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How Should Indian States Choose New Power Generation Capacity?

A Case Study of Rajasthan

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Image: iStock

Executive summary

India's electricity demand crossed 270 GW in May 2026 (MERIT India, n.d.). It is expected to grow rapidly in the coming years, driven by economic growth, urbanisation, and frequent extreme temperatures. At the same time, demand is becoming more volatile and increasingly concentrated in short peak periods, complicating system planning and real-time operations. Consumption patterns across states illustrate this shift. Peak demand is growing faster than the overall demand (Bureau of Energy Efficiency 2024). For instance, in FY25, Delhi's average demand was about 4,000 MW, while it saw a peak load of more than 8,500 MW for only 17 hours that year (MERIT India, n.d.). Distribution companies (discoms) face growing difficulty in meeting these peaks cost-effectively, particularly when reliant on long-term contracts with rigid take or pay obligations and limited flexibility (Aggarwal et al. 2022; Rambani 2025). Inflexible contracts, low liquidity in wholesale markets, and limited resource sharing between states lead to inefficient use of existing capacities and burden the discoms with costly power, especially for managing demand surges. This has increased average cost of electricity supply by 30 per cent between 2017 and 2024—while reducing the financial flexibility available for network upgrades and system modernisation (NITI Aayog, n.d.).

This study examines how states can meet the growing peaks and variability in electricity demand, without increasing the cost burden on consumers. In doing so, it analyses a case from renewable energy-rich state, Rajasthan where new coal capacity has been proposed as a solution to meet the power shortages during non solar hour (Rajasthan Urja Vikas and IT Services Limited 2025). New investments in Indian states must deliver four outcomes simultaneously: **they must minimise the cost of supply to consumers, be fast to deploy to handle any uncertainty in projections, reduce overall imports, and maximise social and environmental benefits.**

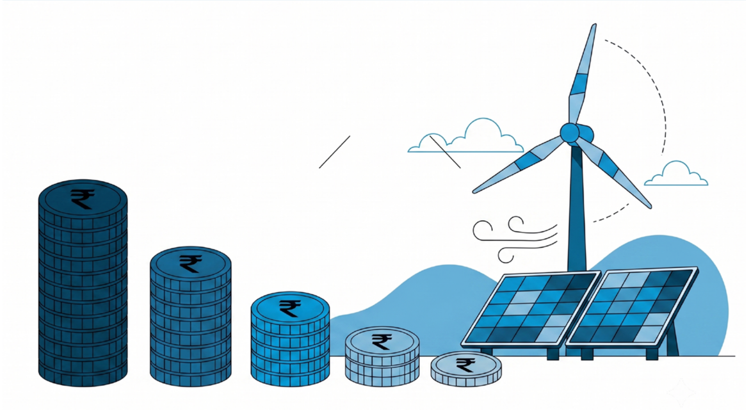
This study compares the outcomes of the proposed coal capacity and an alternate option available with the state. Using a detailed 15 minute production cost simulation for 2030, it assesses three scenarios: (i) a business-as-usual (BAU) pathway with all existing and planned capacities, (ii) a pathway that adds 3,200 MW of new coal capacity, and (iii) an alternative pathway that meets the same reliability requirement using a combination of renewable energy (RE), including solar, wind, and battery energy storage systems (BESS).

The analysis finds that if Rajasthan's demand grows as projected, existing and planned capacities will be insufficient. In 2030, the state could fall short by 5.5 billion units (BUs)—3.4 per cent of the total demand. Nearly 90 per cent of these shortages will occur during non-solar hours.

The state can avoid the shortages through new coal or RE plus storage options and meet demand at a comparable reliability level, but with substantially different system outcomes in terms of overall costs, system operations and long term social and economic benefits for the people of Rajasthan.

