



Decarbonising steel & cement sectors

REPORT SUMMARISING FINDINGS ON LOW
CARBON TECHNOLOGIES FOR STEEL AND CEMENT
SECTORS IN INDIA – SUMMARY VERSION

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Glossary

AFR	Alternative fuels and raw materials	MACC	Marginal Abatement Cost Curve
BAT / BATs	Best Available Technology / Technologies	MNRE	Ministry of New and Renewable Energy
BF-BOF	Blast Furnace – Basic Oxygen Furnace	MoEFCC	Ministry of Environment, Forest and Climate Change
BIS	Bureau of Indian Standards	MoS	Ministry of Steel
CBAM	Carbon Border Adjustment Mechanism	MRV	Measurement, Reporting and Verification
CC	Composite Cement	MSME / MSMEs	Micro, Small and Medium-sized Enterprise(s)
CCfD	Carbon Contract for Difference	MT	Million tonnes
CCS	Carbon Capture and Storage	MTPA	Million tonnes per annum
CCU	Carbon Capture and Utilisation	NDC	Nationally Determined Contribution
CCUS	Carbon Capture, Utilisation and Storage	NGSM	National Green Steel Mission
CEEW	Council on Energy, Environment and Water	OPC	Ordinary Portland Cement
CII	Confederation of Indian Industry	PAT	Perform, Achieve and Trade
CSEB	Compressed Stabilised Earth Block	PCI	Pulverised Coal Injection
DRI	Direct Reduced Iron	PLI	Production-Linked Incentive
DRI-EAF	Direct Reduced Iron – Electric Arc Furnace	PPA	Power Purchase Agreement
DRI-IF	Direct Reduced Iron – Induction Furnace	PPC	Portland Pozzolana Cement
EAF	Electric Arc Furnace	PSC	Portland Slag Cement
EE	Energy efficiency	PSB	Public Sector Bank

EBRD	European Bank for Reconstruction and Development	RCF	Revolving Credit Facility
ESG	Environmental, Social and Governance	RE	Renewable energy
GCCA	Global Cement and Concrete Association	R&D	Research and Development
GGBS / GGBFS	Ground Granulated Blast Furnace Slag	SCM / SCMs	Supplementary Cementitious Material(s)
GHG	Greenhouse gas	SEC	Specific Energy Consumption
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit	SIDBI	Small Industries Development Bank of India
HPGR	High-Pressure Grinding Roll	SLL	Sustainability-linked loan
H₂	Hydrogen	SPT / SPTs	Sustainability performance target(s)
IFC	International Finance Corporation	t	Tonne (metric ton)
IGBC	Indian Green Building Council	tCO₂	Tonne of carbon dioxide
IF	Induction Furnace	tCO₂/tcs	Tonnes of CO ₂ per tonne of crude steel
LC³ / LC3	Limestone Calcined Clay Cement	TERI	The Energy and Resources Institute
LCT / LCTs	Low-carbon technology / technologies	TSR	Thermal Substitution Rate
LCOS	Levelised Cost of Steel	UNDP	United Nations Development Programme
LEED	Leadership in Energy and Environmental Design	WHR	Waste Heat Recovery
LMA	Loan Market Association		

Executive summary

India's steel and cement sectors are central to growth and infrastructure, but together already account for **over 10% of national CO₂ emissions**, driven by coal-based steelmaking and clinker production in cement. As demand for construction and manufacturing rises, these emissions will increase unless **low-carbon technologies (LCTs) and best available technologies (BATs)** scale rapidly. At the same time, India faces intensifying **physical climate risks** and **transition risks** from instruments such as Carbon Border Adjustment Mechanism (CBAM), domestic taxonomies and ESG-aligned lending, which will raise financing costs and stranded-asset risk for high-emitting producers that delay transition.

India has reduced emissions intensity by about **36% from 2005 levels** and crossed **50% non-fossil electricity capacity** ahead of its 2030 target. Yet steel and cement remain pivotal to meeting long-term climate goals and maintaining export competitiveness as global markets increasingly penalise carbon-intensive goods. Globally, decarbonising steel will require around **USD 3.6 trillion by 2050**, with roughly **70% of investment outside the plant gate** (renewables, hydrogen, CCUS infrastructure). Cement needs about **USD 1.42 trillion**, including **USD 390 billion for carbon-capture equipment**. These figures underline the scale of capital that must flow through banks and capital markets.

The report assesses key LCTs and BATs across both sectors - including energy-efficiency measures, increased scrap use and route shifts in steel, green hydrogen-based Direct Reduced Iron (DRI), Carbon Capture, Utilisation and Storage (CCUS), clinker substitution and supplementary cementitious materials, Waste-Heat Recovery (WHR), alternative fuels and renewable energy integration. For each technology, it analyses **emissions-reduction potential, operational impact and financing needs**, and maps them to suitable instruments such as **green loans, sustainability-linked loans (SLLs), transition-labelled structures and blended-finance solutions**.

A core finding for lenders is that **risk lies less in the basic technologies and more in execution and integration**: many interventions are embedded in existing assets and cannot be cleanly ring-fenced; cash-flow benefits depend on the timing of cost savings and on **volatile input markets** (scrap, fuels, power, SCMs, hydrogen); and domestic demand for green steel and cement is still nascent, with carbon-market upside limited until Indian compliance markets deepen. This requires **adapted loan design** - longer or shorter moratoriums depending on gestation, tenors aligned with asset life, milestone-based drawdowns, performance-linked repayment, and where needed, syndication, guarantees and concessional layers.

For **lenders in India**, the analysis shows that **cement offers near-term, lower-risk decarbonization opportunities** (energy efficiency, WHR, blended cements, RE PPAs) suited to replicable green term loans, green project finance and SLLs. **Steel presents higher-impact but more complex transactions**, particularly for route shifts, hydrogen-DRI and CCUS, which often require risk-sharing and bespoke structures.

Overview of the Indian steel and cement sectors

India is the world's **second-largest producer and consumer of both steel and cement**. These sectors underpin infrastructure, housing and manufacturing, but are also among the country's most energy- and carbon-intensive industries. Their size, growth outlook and exposure to climate-related risks make them central to any decarbonization and sustainable-finance strategy for the banking sector.

The Indian steel sector: routes, emissions and risks

India produced about **144 million tonnes of crude steel in FY 2023–24**, around **7–8% of global output**, while per-capita consumption (~98 kg) remains far below the global average, signalling strong future demand. The steel industry uses a **mix of production routes**:

- **BF–BOF** (about 48% share),
- **Coal-based DRI–Induction Furnace (DRI–IF)** (~29%),
- **Gas-based DRI–EAF** (~11%), and
- **Coal-based DRI–EAF** (~12%)

BF–BOF and coal-DRI routes are the most carbon-intensive; gas-based DRI–EAF is cleaner but constrained by limited domestic gas. Structurally, the sector combines a few large integrated steel plants with a **fragmented secondary segment** of smaller IF-based units that often lack capital and technical capacity for upgrades. Key issues for lenders include **high coal dependence**, sensitivity to fuel and power prices, **limited scrap availability** and **wide divergence in borrower strength and technology pathways**.

The Indian cement sector: production, emissions and risks

India's cement capacity is around **600 million tonnes per year**, across large integrated plants, grinding units and smaller facilities. Cement contributes roughly **6% of India's CO₂ emissions**, with:

- **56–60%** from limestone calcination (process emissions),
- **27–31%** from kiln fuel use, and
- **10–13%** from electricity

India has already made progress by adopting **blended cements**; the average clinker ratio (~0.73) is below global norms due to widespread PPC and PSC, bringing emission intensity down to about **0.66–0.68 tCO₂ per tonne**. However, further reductions will increasingly depend on **advanced SCMs (e.g. LC³)**, **large-scale WHR**, **alternative fuels**, **electrification and eventually CCUS**. For banks, the sector is characterised by **larger, better-capitalised corporates**, significant opportunities for **replicable investments** (EE, WHR, RE PPAs) and a growing need to finance more advanced technologies over time.

Cross-cutting implications for finance

Across both sectors, several themes matter for lenders:

- **High capital intensity and concentrated risk** for major LCTs, especially route shifts, AFR systems, deep electrification and CCUS.
- **Integration challenges** because many technologies modify existing kilns and furnaces rather than creating standalone assets, complicating ring-fenced project finance and labelled use-of-proceeds tracking.
- **Input volatility**—for coal, gas, power tariffs, scrap, SCMs and waste-derived fuels— affecting operating margins and debt-service capacity.
- **Potential for templatised, scalable solutions**, particularly in cement (and parts of steel), where technologies such as energy-efficiency upgrades, WHR and RE integration can be rolled out across multiple plants under common corporate borrowers.

This context explains both the **transition risk** embedded in current portfolios and the **scale of opportunity** for banks to develop dedicated green and transition-finance products for India's steel and cement industries.

Financing guide: Iron and steel

India's steel sector comprises integrated BF-BOF plants, DRI-EAF routes, and a large MSME presence via induction furnaces and rerolling mills. Below, each key decarbonization technology is presented with its implications for banks and borrowers.

Increasing energy efficiency in BF-BOF

Energy-efficiency upgrades in the **blast furnace–basic oxygen furnace (BF–BOF)** route – such as improved furnace operation, better burden preparation and advanced control systems – can **cut fuel use and emissions while boosting process performance**.

Together, these measures **reduce fuel consumption, increase energy recovery, improve raw-material efficiency and optimise BF–BOF operations**, delivering substantial energy and CO₂ savings without changing the core production route.

Implications for banks and instrument design

- For financiers, the main challenge is that these measures **cannot typically be ring-fenced to a single asset or project**, because their benefits spread across an integrated process and make project-finance structures difficult.
- Loan structuring should reflect **short moratoriums** to cover temporary operational disruption.
- **Repayment schedules** should be aligned to cost-savings timelines rather than revenue growth.
- **Performance-linked pricing** can be used, based on verified energy-efficiency or emissions-reduction key performance indicators (KPIs).
- There is **limited need for technology-risk mitigation**, as these are proven, low-risk upgrades.
- Because ring-fencing is limited, **corporate-level green term loans** are generally more suitable than project finance.
- **Sustainability-linked loans (SLLs)** fit well when improvements apply across the plant or corporate portfolio, supported by measurable KPIs.
- **Transition-finance labels** may also apply where upgrades form part of a borrower's credible "brown-to-green" pathway.
- Overall, **blast furnace–basic oxygen furnace (BF-BOF) energy-efficiency upgrades** offer

Implications for borrowers' business

- These interventions are **process-level retrofits**, not standalone new assets, meaning they integrate into existing plant equipment and have limited resale or collateral value.
- **Capital expenditure (capex)** requirements are typically moderate, and benefits accrue primarily through operational cost savings (lower coal, electricity, and fuel use), not increased revenue.
- Borrowers may require **workforce training** or small ancillary investments, creating temporary disruption and short-term cost spikes before efficiency gains stabilise.
- As these technologies do not generate new revenue streams and are tied to existing production capacity, **cash-flow improvements depend on lower operating costs**.
- This places greater emphasis on **timing installation during favourable steel-market cycles** and ensuring the plant has the internal capability to operate upgraded systems effectively.
- **Compliance risks are low**, and most equipment is available domestically, which reduces foreign-exchange or import-supply risks.

