How India’s Automotive Lighting Plants Can Cut Energy Costs and Carbon Emissions

TOPTIER ENERGY SERVICES PVT LTD

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A generic automotive headlamp on a fixture in a modern assembly plant

Illustrative image of an automotive lighting line. Industry analysis for plant leaders, CFOs and procurement teams.

A. The headlamp has passed its test. Why is the compressor still working?

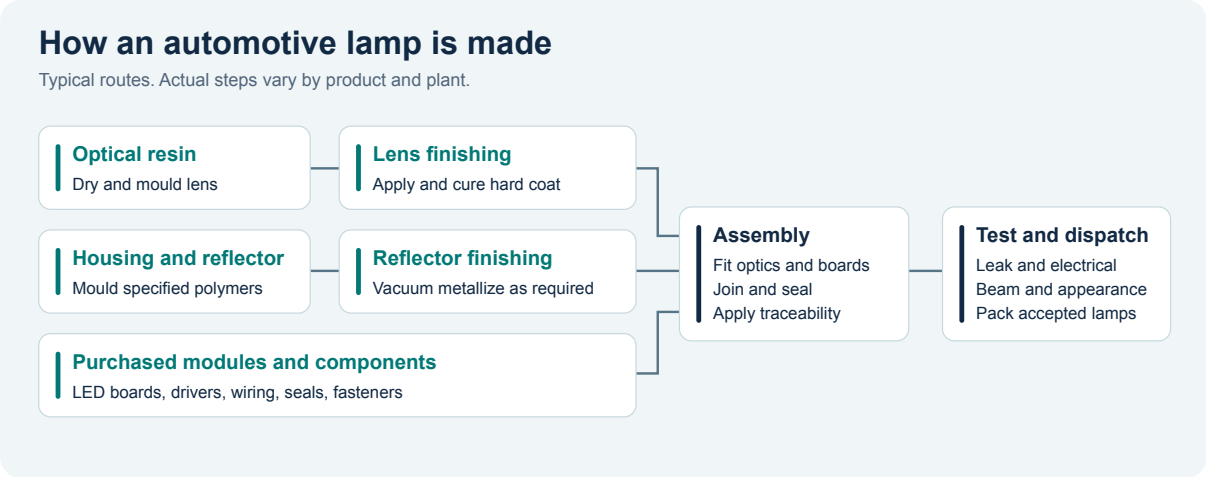
An automotive headlamp can pass its final beam test in seconds. Hours later, the compressor supplying its assembly station can still be running, the chilled-water pumps can still be circulating, and an underfilled coating oven can still be holding temperature. None of that extra

energy makes the beam any brighter. It does, however, become part of the cost of the next lamp.

That gap between electricity purchased and saleable output is a starting point for decarbonizing automotive lighting manufacturing in India. It uncovers bills the plant can reduce directly, and it gives finance a better basis for deciding how much solar, wind or hybrid power to buy. A plant that knows which loads can move, which are quality-critical and which should disappear can negotiate an energy contract around the factory it intends to operate.

B. The hidden energy story inside an automotive lamp

Most finished lamps combine a transparent optical cover, a housing, reflectors or light guides, illumination electronics, seals and fixtures. Moulded parts can include optical-grade polycarbonate or PMMA and engineered housing polymers. Electronic modules, wiring and LEDs may be purchased or assembled on-site. Process routes differ by model, finish and customer qualification. A lens might go through a protective coating step while a separate reflector goes through vacuum metallization. Other designs use different optical architectures. Manufacturing process reference