- **The RE plus storage pathway delivers the same level of reliability at a significantly lower cost.** Rajasthan could save up to INR 85 billion in power procurement costs in 2030 alone by replacing expensive fossil-fuel-based generation with cheaper RE supported by storage. Even under conservative cost assumptions, the RE plus storage option remains more economical than adding new coal capacity. Flexible resources such as batteries meet most of

RE-coupled with storage will deliver same energy as proposed 3,200 MW coal



INR 85 billion

lower power procurement cost in 2030

By replacing costly fossil generation with cheaper RE backed by storage, INR 11 billion under conservative cost assumptions.

INR 35 billion

additional discom revenue from surplus sales

Selling surplus power to exchanges, especially valuable during high net-load ramping hours.

11x

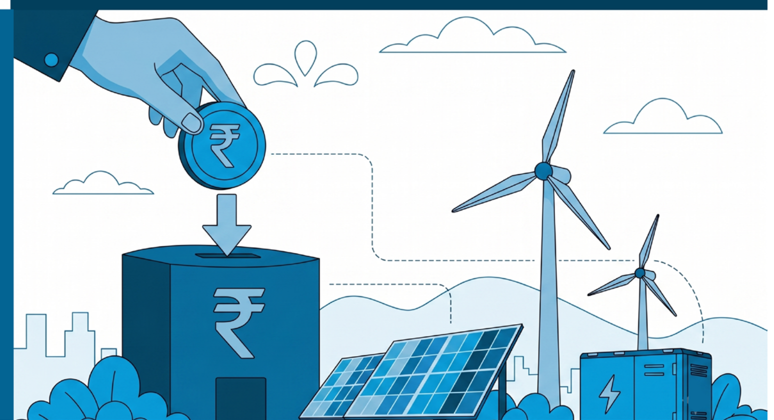
more full-time jobs created by 2030

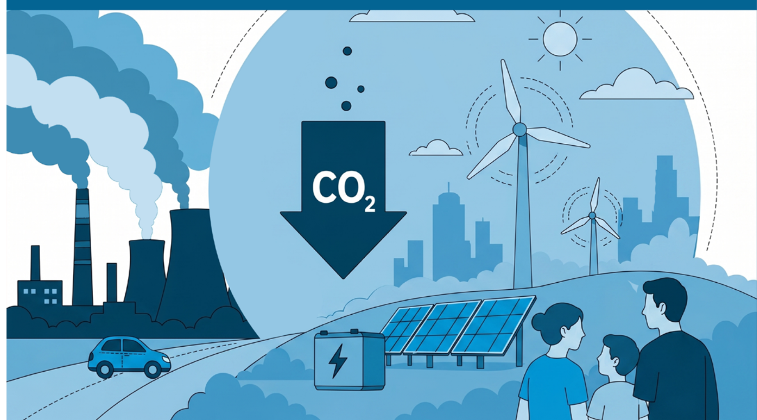
Nearly 11 times the employment of the new-coal pathway.

INR 600 billion

clean energy investment attracted

New capital drawn into the state's economy through solar, wind, and battery storage projects.





24%

lower power-sector CO_2 emissions

Avoiding long-term carbon lock-in while improving air quality and public health

Source: Authors' analysis.

the system's ramping and balancing needs, reducing reliance on inflexible coal plants to do so.

- **The RE plus storage pathway will support efficient system operations.** Under coal heavy scenarios, existing and new coal units are forced into frequent two shift operations and a high number of warm starts, restarting the unit within 8 hours, increasing wear and tear and raising operating costs. In contrast, battery storage will absorb much of the variability in net load, significantly easing stress on existing coal plants and improving overall system efficiency.

- **Beyond direct cost savings, the RE plus storage option also creates opportunities for state discoms to earn additional revenues** by selling surplus electricity to power exchanges. Our analysis shows that surplus sales could generate up to INR 35 billion additional revenue for discoms in 2030, higher than under the new coal option. These surpluses will be particularly valuable during high net load ramping hours, helping other states balance their grids as well.

- **Choosing RE plus storage will result in more jobs, better air quality, and lower emissions, supporting sustained economic growth and the well-being of citizens.** The RE plus storage option could generate nearly 11 times as many full time equivalent jobs by 2030 as the new-coal pathway, and attract INR 600 billion in clean energy investments to the state's economy. Similarly, choosing RE plus storage option will reduce the state's power system CO_2 emissions by 24 per cent, avoiding long-term carbon lock in and improving air quality and public health.

