TOPTIER / INDUSTRY DECARBONIZATION SERIES

The Hidden Energy Cost of Refractories

Indian refractory plants can cut kiln fuel, electricity bills and value-chain emissions while protecting product quality.



Original AI-generated editorial illustration of a fictional refractory plant.

A. The most expensive brick may never leave the factory

A refractory brick that cracks during firing has already absorbed quarrying, grinding, pressing, drying and kiln energy. The plant then spends more to make its replacement. The same brick may show up in the fuel report as part of an apparently normal firing campaign and in the finance report as scrap. Unless someone joins those two records, the true cost of rejecting it stays hidden.

For a CEO or CFO, this is where the energy strategy can start paying for itself. Ask how much electricity and fuel the plant used per tonne of saleable product, then ask which grade, shift and kiln campaign drove the variance. For the plant head, the harder question is whether the next tonne can be made with less energy while meeting the same dimensional, mechanical and service-life requirements. Refractory customers buy dependable performance under severe conditions. A lining that wears out sooner can erase a supplier’s apparent carbon improvement and give the customer another shutdown to plan.

B. Two production routes, two energy bills

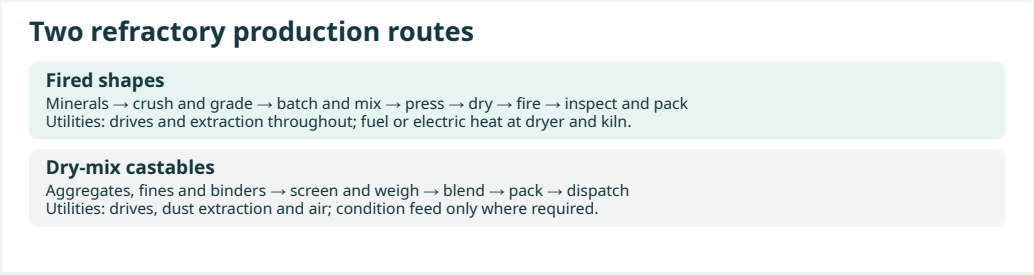
Refractories protect equipment that operates at high temperatures. Steel ladles and furnaces, cement kilns, glass tanks and foundries need products selected for specific conditions. Alumina-rich or fireclay formulations, basic magnesia-based products and carbon-containing grades serve different applications. Their starting minerals and binders, firing conditions and operating life differ. Grouping them under one average can make a production mix change look like a successful energy project.

A typical fired-brick line receives purchased minerals, crushes or grades them, weighs and mixes the recipe, presses shapes, dries

them and fires them to a controlled time–temperature profile. Sorting, machining and packing follow where needed. On a fuel-fired line, dryers and kilns are the first places to meter thermal energy. Grinding drives, presses, fans, dust extraction and compressed air contribute to electricity use. A wet incoming batch can raise dryer fuel use, while a partially loaded kiln car can spread the same standing losses over fewer bricks. Pre-calcined mineral purchases can shift substantial energy use upstream.

A typical dry-mix castable line screens, weighs and blends graded aggregates, fines, binders and additives before packing. Some formulations use calcined alumina, bauxite, magnesia or calcium aluminate cement. The usual dry-mix route ships material without firing the bagged product at the plant. Raw material conditioning, site-specific dryers and separately manufactured precast shapes can change the picture. A plant with low on-site fuel use may still purchase minerals whose extraction and thermal processing carry significant emissions.

Start the map at goods receipt. Link supplier lot, recipe, moisture, shift, tonnes fed, tonnes shipped, rejection code and utilities. Track kWh and GJ per saleable tonne by product family, kiln occupancy and first-pass yield. Document kiln warm-up and standby separately. Meter the kiln, dryers, crushing or milling, and shared auxiliaries before assigning their consumption across the products.



Typical routes. Source: EU JRC ceramics BREF and sector process synthesis.

Where to meter energy and investigate losses

Kiln and dryer | Illustrative 80,000 GJ/year gas input
66,000 GJ kiln + 14,000 GJ dryer → product heating and moisture removal
Investigate stack heat, shell losses, leakage, idle firing and scrap.

Production drives and auxiliaries | Illustrative 8 GWh/year electricity
3.0 GWh grinding and mixing + 2.0 GWh draft/extraction + 1.5 GWh presses + 1.5 GWh other
Investigate idling, throttling, air leaks and coincident demand.

Outputs and accounting
Gas combustion contributes to Scope 1; purchased power contributes to Scope 2.
Useful heat and losses are shown qualitatively. Confirm the split with a measured heat balance.