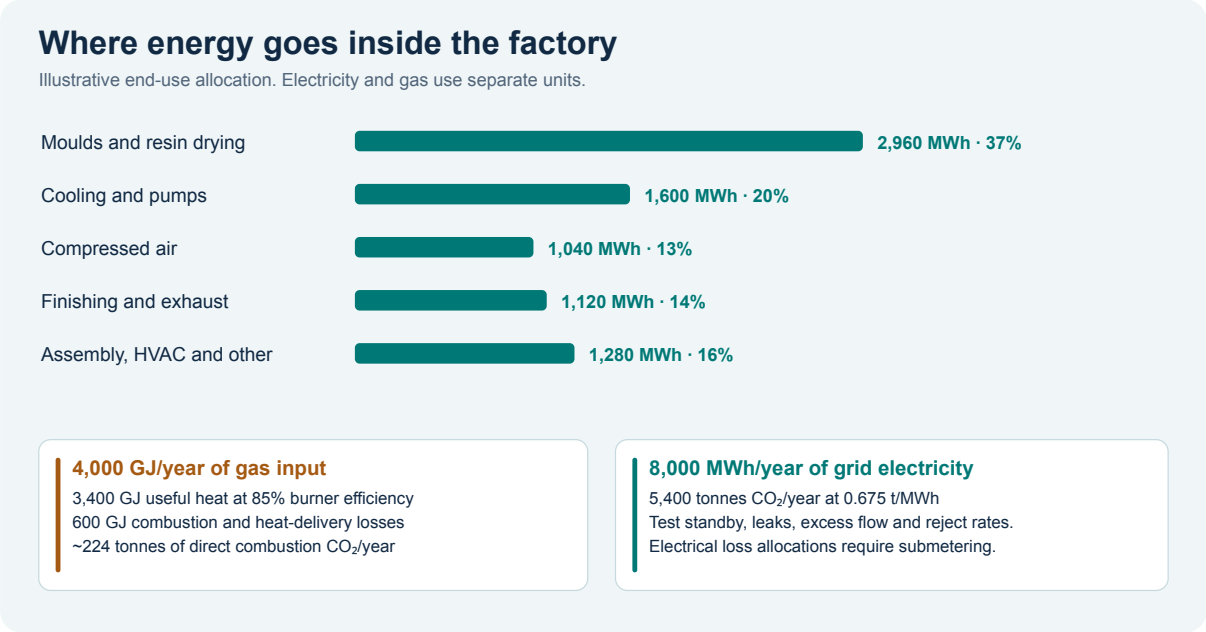


Routes for moulded lenses, metallized reflectors and purchased LED modules converging at lamp assembly

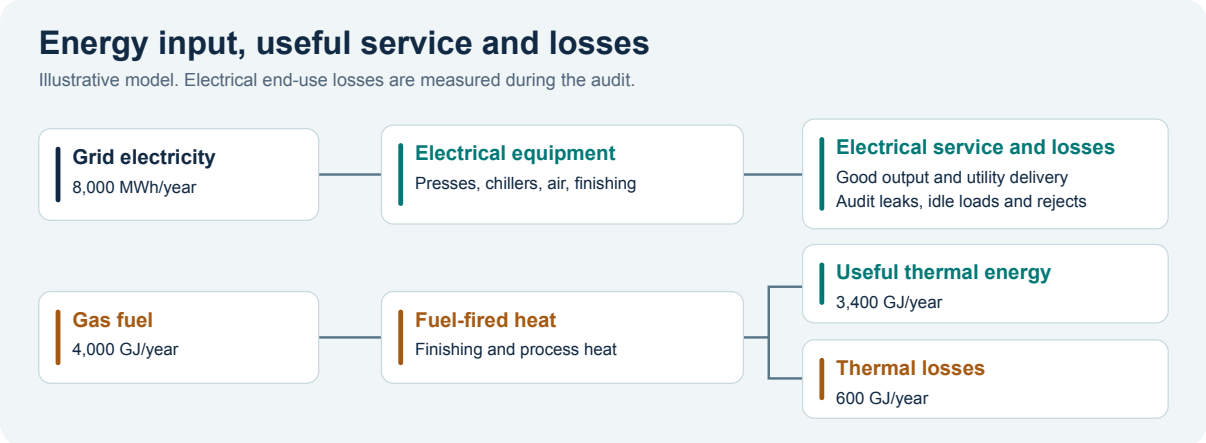
Moulding and drying. A dryer keeps moisture-sensitive resin within its validated range. The press plasticizes and injects it, holds pressure, opens the mould and ejects the part. Tool circuits remove heat during the cooling cycle. Measure press, dryer and cooling power independently. A slow cycle or poor cavity yield can raise energy per good part while the press meter shows a perfectly ordinary kW reading. For comparisons, record shot weight, cycle time, cavity count, polymer grade and accepted weight alongside meter readings.

Finishing and utilities. Vacuum chambers, pumps, coating booths, exhaust fans and curing equipment can draw material energy where these processes are in-house. Heat may come from electric heaters or fuel-fired equipment. Chillers, mould temperature units and compressed air can outlast the production shift. Meter useful delivery as well as input, using chilled-water flow and temperature difference and compressed-air flow and pressure. Measure low-load operation before deciding whether a new compressor or a sequencing change solves the problem.

