

SECI's Rs 5.25 thermal-mimic auction: designs, costs, and penalties

Which solar + battery designs could serve the 1000 MW FDRE-RTC-V profile, at what cost, and with what penalties

Umed Paliwal · Amol Phadke · Nikit Abhyankar

umed@berkeley.edu · University of California, Berkeley · August 2026

SECI's 1000 MW thermal-mimic tender cleared at Rs 5.25-5.26/kWh

SECI-FDRE-RTC-V: 1000 MW, ISTS-connected, RfS March 10 2026, e-reverse auction concluded August 7 2026

WHAT THE PPA DEMANDS, PER 15-MINUTE BLOCK

Window	Definition	Required DFR
Peak hours (6 hrs/day)	buyer-chosen day-ahead, 18:00 to 10:00 window	>= 90%
Solar hours (Grid-India)	roughly 08:00-18:00	50% floor, 60% cap
Remaining hours	all other non-solar hours	>= 70%

- **Penalty: 1.5x the PPA tariff** on every block's shortfall below the floor, reconciled monthly. No monsoon relaxation survived the amendments.
- **Escape valve: 5% market energy.** Clause 8.1.j lets the developer buy up to 5% of the annual required energy, about 292 GWh per GW-year, from the green market to fill shortfalls.
- **Excess solar-hour power above the 60% cap** earns only 50% of tariff (buyer holds first right of refusal).

THE RESULT: 7 WINNERS AT RS 5.25-5.26

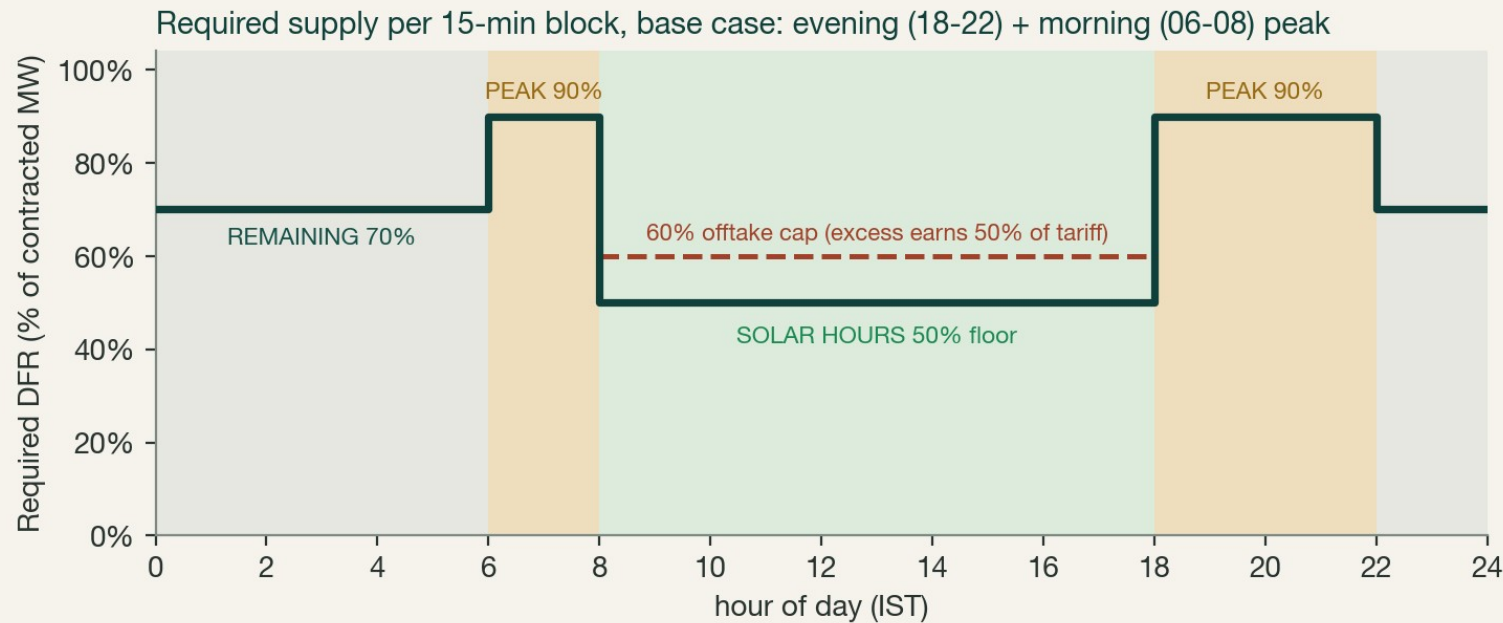
Winner	Capacity	Rs/kWh
Kengeri Prime Solar (Rays Power)	180 MW	5.25
Resolven Four Energy	150 MW	5.25
Hexa Climate Solutions	150 MW	5.26
Hero Solar Energy (Hero Future)	120 MW	5.25
EMIF II Holding V II Cooperatief	100 MW	5.25
Purvah Green Power (RPSG)	70 MW	5.25
Juniper Green Energy	230-300 MW	5.26

16 bidders participated. Profile rewritten mid-tender: Amendment-03 (June 25) turned flat RTC into the three-tier thermal mimic above.

MNRE Secretary, August 7: “we discovered a rate of Rs 5.25 per unit for RE RTC”, **cheaper than recent thermal PPAs at Rs 5.4-6.3 per unit.**

Sources: SECI RfS SECI/C&P/IPP/13/0020/25-26 (Mar 10, 2026), Amendments 01 (Apr 2), 02 (Apr 27), 03 (Jun 25, 2026), Clarifications-01 (Apr 27, 2026), seci.co.in tender SECI000240; results per SaurEnergy and MNRE Secretary statement, Aug 7, 2026 (Juniper reported at 300 MW quoted; 230 MW consistent with the 1000 MW cap and bucket-filling); thermal PPA range per Powerline, Mar 2026.

The required profile: 90% in night peaks, 50-60% in solar hours



The buyer picks the 6 peak hours day-ahead, anywhere from 18:00 to 10:00 the next morning: the design must survive evening, morning, and split peaks.