Energy recovery in electric arc furnaces

Energy recovery through **waste heat recovery (WHR)** systems in **electric arc furnaces (EAFs)** has significant potential and is gaining attention in India as a best available technology for improving energy efficiency and reducing carbon emissions. Up to **25–30% of the energy input** to EAFs is lost as waste heat through off-gases. Capturing and reusing this heat – for **scrap pre-heating** or **boiler feedwater pre-heating** – can substantially cut energy consumption, reduce fuel use in boilers, and lower greenhouse gas emissions.

A typical WHR system for boiler feedwater in an EAF can involve around **₹10 lakh** of investment with a **payback of about three months**, depending on the distance between the EAF and the boiler, and can cut fuel oil consumption and emissions by roughly **1,510 tCO₂ per year**.

Implications for banks and instrument design

- The investment **cannot easily be treated as a single project**, because several components work together over an existing asset. Ring-fencing is possible, but benefits are spread across the process.
- Loan structures can use a **short moratorium** to cover installation and commissioning, rather than long grace periods.
- **Repayments should follow cost-saving patterns**, not expected revenue growth. Front-loaded repayment is possible once savings are visible.
- **Performance-linked pricing** works well, using indicators such as electricity intensity or fuel savings to adjust the margin.
- **Technology risk is low**, as WHR solutions are well-proven; the main concern is **integration risk** with existing operations.
- Where energy is sold outside the group, banks should look for **power or steam purchase agreements** to reduce offtake risk.
- **Green term loans (green loans)** suit cases where WHR assets can be identified and ring-fenced as ICMA-eligible green assets.
- **Sustainability-linked loans (SLLs)** are suitable when WHR is part of broader optimisation of the EAF, with KPIs on energy or emissions. **Transition-finance labels** may apply where WHR sits within a wider decarbonization plan.
- Overall, banks can treat EAF energy recovery as a **low-technology-risk, medium-capex opportunity**, best served by term loans with limited moratorium, front-loaded repayment and performance-linked features.

Implications for borrowers' business

- Energy recovery in electric arc furnaces is a **process-level retrofit**, not a new standalone plant. It is installed on existing furnaces and has limited resale or collateral value.
- **Capital expenditure is moderate** and lower than for many innovative low-carbon options.
- The business case rests on **operational cost savings**: lower grid electricity purchases and reduced boiler fuel use.
- When the system is well designed, **savings start quickly**, easing cash-flow pressure soon after commissioning.
- The retrofit **improves efficiency and utilisation of the existing EAF**, rather than changing output or product mix.
- If recovered heat or power is sold externally, **long-term purchase agreements** can stabilise income from the system.
- Borrowers become **less exposed to electricity price volatility**, since a share of demand is met internally.
- Some specialised equipment may need to be imported, creating **currency and trade risk** that the borrower must manage.

Increasing proportion of scrap steel

Scrap steel is a central pillar of India's **Green Steel Initiative**, with a government target to raise scrap to **50% of steel input by 2047**, sharply cutting reliance on iron ore and coal-intensive blast furnace routes. Scrap-based production in **electric arc furnaces (EAFs) and induction furnaces (IFs)** can lower emissions to around **0.5 tCO₂ per tonne**, compared to about **2.5 tCO₂** from ore-based routes, while consuming up to **75% less energy**. As global scrap trade tightens, India's strategy to scale **domestic scrap availability** (e.g. from ship-recycling and end-of-life vehicles) is becoming critical to maintain competitiveness and support a circular, low-carbon steel system.

Implications for banks and instrument design

- For financiers, this is **not a classic project-finance case**; benefits come from an operating model change across sites, not from one ring-fenced asset.
- Because capex is modest, banks can use **corporate-level term loans** aligned with standard tenors, rather than complex project structures.
- **LMA-aligned green loans are difficult** because scrap is a feedstock, not an ICMA-eligible physical asset, unless a specific asset is ring-fenced to higher scrap intake.
- **Sustainability-linked loans (SLLs)** are a better fit, since impact comes from operational outcomes (emissions per tonne, scrap share), not asset ownership.
- Loan design should include **hedging strategies, liquidity buffers and covenants** linked to input sourcing and inventory to manage volatility in scrap prices and supply.
- Banks may look for **some offtake agreements** for scrap-intensive products, especially where buyers value low-carbon steel or export market access.
- A **slight moratorium** and performance-linked pricing, aligned to long-term cost savings and emission-intensity improvements, can reduce default risk as the model stabilises.
- **Transition-finance labels** may be appropriate only where distinct assets or systems supporting scrap use are part of a credible transition plan.
- Overall, banks can treat scrap-based decarbonization as a **low-technology-risk, input-volatile opportunity**, best served by sustainability-linked loans and corporate-level green term loans with covenants that cushion input-price shocks.

Implications for borrowers' business

- The shift to higher scrap use does **not fund a single asset**; it requires reconfiguration of processes and supply chains across multiple plants.
- **Capital expenditure rises only moderately**, making this one of the most cost-effective low-carbon options in steel.
- Low capex means the **gearing ratio is not significantly disrupted**, although peripheral investments (such as logistics and quality control) must be carefully planned.
- Operating costs **decline over time** due to lower fuel and energy use, but savings may take time to stabilise as scrap procurement, quality and yields improve.
- The main risk for borrowers is **logistics and market risk**: volatility in scrap price and availability can affect production and cash flows.
- There is a **risk of some customers resisting scrap-intensive steel**, so long-term offtake or purchase agreements can help secure demand.
- Technology risk is low: **using steel scrap is well-established and widely accepted**, with measurable emissions-reduction potential.
- Compliance risks are nominal, though imported scrap can introduce **currency and trade risk** that needs managing.
- Overall, increasing scrap share offers **strong emission and energy savings with modest capex**, but demands careful management of input volatility and logistics.

Using green hydrogen as reducing agent for DRI

Green hydrogen–based **direct reduced iron (DRI)** replaces natural gas in the reduction process, producing water vapour instead of CO₂ and enabling a pathway to near-zero-emission steel when combined with electric arc furnaces (EAFs). Costs remain high and full commercial roll-out is still early-stage, but **government-backed pilots and private investments** are rapidly building experience, making green hydrogen DRI one of the most strategic – and capital-intensive – options in India’s future steel decarbonization mix.

Implications for banks and instrument design

- For financiers, this is a **fundamental process change**, not a marginal retrofit, and will usually require **ring-fenced, bespoke structures** rather than standard corporate term loans.
- Banks are likely to favour **ring-fenced project-finance structures with tighter covenants** to manage construction, ramp-up and input-supply risk.
- High capex increases exposure per facility; **consortium or syndicate lending** can pool risk across multiple banks.
- Loan structures may include **time-staggered commitments and phased disbursements**, tied to commissioning milestones and the availability of key inputs such as hydrogen and renewable power.
- An **extended moratorium** is often needed, with repayment tranches that **step up gradually** as operations stabilise and hydrogen supply improves.
- **Long-term offtake agreements** with buyers, and potentially **carbon contracts for difference (CCfDs)** or similar mechanisms, are important to give revenue and price certainty.
- Strong **technical due diligence, performance guarantees and supply guarantees** are essential, along with conditions precedent tied to regulatory approvals and infrastructure readiness.
- **Blended finance structures** using concessional funds, guarantees, subordinated debt or grants can help de-risk early projects and crowd in commercial capital.
- Overall, banks should treat green hydrogen DRI as a **bespoke, high-risk, high-impact transaction**, best served by **green project finance, transition-aligned structures**, syndication and blended finance, with extended tenors, risk-sharing and performance-linked covenants.

Implications for borrowers’ business

- Funding green hydrogen–based DRI means **transforming core production processes and assets**, often by adding an entirely new DRI module.
- The shift depends on **large, reliable supplies of green hydrogen, renewable energy and associated logistics**, which may take time to scale in most markets.
- **Capital expenditure rises sharply** relative to BF–BOF or gas-based models because of specialised equipment, integration complexity and significant peripheral investments.
- The transformation requires **new skills and workforce training**, creating execution risk and potential delays during transition.
- In the near term, **operating costs are higher**, since green hydrogen is more expensive than fossil fuels; benefits take time to appear.
- Demand for near-zero-carbon steel is still **nascent**, so the commercial upside from green premium pricing is uncertain in the short run.
- The technology is **early-stage**, largely at pilot or first-of-a-kind scale, which raises technology, supply and integration risk for the borrower.
- Some critical equipment and inputs may need to be **imported**, exposing borrowers to currency and trade risk.
- Overall, hydrogen-based DRI is a **high-capex, high-impact, long-horizon investment** that can transform a producer’s emissions profile but requires patient, carefully sequenced implementation.

Carbon capture, utilisation and storage

Carbon capture, utilisation and storage (CCUS) targets **process emissions from blast furnaces and DRI plants** that cannot be eliminated by energy efficiency or renewable energy alone. It is technically complex and capital-intensive: emissions come from multiple points in an integrated plant, costs are high, and the business case depends heavily on **policy support, carbon pricing and blended finance**, rather than higher steel prices.

Implications for banks and instrument design

- The bank is **funding an add-on system**, not the main steel business. Credit analysis must focus on CCUS-related cash flows and risk, not just the existing steel operations.
- Transactions are effectively **project-style capex in brownfield settings**, even when booked at corporate level, and often require bespoke structuring.
- High capex and uncertain benefits increase leverage and execution risk; banks will need **conditional disbursements, careful phasing and strong sponsor support**.
- Banks may prefer borrowers with **strong, stable margins** and robust cash flows, given the higher opex and less direct cost-reduction pathway.
- Revenue support will likely rely on **policy tools** such as carbon pricing, CCfDs, carbon credits, guarantees and subordinated or public capital, rather than higher steel prices.
- CCUS projects need **robust technical DD, performance guarantees and conditions precedent** embedded in loan documentation to manage technology and integration risk.
- Changes in carbon policy introduce **political and regulatory risk**, making long tenors and stable policy frameworks critical for bankability.
- Currency and trade risks may require **hedging and risk-sharing mechanisms**, especially for imported equipment and services.
- Overall, CCUS in steel calls for **bespoke, risk-shared structures** with extended moratoriums and tenors, phased disbursement, performance-linked repayment, and strong reliance on **green project finance, sustainability-linked loans and blended finance**, often via syndicates or consortia.

Implications for borrowers' business

- CCUS in steel **overlays a new system on existing plants**, rather than changing core steelmaking assets. It adds complexity without replacing the underlying production route.
- The investment is **site-specific**, and physical reuse of CCUS assets at other locations is limited.
- **Capital expenditure is very high**, including peripheral infrastructure and networks that are still underdeveloped in many markets, which can strain already leveraged balance sheets.
- **Operating costs increase**, as CCUS systems consume energy and other inputs, while cost savings are less clear than for renewable energy.
- CCUS **does not change the steel product** or create clear new revenue streams. Its value comes from emission reduction and compliance, not from a price premium on "CCUS steel".
- The technology is **early-stage in India**, requiring strong technical due diligence, performance guarantees and close operational oversight.
- There may be **new regulatory requirements**, and outcomes depend heavily on the stability of carbon and climate policies.
- Some equipment and inputs must be **imported**, adding currency and trade risk to already complex projects.
- Overall, CCUS is a **high-capex, policy-dependent option** that manages emissions but does not improve core production economics on its own.