Assembly and dispatch. Welding, fastening, adhesive dispensing, leak tests, electrical checks and photometry combine modest individual loads with many hours of operation. Retests and rework carry the embedded cost of moulding, finishing and purchased electronics. Track the defect that first caused the rejection. Separately document approved handling of plastic rejects, spent coatings, contaminated wipes, wastewater and electronic scrap. Review treatment and air controls against applicable site consent conditions.



Illustrative electricity and gas allocations by process, including five key electricity users



Grid and gas inputs, equipment, useful heat and measured loss opportunities

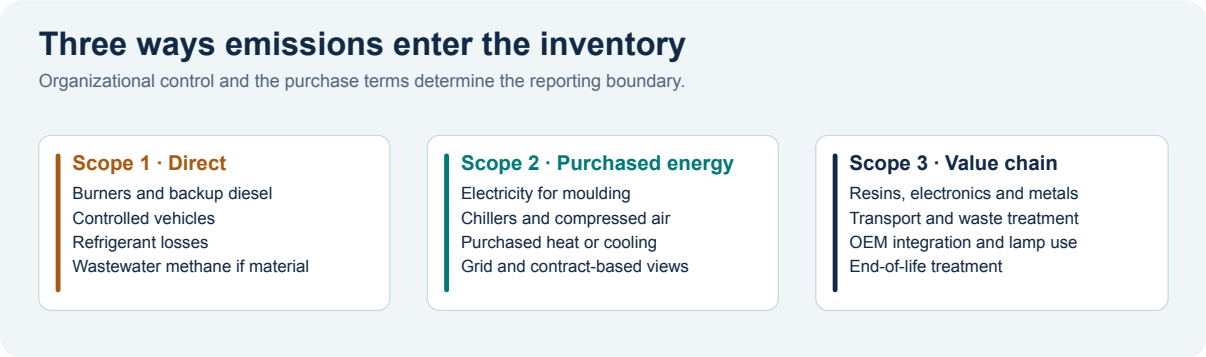
Process	Energy and GHG scope	Loss to test	Engineering response
Moulding and drying	Electricity, Scope 2	Hydraulic standby, excessive residence time, reject parts	Idle states, correctly sized dryers, servo and all-electric comparisons
Cooling and pumping	Electricity, Scope 2	Excess flow, fouled exchangers, setpoints below process need	Loop balancing, cleaning, variable speed, validated reset
Compressed air	Electricity, Scope 2	Off-shift leaks, excess pressure, poorly sequenced machines	Leak survey, zoning, pressure checks, compressor controls
Coating and metallization	Electricity and optional gas, Scopes 1 and 2	Partial batches, exhaust heat, vacuum leaks	Batch sequencing, sealing, exhaust heat recovery where feasible
Assembly, tests and building loads	Electricity, Scope 2	Idle stations, repeat defects, fans on in empty zones	First-pass yield, interlocks, scheduled HVAC
Packaging, storage and freight	Electricity, fuel and purchased services, Scopes 1–3 as applicable	Low load factor, disposable packaging, rejects in transit	Returnable trays, route planning, approved changes

C. Where the carbon footprint comes from

Scope 1 belongs to sources under operational control, such as site combustion, standby diesel, controlled vehicles and refrigerant leakage. An LPG or natural-gas burner emits CO_2 as it supplies process heat. Start with fuel type, lower heating value and purpose. Check whether the heat sink can accept recovered heat or suitable electric heat while maintaining coating adhesion, appearance and cycle time. For a DG set, check run hours, start events and measured fuel. An appropriately engineered UPS or battery may cover a short dip. Extended outages call

for a separate reliability study. Track refrigerant additions, retirement and leakage with equipment-specific refrigerant and GWP factors. Screen on-site wastewater methane where the treatment configuration warrants it. Solvent-related VOC control is a distinct air-quality workstream.

Scope 2 covers purchased electricity and any purchased steam, heat or cooling. Location-based reporting uses grid-average factors appropriate to the geography. Market-based reporting uses qualifying supplier or contractual data and applies the relevant GHG Protocol factor hierarchy for remaining electricity, including a residual mix where available. In applicable markets, report both. Specify who owns the environmental attributes, what may be retired or cancelled, the generation vintage and relevant market boundary. A contractual renewable claim requires evidence of exclusive ownership and compliance with applicable quality criteria. The electricity bill, energy settlement and emissions disclosures should reconcile even though each answers a different question. GHG Protocol Scope 2 Guidance



Scope 1 site fuel, Scope 2 purchased electricity, and Scope 3 materials, logistics, use and end of life