THE DAILY ENERGY MATH, PER GW

Peak, 6 h x 90%	5.4 GWh
Solar hrs, 10 h x 50%	5.0 GWh
Remaining, 8 h x 70%	5.6 GWh
Total per day	16.0 GWh
Effective CUF	67%
Overnight, battery-served	~11 GWh

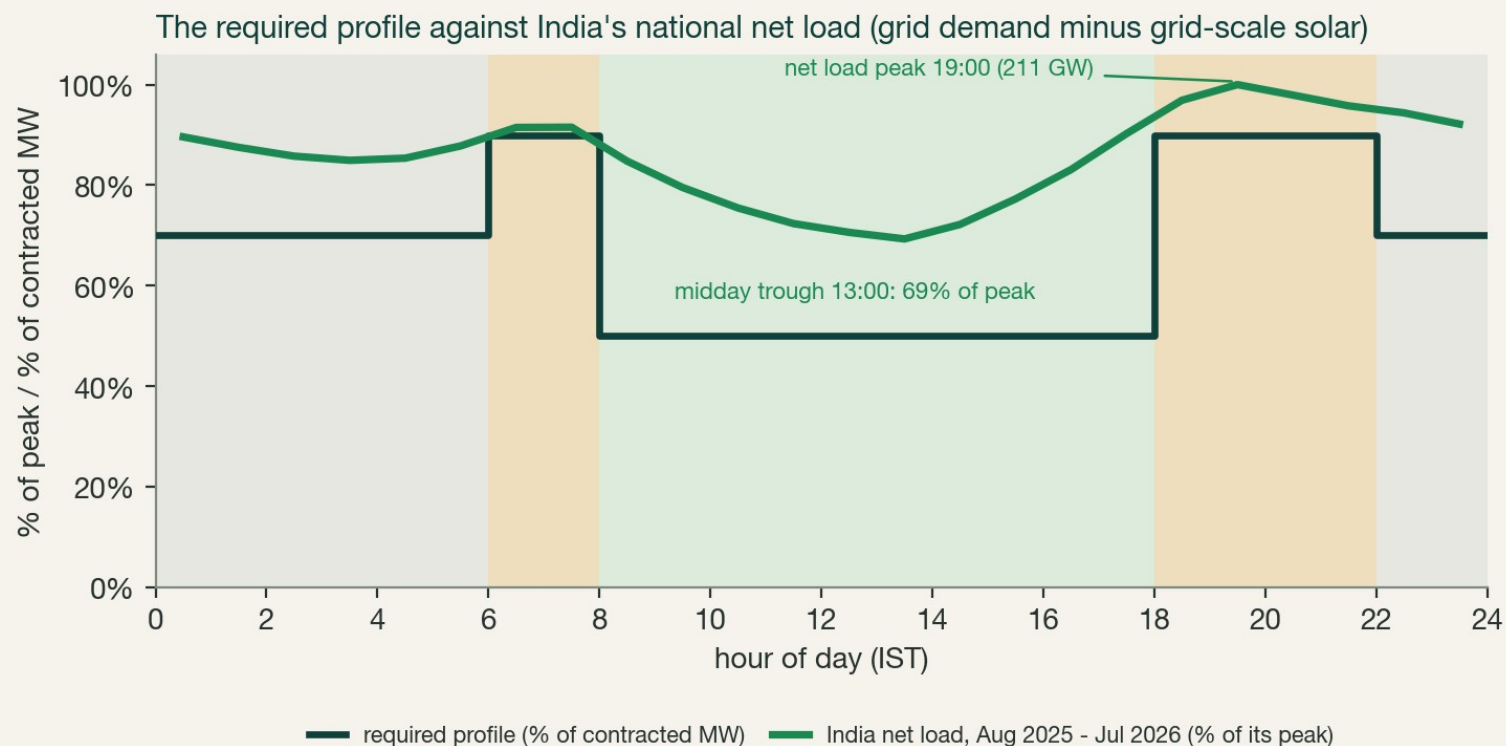
WHAT THINGS COST (BASE CASE)

Solar capex	Rs 3.75 cr/MW-AC
Battery capex, nameplate	Rs 8,550/kWh (\$90)
Battery cell replacement, yr 15	in capex (PV Rs 870 cr)
WACC 10% · 25 yr · O&M 1.5%/yr	
Capex per GW, 3.0 GW + 12 GWh	Rs 22,650 cr
Penalty at Rs 5.25 tariff (1.5x)	Rs 7.88/kWh
Market energy: Rs 4.50/kWh, cap	292 GWh/yr

Why this leans on the battery: the profile demands ~11 GWh through non-solar hours, when the plant runs on storage alone. A 3% equipment failure rate derates all generation, charging included; a charged battery covers the loss. With a 1.4 DC-AC ratio, the battery, not the panels, sets the design.

The profile SECI auctioned is India's net load profile

All-India grid demand minus grid-scale solar, Grid-India 15-minute SCADA aggregated to hourly means, Aug 2025 - Jul 2026



SECI IS PROCURING THE NET LOAD

- **India's peak now comes after sunset:** gross demand peaks at 10:00; solar has pushed the residual peak to 19:00 (211 GW). The tender's evening peak block starts exactly there.
- **The 90% evening floor buys the ramp:** net load climbs 65 GW in the six hours into the peak, the steepest and scarcest hours on the grid; the tender turns that climb into a firm, penalty-backed product.
- **The 50-60% midday band mirrors the solar flood:** midday net load has already fallen to 69% of the evening peak and drops further each year solar grows; the tender caps offtake in exactly those hours.
- **The 70% overnight floor is the one concession:** the grid still runs at ~87% of peak overnight, but holding 90% all night from a battery would price the product out of reach.

A thermal mimic is a net-load product. The demand left after cheap midday solar is what India's coal fleet serves today; the tender packages that residual shape into a PPA. **Solar + storage is the cheapest machine that fits it.**

Sources: Grid Controller of India (NLDC) daily Power Supply Position reports, 15-minute SCADA time series, Aug 1 2025 - Jul 31 2026 (98.0% of blocks), accessed via the Grid-Sentinel open dataset, github.com/HalcyonVector/Grid-Sentinel (CC BY-SA 4.0); demand is grid-served demand met, so rooftop solar and captive appear as suppressed demand; net load = demand minus grid-scale solar; curve normalized to its peak (annual hourly means). Cross-checked against NITI Aayog ICED national load curves (iced.niti.gov.in) and POSOCO daily-report compilations (robbieandrew.github.io/india). Net-load framing and validation: Sanyal and Dev, *The Duck and The Camel: Tracing the Net Load on the Indian Power Grid*, EAC-PM Working Paper 53/2026, Jul 2026 (eacpm.gov.in); this series reproduces its May-2026 ramp and peak statistics exactly.

