



# BRIDGING INDIA'S CEMENT DECARBONISATION GAP

## Why Hard-to-Abate Sectors Need a Credible Transition Finance Framework?

India's transition towards net-zero emissions depends significantly on decarbonising hard-to-abate sectors such as cement, which remains highly emissions-intensive due to clinker-based production and process emissions from limestone calcination. Despite growing investments in renewable energy, waste heat recovery systems, and alternative fuels, emissions from the sector remain relatively stable, highlighting the limitations of existing green finance approaches. This issue brief examines the Indian cement sector through the lens of transition finance and argues that conventional sustainability finance frameworks are inadequate to drive deep industrial decarbonisation.

The study combines sectoral analysis with an exploratory econometric assessment using panel data for major Indian cement firms between FY2021 and FY2025. A pooled Ordinary Least Squares (OLS) model examines whether firm-level financial characteristics (i.e. leverage, profitability, and firm size) significantly influence emissions intensity. The results indicate that these variables are statistically insignificant determinants of



emissions intensity, suggesting that decarbonisation constraints in cement are driven less by financial capacity and more by technological rigidity and carbon lock-in within production systems.

Building on NITI Aayog's Roadmap for Cement Sector Decarbonisation, the brief argues for a credible transition finance framework that moves beyond generic ESG financing to support sector-specific mechanisms capable of measurable industrial transformation. It proposes policy interventions including process-linked finance instruments, clinker-based taxonomies, carbon contracts for difference (CCfDs), and blended finance for scaling high-risk decarbonisation technologies.

## Introduction

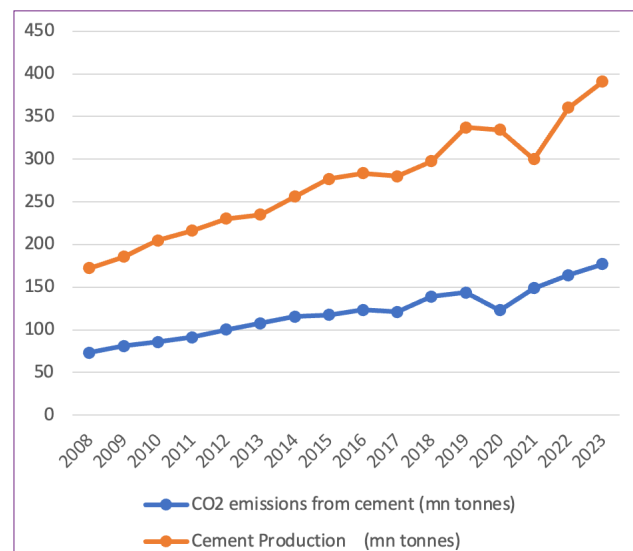
Climate change has intensified the need to transition towards low-carbon and sustainable development pathways. Although substantial progress has been made through the expansion of renewable energy, electrification of transport, afforestation programmes, and international climate cooperation, some sectors remain inherently difficult to decarbonise. Decarbonising these hard-to-abate industries, such as cement, steel, and chemicals, represents one of the most complex challenges because a large share of their greenhouse gas emissions is embedded in core industrial processes rather than arising solely from energy consumption. Among these industries, cement occupies a particularly critical position because its emissions arise not only from energy consumption but also from the chemical decomposition of limestone during clinker production.

India is the world's second-largest producer of cement, with an installed capacity of almost 700 million tonnes, accounting for nearly 8 per cent of global production. This sector contributes around 7 per cent of national carbon emissions (TERI, 2025) and remains essential to the country's economic development, generating approximately 1.2–1.5 per cent of national GDP. As a developing economy, India has a cement-to-steel ratio of 3:1, indicating strong demand for cement. This reflects

the role of regulatory policies driving infrastructure development, rural expansion, urbanisation, industrial corridors, and affordable housing. These trends have further prompted companies to expand their production capacities.