Source: hypothetical TOPTIER example. End-use splits are assumptions for visualisation.



Original AI-generated editorial illustration of a fictional dry-mix castables line.

C. Where the carbon comes from

Scope 1 includes fuel burned in controlled kilns, dryers and backup generators, and fugitive refrigerants from controlled equipment. Examine actual raw material chemistry for process CO_2. If a plant calcines carbonate-bearing inputs on site, the chemistry can release CO_2 independently of burner fuel. If a supplier calcined the material, that upstream footprint generally belongs with purchased

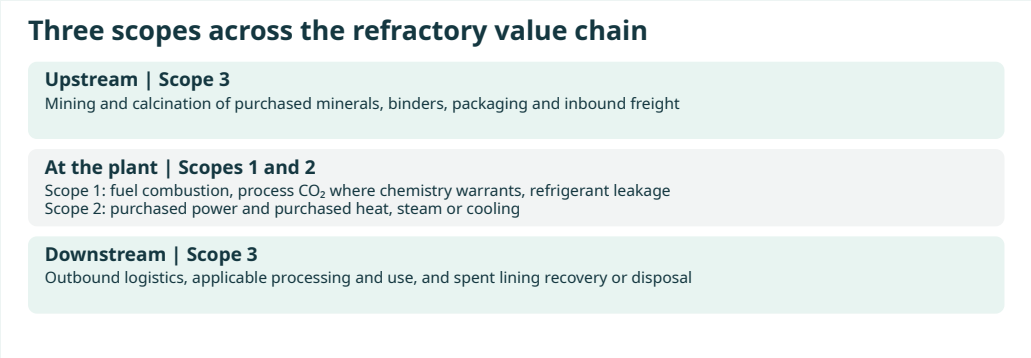
goods. Carbon-containing grades need a chemistry-specific review for carbon losses during production and use. Check wastewater composition and treatment before attributing material methane or nitrous oxide to it. Dust and NO_x deserve air-quality controls and permit monitoring in their own right.

Scope 2 covers purchased electricity and any purchased steam, heat or cooling. Location-based accounting reflects the grid average for purchased power. Market-based reporting reflects eligible contractual instruments and the applicable factor hierarchy. Track who has the renewable attributes, which facility and period can claim them, and the evidence of retirement or cancellation where required. A renewable power contract can change market-based reporting while the same grid-delivered kWh still has a location-based footprint. Keep both figures visible whenever dual reporting applies. Show physically avoided electricity separately from changes in purchased electricity attributes.

Scope 3 starts with purchased minerals and binders. Supplier emissions can vary with ore quality, calcination technology, electricity source, recovery rate, transport and the allocation applied to recycled inputs. Pay particular attention to magnesia, calcined alumina or bauxite, binders and graphite where present. Use supplier-specific data for high-spend and carbon-intensive inputs once quality and comparability are established. Product footprints should record grade, plant boundary, data period, declared unit and allocation method so that a buyer can understand exactly what it is comparing.

Purchasing can change the specification or approved vendor list. The customer has to help qualify reclaimed material for demanding service. Start with traceable spent lining, segregate by chemistry, remove steel and slag, test for contaminants and approve a blend limit grade by grade. Track substitution and service performance

together. Also review inbound and outbound freight, purchased packaging, equipment, waste, travel, commuting, toll processing and product end-of-life. Assess relevant direct use emissions, such as evidenced oxidation in service for specific carbon-bearing grades. Allocate customer process energy only where the accounting method and boundary justify it. A claim that longer lining life avoided the customer's energy or emissions belongs in a separately bounded comparison.



Source: GHG Protocol standards applied to refractory production.

D. The conventional manufacturing challenge

The electricity bill can tell you whether grid procurement deserves attention. It takes production data to tell you whether the plant is buying extra electricity to move dust, run fans against dampers or keep equipment running between jobs. A plant can cut its annual kWh while leaving demand charges practically untouched if its highest coincident peak still occurs when the presses, exhaust fans and mills start together. Meter the demand event and trace which loads caused it before promising a reduction in billed demand.

Thermal losses can be equally stubborn. A kiln can be running safely and still lose fuel through excess air, air leakage, hot exhaust,

poor seals and repeated warm-up cycles. Some operating margin is essential for quality and safe combustion. Tuning by headline oxygen alone can move the problem into carbon monoxide, uneven temperatures or more rejects. Production and engineering should approve trials jointly, with baseline gas, temperature uniformity, exhaust and quality data.