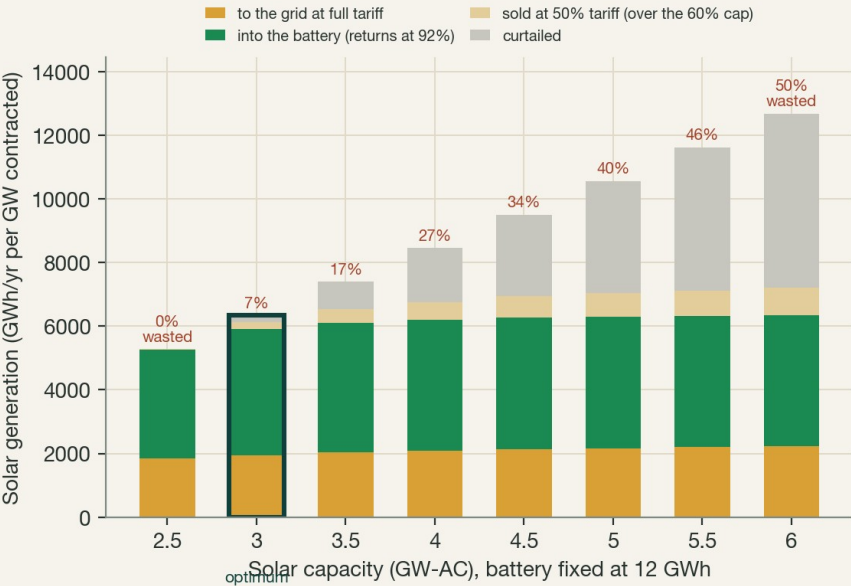
All costs in: Rs 5.15 lean, or Rs 5.28 with zero penalty, in Rajasthan

Hourly dispatch of 10 weather years against the final tender rules; every cost below includes capex, O&M, replacements, market purchases, and penalties

THE COST ANATOMY OF SIX RAJASTHAN DESIGNS (RS/KWH, PENALTIES INCLUDED)

Design (per GW)	Solar	Battery	Market energy	Penalties	ALL-IN	Penalty, avg / worst year
3.0 GW + 12 GWh OPTIMUM	2.37	2.54	0.21	0.03	5.15	0.5% / 3.0%
3.5 GW + 12 GWh ZERO PEN	2.69	2.47	0.13	0.00	5.28	zero in all 10 yrs
4.0 GW + 12 GWh	3.02	2.43	0.08	0.00	5.53	zero
3.0 GW + 14 GWh	2.38	2.97	0.18	0.01	5.53	0.1% / 1.1%
3.5 GW + 14 GWh	2.69	2.88	0.09	0.00	5.67	zero
4.0 GW + 14 GWh	3.03	2.84	0.05	0.00	5.92	zero

Half solar, half battery, everywhere. Battery cost falls slightly with more solar (fewer penalties, fuller charging); the market-energy and penalty components shrink to nothing as solar grows. Rs 5.25 buys either the optimum with modest penalty risk, or 3.5 GW nearly penalty-free at Rs 5.28.

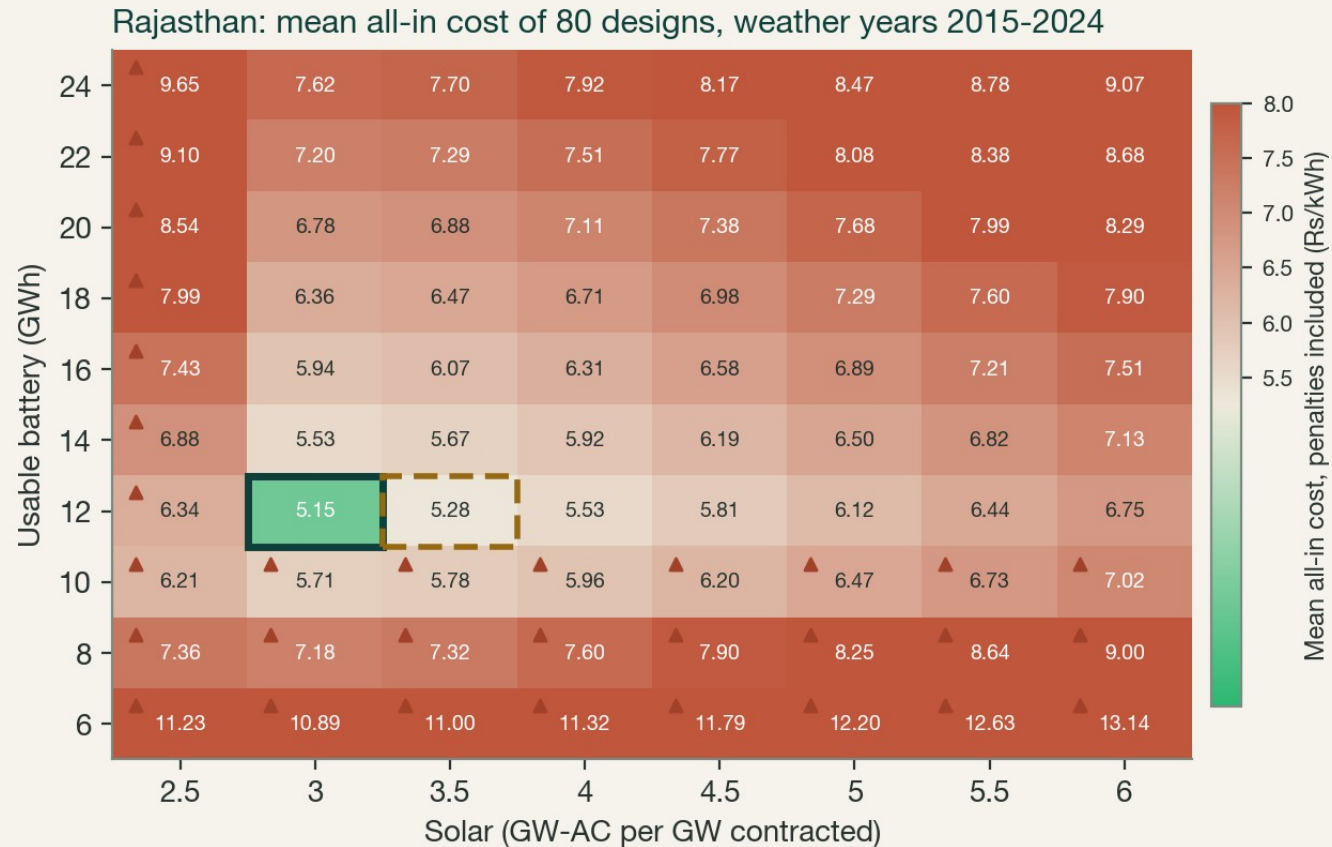


The design walks a ridge: cut solar to 2.5 GW and the worst weather year pays 20% of revenue in penalties; add it beyond 3 GW and the new generation mostly goes unsold: 7% of solar is spilled or curtailed at the optimum, 50% at 6 GW. The full cost grid is on the next slide.

