

SCALING RENEWABLES WITHOUT BREAKING THE GRID



National roundtable-cum-capacity building workshop

Anil Agarwal Environment Training Institute (AAETI)
23–25 SEP 2026

- Focus areas
- Grid integration · transmission · flexibility · market design · forecasting · curtailment · Centre–State governance



Why this Roundtable?

India is moving from a capacity-addition problem to a whole-system integration problem.

NON-FOSSIL CAPACITY

304.4 GW

54%+ of total capacity; 31 Aug 2026

SOLAR + WIND

**168.0 + 58.5
GW**

Installed capacity; 31 Aug 2026

RE CURTAILMENT

7.62 TWh

FY 2025–26; CSE analysis

RAJASTHAN BOTTLENECK

~60 GW

Projects reported awaiting transmission

BACKGROUND

- The 500-GW non-fossil ambition is close enough to require **operating-model** changes, not only more generation.
- The main challenges are at the points where generation, transmission, balancing, contracts, forecasting and planning come **together**.
- More variable generation must be **absorbed** while managing evening net-load ramps, network constraints and reliability requirements.

OBJECTIVE OF THE DISCUSSION

- Align planning - treat generation, transmission, flexibility, storage and demand as one system.
- Reduce bottlenecks, identify regulatory, commercial and operational frictions that delay usable capacity.
- Scale what works, translate state and project-level good practice into repeatable frameworks.



The integration challenge is a five-part system architecture

1 · DEPLOYMENT

- Solar, wind, hybrids
- 295.6 GW RE
- Accelerating deployment and rising integration needs

2. EVACUATION

- ISTS, InSTS, pooling stations
- Substation transformation
- Reactive power and voltage management

3 · FLEXIBILITY

- Thermal, hydro, BESS, PSP, AGC
- 55% → 40% MTL ambition
- ramp-up and ramp-down capability

4 · MARKET

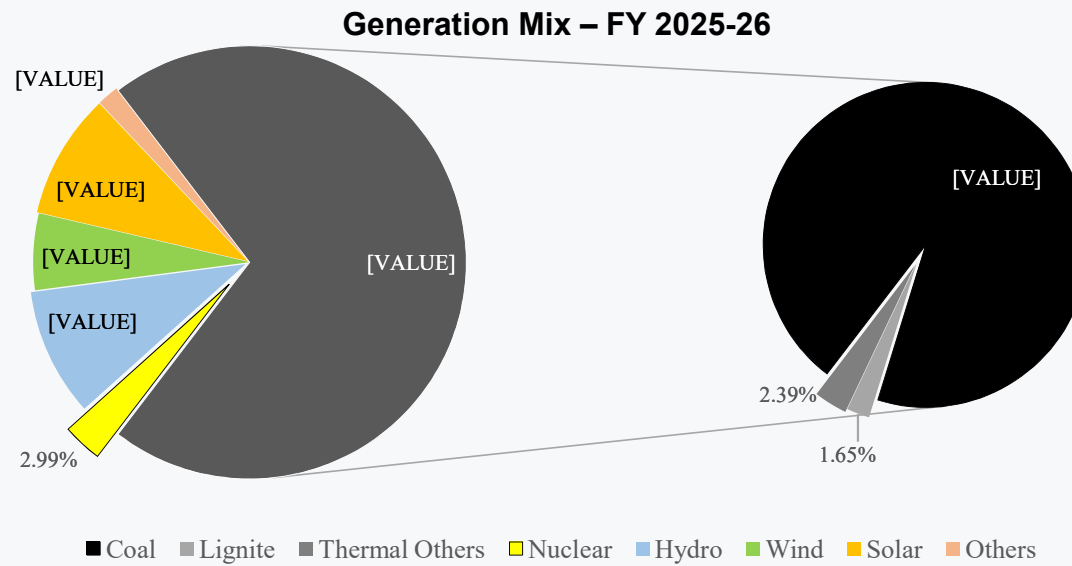
- Bids, PPAs, RTM, capacity
- FDRE + VPPA + capacity procurement
- Forecasting and Portfolio Optimization

5 · GOVERNANCE

- Centre–State planning & tracking
- State RA frameworks expanding

Power Sector: At a glance

Despite progress, in FY 2025-26, fossil fuel, primarily coal has dominated the power generation share with 67.6 percent.