Scope 3 follows the product upstream and downstream. Begin with a weight- and spend-based estimate for plastic, electronics and metals. Spend is a useful screening tool when supplier data are sparse. Progress to grade-specific, boundary-consistent footprints for major suppliers. Comparing an optical resin with a different recycled grade requires approval for optical clarity, weathering and reliability. Start recycled-content trials where the specification and OEM validation allow it, often with packaging or non-optical components in suitable designs. To screen use-phase emissions, estimate electrical draw by lamp function, annual hours, vehicle lifetime and energy pathway. Allocate only the lamp-related energy within the chosen boundary. Use OEM data to test assumptions and show the uncertainty. GHG Protocol Scope 3 Calculation Guidance

Category	Lighting industry screening and action
1 Purchased goods and services	Likely high. Calculate resin, PCBs, aluminum, coatings and packaging footprints. Manufacturer sets specifications, suppliers provide primary data.
2 Capital goods	Include purchased moulds, presses, test systems and major infrastructure. Procurement obtains equipment footprints.
3 Fuel- and energy-related activities	Screen fuel extraction, upstream electricity and transmission losses outside Scopes 1 and 2. Match factors to actual fuel and supply routes.
4 Upstream transport and distribution	Include inbound freight and eligible shipper-paid outbound freight. Collect load, distance and mode from carriers.
5 Waste generated in operations	Track scrap, sludge, packaging and vendor treatment by actual routes. Segregate clean polymer and obtain manifests.
6 Business travel	Collect air, rail, road and accommodation data as relevant. Apply travel policy.
7 Employee commuting	Survey shifts, distances and modes. Coordinate pooled shuttles where feasible.
8 Upstream leased assets	Screen leased equipment and space outside operational Scopes 1 and 2. Confirm landlord data.
9 Downstream transport and distribution	Screen post-sale freight and warehousing outside Category 4. Coordinate with customers.
10 Processing of sold products	Screen applicable OEM integration of intermediate components. Agree allocation with the OEM.

Category	Lighting industry screening and action
11 Use of sold products	Screen electricity use over service life and assess applicable direct and indirect use-phase accounting. Model by function and vehicle pathway with the OEM.
12 End-of-life treatment	Model lamp BOM, expected disposal and dismantling pathways. Evaluate design for repair and disassembly with the OEM.
13 Downstream leased assets	Include applicable leased-out assets beyond operational boundary. Screen contracts.
14 Franchises	Generally low relevance to a pure Tier 1 supplier. Verify business structure.
15 Investments	Screen unconsolidated holdings under the reporting approach. Finance documents coverage and exclusions.

D. What three otherwise similar plants would do differently

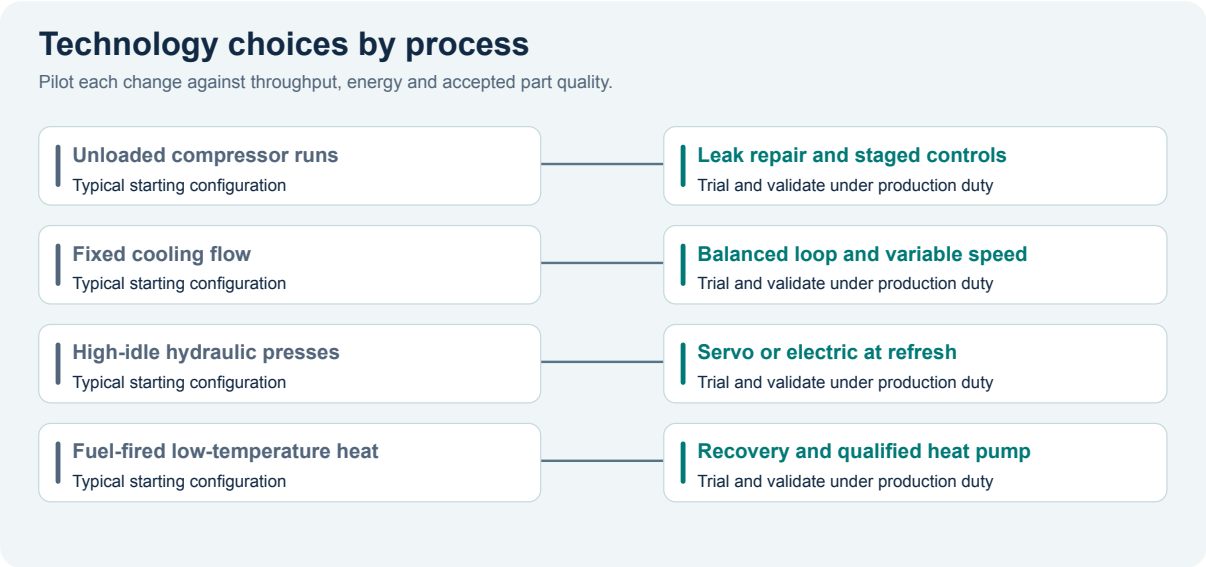
Illustrative operating profile	Energy and carbon position	Management consequence
Conventional	Grid-heavy electricity, fuel-fired heat where installed, bill-level monitoring and price-led materials sourcing	Higher exposure to tariffs and leakage. The budget cannot explain which line drove the change.
Transitioning	Submetering, targeted upgrades, partial renewables, heat recovery and initial supplier data	Lower variable costs where changes are verified. Exposure remains in unserved hours and input materials.