All-in cost = (annualized capex + O&M + market purchases + penalties) ÷ billed energy (incl. spill at 50% tariff)

Every design priced: the auction lands in a one-cell green corner

Mean all-in cost of 80 Rajasthan designs, solar 2.5-6.0 GW-AC x usable battery 6-24 GWh, ten weather years, penalties included



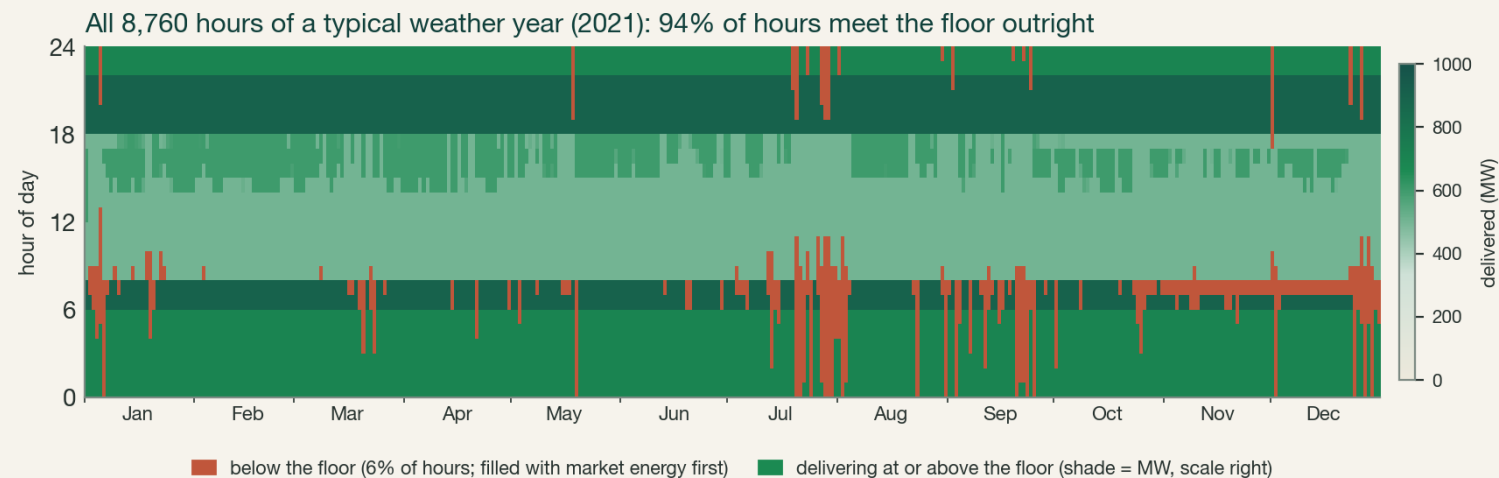
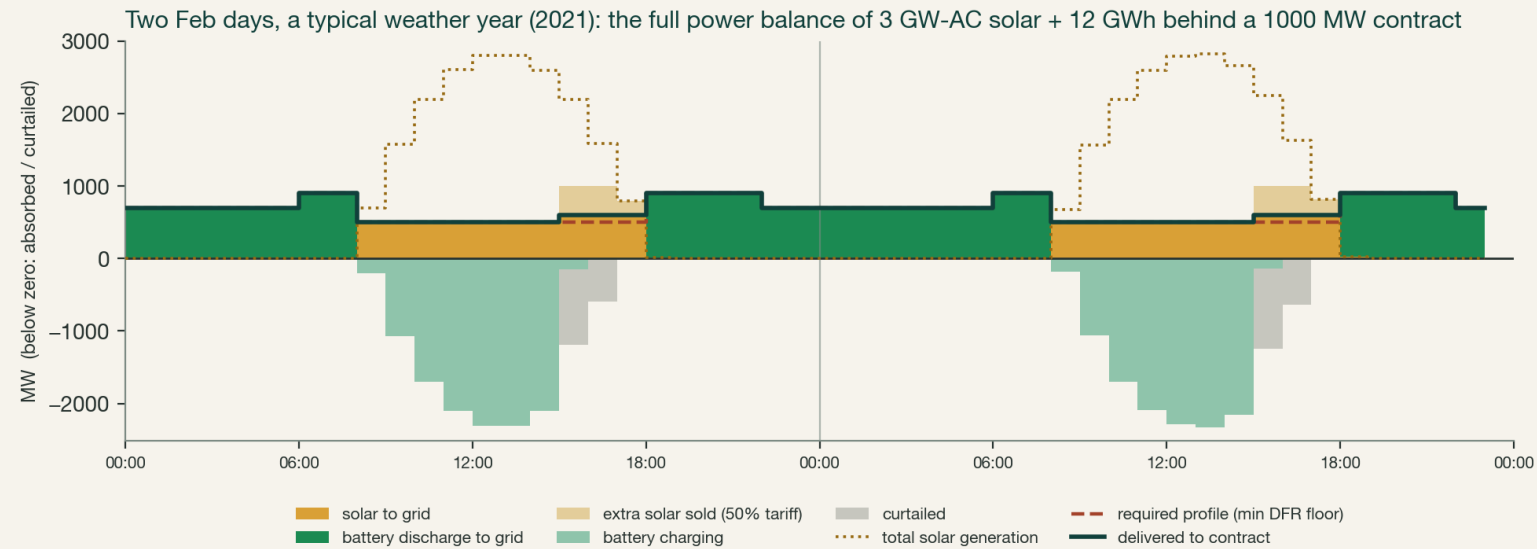
THE AUCTION HAS NO SLACK IN IT

- **One cell of 80 beats the discovered price:** 3 GW + 12 GWh at Rs 5.15 (solid box). Rs 5.25 is the frontier itself, not a comfortable bid: the winners are committed to building this exact design, in Rajasthan-class sun, executed at \$90/kWh batteries.
- **Mis-sizing is punished asymmetrically:** the valley is flat along the battery axis (10-14 GWh sit within ~Rs 0.1) and brutal along solar: half a gigawatt less sends the worst weather year to 20% of revenue in penalties (triangles); half more starts the slide into half-tariff spill. Real design freedom is about one cell wide.
- **Battery size stops mattering at 12 GWh:** every column's cheapest cell sits at 10-12 GWh; beyond it capex rises with no penalty relief, because bad weeks are an energy deficit, not a duration problem. The hedge the design buys with money is solar, never more battery.
- **Reading aids:** colour pivots at Rs 5.25 (gold line on the scale); dashed box = zero-penalty design (3.5 GW + 12 GWh, Rs 5.28); cells above Rs 8 saturate dark red.

UC Berkeley simulation, Aug 2026: uniform-grid re-run of the same dispatch and cost model as the previous slide (sim/run_heatmap_sweep.py, results/agg_Rajasthan_heatmap.csv, identical to the v4 basis on shared cells); mean of weather years 2015-2024, 3% equipment failure rate, market energy and penalties inside every cell; split peak scenario. Colour scale capped at Rs 8/kWh.

