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How India’s Capsule and Pharma Packaging Plants Can Cut Energy Costs and Carbon

The capsule shell leaving the dryer weighs almost nothing. The plant has still paid to condition thousands of cubic metres of air, move that air through filters, and remove moisture at a controlled rate. In a blister-material plant, the roll ready for dispatch tells a similarly incomplete story. Electricity, heat and virgin material may already have been spent on edge trim and rejected runs.

For a CFO, the opportunity starts with the cost of a million saleable capsules or a tonne of approved barrier material. For a plant head, the same calculation comes with a condition: the product still has to meet its validated requirements. Putting energy, yield and quality on the same dashboard shows where those two priorities reinforce one another.



Generated editorial illustration of a generic facility.

The hidden energy story inside pharmaceutical component plants

Empty hard capsules are formed around pins. A prepared gelatin or HPMC solution coats the pins, and the coating is then dried, stripped and trimmed. Caps and bodies are brought together for inspection and packing. Uniform air distribution, moisture control and line speed affect how much saleable product each run yields. The fans and conditioning equipment that protect that quality can remain significant electrical loads, especially when utilities continue to serve idle areas.

Barrier films and foils follow a different route. Depending on how integrated the factory is, processes can include film extrusion, coating, lamination and curing. Slitting and quality inspection prepare reels for dispatch. Customers downstream may heat and form polymer films into cavities or cold-form a laminate containing aluminium. Those customer operations belong on the value-chain map. The converter’s own meter registers its extrusion, drives,

coating and drying duties, chilled water and extraction where applicable. USITC capsule production · Pharmaceutical packaging lifecycle study

Hard capsule shells

Gelatin or HPMC → solution preparation → pin dipping → conditioned drying → strip, trim and join → inspect and pack

Blister materials

Polymer and foil inputs → film production where integrated → coat or laminate and cure → slit → inspect and dispatch

Utility inputs

Conditioned air, chilled water, process heat, drives and compressed air enter at different stages.

Manufacturing pathways. Individual formulations and line configurations vary.

Map the hot-water and air systems before buying equipment. Capture when a dryer starts, how long it spends warming up, when the line is productively loaded, and how long exhaust continues after the last good unit. At the same time, log humidity, chilled-water temperatures, supply and return airflow and batch rejects. Compare similar SKUs and weather conditions. A humid monsoon shift and a dry winter shift can look like two different factories if the comparison ignores the moisture load.

Electrical input · 10 GWh

4 HVAC and dehumidification → controlled air; 2 chilled water and process cooling → temperature control; 2.3 production lines and drives → forming and conversion; 1.7 air compression and other loads.

Gas input · 20,000 GJ

8,000 dryer air/reheat + 5,000 solution and washwater heating + 3,400 coating or other duty → 16,400 GJ modeled useful heat; 3,600 GJ modeled conversion and distribution losses.

Emission pathways

Electricity → grid generation emissions. Gas → combustion emissions. Material yield and rejects → additional upstream footprint per good unit.

Illustrative final energy allocation. Electricity categories are metered end-use buckets designed to avoid overlap. Electrical end-use losses are not separately quantified.

Where the carbon footprint comes from

Scope 1 starts with fuels burned on site. A natural gas boiler may supply hot water for solution preparation or dryer heating. Diesel backup and refrigerant leaks can also matter. Where coating uses solvents, the emissions inventory and the air-quality inventory serve different purposes. Capture solvent use separately and quantify combustion or process GHGs where the treatment process emits

them. Check on-site wastewater treatment for methane or nitrous oxide where the system design makes these relevant.