The Rajasthan case holds relevance across states. Our findings show that Rajasthan can meet its rising electricity demand reliably without burdening consumers with costly power. However, a persistent gap remains between power system planning and procurement—a challenge not unique to Rajasthan.

- First, **planning practices do not reflect changing power system dynamics**. Across states, project level tariffs are guiding the procurement decisions, rather than robust, least-cost assessments. Nearly 70 per cent of Indian discoms rely on simplistic compound annual growth rate (CAGR) based demand forecasting, without properly assessing the changing demand patterns, peak requirements, or emerging critical hours (Pandey and Shweta Kulkarni 2024).

Traditional planning for isolated state peaks has previously led to overcapacity. (Kahrl et al. 2021) estimate that India could have avoided nearly 45 GW of coal capacity and saved about INR 340 billion in FY20 if states had coordinated resource planning and enabled capacity sharing across state boundaries. At the same time, evolving grid dynamics are shifting system planning or stress hours from peak demand hours to peak net load or peak flexibility need hours.

In Rajasthan, for example, the plan to add 3,200 MW of new coal capacity (capable of generating over 20 BUs annually) is intended to address a 5.5 BU deficit. Yet, the simulation results show it will still leave around 1 per cent demand unmet, falling short of the CEA's 0.05 per cent reliability criterion. These outcomes underscore the need for a robust, system level least cost analysis across multiple demand and supply scenarios before procurement decisions are taken.

- Second, **recent capacity approvals across states show a mismatch between plans and tendered capacities.** In 2025, Bihar and Assam have contracted 5,600 MW of new long term coal capacities in total, with fixed costs of INR 4.17–4.54 per unit, even though the underlying planning studies assumed capex translating to fixed costs of less than INR 2.55 per unit for the chosen technology.

These examples point to a structural disconnect between planning assumptions and procurement decisions, with limited scenario testing or iterative feedback between the two. The regulators play a vital role here. Regulators decide whether or not states need the proposed capacity and also approve its tariff, once the bids are concluded. This highlights the regulator's role and capacity in demanding robust evidence to ensure the procurement decision aligns with the actual requirement and does not end up in cost burden on the consumers.

Consistent with the *National Tariff Policy, 2016*, procurement frameworks should enable competition across technologies to meet clearly defined reliability and flexibility requirements, ensuring that consumers benefit from true least cost solutions (Ministry of Power 2016).

- Third, **power procurement implications extend beyond discom finances.** Between FY19 and FY23, India spent USD 82 billion (approx. INR 7,600 billion) on importing non-coking coal for power generation—recurring fuel payments that expose the system to global price risks—compared to about USD 24 billion (approx. INR 2,200 billion) on RE and storage technologies, which create domestic assets.

Addressing this structural misalignment requires rethinking how states plan, procure, and regulate new capacity. The solution lies not in adding more capacity, but in aligning procurement decisions with robust, system level planning outcomes. To address the misalignment between planning and procurement, we propose three key interventions:

1. **State discoms must institutionalise robust, scenario-based integrated resource planning (IRP).** Our findings indicate that opting for an RE-and battery storage combination could help Rajasthan discoms save up to INR 85 billion in a year. This highlights the need for states to conduct continuous and rigorous IRP that tests technology options under varying demand, supply and cost scenarios. The state discoms can do so through a dedicated set-up with expertise in demand forecasting, system planning, and power system operations. The mandate must be to regularly assess multiple demand and supply scenarios, and jointly evaluate generation, transmission, storage, and flexible options. For instance, Gujarat Urja Vikas Nigam Limited (GUVNL) has established the Green Energy Transition Research Institution (GETRI), which provides in-house technical support for resource adequacy studies, system planning, and capacity building across the power sector. Regulators should standardise IRP methodologies, require periodic updates aligned with procurement cycles, and ensure planning assumptions and results are publicly available. The regulators must:

   - Standardise IRP methodologies and minimum analytical requirements across discoms.
   - Mandate periodic updates to IRPs aligned with procurement cycles, while assessing the annual revenue requirements for discoms.
   - Ensure the availability of IRP assumptions and scenario results in the public domain to allow for independent evaluation and enhance credibility.

