-financed by the GCF (concessional) and EBRD (market rate). It consists of multiple components: USD 5 million to USD 7 million grant-funded components to support the development of corporate-level low-carbon strategies, sectoral roadmaps, knowledge sharing, and project preparation; and a USD 1.01 billion investment component for providing performance-linked concessional climate financing in high-impact sectors, including industries. The funds are likely to be disbursed through partnering local financial institutions.

Partial Risk Sharing Facility: A USD 43 million partial credit guarantee facility has been set up to strengthen the energy efficiency market, managed by SIDBI, funded by the GEF, and backstopped by the CTF. The facility has two components: one offering partial credit guarantees to lenders for energy efficiency projects, and the second providing TA to projects in the form of capacity building and developmental support. This facility should be expanded in size and scope to include emerging technologies.

TRANSITION FINANCE

Stage of Intervention: TRL 8 – 11

Instrument: Loans, bonds

Source of Funds: Non-banking financial companies, commercial banks, institutional investors, capital markets

Rationale for intervention: Industrial sectors will likely undergo a gradual transition – adopting the best available and commercially viable technologies while investing in the demonstration and scaling up of breakthrough technologies until they become competitive. In the transition phase, best-available technologies that offer 'incremental' abatement but are not green/low-carbon/near-zero emissions— and therefore not fully compatible with net-zero targets— are needed to gradually reduce emissions intensity, and minimize cumulative sectoral emissions. Most of these technologies are capex and opex-heavy, and require large-scale investment.

Transition finance is emerging as an important category of finance to enable private finance flows towards 'transition activities' that are otherwise disqualified from green finance markets. The OECD defines transition finance as "intended for economic activities that are emissions-intensive, do not have a viable green (near-zero emissions) substitute...but are

important for socioeconomic development" (Tandon, 2021). Transition loans and bonds can help trigger entity-wide transformations and reduce exposure to transition risks. It is important to define and differentiate between transition finance and green finance, as highlighted in Table 2.

Current status: There is a lack of global consensus on a definition of and framework for transition finance. As a result, the market for this type of finance is small and there is ambiguity on the role of financial institutions in financing transition activities. A few independent organizations have developed their own frameworks and guiding principles. Such frameworks should specify eligible best-available technologies, sector-specific benchmarks, and targets to be used as a reference for transition pathways, and consider global alignment while accounting for country and industry constraints.

Table 2: Differences between green and transition finance

	Green Finance	Transition Finance
Definition	Financing technologies that are (near-)zero emissions, and are aligned with the Paris Agreement	Financing to reduce emissions for hard-to-abate sectors, or technologies that are important for emissions reductions in other sectors (as enablers). In most cases, these activities are not aligned with the Paris Agreement but are important due to a lack of suitable 'green' alternatives.
Examples	Solar PV, wind energy generation technology	Steel, Cement, Shipping, Aviation, Heavy-duty transport, etc.

Source: Mohanty and Sarkar (2024)

Transition finance flows in India need to be scaled up. The following measures can be taken to achieve this:

- **Country- and sector-level transition pathways** linked to definite net-zero/climate neutrality targets that provide guide on the technologies required. Timeline and financing requirements for deployment is a critical pre-requisite. Such pathways must clarify which activities qualify as transition activities. Companies also need to set targets, for instance, by signing up with existing credible initiatives such as the Science-based Targets Initiative.
- **A formal definition of and a framework/taxonomy on transition finance** is needed to provide clarity to companies and financial institutions.
- **Robust monitoring and reporting standards** are needed for entities accessing transition finance to ensure transparency.
- **Incorporating climate risk in risk assessment models** can divert capital away from emissions-intensive activities to low-carbon alternatives. Transition risk can be measured using alternative rating frameworks such as 'carbon ratings' – a measure that captures the exposure of the financier to transition risk by accounting for the carbon intensity of the financed activity.