A conventional plant buys most electricity at retail rates and manages burners and suppliers through operational experience. It carries the most exposure to energy-price swings and has fewer records for customers. A transitioning plant has better meters, burner controls, some recovered heat and renewable supply, with an initial supplier footprint programme. An advanced plant integrates heat and power forecasts with production planning, qualifies secondary minerals and can show savings by grade. These profiles describe operating choices. Even an advanced plant can have a higher absolute bill or emissions intensity than another plant if it makes a different, more heat-intensive mix.

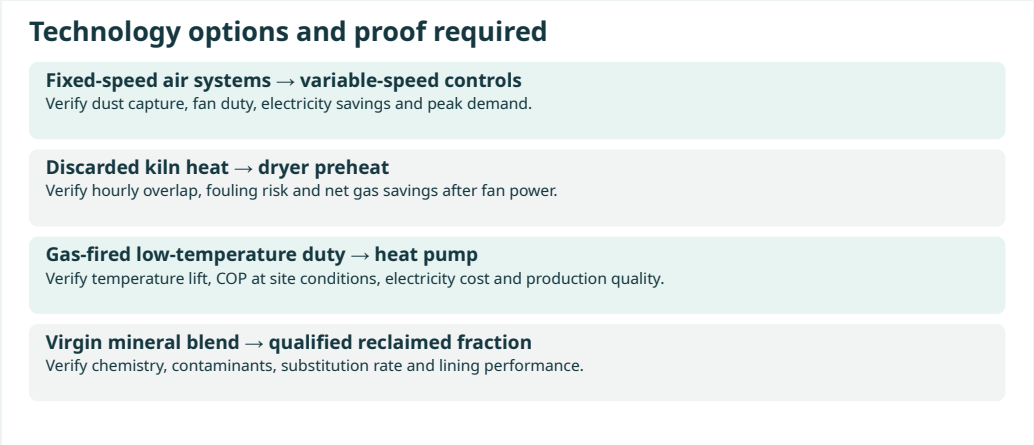
E. Technology alternatives worth pricing

Start by recovering the capacity the plant already owns. Repair compressed-air leaks, set pressures to the lowest compatible level and turn idling machines off when the process permits. Use variable-speed drives where airflow or volume genuinely changes. Maintain dust capture at the required flow at critical points and verify under adverse conditions. A smaller fan bill is of little value if silica-containing dust escapes.

Where kiln exhaust and dryer duty overlap, test heat recovery. A heat exchanger can transfer energy to dryer make-up air without

sending the kiln exhaust through the product. A heat balance should account for actual flow, temperature, fouling, corrosion, fan electricity and the dryer’s hourly heat sink. Include bypasses and maintenance access. Measure useful heat delivered and purchased fuel displaced before approving the next unit.

Industrial heat pumps make most sense where the duty can be met at a modest temperature lift and a stable heat source is available. A low-temperature dryer zone or wash-water loop is a plausible pilot. An electric resistance heater can be simpler for controllable local heat but requires a tariff and transformer check. High-temperature kiln electrification needs a grade trial covering throughput, temperature uniformity, atmosphere, refractory life and outage response. Allow for demand charges, connection upgrades and backup arrangements. Electrification can cut on-site emissions while increasing purchased-power emissions if the power mix is carbon intensive. A biomass or biogas option also needs firm fuel supply, air-permit checks and credible lifecycle accounting. Treat hydrogen as a later option where a specific burner, fuel price, verified emissions and firm supply support the case.



Source: TOPTIER engineering screening, informed by the EU JRC ceramics process reference.