Scope 2 captures emissions from acquired electricity, steam, heat and cooling. Location-based reporting applies the grid factor to electricity drawn from the relevant grid. Market-based reporting uses qualifying contractual instruments, including certificates where applicable, and a suitable factor for uncovered purchases. Eligible instruments must meet the Scope 2 quality criteria, including exclusive claims and appropriate market and vintage. Keep retirement records, specify ownership of the attributes in the PPA and reconcile the claimed MWh with consumption. An open-access allocation may reduce the bill while its environmental attributes are assigned elsewhere. GHG Protocol standards · Scope 2 Guidance

Scope 3 can start with the bill of materials. Aluminium production, polymer resins, the inputs used to produce gelatin and cellulose derivatives, cartons and outsourced components can all affect the result. Ask suppliers for the manufacturing geography, product footprint boundary, electricity assumptions and allocation approach. Screen all 15 categories for applicability, then deepen the data for purchased goods, upstream energy, inbound freight, waste, downstream processing and end-of-life where relevant. Include capital equipment, commuting, travel and other categories where material. Ownership of freight and the position of the customer in the chain matter for classification. Model a lighter laminate on equivalent barrier performance, shelf life and reject rates. A comparison per kilogram alone can favour a design that consumes more material per functional pack or raises medicine loss.

Scope 1 · On site

Gas combustion, diesel, cooling system leaks and material process sources.

Scope 2 · Purchased energy

Grid and acquired power, heat, steam or cooling. Track both accounting methods where required.

Scope 3 · Value chain

Gelatin or HPMC, polymers, aluminium, logistics, scrap management and downstream use or disposal as relevant.

Representative source map using GHG Protocol boundaries.

Where conventional operations cost the most

A facility that cools outdoor air below its dew point and then reheats it can add cooling and heating loads in the same air-handling system. Reheat may be essential for the required moisture level. Heat recovery, coil selection, dew-point control and validated scheduling determine how much energy the arrangement consumes. Log simultaneous cooling and reheat before deciding whether to work on the chiller, boiler or air system first.

The coating and converting line presents a different challenge. Lower utilisation increases the amount of warm-up energy and start-up scrap per approved tonne. Changeover sequencing, tension control and in-process inspection can reduce losses. Any change in coating dryer airflow must satisfy product validation and the solvent ventilation and safety requirements for the actual process. Capture

the cost of material, waste treatment and rejected output alongside the energy bill.

Business-as-usual also leaves procurement exposed to grid tariff and fuel-price changes. Product-level carbon requests from customers may arrive before a factory has the supplier records to respond. Financing and procurement teams can gain more from a traceable improvement baseline than from broad claims about an upgraded plant. A credible baseline gives the CFO a way to test whether a project improved margin after changes in production volume, product mix, weather and the price of energy.

Technology options for plant teams

Existing duty	Practical replacement or upgrade	What to verify before approval
Fixed-speed fans and continuous air conditioning	Validated scheduling, airflow reset, efficient fans and variable-speed drives	Maintain differential pressure, product moisture and room conditions through changeovers and low-load periods.
Boiler-supplied wash water or low-temperature reheat	Recover chiller condenser heat and use a heat pump for remaining compatible duties	Confirm coincident source and sink, seasonal COP, sanitation temperature and backup capacity.
Chillers operating at fixed chilled-water settings	Plant sequencing, condenser optimisation and chilled-water reset within process limits	Check dew-point requirements in monsoon conditions and measure plant kW/TR at part load.
Fuel-fired high-temperature duty	Insulation and heat recovery first, followed by electrification where temperature and economics permit	Check power capacity, outage plan, temperature lift, hourly marginal cost and carbon.
Compressed air for cooling or blow-off	Leak repair, lower pressure where validated, and fan-based solutions where suitable	Trend compressor kWh and line pressure. Protect validated product-contact requirements.
Long changeovers and multilayer trim	Sequence orders, optimise width and reduce off-spec coating and lamination	Keep barrier, sealing and stability requirements in the approval criteria.