Examples:

Use of sustainability-linked debt instruments: Transition or sustainability-linked loans and bonds can be used to raise debt financing for transition activities. The choice of instrument depends on factors such as the stage of technology/project, use of proceeds, targets, etc. So far, there have been no instances of the use of transition loans or bonds by industry players in India, but a few large companies have raised financing through sustainability-linked instruments that may include several sustainability indicators, including carbon abatement, as part of the KPIs:

- Ultratech Cement raised USD 400 million through India's first issuance of sustainability-linked bonds.
- JSW Cement raised USD 50 million through a sustainability-linked loan.
- JSW Steel raised USD 1 billion through the issuance of sustainability-linked bonds, becoming the world's first steel company to do so.

4. CONCLUSION

By focusing on the iron and steel sector, the highest emitting industrial sector in India, this paper has highlighted the complexities and challenges of decarbonizing industries and also discussed a conceptual framework consisting of industry- and financial sector-level measures to enable financing for low-carbon industrial production.

While investment in green steel production seems to be picking up globally, mainly supported by ambitious climate policies in developed economies, a large financing gap remains. Several barriers contribute to this gap, most importantly reconciling the objective of decarbonization with industrial competitiveness. So far, there has been no investment in green steel production in India, and given the nascency of deep-decarbonization technologies, it is expected that pre-2030, emissions abatement in iron and steel (and other sectors such as cement, chemicals, and aluminum) will need to come through best-available technologies, which have a negative or near-zero marginal cost of abatement. Post-2030, emerging and breakthrough technologies will be needed to transition the low-carbon emissions asset base, aligned with net-zero emissions pathways.

Significant finance is needed for low-carbon technologies at various stages of development to prevent carbon lock-in from the predominantly fossil fuel-based steel capacity expected to be added in India over the next 15 years. Increasing the availability of and access to finance—particularly from private sources—for industrial decarbonization in India will require concerted efforts from a range of stakeholders including policymakers, regulators, industry, associations, and financiers.

Key measures include: implementing (green) sectoral industrial policies that combine a mix of instruments to achieve multiple objectives (i.e., competitiveness, growth, and decarbonization); improving sector-level ecosystems' readiness to attract and absorb investment; structuring innovative business models; implementing tailored financing and derisking mechanisms suited to technology financing needs at each stage of development; and introducing climate-positive regulations for the financial sector.

4.1 FUTURE RESEARCH AND ANALYSIS

Certain priority areas have emerged for immediate efforts to accelerate the transition of the Indian steel sector. We propose central research questions about each of these below:

1. **Green Steel Policy:** What would an optimal green steel policy look like? Which policy instruments should be included, and what are their design considerations to maximize efficacy and economic efficiency?
2. **Transition Finance:** What are the gaps and solutions to scaling up the use of transition finance instruments in steel and other heavy industries?
3. **CCU/S:** What is the potential role of CCU/S in decarbonizing the Indian steel sector, which is expected to be increasingly dominated by the BF-BOF route?

CPI plans to engage in each of these areas as part of its efforts to support stakeholders in decision-making backed by high-quality research and robust analysis.

5. REFERENCES

1. ADB. (2018). Decoding Article 6 of the Paris Agreement. https://doi.org/10.22617/TIM189218-2
2. Anderson, R. (2022). Non-market mechanisms under article 6.8 of the Paris Agreement: a transnational perspective. Transnational Legal Theory, 13(2–3), 321–351. https://doi.org/10.1080/20414005.2023.2174718
3. CPI. (2023a). Global Landscape of Climate Finance 2023. https://www.climatepolicyinitiative.org/wp-content/uploads/2023/11/Global-Landscape-of-Climate-Finance-2023.pdf
4. CPI. (2023b). Policies and Enabling Environment to Drive Private Investments for Industrial Decarbonization in India Identifying Priority Actions for Decarbonizing Steel and Cement Sectors. www.climatepolicyinitiative.org/wp-content/uploads/2023/04/Industrial-Decarbonization-in-India_Policy-Brief_Final.pdf
5. GIZ. (2021). Potential of Article 6 and other financing instruments to promote Green Hydrogen in the Steel, Cement and Mining Industries.
6. Global Energy Monitor. (2023). Global Steel Plant Tracker.
7. Gupta, R., Sankhe, S., Unni, N., and Malik, D. (2022). Decarbonising India: Charting a Pathway for Sustainable Growth (Issue October).
8. Hall, W., Spencer, T., and Kumar, S. (2020). Towards a Low Carbon Steel Sector.
9. IEA. (2021). India Energy Outlook 2021 – Analysis - IEA. https://www.iea.org/reports/india-energy-outlook-2021
10. Maltais, A., Linde, L., Sanchez, F., and Mete, G. (2022). The role of international finance institutions in the transition to low-carbon steel production.
11. Mazzucato, M. (2011). The Entrepreneurial State.
12. Mission Possible Partnership. (2022). Making Net-Zero Steel Possible (Issue September).
13. MNRE. (2024, February 2). Government issues Pilot Project Guidelines for Utilizing Green Hydrogen in Steel Sector. https://pib.gov.in/PressReleaseIframePage.aspx?PRID=2002034
14. Mohanty, M., and Sarkar, R. (2024). The Role of Coal in a Sustainable Energy Mix for India. Routledge.
15. Mondini, N., Maltais, A., and Moberg, A. (2023). IFIs and heavy industry decarbonization in emerging and developing economies.
16. MoS. (2021). Annual Report 2019-2020.
17. OECD. (2022). Framework For Industry's Net-Zero Transition. https://www.oecd.org/environment/framework-for-industry-s-net-zero-transition-0c5e2bac-en.htm