2. **The Forum of Regulators should anchor procurement in technology-neutral, system defined requirements.** Procurement frameworks must specify the service required such as firm energy, peak support, or ramping capability and allow all eligible technologies to compete using common reliability metrics (e.g., effective load carrying capability). This prevents technology lock in and enables least cost solutions to emerge through competition. The regulators must:

   - Develop technology neutral tender guidelines with defined standard metrics and evaluation templates for such procurements.
   - Pilot technology-neutral tenders for identified needs of the system.
   - Periodically review procurement outcomes against system performance.

3. **State electricity regulatory commissions (SERCs) must strengthen in house technical capacity to independently evaluate procurement proposals.** Regulators should build analytical capability to assess peak adequacy, flexibility needs, and system costs, and require transparent disclosure of planning assumptions. Independent technical scrutiny ensures that procurement decisions protect consumer interests and align with long term fiscal resilience and energy sovereignty. The regulatory commissions must:

   - Introduce targeted training for technical staff at SERCs in system planning, resource adequacy, and flexibility assessment.
   - Establish standard analytical questions for reviewing procurement approvals.
   - Create internal technical cells or expert panels for examining large or long term procurement proposals.

1. Rajasthan power sector: Current landscape and future outlook

Rajasthan's electricity demand is rising fast. Between FY22 and FY25, annual electricity requirement and peak demand have grown at compound annual growth rates (CAGRs) of 8 per cent and 7 per cent, respectively, with demand peaking to 19-GW levels (Central Electricity Authority, n.d.). In response, the state added approximately 2 GW of solar, 300 MW of wind, and 1.7 GW of coal to its procurement portfolio during the same period (Ajmer Vidyut Vitran Nigam Limited 2025). With these additions, Rajasthan met 17 per cent of its demand with solar and wind in FY25, 65 per cent with coal and remaining by nuclear, gas and hydro power (Rajasthan Urja Vikas and IT Services Limited, n.d.).

However, shortages persist, between FY23 and FY26, Rajasthan has consistently had the highest power shortages amongst all states, typically in the non-solar hours (Central Electricity Authority, n.d.). Despite the shortages, Rajasthan bought only 23 per cent of total renewable electricity generated within the state for self-consumption in FY25, with the remainder exported to utilities and industries in other states (Central Electricity Authority 2025a; Rajasthan Urja Vikas and IT Services Limited, n.d.).

The state has been slow in contracting new capacities, due to a combination of reasons, including poor planning, not enough focus on strengthening the state transmission infrastructure, and challenges with procuring new wind capacities, despite highest wind energy potential within the state (Rajasthan Rajya Vidyut Prasaran Nigam Limited 2025; National Institute of Wind Energy 2023). As a result, the state continues to rely heavily on existing capacities even as it experiences recurring shortages during peak demand periods.

The Central Electricity Authority (CEA) projects the state's electricity demand in FY30 will be 1.5 times that in FY25 (Central Electricity Authority 2022). State plans to add 2.4 GW of coal-based capacity (Central Electricity Authority 2023b), along with 21 GW of RE to meet 2030 renewable consumption obligation (RCO) targets (Bureau of Energy Efficiency, n.d.). However, multiple studies (Agrawal et al. 2023; Idam Infrastructure Advisory Pvt Ltd 2023) indicate that the state will continue to face significant power shortages even if all planned capacities materialise. These findings underscore the need for adding new capacities fast, while keeping supply affordable for consumers.

In February 2025, Rajasthan discoms proposed contracting 3,200 MW of new coal capacity, beyond that already planned, as a possible solution to avoid the likely power shortages (Rajasthan Urja Vikas and IT Services Limited 2025).[1] The study assesses if this is the right technology choice for Rajasthan to meet its expected demand in 2030, given the urgency, and reliability and cost concerns. We simulate the state's power system for every 15-minute in 2030 using GridPath,[2] to compare an alternate choice–RE and storage–and its implications on the system wide costs and grid operations.