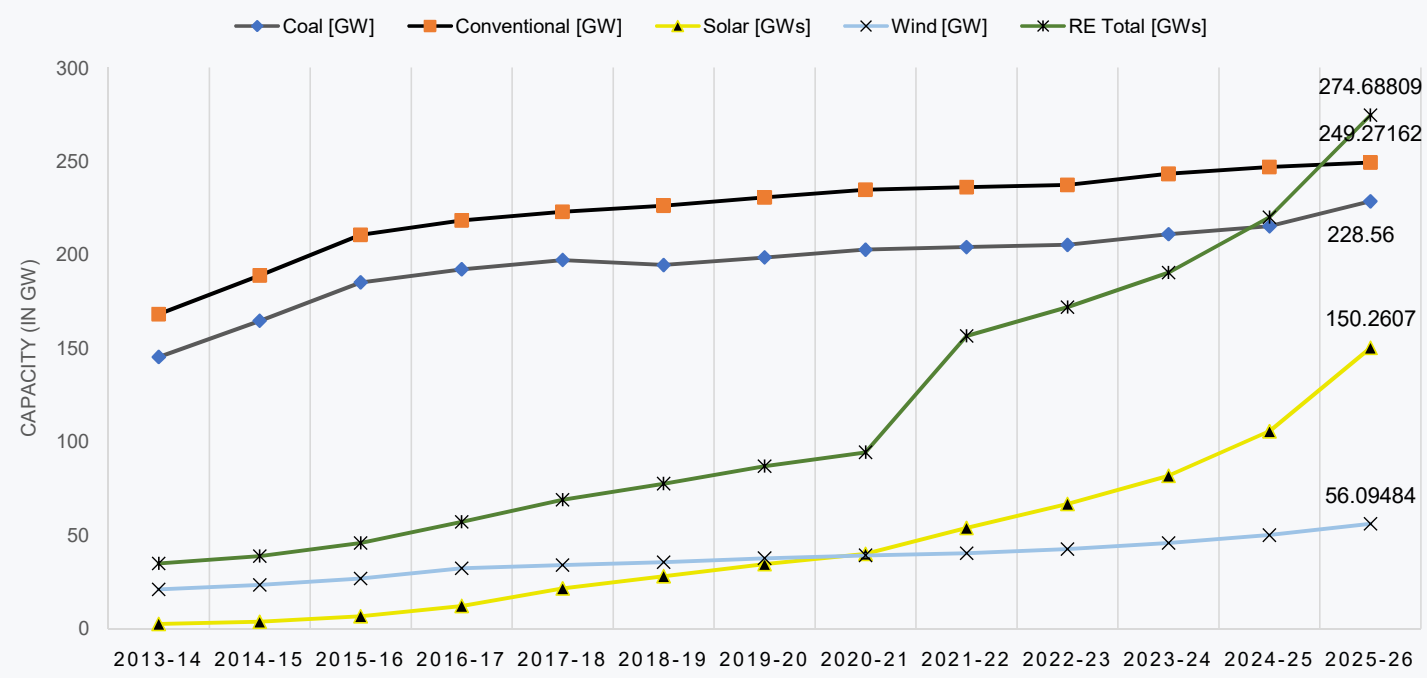


India's Long-term Resource Adequacy targets coal share to be around 55 percent over the coming decade, though this target was earlier set for NEP, 2021-22.