18. OECD. (2023). Financing solutions to foster industrial decarbonization in emerging and developing economies. https://doi.org/10.1787/24a155ab-en

19. Polzin, F. (2017). Mobilizing private finance for low-carbon innovation – A systematic review of barriers and solutions. Renewable and Sustainable Energy Reviews, 77 (April), 525–535. https://doi.org/10.1016/j.rser.2017.04.007

20. Polzin, F., Egli, F., Steffen, B., and Schmidt, T. S. (2019). How do policies mobilize private finance for renewable energy?—A systematic review with an investor perspective. Applied Energy, 236 (September 2018), 1249–1268. https://doi.org/10.1016/j.apenergy.2018.11.098

21. Richstein, J. C., and Neuhoff, K. (2022). Carbon contracts-for-difference: How to de-risk innovative investments for a low-carbon industry? IScience, 25(8). https://doi.org/10.1016/j.isci.2022.104700

22. Sandler, E., and Schrag, D. P. (2022). Financing the Energy Transition through Cross-Border Investment: A New Model for Article 6 of the Paris Agreement. www.blfercenter.org/project/cyber-project

23. Singh, T., Ahuja, R., Mishra, J., and Malhotra, S. (2020). Transitioning India's steel and cement industries to low carbon pathways. SNAPFI Country Studies (July Issue). https://climatestrategies.org/wp-content/uploads/2021/03/cs-ndc_tracking_india_jul_2020.pdf

24. Tandon, A. (2021). Transition finance: Investigating the state of play: A stocktake of emerging approaches and financial instruments. In OECD Environment Working Paper (Issue 179). https://dx.doi.org/10.1787/68becf35-en

25. UNEPCCC. (2024, March). Article 6 Pipeline. https://unepccc.org/article-6-pipeline/

26. Vogl, V., Sanchez, F., Torres Morales, E., Gerres, T., Lettow, F., Bhaskar, A., Swalec, C., Mete, G., Åhman, M., Lehne, J., Schenk, S., Witecka, W., Olsson, O., and Rootzén, J. (2023). Green Steel Tracker, Version 04/2023, Stockholm, Dataset.

27. Waissbein, O., Glemarec, Y., Bayraktar, H., and Schmidt, T. (2013). Derisking Renewable Energy Investment. United Nations Development Programme, 1–156. https://doi.org/10.1002/eji.1830230227

28. World Economic Forum and Oliver Wyman. (2021). Financing the transition to a Net-Zero Future. https://www.oliverwyman.com/our-expertise/insights/2021/oct/financing-the-transition-to-a-net-zero-future.html

6. ANNEXURES

ANNEXURE A: POLICIES ADOPTED BY MAJOR ECONOMIES TO DECARBONIZE INDUSTRIES

Table 3: Policies implemented by major economies to promote sustainable industrial growth