F. Choose renewable power to fit the shift pattern

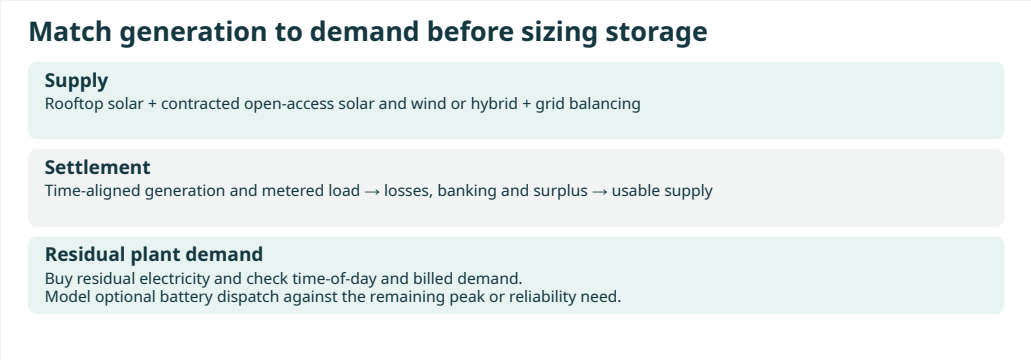
Build a 12-month settlement-interval demand profile, often available at 15-minute resolution, and cross-check it against bills. Retain maintenance days, weekends, seasonal production changes and pre-existing renewable allocations. Rooftop solar may fit daytime grinding and mixing. Wind can improve coverage outside solar hours where the actual project profile supports it. A hybrid contract can improve utilization if the two profiles complement each other at the metered load. Ask developers for timestamped generation and loss assumptions, and back-test multiple weather years. Compare usable energy rather than annual generation quoted at the project meter.

Compare rooftop ownership or a PPA, third-party green open access, captive and group captive on the same year-by-year landed basis. Include energy charges, transmission and wheeling and losses, banking charges and expiry, applicable surcharges, scheduling and imbalance, minimum offtake exposure, credit security and contract exit terms. Add captive equity and compliance costs where relevant. Keep residual DISCOM energy and demand in the model. An attractive source tariff often changes once unused output and grid charges are reflected.

India’s Green Energy Open Access rules generally use a 100 kW eligibility threshold for non-captive consumers, with aggregation conditions under the amended framework, and provide captive consumers a route without the load limit. The March 2026 captive amendment retained the core 26% ownership and 51% financial-year consumption tests and changed the treatment of proportionality and verification in specified structures. Stress-test ownership, eligible consumption and declarations before signing. A

qualification failure can create surcharge and carrying-cost exposure. For a Maharashtra screening, use the MERC open-access register and the applicable MSEDCL orders or the relevant licensee's current schedule for voltage, time of day, banking and settlement. A Maharashtra result cannot serve as a tariff proxy for another state.

Once the hybrid is fitted, test battery storage against the remaining deficit by settlement interval. Peak shaving needs dependable discharge power when billed demand is set. Arbitrage needs a spread large enough to cover charging energy, losses and degradation. Storage for resilience needs isolation, controls and ride-through capability appropriate to the load. Use an availability guarantee, usable capacity at end of warranty and replacement assumptions. An illustrative 1 MW / 2 MWh usable battery operated for 250 full-equivalent cycles at 88% efficiency delivers 500 MWh and needs about 568 MWh to charge. At ₹10/kWh avoided and ₹5/kWh to charge, the gross energy spread is about ₹21.6 lakh/year before fixed costs and degradation. Add bankable demand or reliability value only when the same dispatch can deliver it.



Source: TOPTIER screening method. Apply current state settlement rules.

G. Case study: a hypothetical mixed-line plant

Assume a plant ships 30,000 tonnes a year using 8 GWh of purchased electricity and 80,000 GJ of natural gas. The starting intensities are 267 kWh/t and 2.67 GJ/t. Those figures are hypothetical and represent a particular production mix. The illustrative avoidable grid charge is ₹7.50/kWh. Landed renewable energy costs ₹5.00/kWh applied to usable power, with unused energy and firm billing terms assumed to have been resolved in the screened contract. Gas costs ₹490/GJ on a net calorific basis. The model uses IPCC natural-gas CO_2 of 56.1 kg/GJ and an illustrative grid factor of 0.70 t CO_2/MWh. Replace the grid factor with the appropriate CEA reporting-year electricity factor and document the accounting boundary. No company data, tax benefit or carbon-credit income appears in the case.