Renewable energy integration

Renewable energy integration in steel—through **captive solar and wind plants and power purchase agreements (PPAs)**—is emerging as a core decarbonization lever, especially for **DRI-EAF and standalone EAF routes** that are highly electricity-intensive. By replacing grid-supplied fossil power with renewables, steel plants can achieve **rapid and predictable**

operating cost savings, cut exposure to volatile fossil-fuel prices, and significantly lower Scope 2 emissions.

Implications for banks and instrument design

- From a financing perspective, this involves both **project-specific assets** and **corporate-level contracts**, so a combination of **project finance** and **corporate term loans** is often relevant.
- The main risks are **asset-performance risk** for captive plants and **contract risk** for PPAs, both of which can be addressed through robust technical and legal due diligence.
- Moderate capex can usually be absorbed on the balance sheet, especially because it is **offset by lower exposure to future electricity tariffs**, keeping leverage manageable.
- Loan structures can use **lower or no moratorium** if benefits accrue quickly, combined with **longer tenors** that match the long economic life of renewable assets.
- **Performance-linked pricing** tied to reductions in fossil electricity use or Scope 2 emissions can strengthen alignment between the borrower's savings and the bank's risk profile.
- Because technologies are mature and widely deployed, **technology risk is low**, making renewable integration a **lower-risk low-carbon option** from a credit perspective.
- **LMA-aligned green loans** work well when financing is asset-specific and clearly ICMA-eligible; **sustainability-linked loans (SLLs)** are suitable where performance across multiple sites is the focus.
- Within green loans, **green project finance** is well suited to captive projects, while **green term loans** suit incremental renewable integration into existing plants. **Transition-labelled finance** is possible where distinct renewable assets form part of a broader transition plan.
- Overall, banks can treat renewable integration as a **moderate-ticket, low-technology-risk opportunity**, best served by green term loans, green project finance and SLL structures with somewhat longer tenors and clear performance metrics.

Implications for borrowers' business

- Renewable energy integration **funds a mix of physical assets and contractual arrangements**, such as captive solar or wind plants and PPAs with third-party generators.
- Captive renewable assets are **project- and site-specific**, while PPAs sit at the corporate level and cover multiple plants or operations.
- **Capital expenditure rises moderately**, including peripheral investments in transmission connections, integration and, in some cases, storage.
- In the near term, operating costs may **temporarily increase** due to integration and ramp-up, but over time the **marginal cost of energy becomes lower and more predictable**.
- The main operating benefit is **reduced grid electricity purchases**, which delivers **long-term operational savings and Scope 2 emission reductions**.
- Solar and wind technologies are **proven and commercialised**, while storage remains in earlier stages of deployment.
- The steel sector benefits from a well-developed **EPC ecosystem and established compliance frameworks**, which reduces execution and regulatory risk.
- Borrowers become **less exposed to fossil-fuel price volatility**, improving long-term cost visibility and resilience.
- Overall, renewable integration offers **moderate capex and fast, measurable operating benefits**, supported by a mature technology and regulatory environment.

Shifting from BF-BOF production route

Shifting from the **blast furnace–basic oxygen furnace (BF–BOF)** route to electric arc furnace (EAF) or induction furnace (IF) routes can **dramatically lower emissions and energy use**, as scrap- and DRI-based production is far less carbon-intensive than ore- and coal-based BF–BOF. While the underlying technologies are proven, this is a **system-level overhaul** of core production assets, involving multi-phase investments, new input markets (scrap, electricity, gas) and substantial implementation complexity.

Implications for banks and instrument design

- For financiers, this is a **system-wide replacement**, not a single-asset upgrade, which makes standard green-loan structures harder and calls for more bespoke approaches.
- Loans will often require **longer tenors** to match asset lifespans, with covenants and repayment focused on the period after the new system stabilises.
- Banks must manage **peaks in funding needs** across phases, using **milestone-based drawdowns** and covenants linked to progress and commissioning.
- Peripheral capex and balance-sheet stretch make **ring-fenced structures** more practical where parts of the new system can be clearly isolated and financed.
- Extended **moratoriums and patient capital** are needed because operating benefits and cost savings **do not appear immediately** and depend on volatile input markets.
- Repayment profiles should reflect **back-ended benefits**, with more conservative assumptions on when the new route reaches stable, efficient operation.
- Banks may require **liquidity buffers and hedging** (e.g. for scrap, power, gas) and include covenants to manage input-price and supply volatility.
- Loan documentation may include **conditions precedent** tied to regulatory and permitting milestones to reduce regulatory and implementation risk.
- **Offtake agreements** can help reduce demand and price uncertainty, especially with customers that have long investment horizons or export exposure.
- Overall, financial instrument design should emphasise **longer tenors and moratoriums, milestone-based drawdowns, operating-risk mitigants, input-hedging and offtake arrangements**, with a preference for **sustainability-linked loans and green term loans** at the corporate level, and **transition-aligned structures** for distinct replacement assets.

Implications for borrowers' business

- This shift involves a **fundamental change in the production system**, adding new core assets and infrastructure rather than retrofitting existing lines. It is site- and project-specific.
- A new production system **requires longer asset lifespans**, so borrowers need financing that matches these longer economic lives.
- **Capital expenditure rises**, and implementation can involve **multiple phases and modules**, creating construction, operational and execution risks.
- Peripheral investments (e.g. utilities, logistics, ancillary systems) are **significant and non-optional**, which can stretch balance sheets alongside legacy asset depreciation.
- In the near term, **operating costs may rise**, and long-term cost savings depend on input price trends, maintenance, and technology evolution.
- **Cash-flow benefits accrue only after the new system stabilises**, so they are not front-loaded.
- Although the technologies (EAF, DRI-EAF, IF) are **mostly proven**, the shift exposes the borrower to **new input markets** (scrap, electricity, gas) and associated volatility.
- There may be **additional compliance requirements** in the near term, increasing the need for permits, environmental clearances and reporting.
- Demand for low-carbon steel is **still nascent in India**, so offtake risk remains, even if long-term trends are favourable.
- Overall, shifting from BF–BOF is a **moderate-to-high capex, complex multi-stage transition** with substantial long-term emissions benefits.

Financing guide: Cement

The cement industry is a cornerstone of India's infrastructure development but also one of the largest industrial sources of carbon emissions, driven primarily by process-related CO₂ from limestone calcination and fossil fuel combustion. To align with India's net-zero and energy efficiency goals, the sector must accelerate the adoption of LCTs or BATs that enhance

material and energy efficiency, reduce the clinker factor, and enable partial fuel switching. This section outlines the key LCT/BAT options suitable for deployment in the Indian context.

Designing to use cement more efficiently

Designing buildings and infrastructure to **use less cement for the same performance** is a powerful but underused decarbonization lever. Material-efficiency strategies—optimised structural design, modular and prefabricated construction, alternative materials like compressed stabilised earth blocks (CSEB), and 3D-printed components with industrial by-products—can **cut cumulative CO₂ emissions from the built environment by an estimated 25–30%**, while also reducing waste and speeding up project delivery.

Implications for banks and instrument design

- For financiers, this is **not an asset-specific project**, but a change in how the borrower designs and operates. It calls for instruments that link financing to performance, not to a discrete asset.
- Banks may offer **slightly longer moratoriums** where borrowers are already highly geared, to ease initial cash-flow pressure during adoption.
- Some peripheral investments need to be **built into the loan sizing** to reduce execution risk and avoid under-financing the transition.
- Repayments can be structured so that **instalments increase gradually as the new processes stabilise**, reflecting a ramp-up in savings.
- **Milestone-based drawdowns** and covenants can be tied to completion of key steps (training, integration, pilot projects) to manage transition risk.
- **Performance-linked pricing** is suitable, with loan margins tied to indicators such as clinker or cement use per unit of output, or other efficiency metrics, where data allow.
- Proven technologies and clear metrics make **sustainability-linked loans (SLLs)** an appropriate tool, linking interest rates to verified emission or efficiency improvements.
- **LMA-aligned green loans** are generally difficult because this is an operating design choice, not a single ICMA-eligible asset. **Green term loans** can still support broader efficiency programmes where use-of-proceeds can be demonstrated.
- Overall, financial design should emphasise **longer moratoriums where needed, progressive repayments, milestone-based drawdowns and performance-linked pricing**, using SLLs and green term loans as the primary instruments, and transition-labelled finance only for distinct, ring-fenced low-carbon design assets.

Implications for borrowers' business

- This approach **funds process and design upgrades**, not a single physical asset. It focuses on redesign, optimisation and new construction practices that can be replicated across multiple plants or projects.
- Capital expenditure **rises at low to moderate levels**, for software, design capabilities, training and some ancillary equipment. Highly leveraged companies may still feel this additional capex.
- Integration of new design processes into **legacy kilns and production lines** can create execution challenges and temporary disruption.
- Operating-cost benefits **accrue over time** as material use and energy consumption fall, but there is often a **gestation period** before savings fully show up.
- Workforce training is needed to implement **new design tools and construction methods**, which, if poorly managed, can increase operational and execution risk.
- The main benefit is **lower resource and energy cost**, not higher output or revenue, so gains show up in operating margins rather than sales volumes.
- Efficiency-related technologies and practices are **mostly proven**, with measurable impact where data systems exist, which keeps technology risk low.
- Compliance burdens are **minimal**, and most inputs are sourced locally, limiting currency and trade risk. Some input-price volatility remains a concern and may require buffers.
- Overall, designing to use cement more efficiently delivers **gradual but meaningful operating-cost and emissions reductions**, with relatively modest capex but some integration and gestation risks.

Energy efficiency

Energy efficiency is a **key decarbonization lever** for India's cement industry. Average plants already outperform global benchmarks, but **best-performing units use far less thermal and electrical energy** (down to 675 kcal/kg clinker and 56.1 kWh/tonne cement), showing large, untapped potential. Wider adoption of process optimisation, waste heat recovery (WHR), modern kilns and efficient grinding systems can **further cut energy use, opex and CO₂ emissions** across the sector.

Implications for banks and instrument design

- For financiers, these are **operational retrofits rather than discrete projects**, so lending should focus on how upgrades affect overall plant performance and cash flows.
- Banks may offer **slightly longer moratoriums** where leverage is high, especially in multi-plant programmes, to ease the initial impact on cash flows.
- Loan sizing should include **peripheral investments** (integration, ancillary works) to avoid under-financing and implementation risk.
- Repayments can **increase gradually as the new systems stabilise**, matching debt service more closely to realised savings.
- **Milestone-based drawdowns** (e.g. tied to commissioning and early performance tests) help manage transition risk and ensure funds follow progress.
- **Performance-linked pricing** can reward verified reductions in specific energy consumption or emissions, where data quality allows.
- This makes **sustainability-linked loans (SLLs)** attractive, linking pricing to clear energy or emissions KPIs, alongside **green term loans** where specific assets can be identified.
- **LMA-aligned green loans are difficult** where improvements are purely operational; they work best when specific energy-efficient equipment can be ring-fenced as an ICMA-eligible asset.
- Overall, the instrument mix should mirror that for “designing to use cement more efficiently”: **longer moratoriums where needed, progressive repayments, milestone-based drawdowns and performance-linked pricing**, using SLLs and green term loans as primary

Implications for borrowers' business

- Energy-efficiency projects **fund upgrades to existing processes and equipment**, not standalone new plants. They are process-level retrofits that can be replicated across multiple lines or sites.
- **Capital expenditure rises at low to moderate levels**, which can still be challenging for highly leveraged companies.
- Integrating new control systems, WHR units or grinding technologies into **legacy kilns and mills** can create execution challenges and temporary disruption.
- Operating-cost benefits **accrue over time** as energy use falls, but there is usually a **gestation period** before savings fully stabilise.
- Workforce training is needed to run **advanced process control and new equipment**, and poor implementation can raise operational and execution risk.
- The main benefit is **lower resource and energy cost**, not higher output; gains show up in margins rather than sales volumes.
- Efficiency-related technologies are **mostly proven**, with good scope for monitoring and measurement where data systems exist, so technology risk is low.
- Compliance requirements are **minimal**, and most inputs are locally available, which limits currency and trade risk; input-price volatility remains a concern.
- Overall, energy-efficiency investments deliver **steady cost and emissions reductions** with manageable capex, but require good planning and integration.