Country/ Region	Policy	Objective	Beneficiary Industries	Details	Potential Impact on the Steel Sector	Expected Outcomes
India	National Green Hydrogen Mission (2023)	To make India a global hub for the production, utilization, and export of green hydrogen and its derivates.	Fertilizers, petrochemicals, steel, heavy-duty transport, shipping, and energy storage.	Budgetary Allocation: Total capital outlay of USD 2.3 billion (INR 19,744 Crore). Financial Instruments: Grants, concessional loans, and financial incentives for businesses for the manufacture of electrolyzers and the production of green hydrogen. Funding Source: Indian Government.	USD 54.8 million (INR 455 Crore) allocated for pilot projects substituting fossil fuels with green hydrogen in steelmaking until 2029-30.	Target to reach 5 MMT of green hydrogen production per year by 2030 and 125 GW of associated RE capacity. Aims to stimulate nearly USD 100 billion in total investments, create 600,000 jobs, and abate 50 MtCO2 emissions by 2030.
USA	Inflation Reduction Act (IRA), 2022	To combat inflation by addressing the Federal Budget deficit, and, among others, promote clean energy investments over a 10-year period.	Various sectors, including those aimed at lowering energy costs, enhancing energy security, improving public health, mitigating climate change, creating jobs, and addressing inequities.	Budgetary Allocation: Nearly USD 400 billion to clean energy through tax incentives, grants, and loan guarantees. Financial Instruments: Grants, concessional loans, and other financial incentives. Funding Source: Federal funding.	USD 4.5 billion allocated to reduce embodied carbon in construction materials, promote low-carbon cement and steel, and invest in green technologies.	Aims to drive a 40% reduction in GHG emissions by 2030, including those associated with steel and cement production.

Country/ Region	Policy	Objective	Beneficiary Industries	Details	Potential Impact on the Steel Sector	Expected Outcomes
EU	Green Deal Industrial Plan for the Net-Zero Age	To position Europe as a hub for industrial innovation and clean technology, while ensuring sustainability.	Sectors such as RE, energy-intensive industries like steel and cement, and the transport sector.	Budgetary Allocation: Flexible policy framework adaptable to diverse national circumstances and development stages. Financial Instruments: Facilitate access to financing for clean tech innovation, manufacturing, and deployment through existing EU funds (REPowerEU, InvestEU, and the Innovation Fund) and the European Sovereignty Fund. Funding Source: Public and private sector.	Addressing of challenges hindering the low-carbon transition, explore low- and zero-emission production technologies.	Enhanced competitiveness and supply chain resilience, reduced emissions in steel and cement sectors, and promotion of green practices.
Germany	Carbon Contracts for Difference Program	To expedite the phase-out of fossil fuels in energy-intensive industries, transition to environmentally friendly production processes.	Industries reducing CO2 emissions and transitioning to climate-friendly production, including for SMEs.	Budgetary Allocation: EUR 50 billion over 15 years, with flexibility to tailor support based on clean energy requirements. Financial Instruments: Carbon contracts providing compensation for additional costs during the transition to green production. Funding Source: German Government.	Incentivization of adoption of low-carbon technologies, promoting green steel and low-carbon cement.	Attainment of climate targets, and substantial emission reductions in steel and cement sectors.
France	France 2030 Investment Plan - Heavy Industry Decarbonization	To drive reduction in GHG emissions, with EUR 5.6 billion for CO2 reduction in domestic heavy industries.	Key domestic heavy industries, including steel, cement, and aluminium.	Budgetary Allocation: EUR 610 million for innovation and EUR 5 billion for decarbonization solutions such as hydrogen and carbon capture. Financial Instruments: Grants and concessional loans. Funding Source: French Government.	Promotion of green steel, low-carbon cement, and emissions-reducing technologies.	Significant reduction in GHG emissions from heavy industries in France.
UK	Net-Zero Strategy	To achieve net-zero GHG emissions across all sectors of the UK economy by 2050.	All sectors including power, transport, construction, industry, and agriculture.	Budgetary Allocation: Emphasizes government investment in research, development, innovation, and infrastructure. Financial Instruments: Grants, concessional loans, and financial incentives for businesses and consumers. Funding Source: Public and private.	Promotion of green steel, low-carbon cement, and R&D for emissions reduction.	Creation of jobs, emissions reduction, and growth of green industries, including green steel and low-carbon cement.