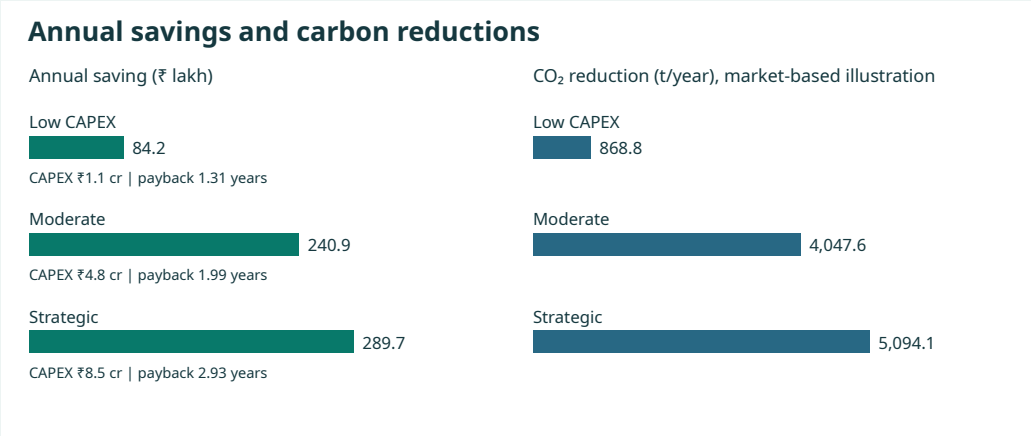
The first scenario reduces electricity consumption by 0.6 GWh and gas by 8,000 GJ through controls, repairs and loading practice. The moderate scenario reaches cumulative reductions of 1 GWh and 16,000 GJ with additional recovery, and supplies 3.5 GWh of the remaining 7 GWh from a matched renewable contract. The strategic scenario improves underlying efficiency by 1.2 GWh and 20,000 GJ, then substitutes heat-pump output for a further 8,000 GJ of gas at 75% boiler efficiency. Six thousand GJ of useful heat at COP 2.5 adds 0.667 GWh. A matched renewable contract supplies 4.5 GWh of the resulting 7.467 GWh. The heat pump serves suitable low-temperature duty in this scenario.

H. What the investment committee sees

Baseline modeled electricity and fuel cost is ₹9.92 crore per year. The moderate case saves ₹75 lakh in electricity efficiency, ₹78.4 lakh in fuel and ₹87.5 lakh from the renewable price spread. The

location-based carbon reduction is 1,598 t CO_2/year, from less power and gas use. The market-based illustration is 4,048 t CO_2/year if the renewable tranche qualifies at a zero generation factor and the residual and baseline factors are modeled at 0.70. Those are two reporting views, and the values should never be added. Procurement matches and operational energy efficiency should be shown separately to the committee.

The chart's CAPEX figures are budget assumptions for on-site measures and integration. Simple payback excludes tax, financing, discounting, variable O&M differences and timing. It assumes a third-party PPA with zero upfront generation investment and no captive equity. An actual captive comparison would include equity, its financing or opportunity cost and any contingent surcharge. A ₹1/kWh smaller renewable spread reduces moderate-case annual savings by ₹35 lakh. A ₹100/GJ gas price decrease cuts savings by a further ₹16 lakh. Under both changes the assumed ₹4.8 crore moderate project pays back in about 2.53 years, versus about 1.99 years at baseline prices. Validate this with vendor guarantees and actual tariff orders before allocating capital.



Hypothetical model based on assumed energy prices and capital costs. Carbon bars use the market-based illustration; location-based figures appear in the table.

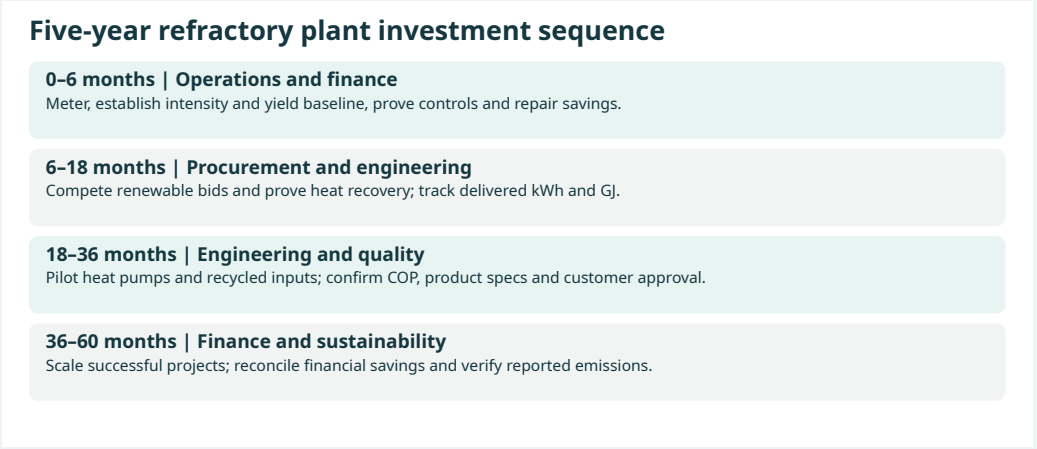
Scenario	Power (GWh/y)	Gas (GJ/y)	Renewables (GWh/y)	Cost (₹ cr/y)	Saving (₹ lakh/y)	CAPEX (₹ cr)
Conventional	8.000	80000	0.0	9.92	0.0	0.00
Low CAPEX	7.400	72000	0.0	9.08	84.2	1.10
Moderate	7.000	64000	3.5	7.51	240.9	4.80
Strategic	7.467	52000	4.5	7.02	289.7	8.50