Illustrative operating profile	Energy and carbon position	Management consequence
Advanced	Energy per good part, time-matched renewable procurement, qualified electrification and supplier-specific carbon data	Stronger control of energy and disclosure risks. More demanding engineering, contract governance and data validation.

A factory can look efficient on an annual kWh trend during a slow year even while energy per delivered lamp deteriorates. Compare like-for-like product families and normalize for output mix and operating time. Finance should see kWh per thousand accepted lamps, consumption during unoccupied hours, monthly demand and actual landed cost. Where moulded-part weight changes materially, kWh per accepted kilogram helps explain what happened. The plant team should also see its first-pass yield, because an efficiency project that creates more rejects can raise both cost and carbon.

Delaying that work leaves the next contract exposed to avoidable load. It also makes it harder to substantiate customer requests for product footprints, primary supplier data and renewable sourcing. Exposure is commercial even where a factory has no immediate direct carbon-price obligation. A defensible cost and carbon record can support supplier qualification and conversations with lenders without assuming an automatic pricing premium.

E. Practical technologies for the next investment cycle



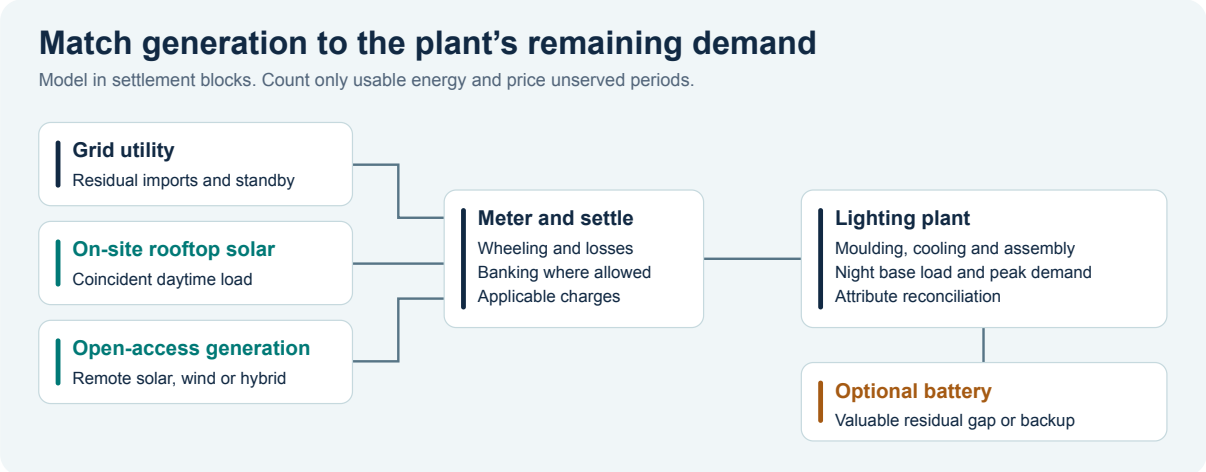
Conventional production and utility equipment matched with practical lower-energy alternatives

1. **Tighten air and cooling first.** Run an off-shift compressed-air leak test, repair the highest losses and isolate unused branches. Validate air pressure at the point of use and tune controls after fixing leaks. The US DOE documents leaks sometimes wasting 20–30% of compressor output. Treat it as a diagnostic range for poorly maintained systems. Electrical savings depend on control response. Chiller and pump optimization also needs a quality trial through the hottest working conditions. US DOE compressed-air sourcebook
2. **Test the moulding cell as a system.** Compare a tuned existing hydraulic press with servo or all-electric equipment using the same product, cycle, accepted output and auxiliaries. An MIT study gives selected machine-only historical comparisons of roughly 0.94, 0.46 and 0.41 kWh/kg for hydraulic, hybrid and all-electric machines. These values exclude the grid energy penalty and are suited to understanding technology differences. Obtain vendor guarantees on a validated cycle and plan substitutions at tooling or asset refresh. MIT injection moulding study
3. **Use recovered heat where there is a dependable sink.** A heat exchanger can preheat make-up air or a low-temperature water loop where duty overlaps. Check contamination, corrosion, pressure drop and maintenance. A heat pump needs a stable evaporator source and a suitable delivery temperature. Test seasonal COP, electrical headroom and downtime contingencies. The model below uses a low-temperature heat sink. High-temperature cure requirements may need a different design and qualification.