Source: CPI analysis

ANNEXURE B: PUBLICLY FUNDED PROGRAMS SUPPORTING INDUSTRIAL DECARBONIZATION

Table 4: Funding programs for heavy industries and hard-to-abate sectors capitalized by public sources

Initiative	Description	Scope	Instrument	Funding source
Public Funding Opportunities				
Climate Investment Funds (CIF) Industry Decarbonization Programme	World's first multilateral investment program to help developing countries decarbonize hard-to-abate industries. Aims to deploy at least USD 500 million to pilot and scale innovation. Uses concessional finance to address barriers to investment, by providing TA and investment support. Beneficiaries: Industrial facilities, corporations, and governments.	Geography: Developing countries Sectors: Hard-to-abate industries TRL: 7 – 10 Funds: At least USD 500 million	Grants, Concessional finance	International public: UK, Sweden as of 2022 with more donors expected
Strategic Interventions for Green Hydrogen Transition Programme (SIGHT)	Financial incentives to support domestic manufacturing of electrolyzers and production of green hydrogen. Beneficiaries: Industrial facilities, corporations.	Geography: India Sectors: Hard-to-abate industries TRL: 7 – 10 Funds: USD 2.1 billion (INR 17,490 Crore)	Grants, Subsidies	Domestic public
Horizon Europe (HEU)	The EU's key funding program for research and innovation focused on climate change, the UN Sustainable Development Goals, and the EU's competitiveness and growth. Beneficiaries: Universities, research centers, corporations, and individuals.	Geography: EU Sectors: All major economic sectors TRL: 3 – 7 Funds: EUR 80 million (2021-30) for steel; EUR 100 billion (2021-27) in total. Typically 50-70% for a project dimension from EUR 4 million to 20 million.	Grants	Domestic public
Research Fund for Coal and Steel (RFCS)	EU funding program supporting research and breakthrough projects in coal and clean steelmaking. Beneficiaries: Universities, research centers, corporations.	Geography: EU Sectors: Coal and Steel TRL: 2 – 5 Funds: EUR 300 million (2021-30) for steel; EUR 400 million (2021-30) in total. Co-financing of ≤50% of total costs for demonstration projects ranging from EUR 3 million to EUR 4 million.	Grants	Revenues in liquidation assets of the European Coal and Steel Community fund

Initiative	Description	Scope	Instrument	Funding source
Public Funding Opportunities				
Clean Steel Partnership (CSP)	Develop technologies at TRL 8 to reduce CO2 emissions from steel production and transform it into a climate-neutral sector, while preserving the competitiveness and viability of the industry. Beneficiaries: Corporations.	Geography: EU Sectors: Steel TRL: 5 – 8 Funds: EUR 975 million (2021-30) for steel. Co-funding of 50-100% for projects ranging from EUR 10 to EUR 100 million.	Grants	Domestic public (HEU funds, ECSC), domestic private (corporations)
Innovation Fund (IF)	One of the world's largest funding programs for the demonstration of innovative low-carbon technologies that will contribute to GHG reduction. Beneficiaries: Corporations.	Geography: EU Sectors: RE, energy efficiency, storage, CCUS, other innovative technologies TRL: 7 – 9 Funds: EUR 500 million (2021-30) for 20 sectors. Covers up to 60% of additional costs related to innovative technologies for big projects (> EUR 7.5 million) and up to 60% of capex for small projects.	Grants	Carbon markets - EU ETS revenues from the auction of allowances
Industrial Decarbonization and Emissions Reduction Demonstration-to-Deployment funding opportunity announcement (FOA)	Aims to catalyze high-impact, large-scale, transformational advanced industrial facilities to significantly reduce GHG emissions in energy-intensive subsectors. Beneficiaries: Corporations.	Geography: USA Sectors: Iron and steel, cement and concrete, chemicals and refining, food and beverages, paper and forest products, aluminum, and other energy-intensive manufacturing industries. TRL: 7 – 9 Funds: USD 6.3 billion in total. Funding awards cover ≤50% of total project costs and per project awards could vary between USD 100 million to USD 250 million for full new near-zero emissions facilities; USD 75 million to USD 500 million for large-scale overhauls/retrofitting in existing facilities; and USD 35 – 75 million for small-scale retrofits.	Grants, others	Domestic public (government budget)
Industrial Efficiency and Decarbonization FOA	Funds high-impact, applied research, development, prototyping, piloting, and demonstration projects to expedite the adoption of transformational industrial technology necessary to increase energy efficiency across industries and in high-emitting industrial subsectors, reducing both energy usage and GHG emissions. Beneficiaries: Corporations.	Geography: USA Sectors: Iron and steel, cement and concrete, chemicals, food and beverage, paper and forest products, cross-cutting technologies TRL: 4 – 7 Funds: USD 104 million in total. Maximum of USD 4 million funding for TRL 4 – 5 R&D activities, and USD 10 million for TRL 6 – 7 R&D, prototyping, and piloting activities on a cost-sharing basis in both steel and cement sectors.	Grants	Domestic public (government budget)