Clinker substitution & the use of supplementary cementitious materials

Reducing the **clinker-to-cement ratio** is one of the most powerful ways to cut cement's carbon intensity, since clinker production accounts for **80–90% of total CO₂ emissions** from cement manufacturing. India is already a global leader in blended cements (average clinker factor ~0.73), using fly ash and ground granulated blast furnace slag (GGBS) to produce PPC, PSC and composite cements that make up over 70% of output. Going forward, scaling **alternative SCMs** such as calcined clays (LC³), limestone and natural pozzolans will be critical to sustain and deepen this low-clinker trajectory.

Implications for banks and instrument design

- For financiers, this is **not a single green asset**, but a change in input mix and process design that can support **replicable loan structures** across a corporate's portfolio.
- **Milestone- or condition-based disbursements** and somewhat longer tenors can help manage capex pressures for more leveraged borrowers.
- Loan sizing should explicitly include **peripheral capex** needed to meet standards and ensure demand, reducing the risk of under-investment.
- **Milestone-based drawdowns and covenants** tied to integration steps and quality benchmarks can help manage execution risk.
- Because benefits start early, loans can be structured with **little or no moratorium**, which is attractive for banks and keeps repayment more front-loaded.
- **Performance-based pricing** can be linked to energy and clinker-related KPIs (e.g. clinker factor, emissions per tonne), where data are available.
- This supports the use of **sustainability-linked loans (SLLs)**, where pricing depends on achieving clinker-factor or emission-intensity targets.
- Banks may use **buffers and covenants to cushion input-price shocks**, and milestone-based disbursement to manage operational risk.
- Overall, financial design should focus on **performance-linked repayment, milestone-based drawdowns and input-risk mitigation**, using SLLs and **corporate-level green term loans** as primary tools; green-loan labelling is generally harder because the emissions savings come from input substitution rather than a discrete asset.

Implications for borrowers' business

- Clinker substitution funds a **process-based technology and its optimisation**, plus some plant-level assets (e.g. blending, grinding, quality control). These can be replicated across multiple plants.
- **Capital expenditure rises only slightly**, depending on the degree of replacement, but can still stress highly geared companies.
- Additional **peripheral investments** (testing, quality control, logistics) are needed to ensure product quality and standardisation for customers.
- If not well integrated with existing processes and systems, clinker-substitution measures can create **operational and execution risk**.
- Benefits typically **accrue quickly**, as lower clinker content and SCM use reduce fuel and electricity needs and thus operational costs. There is usually **minimal need for moratorium**.
- The main operating benefit is **reduced fuel and electricity cost**, alongside lower specific emissions.
- The technology is **relatively mature and stable**, especially for established SCMs such as fly ash and GGBS.
- The main risks are **operational/execution risk** and **input volatility** (availability and price of SCMs), with some currency/trade risk for imported inputs.
- Overall, clinker substitution delivers **fast, high-impact emission and cost reductions** with minor capex but depends on SCM supply and quality management.

Waste heat recovery

Waste heat recovery (WHR) captures high-temperature exhaust gases from kilns and clinker coolers and converts them into **electricity or process heat**, instead of venting them to the atmosphere. In India, WHR can already provide **25–30% of a plant's electricity demand with 14–18% cost savings** and paybacks as low as about **14 months**, making it one of the most cost-effective and mature decarbonization options for the cement sector.

Implications for banks and instrument design

- For financiers, WHR is a **clearly identifiable asset** with its own energy output, suitable for project-style analysis and ring-fenced financing when cash flows can be isolated.
- Replicability across sites allows banks to **standardise loan terms and covenants** for a portfolio of similar WHR projects.
- Loans to more leveraged borrowers may need **longer tenors, performance-linked repayment, or blended structures** to keep debt service manageable.
- Loan documentation should provide for **milestone-based disbursement**, tied to engineering, procurement, construction and commissioning stages, to manage integration and execution risk.
- Because savings start early, banks can use **minimal moratoriums** and begin repayment once WHR generation is stable, improving capital recycling.
- Banks may set **longer tenors and maintenance-linked covenants**, ensuring plant upkeep supports long-term performance and cash-flow strength.
- Clear metering and impact data make **performance-linked repayment** (e.g. margin linked to kWh generated or emissions avoided) feasible and credible.
- Banks can manage compliance and integration risk with **conditions precedent** (permits in place) and **stepwise disbursement** to control construction and commissioning risk.
- Overall, **LMA-aligned green loans** are well suited, as WHR is an ICMA-eligible green project. **Green project finance** works where WHR cash flows are ring-fenced; **sustainability-linked loans** can support broader operational efficiency programmes where WHR is one component, and transition-labelled finance is possible where WHR forms part of a wider decarbonization plan.

Implications for borrower's business

- WHR in cement funds a **specific asset and process-based technology** (turbines, boilers, heat-exchange and electrical systems) that must be tightly integrated with existing kilns and coolers.
- Once the design is proven, WHR systems can be **replicated across multiple plants**, enabling a repeatable technical and financing model for a given corporate.
- **Capital expenditure rises moderately**, and ticket size depends on installed MW and plant layout. Highly geared corporates may require longer tenors or tailored structures.
- Successful operation depends on **stable process conditions**: consistent clinker production, stable kiln operation and effective dust control. Poor integration can create operational risk.
- Operating benefits usually **accrue quickly** through lower grid electricity purchases and fuel savings, reducing the need for long grace periods.
- The **investment lifespan of WHR assets** can be longer than typical loan tenors, requiring careful alignment of debt maturity with asset life and maintenance plans.
- WHR is a **mature, relatively stable technology** with clear, metered energy-saving and emissions-reduction data, supporting robust performance tracking.
- Compliance requirements are **straightforward**, mainly related to environmental permits and safety; operational risk lies more in integration than in regulatory complexity.
- Overall, WHR offers **moderate capex, fast operational benefits and strong emissions cuts**, making it a practical and attractive decarbonization option.

Alternative fuels & raw materials

Using alternative fuels and raw materials (AFR) in cement kilns allows plants to **replace coal and petcoke with waste-derived and biomass fuels**, cutting emissions, lowering fuel costs and supporting circular-economy solutions. With India's average thermal substitution rate (TSR) only around **7%** versus **25% globally**, scaling AFR—through better pre-processing, handling systems and stable waste supply—offers substantial potential to reduce CO₂ (by **70–150 kg CO₂/tonne cement** at ~25% TSR) while diverting waste from landfills.

Implications for banks and instrument design

- For financiers, these are **site-specific but replicable process upgrades**, suitable for standardised loan templates once a configuration is proven.
- Offtake risk relates to **market demand for low-carbon cement; long-term purchase agreements** can support demand certainty where buyers value lower-emission products.
- Higher capex and complexity suggest **longer tenors, performance-linked repayment, equity co-investment and partial guarantees**, particularly for large new AFR systems.
- Loan structures should include **input-sourcing contracts and covenants**, with diversified suppliers and milestone-based disbursement to manage feedstock and implementation risk.
- Where systems ramp up quickly, banks can keep **moratoriums minimal to short**, while still offering **longer tenors** to reflect longer investment lifespans.
- **Performance-linked repayment** can be tied to TSR levels, fuel-cost savings, or emissions reductions, with **impact verification** built into loan monitoring.
- **LMA-aligned green loans** may work where discrete AFR systems meet ICMA eligibility and emissions savings can be quantified; **sustainability-linked loans (SLLs)** are suitable when AFR forms part of a wider operational decarbonization plan.
- Green **project finance** is appropriate for large, high-capex AFR systems where efficiency-related cash flows can be ring-fenced; **transition-labelled finance** fits projects that directly replace fossil fuel use. Guarantees can help de-risk early or complex AFR expansions.
- Overall, banks should focus on **input-linked contracts and covenants, performance-linked repayment, longer tenors, milestone-based disbursement, impact verification and selective use of guarantees and carbon-credit upside**, using green project finance and SLLs as core instruments.

Implications for borrowers' business

- AFR projects mainly **fund process changes** and specialised in-plant systems (shredders, weigh feeders, multi-channel burners, calciner upgrades, bypass and emission controls), with scope to replicate across multiple plants.
- The shift does **not create a new product**; the cement remains similar, so demand depends on broader appetite for low-carbon cement rather than a distinct offtake market.
- **Capital expenditure is relatively high**, and systems are operationally complex, especially at higher TSRs. Peripheral capex (pre-processing, storage, emission controls) is essential.
- Operating performance depends heavily on **supply, cost and quality of AFR feedstocks** (e.g. MSW-RDF, biomass, industrial and hazardous wastes). Poor feedstock can create operational and execution risk.
- If AFR supply chains are established quickly, **fuel-cost savings and emission reductions can accrue relatively fast**, limiting the need for long moratoriums.
- AFR use **reduces emission intensity and fossil-fuel dependence**, but operating costs can rise if waste processing, logistics or regulatory compliance are not well managed.
- The underlying AFR technologies are **well established**, so technology risk is modest; the main challenges are feedstock logistics, quality consistency and regulation.
- Implementation depends on **quality and consistency of waste streams**, and on timely approvals and coordination with municipalities and other suppliers. Imported materials and regulatory shifts can add risk.
- Overall, AFR offers **significant emissions and fuel-cost benefits**, but success hinges on robust waste-supply chains, infrastructure and regulatory support.

Electrification and renewable energy integration

Electrification and renewable energy integration in cement aim to **replace coal- and petcoke-based heat and power with clean electricity**, green hydrogen and on-site solar or wind. These pathways—backed by India's rapid RE expansion and emerging deep-electrification technologies—can significantly cut emissions and long-term energy costs and are expected to attract **billions of dollars of new investment** across the sector by 2030.

Implications for banks and instrument design

- For financiers, these are **asset- and process-level upgrades** that can support **templatised loan structures** once a configuration is proven.
- Where surplus RE is exported, banks may look for **offtake contracts or PPAs** and, where relevant, participation in voluntary carbon mechanisms to underpin revenue.
- Banks may consider **tiered financing structures** that combine **long tenors, performance-linked incentives, consortium lending and partial guarantees** to manage higher exposure.
- Loan sizing must include **peripheral capex** to avoid under-funding integration and to reduce execution and performance risk.
- A **moratorium may be preferable** during early integration, with repayments aligned to when the system reaches stable productivity and savings.
- Operating benefits from electricity-cost savings should drive **cash-flow-based repayment schedules**, with conservative assumptions on the ramp-up of savings.
- Proven technologies and measurable energy savings create scope for **performance-linked instruments**, where pricing depends on verified energy or emissions outcomes.
- Banks should emphasise **strong technical due diligence, performance guarantees, milestone-based disbursements and periodic audits**, as well as hedging where imported components create currency exposure.
- Overall, financial design should focus on **managing operational integration, milestone-based disbursement, performance audits and guarantees, long tenors, and offtake or PPA arrangements**, using **LMA-aligned green project finance, green loans and sustainability-linked loans**, often supported by syndicate lending for larger projects.