Cement production is expected to grow to almost 1,546 million tonnes by 2070 (Decarbonization Roadmap for the Indian Cement Sector Net-Zero CO<sub>2</sub> by 2070). More than 90 per cent of the cement produced is consumed domestically. At the same time, annual carbon dioxide emissions from India's cement sector have risen in step with growing production (Figure 1). Therefore, the decarbonisation of cement production must be prioritised to help India achieve its net-zero ambitions.

**Figure 1: Annual CO<sub>2</sub> Emissions from Cement Production in India**



Source: Author's calculations based on data from NITI Aayog and World Bank Group.

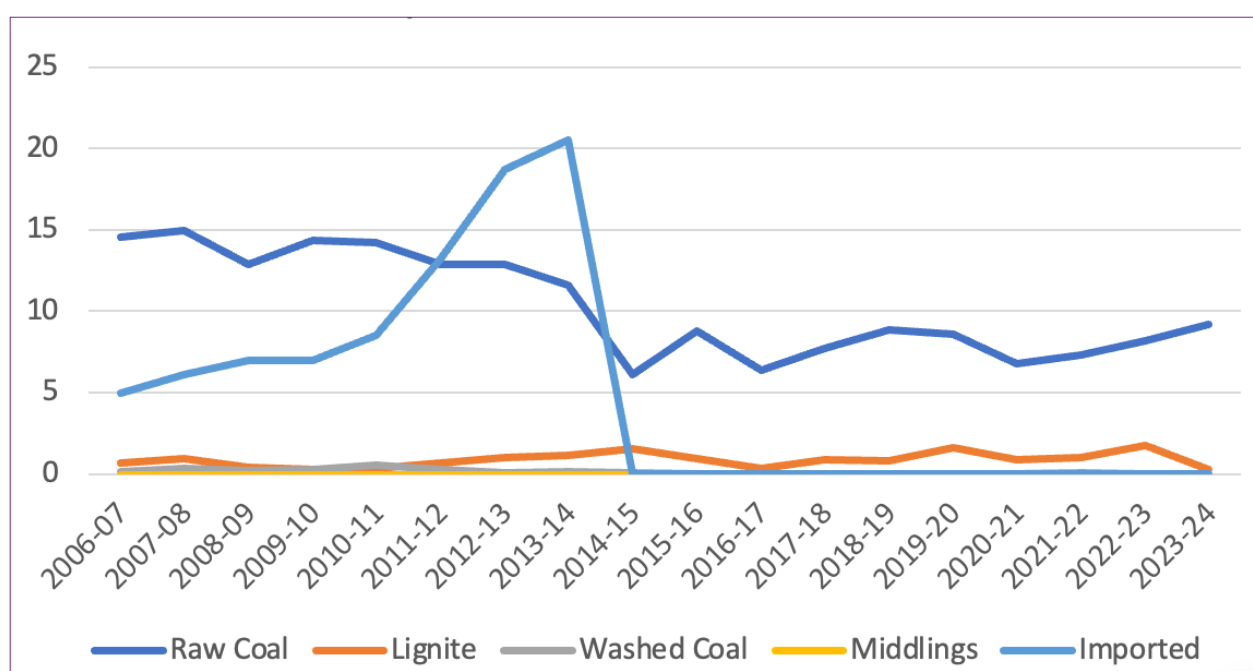
## The Clinker Saga

The primary component of cement is clinker, produced by heating raw materials in a rotary kiln to approximately 1,450°C to facilitate chemical and physical changes (Ige et al. 2021). The calcination of limestone for clinker production and fossil fuel combustion for electricity and thermal energy generation together contribute between 86–90 per cent of GHG emissions. Nearly 90–95 per cent of

coal consumption within the cement industry is concentrated in this clinker production phase.

There has been an intentional reduction in coal consumption to reduce carbon emissions over the past decade. As shown in Figure 2, the consumption of raw coal for producing cement has declined by 37 per cent over the past two decades, indicating a transition towards greener fuel-based production pathways. The quantity of low-carbon-based coal, such as lignite and middlings, is more or less unchanged over 2006–24. This trend indicates that companies are trying to switch either to renewable sources of energy with green fuels, such as biogas and green hydrogen, or low-carbon-intensity fossil fuels.