How the plant operates: two typical days, and the full year

The optimal Rajasthan design (3.0 GW + 12 GWh): two ordinary days, then all 8,760 hours of a typical weather year (2021)

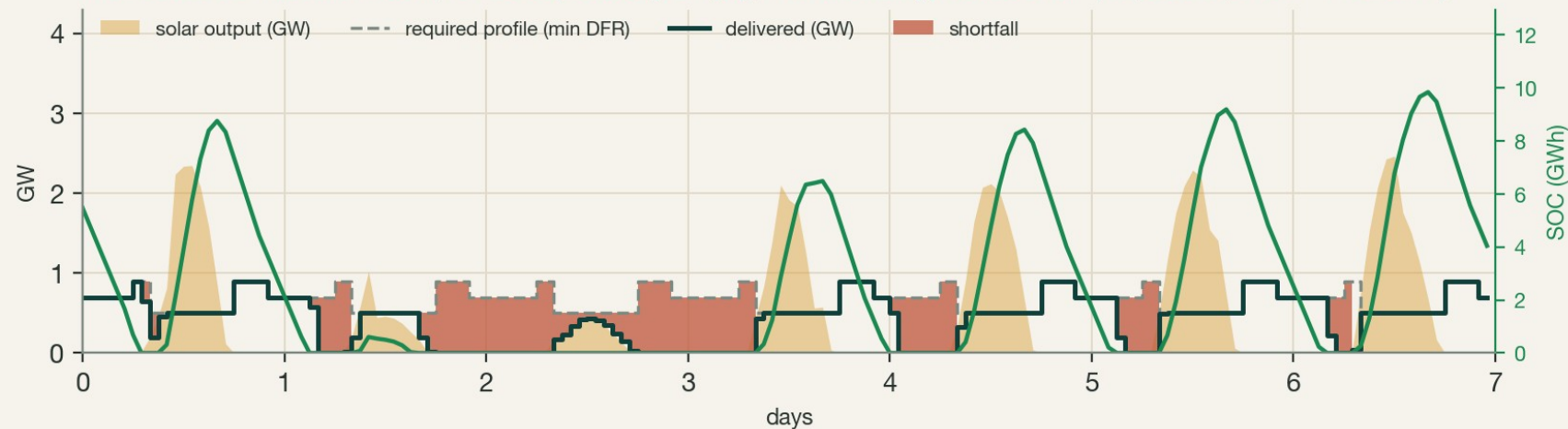


UC Berkeley simulation. Top: the full power balance over two clean Feb days: above zero, what the grid receives (gold solar, green battery discharge, pale gold extra solar sold at 50% tariff); below zero, where the surplus goes (charging, then curtailment); dotted = total solar generation, 4.2 GW-DC behind a 1000 MW contract. Bottom: every hour of 2021 by delivered MW; 94% of hours clear the floor outright, the red rest draws market energy first.

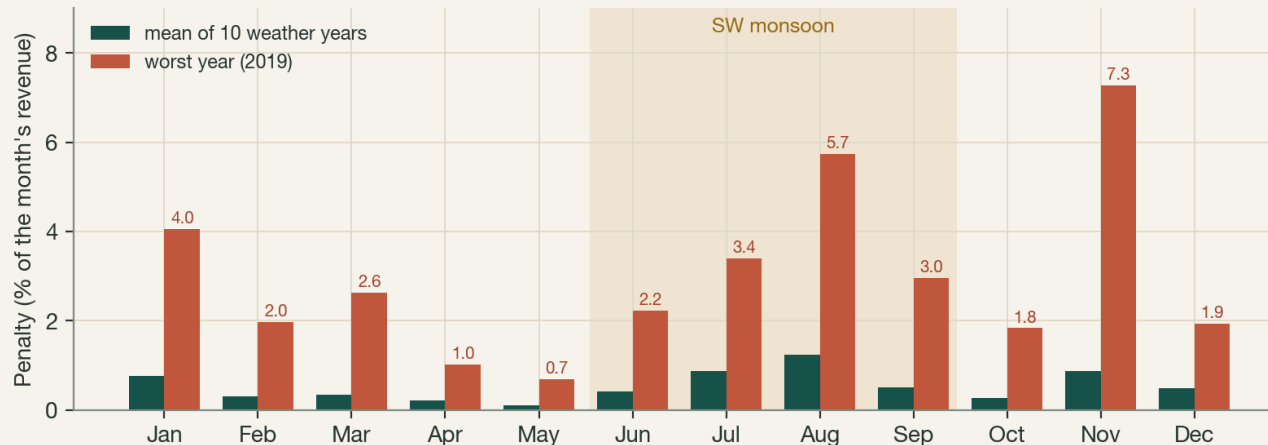
Shortfalls come from monsoon and winter cloudy spells

Rajasthan, the optimal design (3.0 GW-AC + 12 GWh usable); shortfall is bimodal: monsoon plus early winter

The decade's hardest week (Nov 2019): battery empty, market energy takes over (Rajasthan, 3 GW + 12 GWh)