4. **Protect throughput during any redesign.** Set controls for coating windows, dew point, mould temperature, vacuum and first-pass yield before commissioning. Compare electric resistance heat, gas and heat pumps on delivered useful heat and on hourly electricity cost. Biomass or biogas can be screened where adequate thermal demand, compliant infrastructure and dependable sustainable supply exist. Hydrogen is difficult to justify for modest low-temperature loads while heat recovery or a heat pump remains viable. Verify performance at the production shift level.

F. Buy renewable power against the remaining load

Start with a twelve-month load duration and settlement profile, including weekends, holidays and maintenance. Test rooftop solar against coincident daytime demand after efficiency measures. Then compare solar-only, wind-only and hybrid open-access portfolios against the remaining demand in the relevant state settlement blocks. Wind generation can contribute outside solar hours when the proposed sites and seasons support that pattern. Price the leftover utility energy and any export, curtailment or banked energy separately. Optimizing the annual share alone can create a surplus that the plant never gets to use.



Grid, rooftop solar and remote solar and wind supplying a plant, with optional battery after load matching

Compare procurement models on landed cost. A third-party green open-access contract may avoid an equity investment. Captive ownership can offer more control and carries asset risk. Group captive adds equity, compliance and counterparty exposure. Include energy price, applicable wheeling and transmission charges and losses, scheduling and deviation, banking, surcharges, retained utility demand, standby costs, expected surplus and capital at risk. Ask who absorbs losses when a project under-generates, when a factory temporarily shuts, or when a captive user exits. The central green open-access rules set a 100 kW threshold for eligible non-

captive consumers, including qualifying aggregation within the same electricity division. Captive consumers have a load-limit exception in the central rules. Use the applicable state and utility procedures for execution. Ministry of Power green OA amendment

Build compliance into the financial model. India's amended Rule 3 under the Electricity Rules, 2005 retains minimum captive ownership of 26% and annual captive consumption of 51%. Apply these tests to the relevant structure and generating unit(s). The March 2026 amendment includes specific provisions for associations of persons, SPVs, and verification. Track user-wise admissible consumption and ownership throughout the year. For a Maharashtra facility, pull its actual HT category, time-of-day schedules and billing basis from the latest applicable MERC order, along with the notified open-access rules and any subsequent directions. The separately listed MERC BESS draft warrants a check for any superseding notified provision before investment. 2026 captive amendment · MSEDCL tariff orders · MERC notified OA regulations · MERC draft regulations

Size BESS from a service you can value. A 500 kW gap lasting two hours needs 1 MWh usable discharge at the AC boundary. At 85% AC round-trip efficiency, charge energy is about 1.18 MWh. At ₹4 per charging kWh and ₹9 per displaced kWh, the energy-only margin is about ₹4,300 per full discharge before storage capital, O&M, degradation and other charges. Add verified demand and reliability benefits or binding requirements and test whether the benefits can coexist in the dispatch schedule. Capacity must account for state-of-charge limits, inverter power, reserve and end-of-life warranty. Separate shifting from backup and check islanding and critical loads. If renewable matching and load scheduling already cover most valuable hours, a battery gets fewer profitable cycles.

G. A representative plant business case

Imagine a hypothetical factory using 8,000 MWh a year and 4,000 GJ of gas with a 1.8 MW peak. Its average electrical load is 0.91 MW and its implied annual load factor is 51%. For screening, the plant runs two shifts on most production days and retains critical utilities overnight. The profile is conceptual. The delivered rooftop and open-access volumes below are assumed and require interval-level validation. Assume an avoidable grid energy charge of ₹8.50/kWh, a landed open-access price of ₹5.50 per usable settled kWh and gas at ₹1,050/GJ. The bill model holds utility demand charges and taxes flat. The baseline modelled variable energy cost is ₹7.22 crore per year.