Power Sector: At a glance



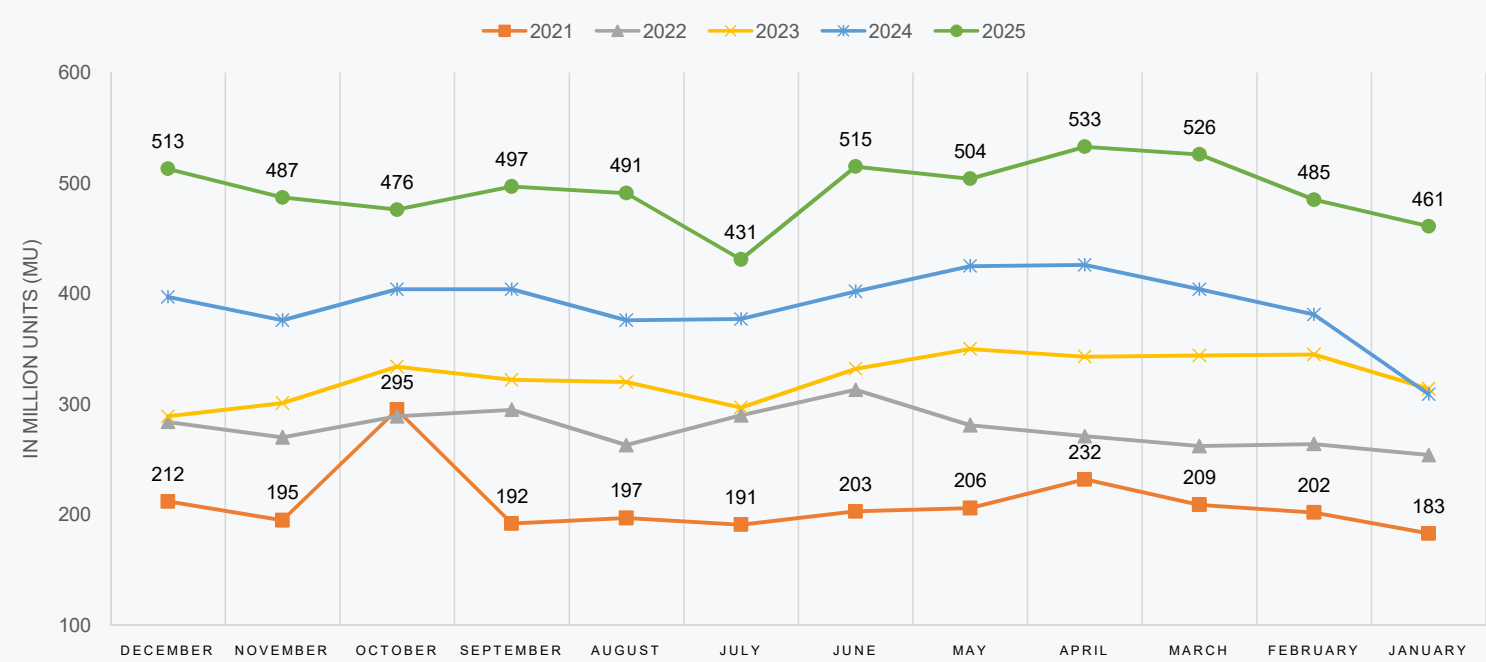
By 2026, RE has overtaken the share of fossil fuels in the installed capacity term, with a further **148.3 GW of RE** under construction.



India’s power sector’s fossil capacity is also rising, with **7.2 GW of coal** added in FY 2025-26, and **37.7 GW under construction**.

Power Sector: At a glance

Year on year, the solar energy penetration is rising in India, the graph is showing the generational peak for the past five years.



Solar energy’s capacity recording **3.5 times increase** over the past 6 years, rising from **40 GW in 2020-21** to **140.6 GW in 2025-26** and **100 GW is under-construction**.

Grid integration at scale: transmission + balancing

The grid is being planned for the target; the implementation question is whether transmission and flexibility arrive in the same time window as generation.

BALANCING STACK

- Thermal flexibility: 55% → 40% MTL; ramp up to 3%/min.
- BESS + PSP: 47 GW BESS / 236 GWh + 26.7 GW PSP / 175 GWh projected for 2031–32.
- AGC, SRAS/TRAS, REMCs and voltage-support technologies.

GRID-READY RE

- Connectivity should reflect deliverability and system conditions, not only MW access.
- Generation, evacuation and balancing should be sequenced together.
- CEA has a 2026 workstream on manufacturing capacity of grid-forming inverters.

DISCUSSION PIVOT

- Should connectivity be assessed against MW of access alone?
- How should congestion risk be allocated between developers, network planners and procurers?
- What minimum grid-support capability should be embedded at the project level?

Regulatory and legal reforms

The reform agenda is moving toward tighter sequencing of connectivity, stronger deviation discipline, and more explicit allocation of grid costs and obligations.

CONNECTIVITY

- CERC's 2026 GNA reform cycle addresses **connectivity milestones**, bank guarantees and project readiness.
- Consultations have considered treatment of connectivity granted on LoA where a **PPA/PSA** is not signed within 12 months.
- Land-document, commissioning and connectivity timelines remain active project bottlenecks.

NETWORK COSTS

- Draft Fifth Amendment to inter-State **transmission charge/loss** sharing remained under consultation in Sep 2026.
- CERC public hearing scheduled for 28 Sep 2026 signals continued evolution of **network-cost allocation**.
- The emerging direction is toward clearer utilisation and responsibility principles as RE and storage use the network.