Heat recovery is commercially strongest where heat supply and demand overlap. Start with a logger on both sides of the proposed exchanger. Use closed-loop separation wherever process hygiene

requires it. Check that exhaust-side recovery can operate without contamination, excess pressure drop or unsafe solvent conditions. Low-temperature heat pumps and high-temperature electric boilers are both commercially available. Their operating economics differ because a heat pump transfers heat and an electric boiler primarily converts electricity to heat. Pharmaceutical energy efficiency guide · UNECE industrial heat pump assessment

For steam or higher temperatures, compare proven heat recovery, an electric boiler, and available low-carbon fuel options on useful-heat cost and reliability. Biomass or biogas needs credible sourcing, local emissions controls, supply continuity and lifecycle accounting. Hydrogen is a low-priority screen for this illustrative facility because the core opportunities involve conditioned air, cooling and low-temperature heat. Track the delivered cost and real emissions of each fuel when and where it would be used.

Procure renewables against the load that remains

Pull a full year of interval data, including idle periods and monsoon peaks, and model the load after efficiency changes. Overlay rooftop solar on daytime load. Then test off-site solar and wind separately and together. Wind may cover some evening, night and seasonal demand, depending on the actual project profile. Ask bidders to provide time-stamped generation, guarantees, downtime assumptions and the settlement waterfall. Compare the cost per usable kWh after charges, losses, curtailment, banking and surplus lapse.

Daytime

Serve the coincident load with self-consumed rooftop solar where suitable.

Day, evening and night

Match off-site solar and wind to residual consumption by settlement block.

Residual demand

Use grid supply. Screen storage only for demonstrated peaks, outages or a positive dispatch spread.

Dispatch sequence for a continuous industrial customer. Validate contract rights, attribute ownership and actual billing settlement.

A third-party green open-access PPA can fit consumers seeking contractual supply without generator equity. Captive ownership puts the capital and operating exposure with the owner. Group captive can spread investment and introduce equity and ongoing compliance commitments. Compare landed cost, balance-sheet exposure, exit provisions, change-in-law allocation, payment security, and environmental attribute rights. The national green open-access framework sets a 100 kW eligibility threshold for relevant non-captive consumers, with aggregation provisions and a captive exception. The amended captive rules maintain the 26% ownership and 51% consumption tests, with updated group rules and verification. Evaluate the site using the applicable state rules, tariff order and nodal agency procedure. For Maharashtra, check MERC's notified rules, MSEDCL's tariff orders and actual billing treatment. MERC lists its 2026 distribution open-access and BESS proposals under draft

regulations. Ministry of Power green open access · 2026 captive amendment · MERC current open access rules · MERC drafts · MSEDCL tariff orders