Figure 2: Coal Consumption for Cement Production



Source: Author's calculations based on data from NITI Aayog

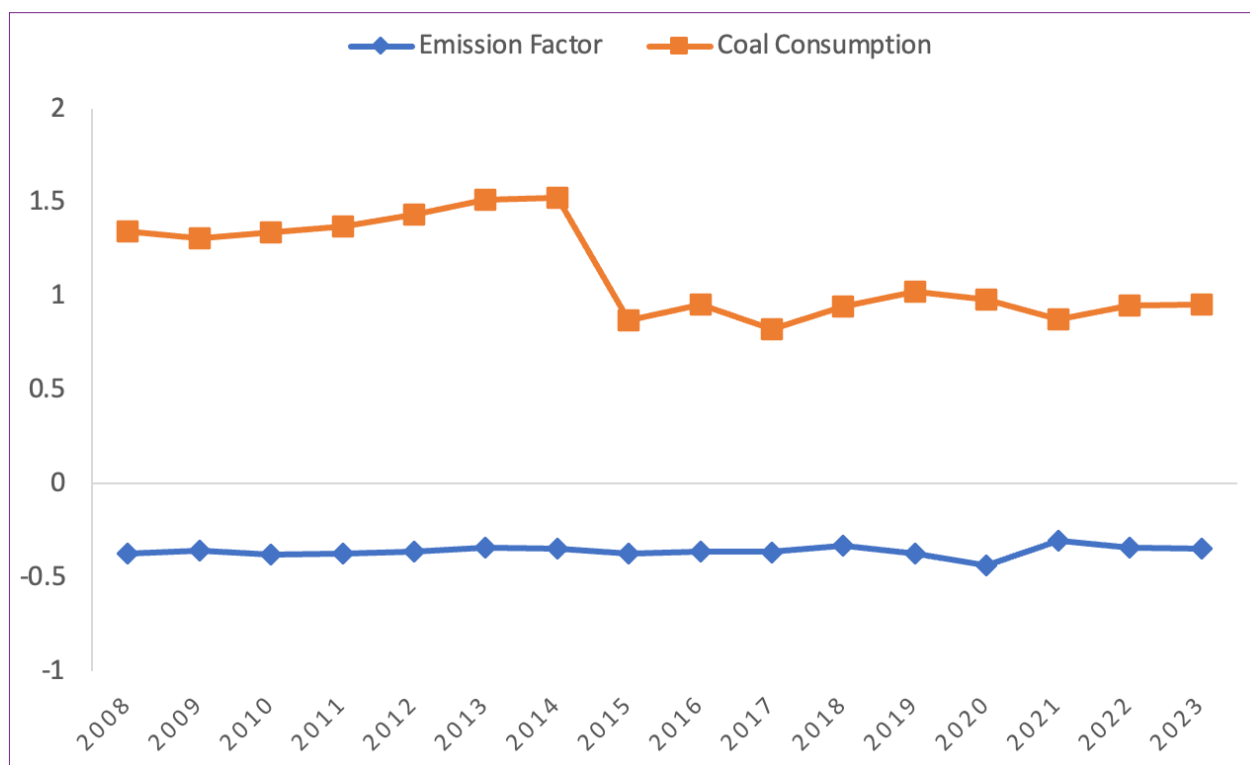
Despite the drastic reduction in coal used in the production process, the carbon emission factor<sup>1</sup> has not changed much and has remained stagnant somewhere around 0.45 per tonne (Figure 3). This is because a substantial amount of CO<sub>2</sub> is released during the chemical decomposition of limestone in the clinkerisation process, irrespective of the fuel used. This accounts for 60 per cent of total emissions. Cement with higher clinker content releases higher emissions. Indian cement producers use a 60–95 per cent clinker-to-cement ratio, meaning that the clinker content in cement varies between 60–95 per cent depending on the kind of cement (Sharma and

KVS, 2021). The high clinker-to-cement ratio makes it difficult to reduce the emission factor despite substituting fossil fuels with greener alternatives.