I. Five years of delivery, in four decisions

In months 0–6, operations and finance should agree on a normalized baseline, assign meter owners and tackle leaks, insulation and standby losses. Measure the change in kWh and GJ per saleable tonne and confirm that yield stays within the agreed limits. In months 6–18, procurement and engineering should put competed renewable bids against the load model, install meters and prove the first recovery project. Track landed cost, utilization, lapsed energy and the buyer’s right to claim renewable attributes.

In months 18–36, engineering and quality should pilot low-temperature electrification and qualified recycled blends. Require a heat-duty meter, operating-cost threshold and performance acceptance criteria from the buyer. In months 36–60, scale projects that worked and consider deeper electrification, storage or fuel substitution against refreshed prices, quality data and supply constraints. Finance and sustainability should reconcile energy

savings to the ledger and carbon claims to meter, fuel and contract records.



Source: TOPTIER implementation roadmap.

J. The future of refractory procurement

The commercial pressure comes from more than energy inflation. A customer comparing furnaces and linings over their service life may ask for the footprint of a specified grade backed by a clear boundary. Develop product data before it becomes a tender gate, and work with customers on the service-performance evidence behind recycled grades. For regulated Indian carbon markets, verify notified entities under the Carbon Credit Trading Scheme’s compliance mechanism and subsequent schedules. Applicability is based on the relevant notified obligations. For listed entities, verify SEBI’s BRSR and BRSR Core requirements by listing rank and reporting year, including the current treatment of value-chain disclosures. An industrial supplier can receive requests for data from customers regardless of whether it directly reports BRSR.

EU CBAM applies by customs classification under its current Annex I. Ordinary refractory bricks under CN 6902 are outside the listed goods in Annex I as checked. Steel customers can still ask suppliers for product-carbon data for procurement and reporting. Check the actual product code and latest EU text at shipment. On site, validate environmental clearance where applicable and the relevant pollution-control consent conditions before modifying fuel, throughput, equipment or stack configuration.

K. TOPTIER’s perspective on business performance

A kiln maintenance project and a renewable power contract compete for the same management time and sometimes the same capital. Rank them by verified effect on cash flow, yield, emissions and production risk. Nail down avoidable charges, credible heat recovery and hourly renewable utilization first. Then price the gaps electrification and storage can address. For a dry-mix plant, shift attention to mineral selection and supplier data earlier. For a mixed plant, keep separate meter and product boundaries so a stronger castable sales month does not disguise wasted kiln fuel.

L. The next tonne is a good place to start

Take one product family and one billing year. Map the fuel, power, material and scrap that went into each saleable tonne. Identify the biggest controllable loss, the strongest renewable supply fit and the supplier change that could make a measurable difference. TOPTIER can help build that baseline, compare landed renewable power bids

and set the technical and commercial gates for a credible five-year plan.

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An effective decarbonization strategy combines energy efficiency, commercial savings, operational reliability and measurable carbon reduction.

References and calculation basis

Sources checked 19 November 2026. Model figures and CAPEX are hypothetical screening inputs. The IPCC fuel coefficient describes combustion CO_2; the case excludes other gases, process emissions and Scope 3.

1. Process and technology (EU JRC BREF, 2007; 2024 revision draft)
2. GHG Protocol Scope 2 Guidance (2015)
3. GHG Protocol Scope 3 Standard (2011)
4. IPCC stationary combustion, Table 2.2 (2006)
5. CEA grid baseline publications, select reporting-year factor
6. Green open access rules, Ministry of Power summary (2023)
7. March 2026 captive amendment, Ministry of Power summary

8. MERC open access regulations, including 2023 second amendment
9. MSEDCL tariff register, including 25 March 2026 Case 75/2025 order
10. Ministry of Power 2023 amendment, connection aggregation
11. MSEDCL open access regulations, procedures and charges
12. BEE carbon market and obligated entities
13. BEE regulations and notified GEI targets (2025 onward)
14. SEBI BRSR Core FAQ (April 2025)
15. EU CBAM Regulation 2023/956 and consolidated versions