Rajasthan, 3 GW + 12 GWh: monthly penalties after the market allowance



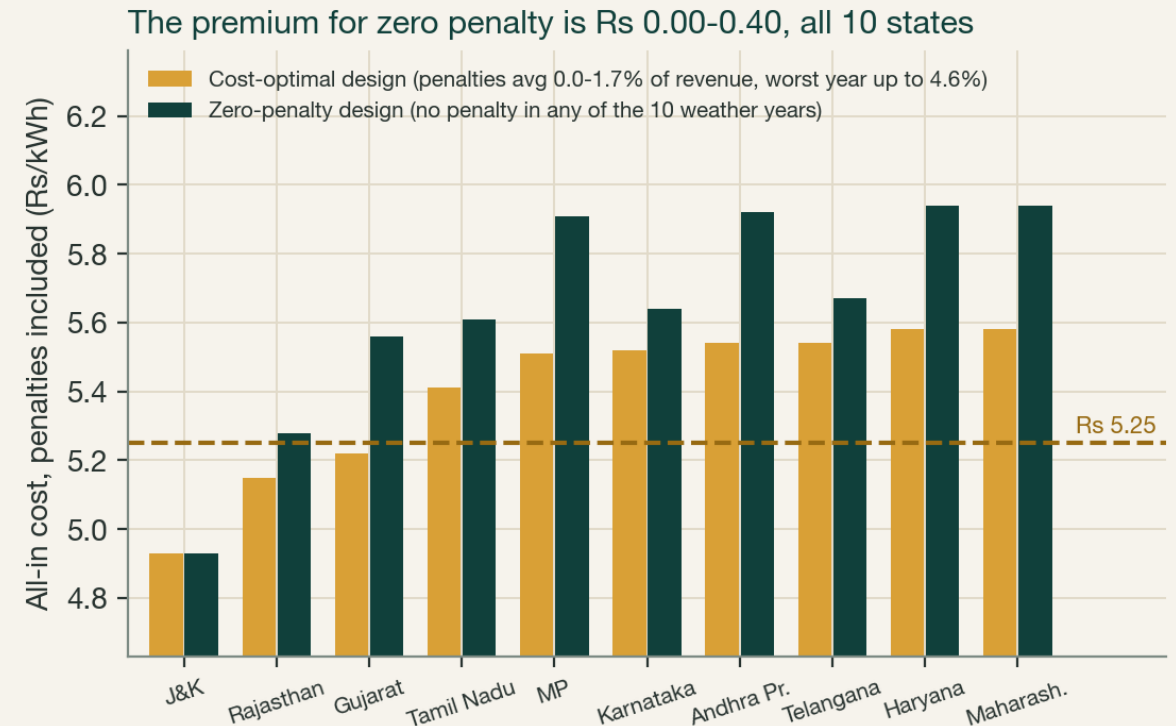
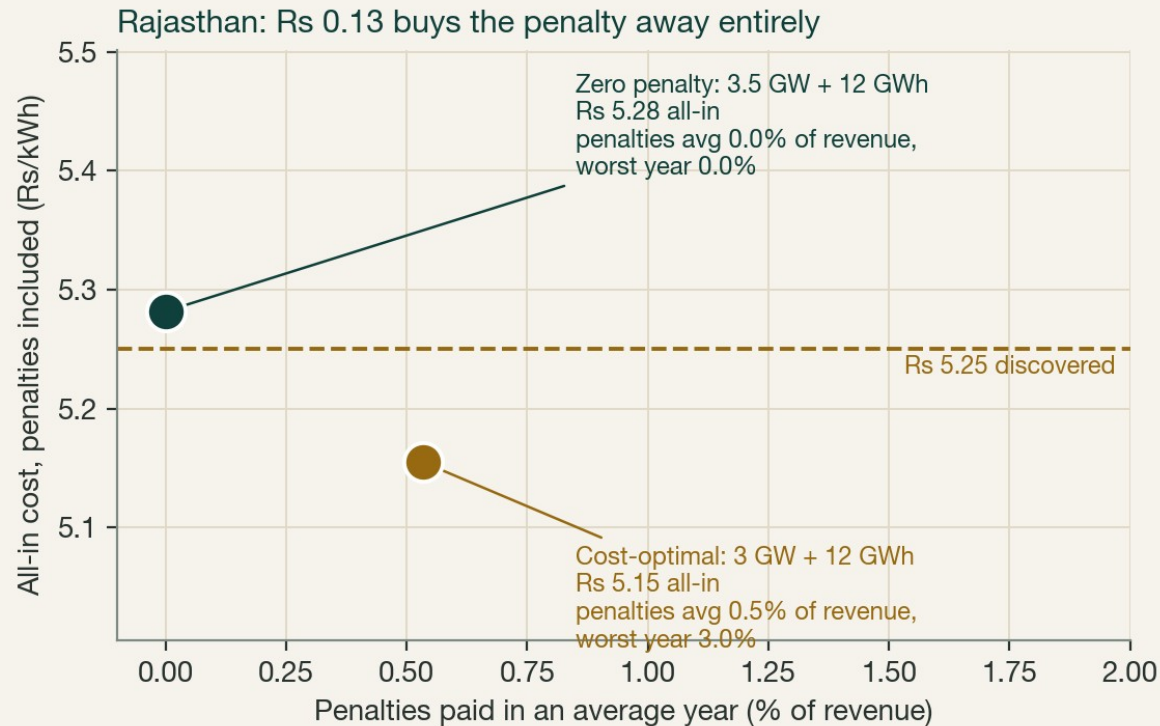
WHAT IT MEANS COMMERCIALY

- Worst-year deficit 6.9%** of required energy (2019): the 292 GWh market allowance maxes out and 115 GWh still goes to penalty, 3.0% of revenue.
- In an average year penalties are 0.5%** of revenue (Rs 0.03/kWh); the allowance is heavily drawn (283 of 292 GWh on average), so bad seasons go straight to penalty.
- Storage cannot fix cloudy weeks:** they are an energy deficit, not a time-shifting problem. Half a gigawatt more solar, not more battery, removes the residual risk entirely.

UC Berkeley simulation, Aug 2026. Top: the decade's hardest week (Nov 2019). Bottom: monthly penalties as a share of the month's revenue; billing is monthly but sums to the annual total. The allowance itself is ANNUAL by Clause 8.1.j and PPA 4.4.9 ('on annual basis'): spring allowance banks into the monsoon, worth ~Rs 0.13/kWh vs a monthly cap. SECI FDRE-RTC-V analysis · solar + storage vs the Rs 5.25 result · 7 of 12

Zero penalty costs Rs 0.13-0.40 more than the cost-optimum

Penalties are inside every cost shown; averages and worst years are over the ten weather years, with the 3% outage rate in dispatch