Implications for borrowers' business

- Electrification and RE integration **fund upgrades to processes and assets** (e.g. RE plants, electric systems, hybrid heat solutions), which can be replicated across multiple plants.
- The investment does **not create a new product**; cement remains similar. Surplus renewable power, if sold externally, can benefit from **power purchase agreements (PPAs)** or carbon-credit mechanisms.
- **Capital expenditure can be moderate to high**, especially for deep electrification or large RE capacity, increasing loan size and repayment obligations and potentially stressing already leveraged corporates.
- Some **peripheral investments** (e.g. grid connections, control systems, integration hardware) are needed to keep hybrid systems operating efficiently.
- Operating performance depends on **how quickly new systems stabilise**; until then, integration complexity can raise operational and execution risk.
- Once stabilised, electrification and RE integration **reduce operational costs through electricity savings and lower fuel exposure**, but timing of savings must be carefully assessed for underwriting.
- The technologies involved (RE, many electrification components) are **commercially proven**, though some deep-electrification pathways remain in earlier stages.
- Hybrid systems can be **complex to integrate**, requiring strong technical design, commissioning support and compliance with relevant standards. Imported components may introduce currency and trade risk.
- Overall, electrification and RE integration offer **material emissions and cost reductions**, but with higher capex, integration complexity and longer investment horizons.

Carbon capture, utilisation and storage

Carbon capture, utilisation and storage (CCUS) is needed to tackle **35–45% of cement emissions** that come from the calcination of limestone and cannot be eliminated through efficiency, fuel switching or renewable energy alone. By capturing CO₂ from kiln flue gases and either **storing it in geological formations** or **using it in products** (e.g. aggregates, chemicals, synthetic fuels), CCUS offers a way to address these unavoidable process emissions—but with **very high capex, complex operations and strong dependence on policy, carbon pricing and public support**.

Implications for banks and instrument design

- For financiers, this is a **complex add-on system** whose economics depend on capture, utilisation/storage and policy support, calling for **bespoke, risk-shared structures** rather than standard loans.
- Long-term sector targets and cluster approaches suggest a need for **phased, multi-project financing strategies**, often involving **consortia and public partners**.
- Banks may need **tiered capital structures** combining senior and subordinated tranches, concessional funds, partial guarantees and blended finance to keep risk at acceptable levels.
- Longer investment lifespans and delayed benefits require **extended tenors, long moratoriums and possibly staggered, consortium-based financing**, rather than standard single-bank term loans.
- Input-price volatility and policy risk reinforce the need for **risk-sharing mechanisms, phased disbursement and conservative cash-flow assumptions**.
- Revenue support may need to come from **carbon pricing, CCfDs, carbon markets or public funding**, making CCUS highly dependent on policy frameworks and carbon-market upside.
- Loans will need **strong technical due diligence, performance guarantees, operational audits and robust carbon-impact measurement**, with phased implementation schedules.
- Banks must incorporate **policy and regulatory risk** into structuring and pricing, and may rely more on **syndicated and blended structures** than on bank-only balance-sheet lending.
- Overall, financial instrument design should emphasise **extended moratoriums, phased disbursement, tiered and blended financing, performance guarantees and audits, and policy/sponsor support**, using **green project finance, sustainability-linked loans and blended-finance structures**, typically within **project-finance or syndicated loan frameworks**.

Implications for borrowers' business

- CCUS in cement **adds a system overlay** to existing kilns and plants rather than replacing the core production process; assets are project- and site-specific but in principle replicable across plants.
- The potential scale is large (hundreds of MTPA of CO₂ by 2070), and projects typically require **significant plant redesign**, integration with transport and storage networks, and close coordination with cluster or hub models.
- **Capital expenditure is very high**, with substantial peripheral investments; the technology is complex and can create major execution and operational risks if not managed well.
- **Operating costs increase** due to energy use and additional inputs for capture, compression and transport, and benefits may only materialise over long timeframes.
- Volatility in energy and chemical inputs can add further uncertainty to already high operating costs.
- **Cash-flow benefits may not be visible for a long period**, especially where carbon prices, utilisation markets or storage incentives are not yet fully established.
- CCUS remains a **relatively early-stage technology** in cement, despite pilots and testbeds, and requires strong technical capabilities and monitoring.
- Compliance requirements are **extensive**, and there is exposure to **currency and policy risk**, especially where equipment is imported and regulations evolve.
- Overall, CCUS is a **high-capex, high-complexity, policy-dependent option** that is essential for deep decarbonization but carries long gestation and delayed benefits.

Strategic implications for financing low carbon steel and cement

Pricing risk and structuring low-carbon transactions

For both steel and cement, most low-carbon technologies combine **new processes with existing assets** rather than creating neatly separable projects. This makes **ring-fenced, pure project finance the exception**, not the rule. The main risks for lenders are therefore:

- **Execution and timing risk** – the ability of borrowers to integrate complex technologies and realise savings on schedule.
- **Input volatility** – exposure to scrap, AFR, power, hydrogen, SCMs and other feedstocks.
- **Demand and policy uncertainty** – domestic demand for low-carbon products is still nascent, and carbon markets and policy support are evolving.

Technology risk is generally lower than these integration and market risks, except for early-stage options such as **green hydrogen–DRI and CCUS**. In this context, risk premium and pricing should be driven less by “newness of technology” and more by the:

- Trajectory and reliability of cost savings,
- Strength of input and offtake contracts, and
- Quality of data and monitoring systems that underpin performance-linked structures.

Across both sectors, **performance-linked loans** are a practical “low-hanging fruit”, provided data on energy, emissions and process performance are credible, consistent and verifiable.

Prioritising instruments across steel and cement

For banks, three families of instruments are most relevant:

- **Green loans** (term loans and project finance),
- **Sustainability-linked loans (SLLs)**, and
- **Transition-labelled structures**, where appropriate.

A concise way to organise them is by **technology archetype**, cutting across steel and cement:

Table 1: Financial Instruments by technology archetype

Process and design efficiency	Steel and cement energy efficiency; “designing to use cement efficiently”	SLLs: green term loans where discrete assets exist	Use SLLs with clear KPIs (SEC, emissions per tonne, material efficiency). Offer modest tenors and limited moratorium, with repayments aligned to stabilisation of savings.

Input and mix changes	Scrap use in steel; clinker substitution and SCMs; AFR	SLLs; corporate-level green term loans; transition-labelled finance where appropriate	Focus on KPIs such as scrap share, clinker factor, TSR. Use covenants and buffers for input volatility and quality, and milestone-based drawdowns for integration steps.
Asset-centric energy projects	WHR in steel and cement; captive RE; selected AFR systems	Green project finance; green term loans; SLL overlays	Treat WHR/RE/AFR systems as identifiable green assets. Use longer tenors, minimal moratorium (where benefits are quick), maintenance covenants and performance-linked pricing.
System-level route shifts	BF–BOF to DRI–EAF/IF; portfolio-level RE integration; deep electrification	SLLs; green term loans; transition-labelled finance	Recognise these as balance-sheet-wide transitions. Emphasise longer tenors, milestone-based drawdowns, input hedging and offtake arrangements, with pricing linked to route-shift and emissions KPIs.
Early-stage and high-capex options	Green hydrogen–DRI; CCUS in steel and cement	Green project finance; blended finance; syndicated loans; SLLs within broader programmes	Use bespoke, risk-shared structures with extended moratorium, tiered capital (senior + subordinated + concessional), guarantees and strong technical due diligence. Carbon-related mechanisms (CCfDs, future carbon markets) should be treated as upside, not core security.

This framing helps banks **standardise their approach** to new proposals: first locate the technology in this archetype table, then apply the instrument and structuring logic consistently.

Design tweaks to manage risk premium

Across both sectors, similar **design tweaks** are needed to manage the additional risk premium for low-carbon investments:

- **Performance-linked repayment and pricing**
 - Link margins and/or amortisation profiles to verified indicators such as energy use per tonne, emissions intensity, clinker factor, scrap share, thermal substitution rate or share of renewable energy.
- **Calibrated moratoriums and tenors**
 - Short or minimal moratorium where benefits accrue quickly (e.g. WHR, many efficiency measures, clinker substitution).
 - Extended moratorium and longer tenors where capex is high and benefits are delayed (e.g. route shifts, green hydrogen–DRI, CCUS).
- **Milestone-based drawdowns and covenants**
 - Tie disbursements to clear technical and integration milestones (engineering, commissioning, performance tests).
 - Use covenants to manage input volatility (scrap, AFR, power, hydrogen, SCMs) and operational integration risk.
- **Risk-sharing and credit enhancement where needed**

- Use syndicated/consortium loans, guarantees, subordinated tranches and blended structures for high-capex, early-stage technologies.
- Treat carbon revenues and export premia as upside, not as the primary basis for debt service.

These adjustments can be systematically mapped into a “**financing cost waterfall**” to show how each risk and each de-risking measure affects required spreads and structure for a given transaction.

Strategic positioning for banks

Beyond individual deals, banks can position themselves as a **national transition financier** for hard-to-abate sectors by:

- Creating a **dedicated green transition finance capability** for steel and cement
- **Standardising green and transition project appraisal** through positive lists, templates and sector-specific MRV requirements.
- Acting as a **risk mitigator and blended-finance platform**, using guarantees and concessional tranches to crowd in private capital for early-stage technologies.
- Innovating **performance-linked products** (e.g. SLLs, transition-linked loans, green trade and supply-chain finance) aligned with measurable emissions outcomes.
- Partnering with government and industry to shape **MRV standards, green labels and policy instruments** that improve bankability.

This combination of **transaction-level discipline** and **system-level leadership** would allow banks to expand their low-carbon portfolio while managing risk and supporting India’s industrial transition.

Barriers and enablers to the adoption of LCTs

For lenders, the barriers and enablers elucidated in this section define the practical space in which low-carbon steel and cement projects can move from concept to bankable transactions. High capex, fragmented policy signals, capability gaps and weak domestic demand explain why many LCTs still struggle to reach scale, and therefore why conservative underwriting has been the norm.

At the same time, emerging export-driven green markets, clearer policy frameworks, targeted concessional finance and capacity-building create a growing pipeline of investable opportunities. A bank’s strategic role is to use the right mix of instruments and structuring tools - green loans, sustainability-linked loans, transition-aligned facilities, syndication and blended structures - to bridge these gaps, price risk transparently and channel capital towards clients that are credibly reducing the carbon intensity of steel and cement production.