This underscores the need to substitute carbon-intensive clinker with alternative materials, such as limestone, calcined clay, and cement capable of reducing CO<sub>2</sub> emissions by up to 40 per cent, or industrial byproducts, such as fly ash and slag (World Economic Forum 2025). However, these byproducts may not be available after 2050, once fossil fuels such as coal are no longer in use.

<sup>1</sup> Carbon emissions per tonne of cement produced

Figure 3: Coal Consumption versus Carbon Emissions (Log Values)



Source: Author's own calculation based on NITI Aayog and World Bank data

## Decarbonisation Mechanisms in the Cement Sector

Over the past few years, attempts have been made to transition to a low-carbon-intensity production process through the utilisation of circular raw materials (e.g. fly ash, slag, synthetic gypsum); promotion of low-emission blended cements; and adoption of available energy-efficient technologies. Investments have been made in research and development to identify commercially viable low-carbon production methods. At present, around 73 per cent of cement production consists of low-carbon blended cement (Singhi and Badola 2024).

The Government of India has also introduced a range of policy measures to support industrial decarbonisation. One of the most significant initiatives is the Perform, Achieve and Trade Scheme, under which energy-intensive industries are assigned specific energy-consumption targets. Firms that exceed these targets by reducing their fossil fuel use are awarded Energy Saving Certificates (ESCerts), which can be traded in the market. The cement

industry was able to exceed targets and achieve a substantial 81.6 per cent and 48.6 per cent reduction in specific energy consumption in both cycles of the scheme (CMA 2021).

Various other policies remain under development, including Carbon Capture, Utilisation, and Storage (CCUS) technology for deep decarbonisation, mandates for the use of low-carbon blended cements and energy efficiency-linked targets, among others. A Carbon Capture and Storage facility or a Carbon Capture and Utilisation facility can capture carbon emissions from the production process and convert them into biofuels using biochemical processes.

Several institutions, including NITI Aayog, The Energy and Resources Institute, and the Council on Energy, Environment and Water, have developed roadmaps outlining pathways for decarbonising the Indian cement sector. Among these, the 2026 roadmap published by NITI Aayog identifies four principal mitigation strategies: alternative fuels, decarbonisation of electricity, clinker substitution,



and CCUS. As shown in Table 1, this NITI Aayog framework reveals that 35–54 per cent of long-term sector abatement depends entirely on CCUS, a technology expected to cost nearly Rs 1,200–1,400 crore and require considerable time to deploy at scale. In India, Dalmia Cement (Chennai) is the sole cement manufacturer to announce a formal CCUS investment target, aimed at 2040 (IEA 2026).

**Table 1: Transition Strategies and the Predicted Emission Reduction Because of Them**

Transition Strategy	Emission Reduction
Alternative Fuels	6–13%
Decarbonisation of Electricity	6–10%
Clinker Substitutes	11–15%
CCUS	35–54%

*Source: Roadmap for Cement Sector Decarbonisation by NITI Aayog*

Other decarbonisation options also involve significant costs. For example, although clinker substitutes such as fly ash and slag are relatively cost-competitive, the use of Refuse-Derived Fuel (RDF) generally costs ₹1,500–2,000 per tonne, excluding transportation expenses. This can make RDF-based thermal energy 30–50 per cent more expensive than conventional fuels such as coal and petcoke (NITI Aayog). The planned decarbonisation of the cement industry will therefore require substantial capital investment. While these mechanisms provide important pathways for reducing emissions, their large-scale adoption remains constrained by the structural characteristics of cement production itself. The

persistence of clinker-intensive manufacturing, long asset lifecycles, existing thermal infrastructure, and established industrial supply chains creates a form of ‘carbon lock-in’, wherein industries remain dependent on carbon-intensive systems despite the emergence of cleaner alternatives. Such lock-in effects arise from the co-evolution of technological systems and institutional arrangements, which together inhibit rapid diffusion of low-carbon technologies (Unruh 2000). In the Indian cement sector, this lock-in is reflected in the continued dominance of process emissions despite the increasing adoption of renewable energy and energy-efficiency measures.