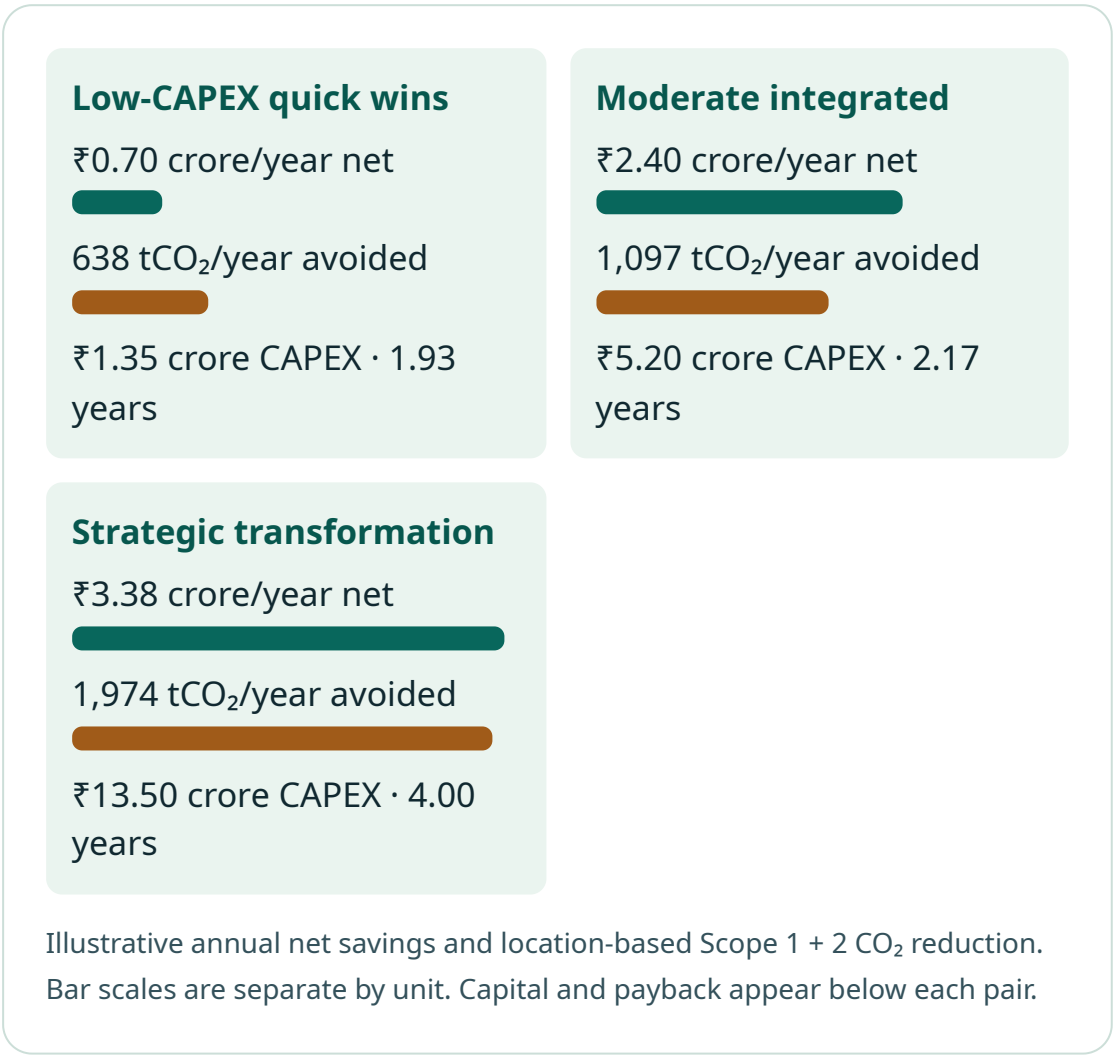
Use a battery only if the residual time blocks justify one. A 1 MW/2 MWh battery delivering 2 MWh at 85% round-trip efficiency needs about 2.35 MWh of charging energy. At ₹5/kWh charging cost and ₹10/kWh avoided energy cost, the gross benefit is about ₹8,235 per full cycle before degradation, losses already reflected in the charging quantity, operating costs and finance. At 250 cycles that is about ₹20.6 lakh a year before adding any demonstrated demand or outage value. Billing demand savings require evidence that storage will reliably cover the peaks that set the bill. Critical-load backup needs its own dispatch and resilience design. A storage investment case should also check whether battery charging would displace renewable energy the plant already consumes directly.

How the economics work for an illustrative Indian plant

Assume a composite plant uses 10 GWh of grid electricity and 20,000 GJ of natural gas per year. Its peak is 2 MW, with about 57% calendar load factor. The model assumes production and quality systems operate across shifts, with rooftop solar used in daytime and off-site purchases sized to usable contracted supply. These are illustrative assumptions. An investment-grade study requires time-block meter data, the local bill and project bids.

The quick-win package saves electricity through air and chiller optimisation and gas through heat-loss control. The integrated package widens those measures, adds heat recovery and purchases 4 GWh of usable off-site renewables. The strategic package further improves electric efficiency, replaces 5,000 GJ of boiler fuel through a

heat pump and supplies 1 GWh from self-consumed rooftop solar plus 4 GWh of off-site renewables. It also starts a supplier data and material-yield programme. No financial or Scope 3 savings from this programme are included in the model.



Illustrative annual net savings and location-based Scope 1 + 2 CO_2 reduction. Bar scales are separate by unit. Capital and payback appear below each pair.