1. In addition to the previously planned 2.4 GW of coal-based capacity.
2. We assessed Rajasthan's needs using the production cost module of GridPath 0.8.2, an open-source python-based mixed-integer linear model widely used for power system planning (Sylvan Energy Analytics, n.d.). A production cost model optimises the cost of generating electricity from numerous power plants meeting the demand at the highest resolution (15-minute), while considering operational constraints for thermal power plants and storage units.

2. Modelling Rajasthan's power system for 2030

Rajasthan's electricity requirement and peak demand are expected to rise annually by 6.3 and 5 per cent, respectively, between 2022 and 2030. We use a business as usual (BAU) scenario (described in Box 1) based on Agrawal et al. 2023, as the reference case for our analysis.

Box 1: BAU scenario

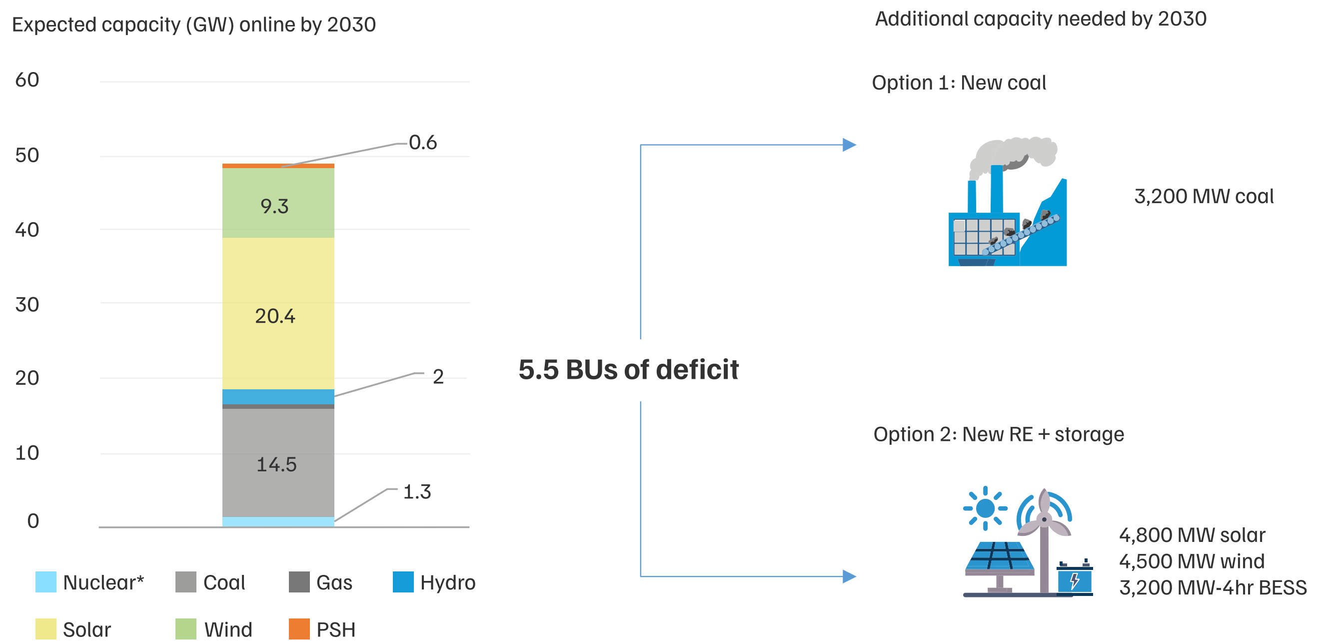
Under the BAU scenario, all existing and planned generation and storage capacities are assumed to be operational by 2030.[3] While the research (Agrawal et al. 2023) assumed the retirement of 1.9 GW of coal-based capacity, we retained these units in operation, reflecting CEA guidance on the continued use of existing assets (Press India Bureau 2023).[4] With the existing and planned generation and storage contracts, we find that 5.5 billion units (BUs) of demand in 2030 will remain unserved. The state could thus face major shortages during non-solar hours.