## Transition Finance and Its Need

Decarbonising the cement sector requires substantial, sustained capital investment. Many of the most effective mitigation technologies are either commercially immature, operationally complex, or associated with long payback periods. Conventional green finance is generally directed towards activities that are already considered environmentally sustainable and therefore provides limited support to emissions-intensive industries that must undergo gradual technological transformation. This underscores the need for a dedicated transition finance framework capable of mobilising patient capital and reducing the risks associated with large-scale industrial transformation. Transition finance refers to the financing required to support hard-to-abate sectors, such as cement, in their decarbonisation efforts.

According to the International Energy Agency (IEA 2025), 'Transition finance refers to financial activities that can contribute to emissions reductions, particularly in hard-to-abate sectors as well as in emerging market and developing economies (EMDE) where finance needs are high but the support from green finance is limited. It is subject to an important process requirement, in that investments need to be grounded in transition plans, strategies or equivalents with mechanisms in place to enable tracking and follow-up'.

## Challenges in Raising Transition Finance for Cement Decarbonisation

The cement industry is governed by high capital and low returns. Decarbonising the sector demands a significant capital outlay, especially in its early stages, with a slow capital recovery period. Moreover, many technologies are still at an early stage of commercial development, which creates uncertainty regarding their technical performance, future competitiveness, and long-term economic viability. Early adopters, therefore, face the risk that subsequent technological advances may render existing investments less efficient or economically obsolete.

These technology-related risks are compounded by institutional and regulatory barriers. The absence of a well-defined national transition finance taxonomy complicates fundraising, especially since many investors lack a comprehensive understanding of decarbonisation frameworks and their urgency. Concerns regarding greenwashing, together with the limited availability of policy incentives and risk-sharing mechanisms, further reduce the attractiveness of transition investments.

Another challenge arises from the structural characteristics of cement production itself. Although firms have increasingly adopted renewable energy and alternative fuels, these measures have had only a limited effect on overall emissions intensity because most emissions originate during clinker production. As a result, investments in cleaner energy alone do not generate sufficiently large and immediate emissions reductions to satisfy many investors. This weakens the commercial case for transition finance and may encourage firms to prioritise accounting-based emissions management strategies rather than undertaking substantive process transformation, resulting in carbon leakage (IEA 2025).

To examine whether firms with stronger financial capacity are better positioned to reduce emissions intensity, and to test whether the principal barriers to decarbonisation are structural rather than purely financial, the following section presents an empirical analysis based on a sample of major Indian cement companies.

## Methodology and Analysis

The analysis uses a panel of 10 Indian companies over the period 2019–20 to 2024–25, yielding 240 observations due to limited publicly available and comparable emissions disclosures. The companies were selected to ensure a mix of large, medium, and small cement producers, thereby enabling an assessment of the impact of finance availability. It was assumed that large players with greater financial resources would be able to obtain transition funds more easily and reduce emissions (Singal 2013).

Data were collected from the annual reports of 10 cement firms: UltraTech Cement, Shree Cement, Ambuja Cement, Dalmia Bharat, JK Cement, Ramco Cements, Star Cements, India Cements, Sagar Cements, and Heidelberg Cement India.

A regression analysis was conducted from the collected data using the equation provided below.

$$\text{Emission Intensity}_{it} = \alpha_0 + \alpha_1 \text{Leverage}_{it} + \alpha_2 \text{EBITDA}_{it} + \alpha_3 \log(\text{Assets}_{it}) + u_{it}$$

where,

- Emission Intensity<sub>it</sub> = Total Scope 1 emissions/ cement production in units
- Leverage<sub>it</sub> = debt-to-equity ratio
- EBITDA<sub>it</sub> = EBITDA margin
- Log (Assets<sub>it</sub>) = natural logarithm of total assets

The dependent variable is Scope 1 emissions intensity, measured as tonnes of CO<sub>2</sub> emitted per tonne of cementitious product. Scope 1 emissions are used because they capture direct emissions from limestone calcination and fuel combustion, which together account for the majority of cement-sector emissions.