Measure	Conventional	Quick wins	Moderate	Strategic
Electricity used (GWh)	10.00	9.20	8.80	8.98
Gas input (GJ)	20,000	19,000	16,000	11,000
Billed utility energy / OA / rooftop (GWh)	10.00 / 0.00 / 0.00	9.20 / 0.00 / 0.00	4.80 / 4.00 / 0.00	3.98 / 4.00 / 1.00
Annual modeled energy + incremental O&M (₹ crore)	10.30	9.60	7.90	6.92
Net annual savings (₹ crore)	0.00	0.70	2.40	3.38
Capital invested (₹ crore)	0.00	1.35	5.20	13.50
Scope 1 avoided (tCO_2/yr)	0	56	224	505
Location-based Scope 2 avoided (tCO_2/yr)	0	582	872	1,469
Market-based Scope 2 avoided, conditional (tCO_2/yr)	0	582	3,780	4,377
Simple payback (years)	—	1.93	2.17	4.00
10-year NPV (₹ crore)	—	2.95	9.55	7.25

Measure	Conventional	Quick wins	Moderate	Strategic
10-year IRR	—	51.0%	45.0%	21.4%
Net abatement cost (₹/tCO_2), location-based	—	-7,532	-14,166	-5,980
Operating margin uplift at ₹150 crore revenue (points)	—	0.47	1.60	2.25

Model inputs: avoidable grid energy ₹8.50/kWh, landed OA ₹5.50 per usable kWh, and natural gas ₹900/GJ. Incremental O&M is ₹0.07 / ₹0.18 / ₹0.35 crore annually. Capital includes plant upgrades and strategic rooftop, with third-party OA and no battery. Rates and CAPEX are illustrative. The grid rate excludes unchanged demand charges. No tax, degradation, tariff escalation, subsidies, financing fees, scrap savings or carbon revenues are included.

Calculation: gas and utility cost avoided less OA energy and incremental O&M. The heat pump uses 5,000 × 82% ÷ 3 ÷ 3,600 = 0.380 GWh/year, with COP 3. The strategic case retains 11,000 GJ of gas input and uses 8.980 GWh of electricity. OA remains grid-delivered for location-based reporting. Rooftop generation is onsite and self-consumed. The conditional market-based illustration assumes qualifying OA attributes, no competing claims, and uses the same factor as a proxy for uncovered electricity. These figures represent illustrative inventory changes and carry no claim about marginal grid displacement.

Carbon inputs: 0.727 tCO_2/MWh (CEA FY2023–24 historical weighted average) and 0.0561 tCO_2/GJ of natural gas (IPCC default combustion CO_2). Baseline is 7,270 tCO_2 location-based Scope 2 and 1,122 tCO_2 gas combustion. The model excludes refrigerants, non-CO_2 gases and Scope 3. Use the current inventory-year factors and appropriate market-based factors for actual reporting. IPCC energy guidelines · CEA database

Investment: 10 years of constant annual savings, 10% discount rate, year-zero CAPEX, no salvage. Annualised CAPEX less annual net savings, divided by physical-inventory Scope 1 and location-based Scope 2 reductions, gives the net abatement cost. Negative values reflect net economic benefit under these assumptions. Margin

uplift is a pre-depreciation operating margin proxy assuming constant revenue and other costs.

Sensitivity: a ₹1/kWh narrowing of the avoidable grid-to-OA spread reduces savings by ₹0.40 crore/year for 4 GWh of matched OA. At 10% over ten years this lowers NPV by about ₹2.46 crore. A ₹100/GJ increase in gas price increases relative annual savings by ₹0.04 crore for moderate and ₹0.09 crore for strategic. Each additional unrecovered GWh of contracted OA requires separate analysis of the PPA payment and grid energy replacement.