Source: Authors' analysis.

To address these shortages, we evaluated two procurement options, as illustrated in Figure 1.

1. Option 1: Procurement of 3,200 MW of new coal based capacity within Rajasthan (four units of 800 MW each).
2. Option 2: Procurement of a renewable-plus-storage portfolio designed to deliver firm energy comparable to the proposed coal capacity, comprising 4,800 MW of solar, 4,500 MW of wind, and 3,200 MW of four-hour battery energy storage systems (BESS).[5]

Figure 1. Simulating Rajasthan's grid with two procurement options



Source: Authors' analysis.

Note: Nuclear* includes nuclear, small hydro and bio-based generation capacity.

3. In our assessment, the planned capacity does not include 3,200 MW of coal capacity (the case of the petition raised by RUVITL). It includes 25.4 GW of existing capacity (as of June 2022), along with 2.4 GW of planned coal, 100 MW of new hydropower, 700 MW of new nuclear, 590 MW of pumped storage hydropower (PSH), and 16 GW and 5 GW of additional solar and wind capacities, respectively (as per state's RCO trajectory) (Agrawal et al. 2023).
4. The deficits will double to 13 BUs (7 per cent of the total electricity requirement) if 1.9 GW of earlier assumed retired capacity is phased out.
5. Option 2 is equivalent electricity requirement considering 70 per cent plant load factor (PLF) for new coal units, i.e., ~20 BUs.

Table 1 summarises the techno-economic assumptions used for each technology.

Table 1. Capacity, capex, and constraints—comparing coal with renewable energy

	Option 1: new coal	Option 2: new RE+storage		
	Coal	**Solar**	**Wind**	**BESS**
Capacity	4 units x 800 MW	4,800 MW	4,500 MW	3,200 MW (4- hour)
			Cost assumptions	
Capex (INR million per MW)	106.4–124.8[6]	40–45	70–80	USD 112–130 per kWh[7]
Weighted average cost of capital[8]			10.8%	
Variable cost (INR per unit)	4.05–5.05[9]			
Landed cost (INR per unit)	VC: 4.05–5.05 FC: 1.76–2.00[10]	LCOE: 2.83 –3.20	LCOE: 4.47 –5.10	LCOS: 3.84 –4.50
			Operations	
Normative utilisation	85% availability	24% CUF	28% CUF	5,000 cycles
Operational constraints	Ramp rate: 1% per minute MTL: 55% Warm starts only	-	-	88% round trip efficiency, 90% depth of discharge

Source: Authors' analysis based on Central Electricity Authority data and stakeholder consultation.