Here, Emission Intensity represents the emissions per unit of cement, leverage represents the external borrowing capacity, EBITDA margin reflects the profitability, and assets indicate firm size. A natural logarithm of total assets (₹ crore) was employed to counter the differences in units.

Because the study uses panel data, three techniques were initially considered. The F-test was employed to check for fixed effects versus the pooled OLS method. The Breusch–Pagan LM test was employed to check for random effects versus the pooled OLS method, and the Hausman test was employed to check for random effects versus fixed effects. However, owing to the limited number of observations, combined with the minimal variation in emission intensity across firms and over time, fixed-effects and random-effects estimators were not statistically feasible. Accordingly, pooled ordinary least squares (OLS) was employed to examine whether leverage, profitability, and firm size are associated with differences in emission intensity.

**Table 2: Pooled OLS Results**

Residuals:				
1st Quartile	Median	3rd Quartile	Max	
-0.039911	0.036039	0.108131	0.512498	
Coefficients:				
	Estimate	Std. Error	T-value	Pr (> t )
(Intercept)	0.093982	1.360070	0.0691	0.9472
Leverage	0.127802	0.445290	0.2870	0.7838
EBITDA	1.602914	2.438972	0.6572	0.5354
Log assets	0.045916	1.003044	0.0458	0.9650
Other Statistics:				
Total Sum of Squares		0.85875		
Residual Sum of Squares		0.79305		
R-Squared		0.076509		
Adj. R-Squared		-0.38524		
F-statistic		0.165696 on 3 and 6 DF, p-value: 0.91568		

Source: Author's own calculations based on data from annual reports

The pooled OLS results indicate that financial variables such as leverage, profitability, and firm size do not significantly explain variations in emission intensity, suggesting that emissions are primarily driven by structural and technological factors rather than financial capacity alone. This highlights the limitation of relying solely on market-based financial mechanisms for decarbonisation in hard-to-abate sectors such as cement. Cement firms show low variation in emissions intensity over time, suggesting homogeneity in the industry.

There is insufficient variation for the random effects tests, as well. To check the validity of the dataset, multicollinearity (Variance Inflation Factor), heteroskedasticity (Breusch–Pagan), and normality (Shapiro–Wilk) tests were conducted. The results indicated that the data were valid.

**Table 3: Regression Results**

Variable	Coefficient	p-value	Interpretation
Leverage	+0.128	0.80	No significant effect
EBITDA	+1.60	0.73	No significant effect
Log (Assets)	+0.046	0.97	No significant effect

The regression results (Table 3) reject the hypothesis that cement producers with more funds can reduce their emissions, pointing to a deeper issue: the lack of efficient green cement production mechanisms. The persistence of emission intensity over time, regardless of financial performance, indicates that decarbonisation in the cement sector is a structural challenge, reflecting continued dependence on clinker-based production. This lack of efficient cement production mechanisms makes it difficult for companies to establish investor trust and raise funds, thereby necessitating targeted policy and financial interventions.

## Policy Implications

The urgent need to decarbonise the cement industry requires targeted policy interventions. The challenge is not merely a financing gap but a structural constraint rooted in process emissions. Therefore, transition finance frameworks must move beyond firm-level capital provision towards process-linked, technology-specific, and demand-supported interventions. Key recommendations include:

### 1. Transitioning from Green to Process-Linked Finance

Since the mere availability of finance does not lead to emission-reduction investments, financial instruments linked to reducing the clinker ratio

and carbon capture per tonne of output must be introduced. Such instruments will not only enable transparency but also encourage green innovation.

### 2. Establishing a Clinker Taxonomy

A clinker taxonomy that provides a clear classification between green and transition activities is required to help creditors and investors benchmark performance. It will also reduce greenwashing while aligning finance with the sector's principal source of emissions.