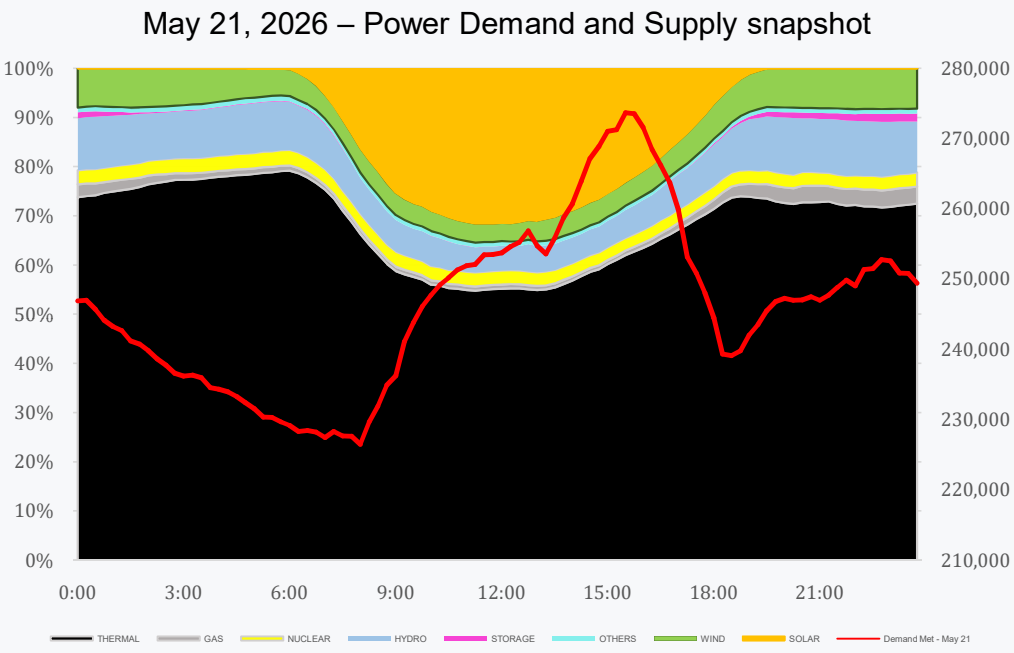
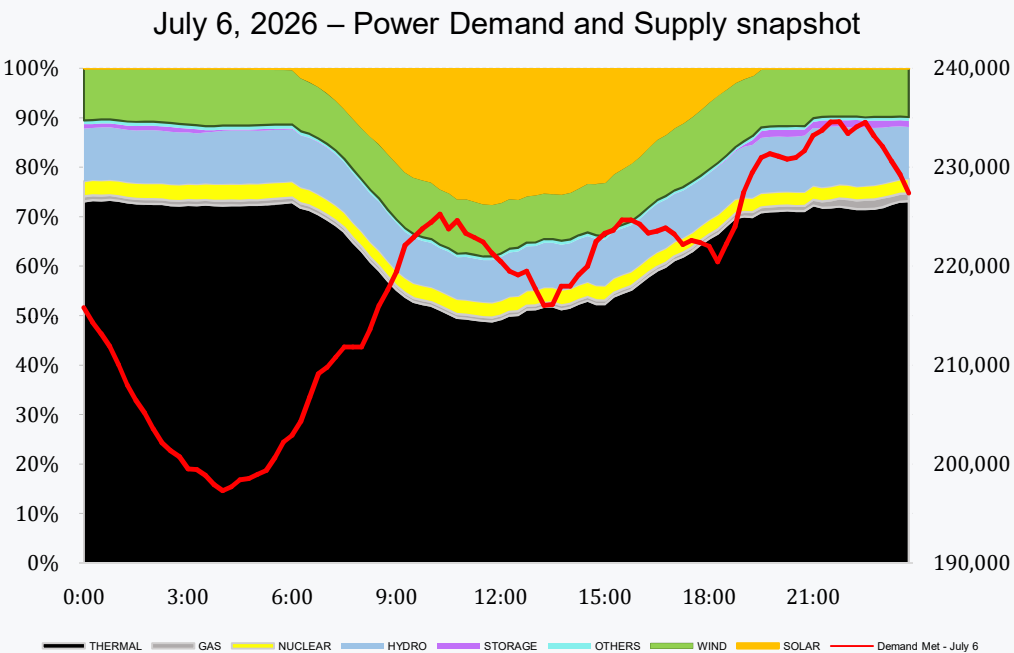
MARKET + DSM

- CERC's Third Amendment to DSM Regulations was notified on 25 Aug 2026.
- For wind and solar, X retained at 100% for the first implementation year through Mar 2027 before calibration.
- 2026 consultations also cover shorter **RTM scheduling** timelines and capacity-market design.

Power Demand and Supply: Variance and need for flexibility



While Solar generation arrives in a similar manner, the power demand varies based on multiple factors.