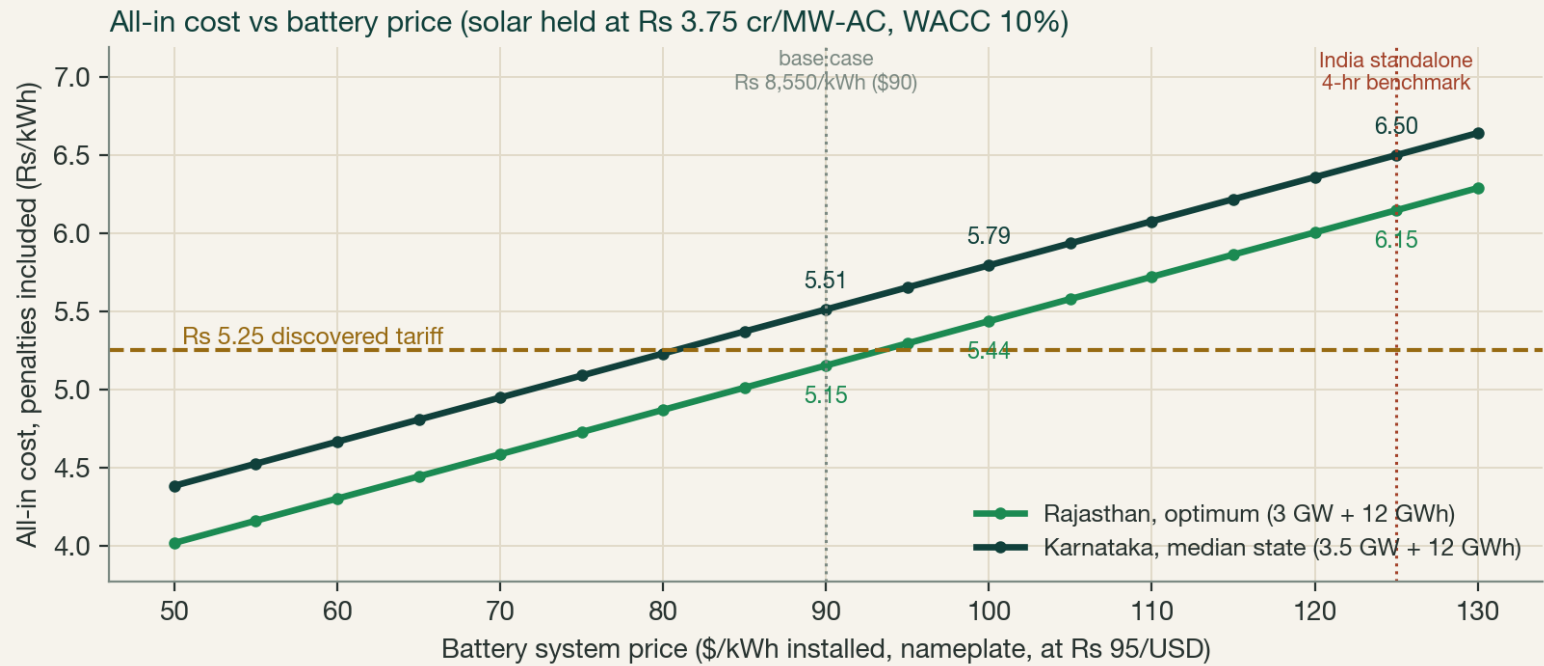


Penalties are inside every number. The cost-optimal designs pay 0-1.7% of revenue in an average year (worst year up to 4.6%); half a gigawatt of extra solar makes them zero for Rs 0.00-0.40 more. **At \$90/kWh batteries, J&K (4.93), Rajasthan (5.15) and Gujarat (5.22) clear Rs 5.25; the Rajasthan penalty-free build costs Rs 5.28, almost exactly the bid.**

UC Berkeley simulation, Aug 2026: penalties as simulated (1.5x tariff on shortfall below the floors, after the 292 GWh/yr market allowance = 5% of required energy), 3% equipment failure rate on all generation, weather years 2015-2024. Cost-optimal configs: 3.0-3.5 GW + 12 GWh; zero-penalty configs: 3.0-4.5 GW + 12 GWh. Full table: [results/scenario_table_v4.csv](#).

Rs 5.25 supports \$89-93/kWh batteries in Rajasthan, penalties included

All-in cost vs battery system price, at Rs 95/USD, solar held at Rs 3.75 cr/MW-AC



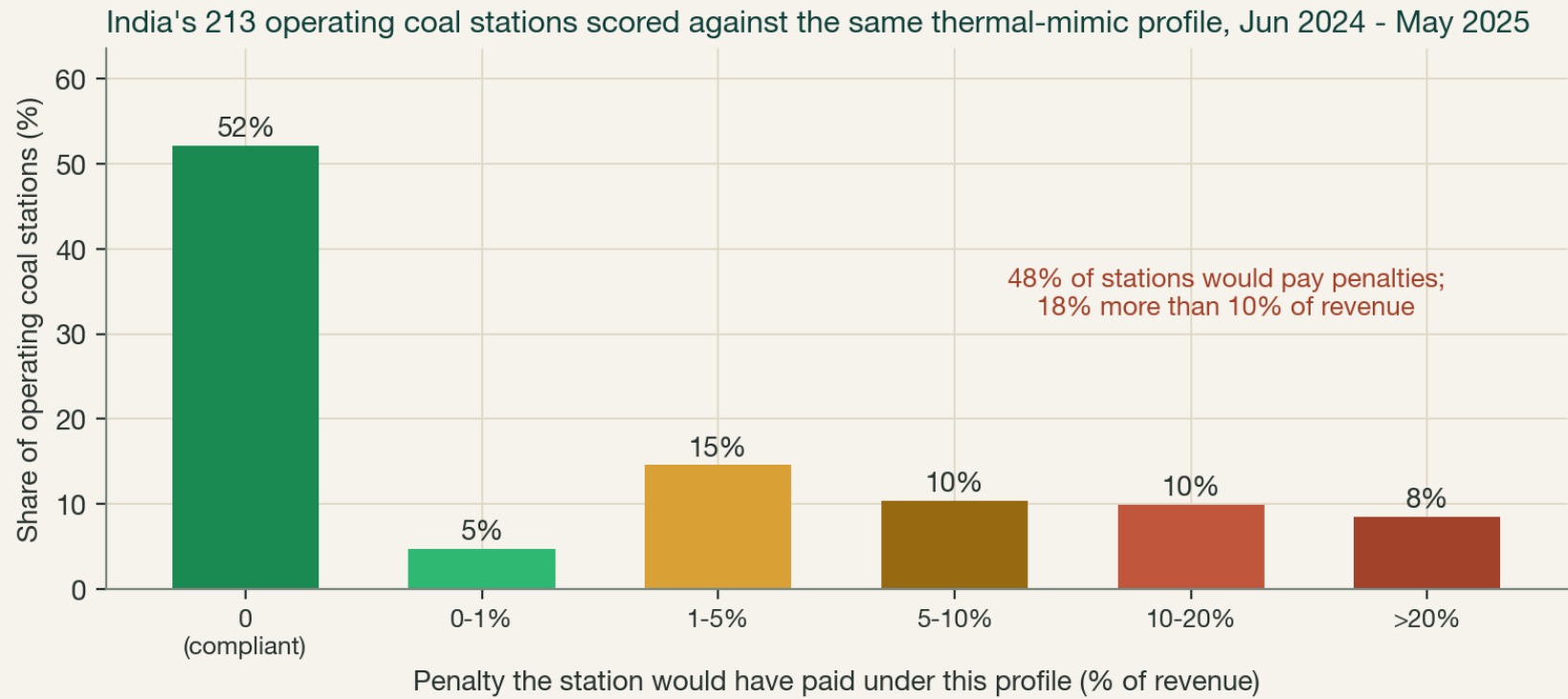
READING THE AUCTION RESULT

- At our \$90/kWh base case three states clear the bid: J&K Rs 4.93, Rajasthan Rs 5.15, Gujarat Rs 5.22; the median state needs Rs 5.52.
- Break-even battery prices: \$93/kWh for the lean Rajasthan build, \$89 for its zero-penalty variant, \$81 in a median state, \$102 in J&K. At BNEF's China turnkey \$73, Rajasthan costs Rs 4.67.
- So Rs 5.25 is a northwest-siting bid at today's battery prices, with margin growing as prices fall toward China's.
- Every \$10/kWh decline cuts ~Rs 0.28: at \$60-65 the next auction clears near Rs 4.3-4.6, decisively under thermal PPAs (Rs 5.4-6.3).