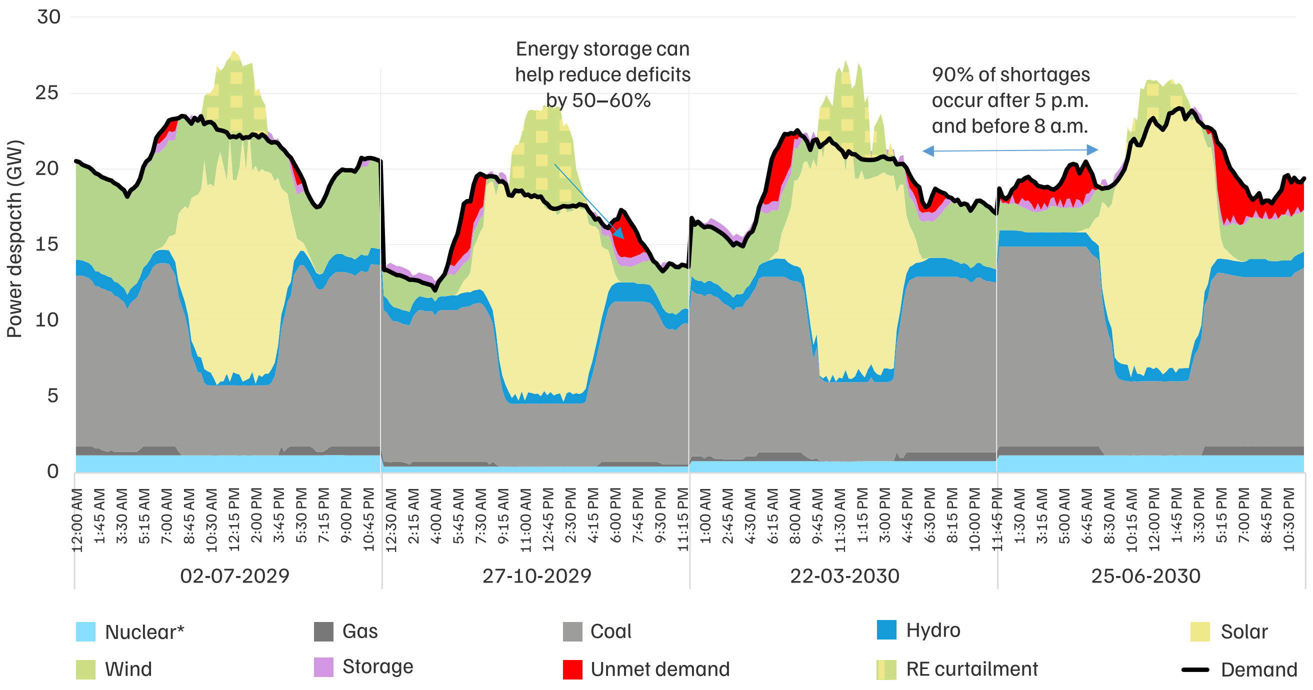
Note: 1. CUF: capacity utilisation factor; VC: variable cost; FC: fixed cost; LCOE: levelised cost of energy; LCOS: levelised cost of storage; MTL: minimum technical load.
2. In addition to these costs, the cost of transmission as INR 10 million per MW is considered separately.

6. Based on average and maximum capex quoted for units awarded in FY25 (Central Electricity Authority 2025b).
7. For a battery pack
8. Considering 70:30 debt to equity ratio, 15 per cent return on equity and 9 per cent interest on loan
9.Here, we considered the variable cost of a new non-pithead coal plant (INR 4.66 per unit, as of FY22 escalated at 1 per cent per annum in FY30 (Central Electricity Authority 2021).
10. At normative 85 per cent. Per-unit FC might change considering the actual utilisation.

3. Renewable energy and storage can support a reliable and affordable electricity supply in Rajasthan

The state's electricity demand is expected to grow at a CAGR of 7 per cent between FY25 and FY30. Our 15-minute production-cost simulations indicate that, under the BAU scenario, around 5.5 BUs of electricity demand, equivalent to 3.4 per cent of the total annual requirement, will remain unserved. Nearly 90 per cent of these shortages will occur during non-solar hours, between 5 p.m. and 8 a.m. (Figure 2).

Figure 2. Rajasthan will face consistent shortages with existing and planned capacities



Source: Authors' analysis for BAU scenario.

Note: 1. Nuclear* includes nuclear, bio-based energy sources, and small hydro project generation.
2. Representative days in each quarter.