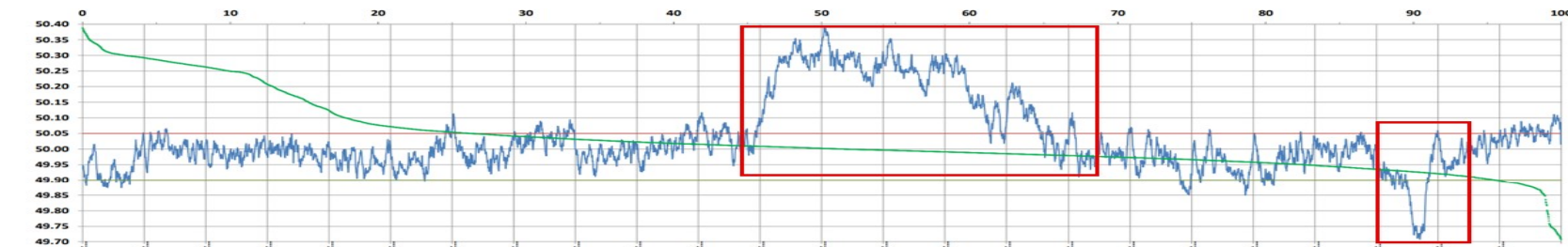


The power demand variability combined with solar generation variation necessitates a flexible power supply system.

Power variance: A risk to the GRID

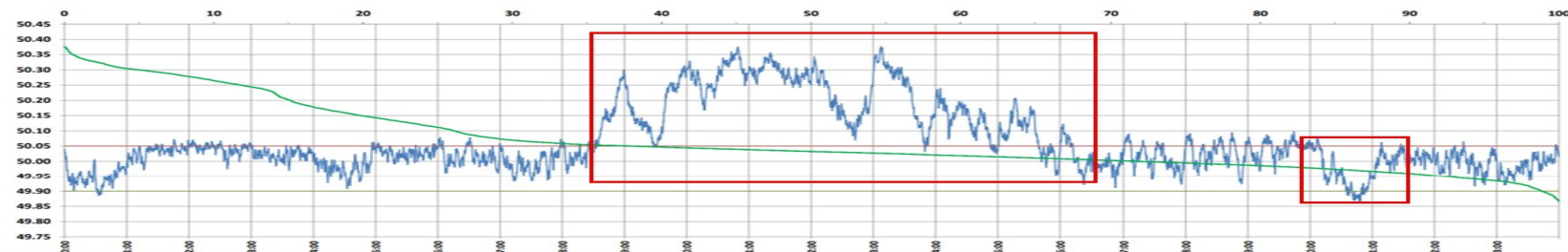
In India, the NLDC is responsible for maintaining system frequency within a narrow operational band of 49.9–50.05 Hz

Figure 6: Indian GRID - Frequency profile: August 4, 2024



Source: GRID India – Daily Frequency profile report

Figure 7: Indian GRID - Frequency profile: August 25, 2024



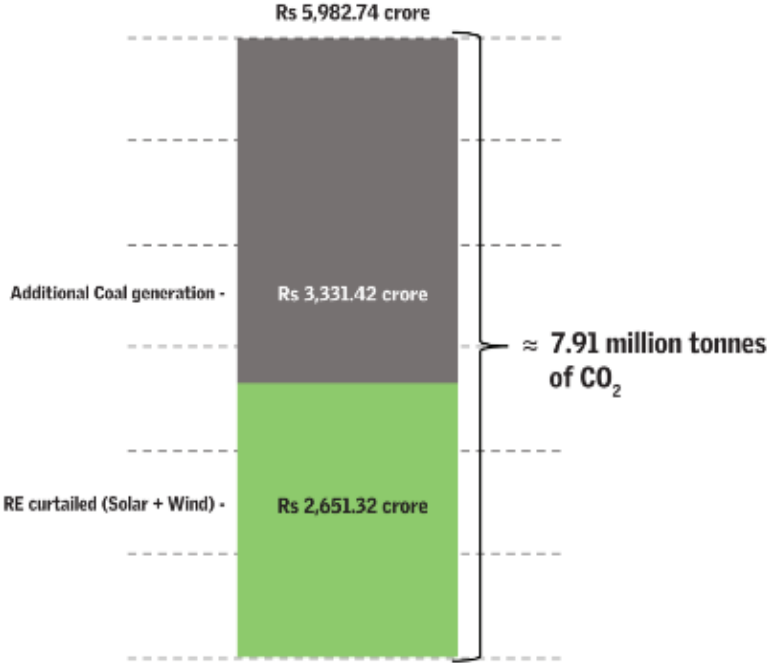
Source: GRID India – Daily Frequency profile report