Table 2: Barriers and enablers

Financial	<ul style="list-style-type: none"> • High upfront capex; in some cases, higher opex than conventional tech • Limited willingness to pay for green premia • SMEs have weak balance sheets and access to finance 	<ul style="list-style-type: none"> • Targeted incentives, tax breaks and interest subventions • Concessional and blended climate finance, guarantees • International partnerships for tech transfer and risk-sharing
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Policy & regulation	<ul style="list-style-type: none"> • Weak/uncertain price and demand signals for green steel/cement • Fragmented regulations and slow approvals (e.g. AFR, CCUS) 	<ul style="list-style-type: none"> • Carbon pricing and CBAM-aligned policies • Green public procurement and standards • Clear, stable roadmaps and co-ordination across ministries, regulators and banks
Technology & skills	<ul style="list-style-type: none"> • Limited awareness and capability, especially in MSMEs • Skill gaps for operating and maintaining BATs and LCTs • Perceived technology risk for early-stage options (H₂-DRI, CCUS) 	<ul style="list-style-type: none"> • Capacity-building, training and demonstration projects • Increased R&D on India-specific solutions and raw materials • Vendor support, performance guarantees and technical assistance in financing packages
Industry structure & scale	<ul style="list-style-type: none"> • Fragmented industry structure; many small plants with low investment capacity • Difficult to standardise and aggregate projects for financing 	<ul style="list-style-type: none"> • Phased adoption of proven, incremental technologies (EE, WHR, SCMs) • Aggregation of similar projects across plants/corporates into standardised financing programmes
Markets & demand	<ul style="list-style-type: none"> • Low domestic willingness to pay for green products • Limited awareness of reliability and benefits of low-carbon alternatives 	<ul style="list-style-type: none"> • Growing export and supply-chain demand for low-carbon inputs (CBAM, OEM procurement criteria) • Emergence of green labels and standards (green/low-carbon steel and cement) • Corporate decarbonization commitments in downstream sectors

References

- [1] Reserve Bank of India, "Report on Currency & Finance: Chapter II: Macroeconomic Effects of Climate Change In India," May 2023. [Online]. Available: <https://www.rbi.org.in/Scripts/PublicationsView.aspx?id=21769>.
- [2] CIA, "Environment - India, The World Factbook," 26 08 2025. [Online]. Available: <https://www.cia.gov/the-world-factbook/countries/india/#environment>.
- [3] World Bank Group, "Carbon dioxide (CO₂) emissions excluding LULUCF per capita (t CO₂e/capita)," 2024. [Online]. Available: <https://data.worldbank.org/indicator/EN.GHG.CO2.PC.CE.AR5>.
- [4] IEA Data Services, "India, IEA," 2022. [Online]. Available: <https://www.iea.org/countries/india/emissions#what-are-the-main-sources-of-co2-emissions-in-india>.
- [5] Press Information Bureau, "National Action Plan on Climate Change (NAPCC)," 01 12 2021. [Online]. Available: <chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://static.pib.gov.in/WriteReadData/specificdocs/documents/2021/dec/doc202112101.pdf>.
- [6] K. Deb and N. Roy, "COP28: Assessing India's Progress Against Climate Goals," 01 12 2023. [Online]. Available: <https://www.energypolicy.columbia.edu/cop28-assessing-indias-progress-against-climate-goals/>.
- [7] G. McGuire, "India cuts fossil electricity output as clean generation hits new peak," 02 09 2025. [Online]. Available: <https://www.reuters.com/markets/commodities/india-cuts-fossil-electricity-output-clean-generation-hits-new-peak-2025-09-02/>.
- [8] Levi, P. et al, "EA: Tracking Industry - Countries, Fuels, Technologies, Analysis, Data, and Policies," 2020. [Online]. Available: <https://coilink.org/20.500.12592/s52tbc>.

- [9] P. Fennell, J. Driver, C. Bataille and S. J. Davis, "Cement and steel — nine steps to net zero," 23 03 2022. [Online]. Available: <https://www.nature.com/articles/d41586-022-00758-4#ref-CR1>.
- [10] P. Kumar, M. Agrawal and K. S., "Decarbonising India: Energy and Hard-to-abate Industrial Sectors," Centre for Science and Environment, New Delhi, 2024.
- [11] "Climate Change Report, Tata Steel," 2024. [Online]. Available: <https://www.tatasteel.com/investors/integrated-report-2023-24/climate-change-report.html>.
- [12] "Climate Change, JSW," 2025. [Online]. Available: <https://www.jsw.in/groups/sustainability-framework-measuring-success-climate-change>.
- [13] GCCA India-TERI, "Decarbonization Roadmap for the Indian Cement Sector," GCCA India-TERI, New Delhi, 2025.
- [14] WEF, "Steel industry net-zero tracker," 2024.
- [15] RMI, "Five Insights on the Concrete and Cement Industry's Transition to Net Zero," 2023.
- [16] BBVA Bank, "What are Green Loans and what are they used for?," BBVA Bank, 17 May 2024. [Online]. Available: <https://www.bbvacib.com/insights/news/what-are-green-loans-what-are-they-used-for/>. [Accessed February 2026].
- [17] Ministry of Steel, "Greening the steel sector in India: Roadmap and action plan," Government of India, 2024b.
- [18] CEEW, "Evaluating net zero for the Indian steel industry," CEEW, New Delhi, 2023.
- [19] Global Cement & Concrete Association (GCCA), Global CCS Institute, Global CCS Fund, "CCUs in the Indian Cement Industry," Global CCS Institute, Washington D. C, 2024.
- [20] CEEW, "Evaluating net-zero for the Indian cement industry," Council on Energy, Environment & Water, New Delhi, 2023.
- [21] S. Kumari, S. Jaglan, A. Chouksey, R. Walia, A. Ahlawat, A. Garg and M. Verma, "Carbon Footprint Analysis of Cement Production in India," *Evergreen - Joint Journal of Novel Carbon Resource Sciences & Green Asia Strategy*, vol. 11, no. 04, pp. 00-00, 2024.
- [22] Max Engineering & Automation Ltd, Powertech Switchgears (I) Pvt Ltd, "Understanding Cement Plants: Processes, Components, and Key Considerations," Max Engineering & Automation Ltd, Powertech Switchgears (I) Pvt Ltd, March 2023. [Online]. Available: <https://powertechmax.com/cement-plant-operations/>. [Accessed October 2025].
- [23] Volaity, S.S., Aylas-Paredes, B.K., Han, T. et al, "Towards decarbonization of cement industry: a critical review of electrification technologies for sustainable cement production.,," *npj Materials Sustainability*, vol. 3, no. 23, 2025.
- [24] Ministry of Steel, "Year-End Review 2024: Ministry of Steel," December 2024a. [Online]. Available: <https://www.pib.gov.in/PressReleasePage.aspx?PRID=2088827>.
- [25] Ministry of Steel, "Energy & Environment Management in Iron & Steel Sector," [Online]. Available: <https://steel.gov.in/energy-and-environment-management-iron-steel-sector>.
- [26] Ministry of Steel, "Green Steel Taxonomy for India," Government of India, 2024c.
- [27] Department of Science & Technology, "India launches first cluster of CCU testbeds in academia-industry collaboration for cement industry," 2025. [Online]. Available: <https://dst.gov.in/india-launches-first-cluster-ccu-testbeds-academia-industry-collaboration-cement-industry>.
- [28] Ministry of Environment, Forest & Climate Change, "Greenhouse Gases Emission Intensity Target Rules, 2025," 2025.
- [29] Climate Policy Initiative, "Landscape of green finance in India," 2024.
- [30] Ministry of Finance, "Draft framework of India's climate finance taxonomy," Government of India, 2025.

- [31] SEBI, "Circular: Farmework for environment, social and governance (ESG) debt securities (other than green debt securities)," 2025.
- [32] D. Stanway, "World Bank's IFC signs green financing deal with Indonesian steel mill," Reuters, 5 September 2024. [Online]. Available: <https://www.reuters.com/business/environment/world-banks-ifc-signs-green-financing-deal-with-indonesian-steel-mill-2024-09-04/>. [Accessed February 2026].
- [33] World Bank, "China: Energy Efficiency Financing Project," World Bank, 27 May 2008. [Online]. Available: <https://www.worldbank.org/en/news/loans-credits/2008/05/27/china-energy-efficiency-financing-project>. [Accessed February 2026].
- [34] Sarralle, "SARRALLE Waste Heat Recovery System," 20 October 2022. [Online]. Available: <https://www.sarralle.com/en/news/view/sarralle-waste-heat-recovery-system>.
- [35] TERI, "Technology compendium on energy efficient technology packages for Electric Arc Furnace," TERI. A study for UNDP, New Delhi, 2017.
- [36] Steel Orbis, "IFC to support Bangladeshi steelmaker's new EAF-based project," Steel Orbis, 21 August 2024. [Online]. Available: <https://www.steelorbis.com/steel-news/latest-news/ifc-to-support-bangladeshi-steelmakers-new-eaf-based-project-1353936.htm>. [Accessed February 2026].
- [37] EWS Data, "Esteel Loan (IFC-51259)," EWS Data, 5 February 2026. [Online]. Available: <https://ewsdata.rightsindevelopment.org/projects/51259-esteel-loan/>. [Accessed February 2026].
- [38] Climate Group, "India net zero steel demand outlook report," Climate Group, 2023.
- [39] A. Goldar, A. Kumar and S. Yadav, "Summary for policymakers - Unpacking India's scrap steel trade dynamics," Indian Council for Research on International Economic Relations, 2025.
- [40] VN Economy, "Standard Chartered extends \$25mln transition trade finance facility to Tung Ho Steel Vietnam," VN Economy, 26 May 2023. [Online]. Available: <https://en.vneconomy.vn/standard-chartered-extends-25mln-transition-trade-finance-facility-to-tung-ho-steel-vietnam.htm?> [Accessed February 2026].
- [41] MUFG Bank, "MUFG Transit: APAC Carbon Offsets CBAM and its Impact on APAC Iron & Steel Sector," MUFG Bank, August 2024. [Online]. Available: https://www.bk.mufg.jp/global/globalnetwork/asiapacific/anncts/pdf/apacnews_20240813_en.pdf. [Accessed February 2026].
- [42] F. Gabriel, "Understanding hydrogen: how is it made, how is it scaled, and what challenges does it bring?," 23 September 2024. [Online]. Available: <https://www.capgemini.com/gb-en/insights/expert-perspectives/understanding-hydrogen-how-is-it-made-how-is-it-scaled-and-what-challenges-does-it-bring/>.
- [43] Societe Generale, "Steel production: Replacing coal with green hydrogen," Societe Generale, 22 January 2024. [Online]. Available: <https://wholesale.banking.societegenerale.com/en/news-insights/clients-successes/clients-successes-details/news/steel-production-replacing-coal-with-green-hydrogen>. [Accessed February 2026].
- [44] Industrial Bank of China, "Fostering Green Productivity: CIB Provides Financing Support for the World's First "Hydrogen Metallurgy" Project," Industrial Bank of China, 2024. [Online]. Available: https://www.cib.com.cn/en/aboutCIB/about/news/2024/20240710_19.html. [Accessed February 2026].
- [45] South China Morning Post, "Climate finance: China's Ping An Bank lends US\$25 million to Inner Mongolia steel maker to capture carbon emissions," South China Morning Post, 27 June 2023. [Online]. Available: <https://www.scmp.com/business/article/3225578/climate-finance-chinas-ping-bank-lends-us25-million-inner-mongolia-steel-maker-capture-carbon>. [Accessed February 2026].
- [46] S. Selvaraju, "Finance and state support for lowcarbon steel: Policy Report," LSE Grantham Institute, December 2025. [Online]. Available: <https://www.lse.ac.uk/granthaminstitute/wp-content/uploads/2025/12/Finance-and-state-support-for-low-carbon-steel.pdf>. [Accessed February 2026].
- [47] D. Das and N. Rodrigues, "RE-powering India's heavy industries: 20 GW today, 24/7 tomorrow," Ember, 2025.