Scenario A corrects compressor sequencing, chiller schedules, idle loads and metering. Scenario B expands equipment optimization, recovers useful heat, installs rooftop solar and uses a hybrid contract. Scenario C adds selective press upgrades, deeper heat recovery and a qualified heat-

pump retrofit. A battery remains a dispatch and reliability option outside the base case. The moderate and strategic examples use third-party OA pricing. Group captive needs separate equity and compliance cash flows.

H. Comparing the investment cases



Scenario comparison of capital, net annual savings, payback and Scope 1 and market-based Scope 2 reductions

Annual or one-time metric	A · Quick wins	B · Efficiency and renewables	C · Electrification and renewables
Gross efficiency savings, MWh/yr	600	950	1,400
Added heat-pump load, MWh/yr	0	0	157

Annual or one-time metric	A · Quick wins	B · Efficiency and renewables	C · Electrification and renewables
Gas avoided, GJ/yr	0	800	3,000
Rooftop generation consumed, MWh/yr	0	600	850
OA energy settled and used, MWh/yr	0	3,200	4,200
Remaining utility purchases, MWh/yr	7,400	3,250	1,707
CAPEX / incremental OPEX, ₹ lakh	40 / 4	320 / 12	570 / 24
Net operating savings, ₹ lakh/yr	47.0	224.2	311.4
Scope 1 combustion CO_2 reduction, t/yr	0	45	168
Location-based Scope 2 CO_2 reduction, t/yr	405	1,046	1,413
Market-based Scope 2 CO_2 reduction, t/yr	405	3,206	4,248
Simple payback, years	0.85	1.43	1.83

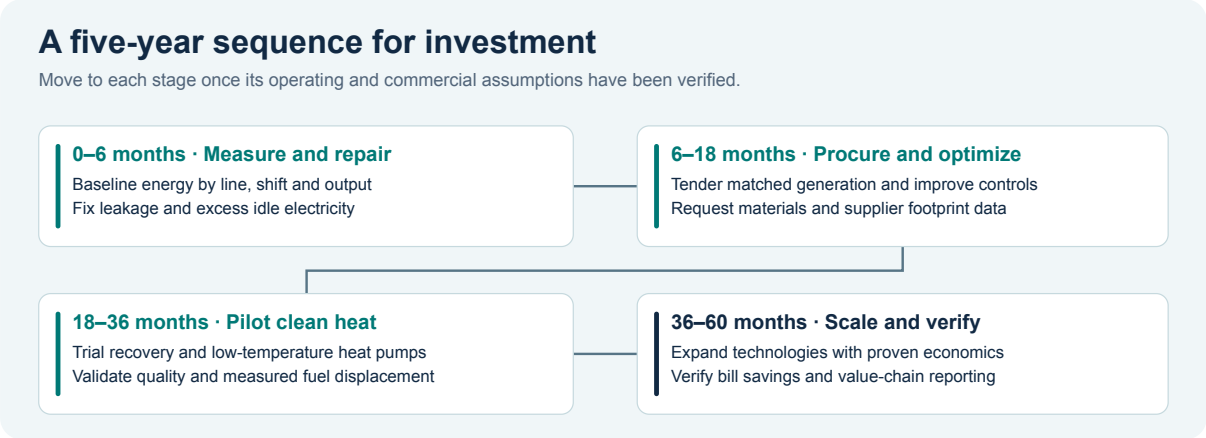
Annual or one-time metric	A · Quick wins	B · Efficiency and renewables	C · Electrification and renewables
10-year NPV at 10%, ₹ lakh	249	1,057	1,343
Illustrative pre-tax project IRR	117.5%	69.7%	53.9%
Levelized cost, ₹/t CO_2 reduction, market-based accounting	−9,998	−5,293	−4,951
EBITDA margin uplift at ₹200 crore sales, percentage points	0.24	1.12	1.56

Net savings equal avoided utility purchases, less OA purchases, plus avoided fuel, less incremental O&M. Scenario C recovers heat equivalent to 1,000 GJ of fuel and replaces 2,000 GJ of gas input. At 85% burner efficiency and heat-pump COP of 3, its added electricity is 2,000 × 0.85 ÷ 3 ÷ 3.6 = 157 MWh. A 0.675 t CO_2/MWh illustrative grid proxy and 0.0561 t CO_2/GJ natural-gas combustion factor underpin the carbon calculations. Market-based modelling assumes qualifying attributes for rooftop and OA power and uses the same grid proxy for unmatched purchases for illustration. The location-based model applies the average to all electricity delivered through the grid, including OA, and recognizes self-consumed onsite generation in this ownership case. The two columns represent alternative accounting views and should be read independently. Scope 3 initiatives carry no quantified benefit in this case. A negative levelized cost means the annualized capital cost is below net operating savings per tonne under the stated inventory boundary. Investment returns assume flat, year-end cash flows, upfront CAPEX, ten years of service and no residual value, tax, financing, replacement or escalation. The model uses combustion CO_2 and an electricity CO_2 proxy rather than a full multi-gas inventory. CEA database · IPCC energy guidance · GHG Protocol Scope 2 Guidance