With high solar generation, in **August 2024**, the Indian grid experienced persistent high-frequency operation on multiple days as coal based thermal stations were scheduled below their MTL but continued to over-inject power to remain near technical minimum operation

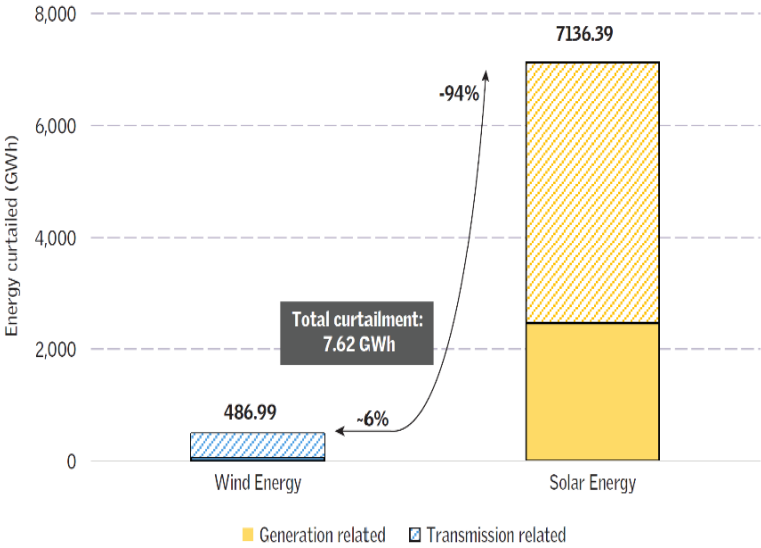
RE Curtailment: The sunk cost of low flexibility

7.61 TWh of RE curtailed in FY 2025-26, with **2.54 TWh** of generation related curtailment, with the rest coming from transmission curtailment.

Figure 11: Total Shadow Cost of RE Curtailment (FY 2025-26)



Graph 7: Renewable Energy Curtailment in India (FY 2025-26)



Source: CSE analysis of GRID-India VRE reports

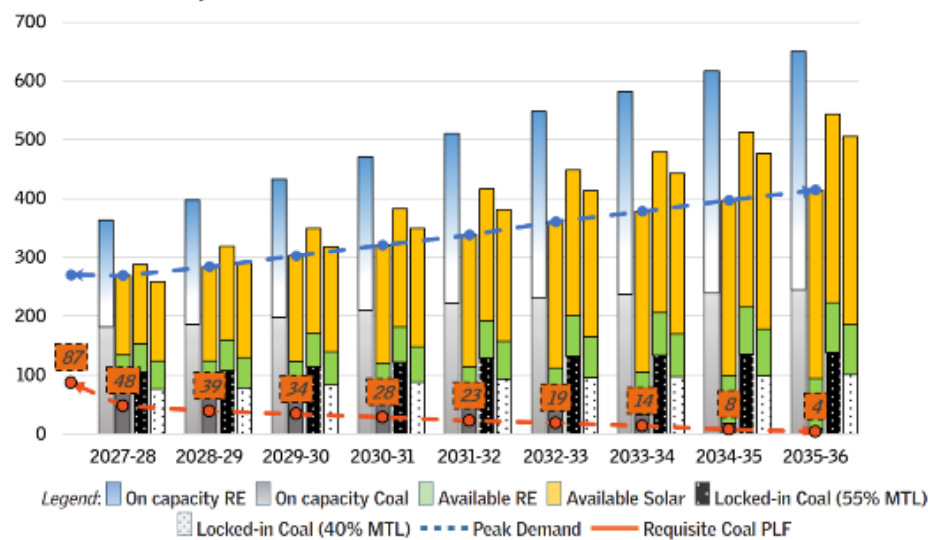
A **total economic loss of ₹5,982/- Cr / \$ 628M**, with ₹2,651/- Cr / \$278M being an unused RE payments and ₹3,331/- Cr / \$ 350M in coal power payouts

CSE Analysis: Stress testing the GRID – Resource Adequacy scenario assessment

- High solar generation alongside low generational flexibility and lack of storage will only increase the risk of curtailment.