### 3. Demand Creation for Green Cement

Policymakers must incentivise the use of green cement by explicitly defining green cement and providing subsidies or tax benefits for its usage to ensure sustained market demand for compliant manufacturing firms.

### 4. Carbon Contracts for Difference (CCfDs) for Cement

The establishment and usage of carbon capture and utilisation technology are expensive, increasing the cost of manufacturing cement and forcing manufacturers who adopt these technologies to increase selling prices. Until competitor firms use the same technology, they will have a cost advantage over the green manufacturer. This imbalance, compounded by the uncertainty surrounding the efficacy of CCUS, deters even large-scale cement

producers from investing in the technology. The government, therefore, must guarantee a fixed carbon price for every tonne of CO<sub>2</sub> reduced through cement-industry-specific CCfDs, ensuring predictable returns for firms.

### 5. Linking Carbon Markets to Physical Performance

Cement units must be required to disclose their emissions from process and energy separately, along with clinker dependency, irrespective of operational scale, to ensure transparency. Carbon credits must be assigned based on process emission reduction and clinker substitution, not just on investments in renewable energy specifically for the cement industry, given that 60–65 per cent of sector emissions are process-based.

### 6. Public–Private Partnerships for Investing in High-Risk Technologies

Technologies such as CCUS and RDF require huge capital investments and are considered risky because they are relatively new. Yet, 80–85 per cent of the reduction is dependent on long-term technologies (NITI Aayog Roadmap). The government must partner with the private market to develop blended finance mechanisms that fund these technologies for improving accessibility, particularly for MSMEs that do not have the same access to capital as large players.

### 7. Aligning Waste Management and Cement Decarbonisation Policies

The NITI Aayog Roadmap prioritises utilising RDF technologies to decarbonise the cement sector. The adoption of RDF is dependent on municipal waste systems. Aligning the two will allow smoother adoption.

## Conclusion

The Indian cement sector illustrates the broader challenge of decarbonising hard-to-abate industries in emerging economies. Despite the growing adoption of renewable energy, waste heat recovery systems, and alternative fuels, emissions from cement production have remained relatively stable due to the structural dependence on clinker-based

manufacturing and process emissions arising from limestone calcination.

To examine whether stronger financial capacity enables firms to achieve lower emissions intensity, this study undertook an exploratory econometric analysis using panel data for major Indian cement companies. The pooled OLS results indicate that leverage, profitability, and firm size are not statistically significant determinants of emissions intensity. Further, the inability to estimate fixed and random effects models due to limited within-firm variation demonstrates the structural rigidity and carbon lock-in characterizing cement production processes, wherein dependence on clinker-intensive manufacturing and existing industrial systems constrains rapid decarbonisation across firms.

These findings suggest that the decarbonisation challenge in cement is not simply a financing gap, but a technological and process-based constraint that cannot be resolved through conventional market-based finance alone. Existing sustainability finance mechanisms focus disproportionately on renewable energy deployment and firm-level ESG performance, while the core emissions drivers in cement remain embedded in industrial production systems.

Accordingly, India's transition finance architecture must evolve beyond generic green finance frameworks towards sector-specific mechanisms that finance measurable industrial transformation. This includes process-linked finance instruments, clinker-based taxonomies, carbon contracts for difference (CCfDs), public-private co-financing for high-risk technologies, and demand-side support for low-carbon cement markets. As India advances towards its net-zero commitments and industrial expansion goals simultaneously, the credibility of its transition finance ecosystem will depend not merely on the availability of capital but on its ability to direct finance towards technologically viable and commercially scalable decarbonisation pathways for hard-to-abate sectors. A credible transition finance framework for cement must shift from 'who receives finance' to 'what transformation is financed'. •

By Khushboo Ashra

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### Recommended Citation

Ashra, K (2026). Bridging India's Cement Decarbonisation Gap: Why Hard-to-Abate Sectors Need a Credible Transition Finance Framework?, Chintan Research Foundation (CRF), New Delhi



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