UC Berkeley analysis, Aug 2026: all-in cost at each battery price on each config's mean dispatch outcome (cell replacement scales with system price; WACC 10%, 25 yr constant). BNEF 2025 China turnkey price \$73/kWh; thermal PPAs Rs 5.4-6.3 (Powerline); SECI FDRE-IV cleared Rs 4.98 (easier profile, Jul 2024).

Coal stations scored on the same profile: 48% would pay penalties

Every operating coal station in India scored against this exact profile, using its actual daily outage record (CEA data, June 2024 - May 2025)

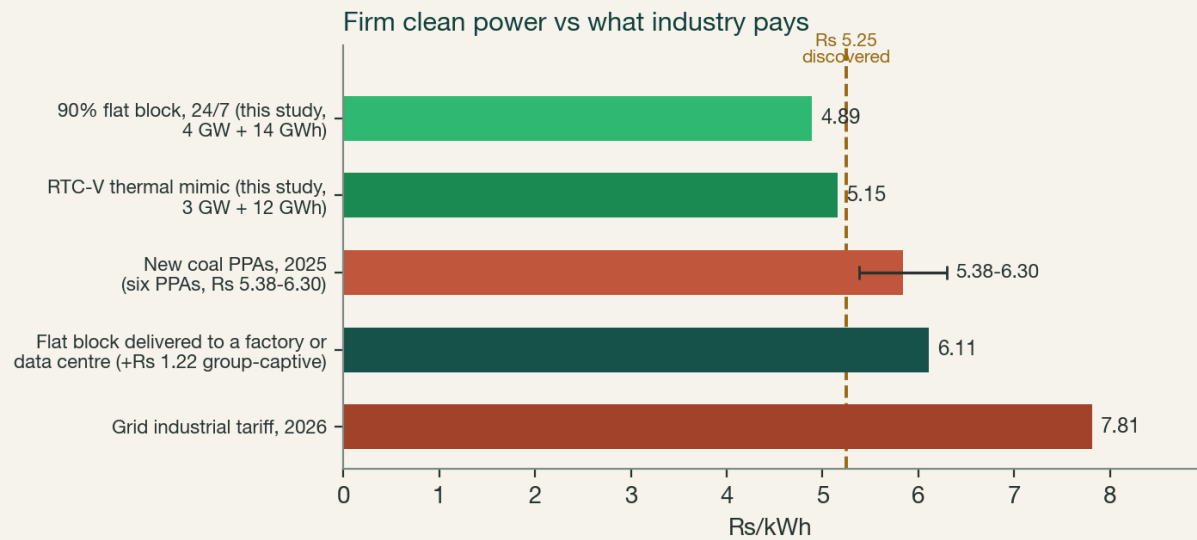


HOW EACH STATION IS SCORED

- From CEA daily outage tables:** a station's availability each day = 1 - MW on outage / station capacity, so sister units cover an outaged one. Its shortfall that day = the profile floors that availability cannot meet, summed over 24 hours.
- Identical rules:** the year's shortfall, less the same 292 GWh market allowance, is penalized at 1.5x tariff; planned and forced outages both count. Economic backdown does not: a 60% PLF station still passes if its capacity was available (median station availability is 90%).
- Of 213 operating stations,** 52% would clear penalty-free; 48% would pay, and 18% would lose more than 10% of revenue. Scored unit by unit instead (619 operating units), only 32% clear, and the median unit loses 7.7% of revenue.
- The punchline:** solar + storage (0.5% average, zero for Rs 0.13 more) performs like the BETTER HALF of the coal fleet, at a price below recent thermal PPAs.

The same machine sells a 24/7 flat block at Rs 4.89

A 90% flat block monetizes the midday solar the tender caps at 60%; delivered through group-captive open access it undercuts the industrial grid tariff by a fifth



Why the flat block is not dearer: the tender's 60% offtake cap throttles what the plant may bill at midday; a flat 90% floor sells that same capped solar at full tariff. Same contract structure (partial credit, 5% market energy, penalties inside): 4 GW + 14 GWh = Rs 4.89. Our earlier UC Berkeley study's stricter product (full 1 GW, binary hour scoring, no market energy) needs 5 GW + 16 GWh at Rs 5.08 plant-gate; this engine reproduces that too.

DATA CENTRES: THE FIRST BUYERS

- Delivered at Rs 6.1-6.5, a fifth below the Rs 7.8 grid tariff:** India's ~1.3 GW of data centres (4-5x by 2030) can wheel this block through group-captive open access; a 100 MW campus saves over Rs 100 crore a year. Lands inside IECC's own Rs 5.5-7.0 band for 24/7 clean DC power; US and EU firm-clean contracts run \$100-150/MWh.
- Hourly matching doubles:** this profile delivers ~90% hourly carbon-free energy by construction; a vanilla solar PPA of the same annual volume scores ~44%.

GREEN STEEL: THE ASSUMPTION IS NOW A PRICE

- Berkeley's green-steel case assumed a \$55/MWh flat block; Rs 5.25 IS \$55** at today's rupee. At 4 MWh per tonne (36% of steel cost), green H2-DRI beats blast-furnace steel into the EU from CBAM day one, and sits ~9% above it domestically, a gap coking-coal and rupee escalation close by ~2030.

GREEN HYDROGEN: THE ONE THAT NEEDS CHEAPER

- Rs 5.25 makes hydrogen ~\$3.7/kg vs the \$3 target:** each Rs 1/kWh moves H2 by \$0.60/kg. Electrolysers want the co-located, off-grid version of this same design at ~Rs 4.1/kWh, not a grid-delivered PPA.

Who switches on price alone: data centres, chlor-alkali, and every industrial buyer paying Rs 7.7-7.9 to the grid. Aluminium's Rs 3 captive coal waits for carbon pricing. **The product now exists at a discovered price; open-access rules, not economics, set the pace.**

UC Berkeley simulation (flat block: `sim/run_flat90_sweep.py`, Rajasthan, v4 basis, no spill revenue) and IECC, UC Berkeley analyses at `iecc.gssp.berkeley.edu`: Plummeting Solar+Storage Auction Prices (May 2025); Economic Case for Green Steel Production in India (May 2026); Clean Energy as Economic Statecraft, Strategy 5 (Feb 2026, data centres); Electrifying Industrial Heat in India (Apr 2026: grid tariff Rs 7.81, group-captive adder Rs 1.22); SAF report App. A.1 (Jun 2026, LCOH). Open access per GEOA Rules 2022; third-party route adds Rs 2.8-4.7 incl. cross-subsidy surcharge.