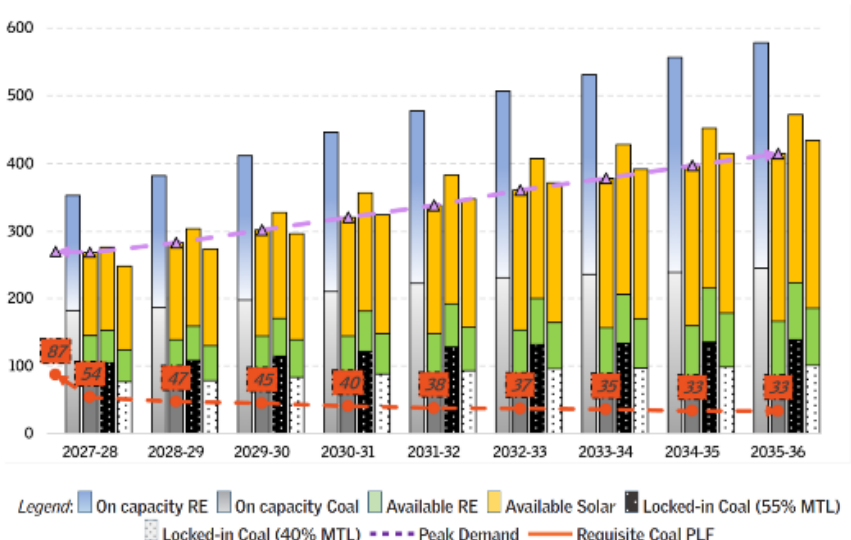


Graph 42: Scenario 2: Gross Noon Squeeze Demand Estimation (11:30 am–12:30 pm)



Source: CSE analysis

Graph 44: Scenario 4: Gross Noon Squeeze Demand Estimation with Storage on System (11:30 am–12:30 pm)



Source: CSE analysis

The need of flexibility is consistent throughout the day, with night time requiring power from coal.

Lower asset utilisation during daytime is an altered reality of coal power.

In FY 2019-20, for every one unit of solar energy consumed, 19 units of coal power was consumed

By FY 2025-26, for every one unit of solar energy consumed, 7 units of coal power is consumed in India

The contractual structure paying coal-based thermal power plant for a uniform availability factor over 24 hours makes little financial sense

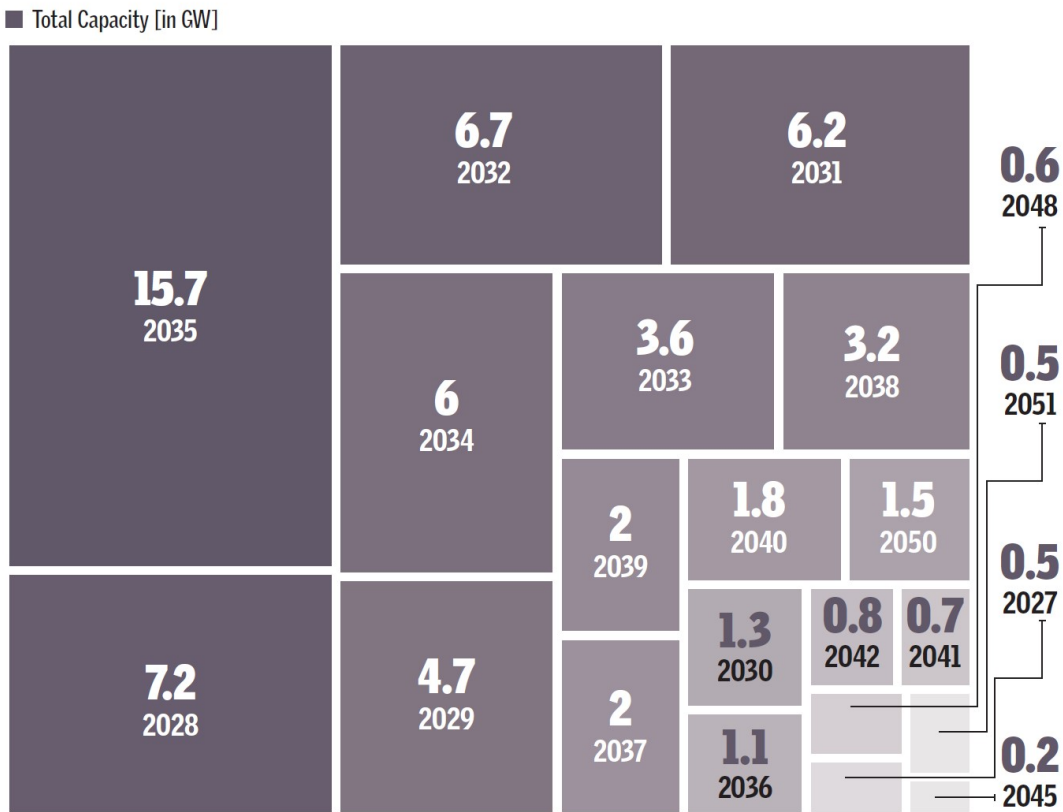


Altered PPA reality: Yet Long-term Lock-ins

Survey across 8 states showcases that bulk of the contracted capacity is locked in rigid, long-term (25-year) contracts with **67.1 GW** of coal capacity assessed



Graph 9: India — select DISCOM’s PPA lock-in | 67.1 GW



Source: CSE analysis of RTI responses from public sector DISCOMs

Similar 25-year long PPAs for coal-based thermal power create systemic roadblock for RE integration while risking system flexibility.