At a ₹1/kWh increase in OA landed cost, Scenario B loses ₹32 lakh in annual savings and its payback extends to about 1.67 years. At 25% less bill-offsetting OA energy with the supplier still paid for contracted volume, it loses ₹68 lakh a year on the assumed grid rate before surplus recovery. This is why the contract’s volume and settlement terms deserve as much attention as quoted capacity. A suits a capital-constrained plant. B balances payback and cash savings in the

model. C can justify its extra capital where suitable heat sinks, stable uptime and a credible contracted supply persist. Compare C incrementally with B to avoid claiming the same efficiency or renewable saving twice.

I. Five-year delivery roadmap



A five-year automotive lighting decarbonization roadmap across four implementation phases

Timing	Accountable teams	KPI and decision dependency
0–6 months	Plant engineering with Finance and Quality	High priority. Build an interval baseline and reduce off-shift kW. Track accepted units and defect rates to validate bill savings.
6–18 months	Power procurement with Legal, Finance and Quality	High priority. Track OA units actually settled, landed ₹/kWh and retained attributes. Confirm connectivity, metering and commissioning. Ask major suppliers for BOM-level data.

Timing	Accountable teams	KPI and decision dependency
18–36 months	Process engineering, EHS and OEM quality	Medium/conditional. Pilot heat recovery and electrification. Track useful GJ, COP, line yield and audited GHG factors. Require process acceptance.
36–60 months	COO, procurement and sustainability	Conditional scale-up. Report absolute Scope 1–3, kg CO_2e per approved SKU and supplier primary-data coverage. Expand qualified measures and verify cost and carbon outcomes.

J. Reporting and export exposure

SEBI's BRSR framework applies to the top 1,000 listed entities by market capitalization. BRSR Core assessment or assurance follows its separate phase-in. The March 2025 circular puts top-250 value-chain ESG disclosure on a voluntary basis from FY 2025–26 and associated assessment or assurance on a voluntary basis from FY 2026–27. Customer requests for data may extend faster than issuer reporting mandates. India's Carbon Credit Trading Scheme compliance mechanism applies to notified obligated entities and their applicable targets. Screen current lists for the specific legal entity and facility before putting a carbon-credit quantity in a proposal. EU CBAM follows the applicable Annex I goods codes. Finished automotive lamps classified under CN 8512 are outside the current product list reviewed. Separately traded in-scope aluminum or steel goods and changing customer requirements merit independent checks. SEBI circular · BEE Indian Carbon Market · EU CBAM sectors and guidance

LED and adaptive optics change the cost, electronics content and use-phase draw of a lamp. Modular designs, validated lower-carbon materials and better supplier evidence give engineering and commercial teams more levers over lifetime emissions. Build the footprint at SKU or product-family level, with an explicit functional unit, service life and allocation method. This gives customers something more actionable than a single corporate intensity figure.

K. TOPTIER’s Perspective: Decarbonization Should Improve Business Performance, Not Just Sustainability Reports.

Authorize metering and repair where the plant is already paying for losses. Use the resulting profile to size renewable contracts. Test clean heat only where useful heat, temperature and quality constraints are known. Keep working capital, captive compliance and plant reliability visible beside the PPA rate. Approve storage when the remaining mismatch or resilience requirement supports quantified service value. A project should survive a downside test on operating hours, tariff, availability, product mix and output. After commissioning, reconcile actual savings and carbon claims against the signed baseline.

L. Start with the energy it takes to ship one good lamp

An OEM buys the lamp that passes its tests and reaches the assembly line. Every failed part, unneeded overnight utility load and unused renewable unit widens the distance between the plant’s electricity bill and the product the customer pays for. Begin with twelve months of bills, interval demand and good-output records. These reveal where engineering can protect margin and what procurement can deliver at the meter.

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> “The most effective decarbonization strategy is not necessarily the one with the most advanced technology. It is the one that delivers the right combination of energy efficiency, commercial savings, operational reliability, and measurable carbon reduction.”