- [48] SSAB, "SSAB secures green financing of EUR 2.3 billion (Press Release)," SSAB, 29 April 2025. [Online]. Available: <https://www.ssab.com/en/news/2025/04/ssab-secures-green-financing-of-eur-23-billion>. [Accessed February 2026].
- [49] S. Pyrkalo, "EBRD lends €21.4 million to Serbia's Metalfer for greener steel production," European Bank for Reconstruction and Development, 12 January 2023. [Online]. Available: <https://www.ebrd.com/home/news-and-events/news/2023/ebd-lends-214-million-to-serbias-metalfer-for-greener-steel-production.html>. [Accessed February 2026].
- [50] IFC, "Strengthening Sustainability in the Steel Industry," IFC, 2020.
- [51] T. Walsh, "Sustainable Loan: Ternium Mexico's US\$1.25bn green loan," International Financing Review, 17 December 2025. [Online]. Available: <https://www.ifre.com/ifr-awards/2333268/sustainable-loan-ternum-mexicos-us1.25bn-green-loan>. [Accessed February 2026].
- [52] European Bank for Reconstruction and Development, "DFF - Arabian Cement Company," European Bank for Reconstruction and Development, [Online]. Available: <https://www.ebrd.com/home/work-with-us/projects/psd/55178.html>. [Accessed February 2026].
- [53] IFC, "IFC Deepens Partnership with Sococim to Boost Low-Carbon Cement Production in Senegal," IFC, 23 December 2024. [Online]. Available: <https://www.ifc.org/en/pressroom/2024/ifc-deepens-partnership-with-sococim-to-boost-low-carbon-cement-production-in-senegal>. [Accessed February 2026].
- [54] CemNet, "Cimsa secures US\$70m green loan from IFC for sustainability initiatives," CemNet, 18 November 2024. [Online]. Available: <https://www.cemnet.com/News/story/178142/cimsa-secures-us-70m-green-loan-from-ifc-for-sustainability-initiatives.html>. [Accessed February 2026].
- [55] CII - Sohrabji Godrej Green Business Centre, "Energy Benchmarking for Indian Cement Industry 6.0," Confederation on Indian Industries (CII), Hyderabad, 2023.
- [56] S. Das, "Supplementary Cementitious Materials Improving Sustainability of Concrete," NBM&CW India's Premier Construction Magazine, [Online]. Available: <https://www.nbmcw.com/product-technology/construction-chemicals-waterproofing/concrete-admixtures/supplementary-cementitious-materials-improving-sustainability-of-concrete.html>. [Accessed October 2025].
- [57] K. Mathur, "SCMs play a pivotal role in reducing the carbon footprint," Indian Cement Review, 22 November 2024. [Online]. Available: <https://indiancementreview.com/2024/11/22/scms-play-a-pivotal-role-in-reducing-the-carbon-footprint/>. [Accessed October 2025].
- [58] Alliance for Low-Carbon Cement & Concrete (ALCCC), "Factsheet and webinar – How SCMs can help make low-carbon cement and concrete a reality," October 2023. [Online]. Available: <https://alliancelccc.com/policy/making-low-carbon-cement-and-concrete-a-reality/>. [Accessed October 2025].
- [59] S. Prakasan, S. Palaniappan and R. • Gettu, "Study of Energy Use and CO2 Emissions in the Manufacturing of Clinker and Cement," *Journal of The Institution of Engineers (India) Series A*, 2019.
- [60] C. Karadumpa and R. Pancharathi, "Study on energy use and carbon emission from manufacturing of OPC and blended cements in India.," *Environmental Science & Pollution Research*, vol. 31, p. 5364–5383, 2024.
- [61] Reuters, "India's Ultratech Cement raises 500 mln via sustainability linked financing," Reuters, 26 August 2024. [Online]. Available: <https://www.reuters.com/world/india/indias-ultratech-cement-raises-500-mln-via-sustainability-linked-financing-2024-08-26/>. [Accessed February 2026].
- [62] IFC, "Economia Circular Y Gestion De Residuos En La Industria De Cemento," IFC, [Online]. Available: https://www.procem.co/economiacircular/presentaciones-economia-circular/IFC-Cement-Decarbonization_NOV292023.pdf. [Accessed February 2026].
- [63] PwC India, "Best Practice Manual for Waste Heat Recovery in Cement Sector in India," EU-India Clean Energy and Climate Partnership; FICEP, New Delhi, 2022.
- [64] Confederation of Indian Industries (CII), "Manual on Waste Heat Recovery in," CII Sohrabji Godrej Green Business Centre, Hyderabad, 2009.

- [65] TSKB Bank, "TSKB and OYAK Cement Cooperate for Investments in Solar Power Plants and Waste Heat Recovery Plants," TSKB Bank, 15 April 2025. [Online]. Available: <https://www.tskb.com.tr/en/about-us/about-us/news/tskb-and-oyak-cement-cooperate-for-investments-in-solar-power-plants-and-waste-heat-recovery-plants>. [Accessed February 2026].
- [66] D. Sarı, "First EBRD loan to Türkiye's cement sector to boost low-carbon investments," European Bank for Reconstruction and Development, 25 June 2024. [Online]. Available: <https://www.ebrd.com/home/news-and-events/news/2024/first-ebrd-loan-to-trkiyes-cement-sector-to-boost-lowcarbon-investments.html>. [Accessed February 2026].
- [67] CII - Godrej GBC; Shakti Sustainable Energy Foundation (SSEF)., "Promoting Alternative Fuels and Raw Materials Usage in the India Cement Industry," Confederation of Indian Industry (CII), Hyderabad, 2016.
- [68] Indian Cement Review, "The AFR Advantage," Indian Cement Review, 11 March 2025. [Online]. Available: <https://indiancementreview.com/2025/03/11/the-afr-advantage/>. [Accessed October 2025].
- [69] Vasudha Foundation, "Exploring deep electrification pathways to abate emissions from cement manufacturing in India," New Delhi, 2024.
- [70] JMK Research & Analytics, "Green power procurement cement sector in India," 2024.
- [71] IFC, "FC Strengthens Partnership with CIMAT/CIMAF to Support Green Energy and Low-Carbon Cement Production in Burkina Faso, Chad, and Mali," IFC, 10 October 2023. [Online]. Available: <https://www.ifc.org/en/pressroom/2023/ifc-strengthens-partnership-with-cimatcimaf-to-support-green-ene>. [Accessed February 2026].
- [72] PIB, "NITI Aayog Organises Workshop on Carbon Capture, Utilisation, and Storage (CCUS) in the Indian Cement Sector," 17 January 2025. [Online]. Available: <https://www.pib.gov.in/PressReleasePage.aspx?PRID=2093760>.
- [73] NITI Aayog, "Workshop on carbon capture, utilisation and storage (CCUS) in Indian cement sector," 2025.
- [74] J. Davila, R. Sacchi and M. Pizzol, "Preconditions for achieving carbon neutrality in cement production through CCUS," *Journal of Cleaner Production*, 2023.
- [75] Ping An Insurance (Group) Company of China, Ltd., "Ping An Bank Grants First Loan to Pioneering CCUS Project amounted RMB 180 million in China's Steel Industry," Ping An Insurance (Group) Company of China, Ltd., 27 June 2023. [Online]. Available: <https://www.prnewswire.com/news-releases/ping-an-bank-grants-first-loan-to-pioneering-ccus-project-amounted-rmb-180-million-in-chinas-steel-industry-301863939.html>. [Accessed February 2026].
- [76] A. Lloyd-Perks, "Heidelberg Materials to begin construction of world's first carbon capture cement facility," World Cement, 25 September 2025. [Online]. Available: <https://www.worldcement.com/europe-cis/25092025/heidelberg-materials-to-begin-construction-of-worlds-first-carbon-capture-cement-facility/>. [Accessed February 2026].
- [77] Reserve Bank of India, *Master Directions - Reserve Bank of India (Priority Sector Lending – Targets and Classification) Directions, 2025*, Reserve Bank of India, 2025.
- [78] UNDP, "Derisking renewable energy investment : a framework to support policymakers in selecting public instruments to promote renewable energy investment in developing countries," UNDP, 2013.
- [79] M. & M. S. Kumar, "India now has a green steel taxonomy - a welcome step that has a long way to go," Down To Earth, 30 December 2024. [Online]. Available: <https://www.downtoearth.org.in/climate-change/india-now-has-a-green-steel-taxonomy-a-welcome-step-that-has-a-long-way-to-go>.
- [80] Y. Kashyap, "Analysis: Costs and impacts of low carbon technologies for steel and cement sectors in India," Climate Policy Initiative, 5 December 2022. [Online]. Available: <https://www.climatepolicyinitiative.org/report-summary-costs-and-impacts-of-low-carbon-technologies-for-steel-and-cement-sectors-in-india/>.
- [81] T. Singh, R. Ahuja, J. Mishra and S. Malhotra, "Transitioning India's steel and cement industries to low carbon pathways," TERI, 2020.

- [82] A. & P. P. Mallett, "Green transformation in the iron and steel industry in India: Rethinking patterns of innovation," *Energy Strategy Reviews*, vol. 44, 2022.
- [83] Elite Blueprints Consultancy, "Geopolymer Concrete: How India's New Tech is Cutting Costs & Carbon," Elite Blueprints Consultancy, 9 September 2025. [Online]. Available: <https://ebcsiliguri.com/geopolymer-concrete-in-india/>. [Accessed October 2025].
- [84] M. Asif and K. Fareeduddin, "The Use of Geopolymer Concrete as a Sustainable Development in Construction Industries and Adaptation in Construction Management," *International Journal of Innovative Research in Technology (IJIRT)*, vol. 12, no. 1, pp. 4985-4988, 2025.
- [85] Holcim, "Decarbonising Holcim with alternative fuels," Holcim, 29 March 2023. [Online]. Available: <https://www.holcim.com/who-we-are/our-stories/decarbonising-holcim-alternative-fuels>. [Accessed October 2025].
- [86] GCCA, "Action & Progress – Case Studies - Holcim – Calcined Clay & Retznei Plant," Global Cement & Concrete Association (GCCA), [Online]. Available: <https://gccassociation.org/2050-net-zero-roadmap-one-year-on/action-progress-case-studies-holcim/>. [Accessed October 2025].
- [87] HYBRIT, "HYBRIT: Large-scale storage of fossil-free hydrogen gas successfully proven," HYBRIT, 27 February 2025. [Online]. Available: <https://www.hybritdevelopment.se/en/hybrit-large-scale-storage-of-fossil-free-hydrogen-gas-successfully-proven/>.
- [88] European Commission, "Overview of sustainable finance," European Commission, [Online]. Available: https://finance.ec.europa.eu/sustainable-finance/overview-sustainable-finance_en. [Accessed February 2026].
- [89] ICMA, "Green Bond Principles (Voluntary Process Guidelines for Issuing Green Bonds)," ICMA, 2025.
- [90] Loan Market Association (LMA), "Green Loan Principles," Loan Market Association (LMA), 2018.
- [91] Loan Market Association (LMA), "Sustainability Linked Loan Principles," Loan Market Association, 2019.
- [92] ICMA, "Transition Finance in the Debt Capital Market," ICMA, 2024.
- [93] World Bank, "Blended Finance," World Bank, [Online]. Available: <https://ppp.worldbank.org/blended-finance>. [Accessed February 2026].
- [94] Deloitte Global. (2021). *Decarbonising the steel value chain: Forging new paths together*. Deloitte. Retrieved from <https://www.deloitte.com/global/en/Industries/energy/perspectives/decarbonising-the-steel-value-chain.html> (Deloitte)
- [95] IFC. (n.d.). *Cement Decarbonization Tool*. International Finance Corporation. Retrieved from <https://www.ifc.org/en/what-we-do/sector-expertise/manufacturing/decarbonization/cement-decarbonization-tool> (IFC)
- [96] Industry Transition. (n.d.). IFIs and heavy industry decarbonization in emerging and developing economies. Leadership Group for Industry Transition. Retrieved from <https://www.industrytransition.org/insights/ifis-and-heavy-industry-decarbonization-in-emerging-markets-and-developing-countries/> (Leadership Group for Industry Transition)
- [97] RMI. (2021, May 27). Six Global Banks Come Together to Decarbonise Steel [Press release]. Rocky Mountain Institute. Retrieved from <https://rmi.org/press-release/six-global-banks-come-together-to-decarbonise-steel/> (RMI)
- [98] RMI. (2022). *Money Talks, Carbon Walks: 2022 Annual Report*. Rocky Mountain Institute. Retrieved from <https://rmi.org/annual-report-2022/money-talks-carbon-walks/> (RMI)
- [99] The Energy and Resources Institute (TERI) & DIW Berlin. (2023). *Financing the Decarbonization of Indian Secondary Steel Sector: Towards an Enabling Environment*. New Delhi: TERI. Retrieved from