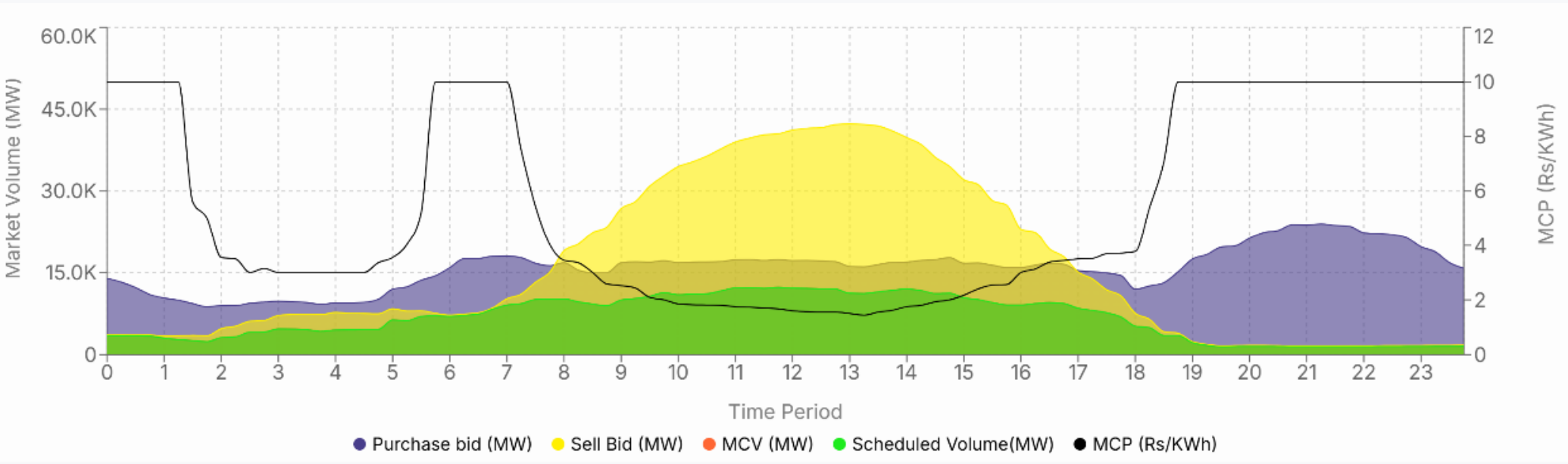
BEST (Mumbai) stands out as the **sole entity** among the surveyed DISCOMs for utilizing five-year thermal PPAs for their electricity supply.

Table 10: Net daytime solar power surplus

Scenario	Installed capacity (GW)	Gross surplus (GW)	Deduction: Auxiliary (10%) + outage (15%) (GW)	Net surplus (GW)
55% technical minimum load	228.6	102.87	57.15	45.72 GW
40% technical minimum load	228.6	137.16	57.15	80.01 GW

Role of Markets: Incentive opportunity

The GRID faces a shortage of power in the evening, with power prices regularly *touching their ceiling of Rs. 10 / kWh*.



This is an opportunity for flexible power plants, including RE with ESS, to cash in on this by selling power at a higher cost during the evening hours.

Five questions to carry into the discussion

Use the evidence to move the conversation from “how much RE?” to “how much usable, deliverable RE under which system conditions?”

01

CONNECTIVITY

Should access be allocated only by MW, or by time-block deliverability, congestion and planned flexibility?

04

CURTAILMENT

What data, compensation and accountability rules make curtailment transparent and economically efficient?

02

FLEXIBILITY

Who pays for flexibility: generators, DISCOMs, network users, storage procurers, or a system-level pool?

05

GOVERNANCE

What five indicators should Centre and States review quarterly to identify deployment-to-grid bottlenecks early?

03

COMMERCIAL DESIGN

What is the right product definition for competitive bidding: energy, capacity, peak supply, firm dispatchability, or a bundle?

We look forward to a productive dialogue



Thank You!



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