Initiative	Description	Scope	Instrument	Funding source
Public Funding Opportunities				
Industrial Decarbonisation Challenge	Supports the development of low-carbon technologies and infrastructure (clusters), increasing industrial competitiveness, to reduce the carbon emissions from energy-intensive industries and contribute to the UK's clean growth. Beneficiaries: Corporations.	Geography: UK Sectors: Iron and steel, cement, refining, and chemicals. TRL: 7 – 9 Funds: GBP 210 million (2019-24) and industry co-funding of GBP 261 million. Projects under the 'Deployment' (industrial-scale demonstration projects and shared infrastructure) stream have been awarded an average of GBP 18 million. Projects under the 'Cluster' (plans and feasibility studies for industrial clusters) stream have been awarded an average of GBP 1 million.	Grants	Domestic public (government budget), domestic private (corporations)
Industrial Energy Transformation Fund	Objective: Help businesses with high energy use to cut their energy bills and carbon emissions through investing in energy efficiency and low-carbon technologies. Beneficiary: Corporations.	Geography: UK Sectors: Energy efficiency and innovative technologies for industrial subsectors. TRL: 5 – 9 Funds: GBP 315 million (2018-27). Energy efficiency deployment projects can receive up to GBP 14 million; deep decarbonization deployment projects up to GBP 30 million; feasibility and engineering study projects up to GBP 7 and 14 million, respectively.	Grants	Domestic public (government budget)

Source: CPI analysis

ANNEXURE C: EXAMPLE OF INVESTMENT RISKS AND MITIGATION MEASURES: GREEN H-DRI PROJECT

Table 5: Major investment risks and mitigation measures for a hypothetical green Hydrogen – Direct-Reduced Iron project

Risk(s)	Mitigation Measures	Responsible Stakeholders
Policy and regulatory risk	Definition and standards for green hydrogen	Government
	Fiscal and financial incentives for green hydrogen use in the steel sector	Government
	Price support subsidies through Contract for Difference (CfD)	Government
Technology and construction risk	Independent technology verification, equipment, and construction guarantees	EPC company
	Technology and construction risk insurance	Insurers
Technology and business model risks	Deconsolidated project structure with separate financing for the hydrogen plant (non-recourse) and the DRI-EAF steel plant. A hydrogen plant special purpose vehicle can be co-financed by multiple entities (steel companies, technology providers, energy companies, and government) as risk-sharing sponsors.	Project developer
Business model risks (demand side)	Long-term offtake agreement for green steel with green premium to secure offtake price and volume	Private Off-takers
	Public procurement of green steel for use in public infrastructure and goods	Government
Business model risk (supply side)	Long-term power-purchase agreements for the supply of RE for the production of green hydrogen to ensure stable and predictable operating costs	Sponsors, RE developers
	Tolling structure for green hydrogen plant (multiple industry off-takers of green hydrogen paying for key inputs such as electricity and water to diversify revenue stream)	Project development
Performance risk	Contracts with strong counterparties	Sponsors, other private companies
Credit risk	Credit guarantees and credit enhancement	Government, DFIs, Insurers, Export credit agencies
Financing risk	Subordinate/concessional capital to crowd in private investors and improve availability and terms of financing (cost, tenure)	Government, DFIs
Currency risk	FX hedging	Hedging facilities, traders
Political risk	Political risk insurance	DFIs

Source: CPI analysis, and World Economic Forum and Oliver Wyman (2021)

climatepolicyinitiative.org