- <https://www.teriin.org/press-release/teri-and-diw-berlin-unveil-radical-report-financing-decarbonization-indian-secondary-steel-sector> (TERI)
- [100] United Nations Environment Programme – Finance Initiative; European Banking Federation. (2022, February). Practical approaches to applying the EU Taxonomy to bank lending. UNEP FI & EBF. Retrieved from <https://www.unepfi.org/industries/banking/practical-approaches-to-applying-the-eu-taxonomy-to-bank-lending/> (unepfi.org)
 - [101] Vibhuti Garg, Jyoti Gulia, Kapil Gupta, Nagoor Shaik, & Shantanu Srivastava. (2023, September 14). Steel decarbonization in India. Institute for Energy Economics & Financial Analysis (IEEFA). Retrieved from <https://ieefa.org/resources/steel-decarbonization-india> (IEEFA)
 - [102] Bataille, C., Stiebert, S., Algers, J., & others. (2024, August). Decarbonising Steel and Cement. Columbia University – Center on Global Energy Policy. (energypolicy.columbia.edu)
 - [103] Climate Policy Initiative. (2022, September). Financing Steel Decarbonization: Instrument Analysis. <https://www.climatepolicyinitiative.org/wp-content/uploads/2022/10/FSD-report.pdf> (CPI)
 - [104] Highwaysteyn, A. (2023). Managing carbon price risk in a low-carbon industry. SSRN. (SSRN)
 - [105] International Energy Agency / IRENA. (2022). Innovation landscape for smart electrification – Power to hydrogen, Chapter on Carbon Contracts for Difference. IRENA. (See “Carbon contracts for difference”) (IRENA)
 - [106] Organisation for Economic Co-operation and Development (OECD). (2025). Implementing the OECD Framework for Industry’s Net-Zero Transition in South Africa: Decarbonising the Iron and Steel Sector. OECD Publishing. <https://doi.org/10.1787/841540e8-en> (OECD)
 - [107] Richstein, J. C. (2022). Carbon contracts-for-difference: How to de-risk innovative projects in industrial decarbonization. PMC / NCBI. (PMC)
 - [108] Richstein, J. C., & others. (2025). Carbon Contracts for Difference 101. IETA. https://www.ieta.org/uploads/wp-content/Resources/Old-resources-and-videos/IETA_101_CarbonContractsforDifference_Sept2023.pdf (IETA)
 - [109] United Nations (via BIS / IFC). (2024, October 2). Financing the decarbonization of hard-to-abate sectors: Trends, issues, and ways forward. https://www.bis.org/ifc/publ/ifcb63_26.pdf (Bank for International Settlements)
 - [110] Asian Development Bank. (2023). Financing Clean Industrial Transitions in Asia and the Pacific: Opportunities for Hard-to-Abate Sectors. Manila: Asian Development Bank. <https://www.adb.org/publications>
 - [111] Carbon Pricing Leadership Coalition. (2021). Report of the Task Force on Net-Zero Financing and Carbon Pricing Mechanisms. Washington, DC: World Bank Group. <https://www.carbonpricingleadership.org>
 - [112] European Commission. (2022). REPowerEU Plan: Accelerating the Green Transition. Brussels: European Union. https://commission.europa.eu/energy-strategy/repowereu_en
 - [113] European Investment Bank. (2023). Financing the Net-Zero Industry: The Role of Public and Private Instruments in Industrial Decarbonization. Luxembourg: EIB. <https://www.eib.org/en/publications>
 - [114] Global Cement and Concrete Association. (2021). Cement Industry Net Zero Roadmap: Pathways to 2050. London: GCCA. <https://gccassociation.org>
 - [115] Hybrit Development AB. (2021). HYBRIT: Towards Fossil-Free Steel. Stockholm: HYBRIT Project Consortium (SSAB, LKAB, Vattenfall). <https://www.hybritdevelopment.com>

- [116] International Energy Agency. (2020). Iron and Steel Technology Roadmap: Towards More Sustainable Steelmaking. Paris: OECD/IEA.
<https://www.iea.org/reports/iron-and-steel-technology-roadmap>
- [117] International Energy Agency. (2020). Cement Technology Roadmap: Carbon Capture and Beyond. Paris: OECD/IEA.
<https://www.iea.org/reports/cement-technology-roadmap>
- [118] International Finance Corporation. (2022). Blended Finance for Industrial Decarbonization: Lessons from Emerging Markets. Washington, DC: World Bank Group.
<https://www.ifc.org>
- [119] International Renewable Energy Agency. (2022). Decarbonising Industry: Hydrogen and Renewable Energy Pathways. Abu Dhabi: IRENA.
<https://www.irena.org/publications>
- [120] McKinsey & Company. (2022). The Net-Zero Transition: What It Would Cost, What It Could Bring. New York: McKinsey Sustainability.
<https://www.mckinsey.com>
- [121] Organisation for Economic Co-operation and Development. (2022). Financing Industrial Transitions: Policy Instruments for Hard-to-Abate Sectors. Paris: OECD Publishing.
<https://www.oecd.org>
- [122] United Nations Industrial Development Organisation. (2021). Industrial Deep Decarbonization Initiative (IDDI): Green Public Procurement and Financing Frameworks. Vienna: UNIDO.
<https://www.unido.org/iddi>
- [123] World Bank Group. (2021). State and Trends of Carbon Pricing 2021. Washington, DC: World Bank.
<https://openknowledge.worldbank.org>
- [124] World Economic Forum. (2022). Financing the Low-Carbon Industrial Transition: Unlocking Capital for Hard-to-Abate Sectors. Geneva: WEF.
<https://www.weforum.org/reports>
- [125] World Steel Association. (2021). Sustainable Steel: Indicators 2021 and Pathways to Net-Zero. Brussels: World Steel Association.
<https://worldsteel.org>
- [126] Asian Development Bank (ADB). (2021). Asian Development Outlook 2021: Financing a green and inclusive recovery. Manila: Asian Development Bank. <https://www.adb.org/publications/asian-development-outlook-2021>
- [127] Asian Development Bank (ADB). (2023). Harnessing blended finance for the clean energy transition in Asia and the Pacific. Manila: Asian Development Bank. <https://www.adb.org/publications>
- [128] Bureau of Energy Efficiency (BEE). (2022). PAT scheme documents and performance reports. Government of India. <https://beeindia.gov.in>
- [129] Climate Policy Initiative (CPI). (2022). Landscape of green finance in India 2022. Climate Policy Initiative India. <https://www.climatepolicyinitiative.org>
- [130] International Energy Agency (IEA). (2020). Iron and steel technology roadmap: Towards more sustainable steelmaking. Paris: IEA. <https://www.iea.org/reports/iron-and-steel-technology-roadmap>
- [131] International Energy Agency (IEA). (2023). Cement technology roadmap: Low-carbon transition in the cement industry. Paris: IEA. <https://www.iea.org/reports/cement>
- [132] International Finance Corporation (IFC). (2021). Green banking and climate finance: Building financial system resilience. Washington, DC: World Bank Group. <https://www.ifc.org>

- [133] International Renewable Energy Agency (IRENA). (2022). Decarbonising industry: Electrification and renewables in the manufacturing sector. Abu Dhabi: IRENA. <https://www.irena.org/publications>
- [134] Ministry of Finance, Government of India. (2022). Report of the Task Force on Sustainable Finance. Department of Economic Affairs. <https://dea.gov.in>
- [135] Organisation for Economic Co-operation and Development (OECD). (2021). Blended finance in the least developed countries 2021. Paris: OECD Publishing. <https://doi.org/10.1787/ba7c22e3-en>
- [136] Sustainable Banking Network (SBN). (2022). Guidance on transition finance for financial institutions. Washington, DC: International Finance Corporation.
- [137] The Energy and Resources Institute (TERI). (2021). Financing India's low-carbon transition: Role of public finance institutions. New Delhi: TERI Press.
- [138] United Nations Environment Programme Finance Initiative (UNEP FI). (2021). Net-zero banking alliance: Financing a sustainable transition. Geneva: UNEP. <https://www.unepfi.org>
- [139] World Bank Group. (2022). Decarbonising development: Three steps to a zero-carbon future. Washington, DC: World Bank. <https://www.worldbank.org>
- [140] World Economic Forum (WEF). (2023). Financing the net-zero transition: Role of public and private finance in heavy industry. Geneva: WEF. <https://www.weforum.org>
- [141] World Resources Institute. (n.d.). Insider: Designing Low-carbon Product Standards for Cement and Steel in the United States. It notes: "Cement and steel ... together account for approximately 15% of global emissions (about 7% for cement and 8% for steel).
- [142] References for capex and cost values:
- [143] CEEW (2023). Evaluating net-zero for the Indian cement industry – Marginal abatement cost curves of carbon mitigation technologies. New Delhi.
- [144] CEEW (2023). Evaluating net-zero for the Indian steel industry – Marginal abatement cost curves of carbon mitigation technologies. New Delhi.
- [145] Cement Manufacturers Association (2023). Sectoral challenges and opportunities for CCUS in the cement sector. New Delhi.
- [146] PwC (2022). Best practice manual for waste heat recovery in cement sector in India. EU-India Clean Energy & Climate Partnership.
- [147] Niti Aayog (2025). Carbon capture, utilisation, and storage (CCUS) in Indian cement sector. New Delhi.
- [148] Confederation of Indian Industries (CII) (2009), Manual on Waste Heat Recovery in Indian cement industry. CII Sohrabji Godrej Green Business Centre, Hyderabad.