The modeled moderate package gives the largest ten-year NPV at the central assumptions. Its advantage depends on the cost spread between contracted renewable electricity and avoidable utility charges. The strategic package reduces on-site fuel and increases self-consumed renewable supply, and its case improves when gas is costly, electricity is affordable or the heat pump's temperature lift is modest. Meter both the heat delivered and the power consumed through a seasonal pilot. At ₹8.50/kWh and ₹900/GJ of gas with an 82% boiler, parity on energy costs requires a COP of approximately 2.15. If the additional electricity has a location-based factor of 0.727 kg CO_2/kWh, emissions parity requires a COP of about 2.95 before adding refrigerant and upstream effects. A financial pass can still produce a weak carbon result if extra electricity is grid-intensive. CEA historical factor

A five-year investment sequence

0–6 months · Operations and ESG

High priority. Baseline utility meters and Scope 1–3; track kWh/million good shells and kWh/tonne. Requires meter and output data.

6–18 months · Procurement and finance

High priority. Improve controls and sign matched supply where viable. Track usable renewable MWh and ₹/kWh. Requires allocation, eligibility and quality sign-off.

18–36 months · Engineering and quality

Conditional capital. Recover heat and pilot electrification. Track useful GJ, seasonal COP and yield. Requires a heat balance, power capacity and hygiene approvals.

36–60 months · Leadership and supply chain

Scale verified projects and engage core suppliers. Track savings, supplier evidence coverage and product CO_2e. Requires verified baselines and supplier data.

Four investment stages with owners, KPIs and approval dependencies.

In the first year, the operations team can target idle utility consumption, prevent leaks, and benchmark rejects at comparable loading. At the same time, finance and procurement can collect real tariff and generation data. A useful first management review asks how much energy was avoided, whether quality or output changed, and how much cash the bill actually saved.

The next step is to separate work that needs a shutdown from work that needs a contract. Chiller sequencing may be implemented quickly within validated bounds. Heat recovery can need a shutdown

window and a hygiene review. A renewable PPA requires metering, allocation and approval checks, and a method for verifying savings under actual settlement. Plan those workstreams together so the power contract reflects the new demand profile.

Supplier work can run alongside both. Ask a small group of high-spend vendors for evidence covering material production, electricity mix, transport and allocation. Pair that request with purchasing and quality criteria. A supplier with a low stated footprint and poor yield may increase the footprint of good output. A supplier that can provide comparable, reviewable data makes a more defensible commercial partner.

What will shape competitiveness

Customers may ask for product footprint data and traceable upstream claims as part of procurement, regardless of direct reporting obligations. For India's Carbon Credit Trading Scheme, check BEE procedures and the notified obligations applicable to the actual entity. Screen potential offsets under the relevant eligibility and methodology. Keep carbon credit revenues outside the base case until eligibility and issuance assumptions are verified. SEBI's BRSR framework concerns listed entities within applicable thresholds and reporting schedules. SEBI's April 2025 FAQ describes voluntary value-chain disclosures from FY2025–26 for the top 250 listed entities. Supplier requests can be commercial even where the supplier has no direct filing requirement. BEE carbon market · SEBI BRSR Core FAQ

For EU exports, assess CBAM by product customs code, particularly when exporting aluminium goods that may fall within covered tariff codes. The mere presence of aluminium in a finished pharmaceutical pack does not determine the customs treatment. For environmental compliance in India, confirm state pollution-control permissions,

hazardous waste requirements and applicable solvent and effluent limits for the actual operation. Quality, permits and product specifications should form part of the gate for every plant modification. EU CBAM framework

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

Start with the cost of a good unit. Match electricity and heat metering to production, yield, quality and humidity. Target the avoidable consumption first, procure solar and wind against the remaining load, and validate the thermal opportunities with measured temperatures and duty. Evaluate batteries after testing the residual mismatch and the value of reliable peak coverage. Use the same records that support cost savings to verify carbon accounting, with distinct treatment for contractual electricity claims and on-site fuel avoided.

In the next capital review, ask which proposal improves the cost of a good unit while safeguarding the quality of that unit. The answer can change how much renewable electricity the plant should buy, when it needs it, and how much capital it needs to commit.

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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.”