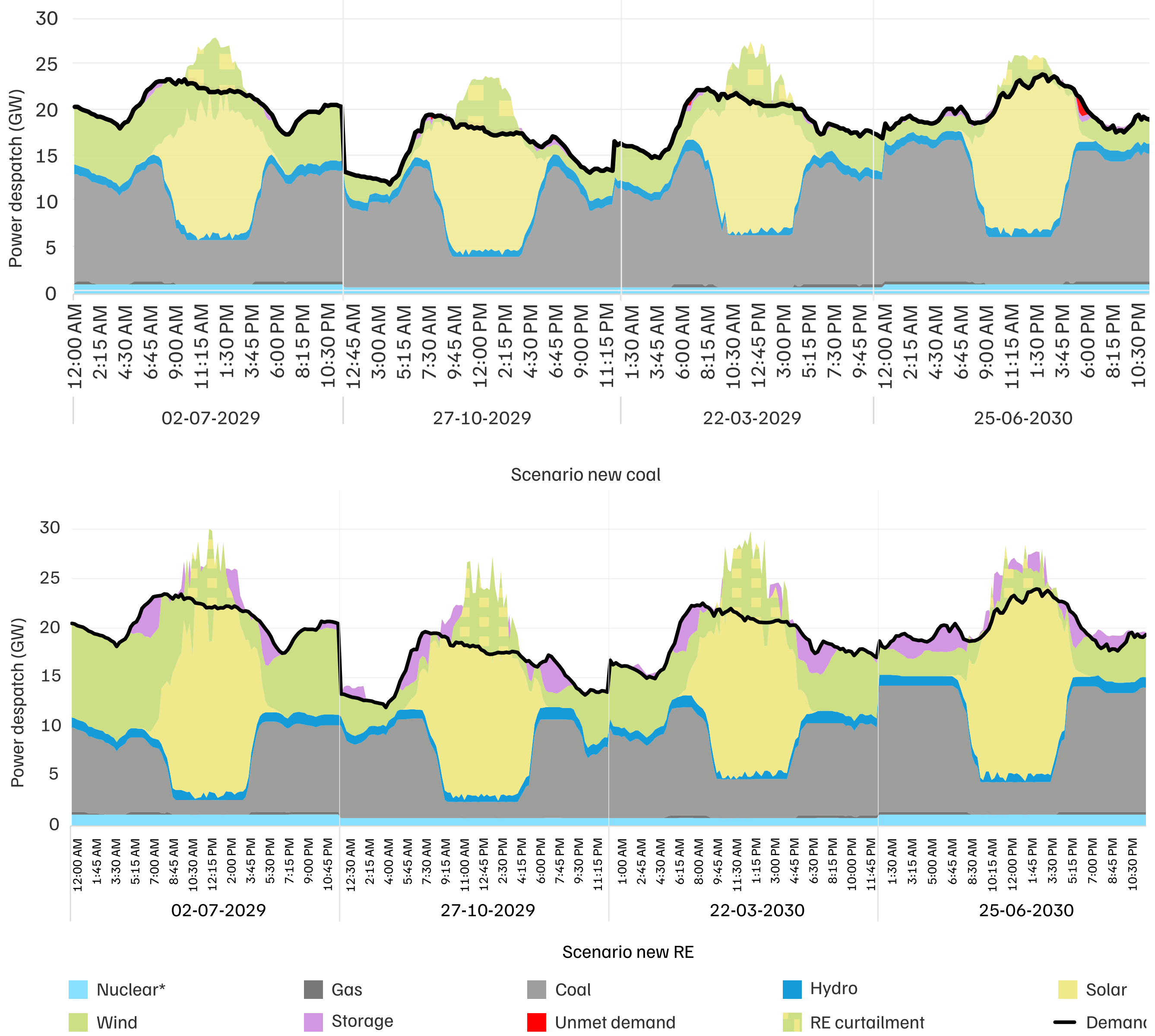
This section discusses the implications of two proposed procurement strategies.

3.1 Renewable energy and storage provide comparably reliable electricity while easing the operations

While the system faces 5.5 BUs of electricity deficit, it is also expected to curtail approximately 3.8 BUs of cheap RE generation in 2030, with solar accounting for about 86 per cent of total curtailment. Storage solutions can partially mitigate the temporal mismatch by shifting surplus renewable generation from the solar hours to non-solar deficit hours. Further analysis shows that unmet demand overlaps with wind-rich periods in Rajasthan, indicating an opportunity to reduce shortages. Sensitivity simulations combining wind capacity with battery energy storage reduce annual unmet demand by half relative to the BAU scenario, to 1.7 per cent of overall demand in 2030 (Annexure 1).

- **Both procurement options reduce the projected deficits to comparable reliability levels.** The deficits seen in Figures 2 can be partially addressed by two options (Figure 3). In each case, normalised energy not served (NENS) is limited to around 1 per cent of annual demand.[11] While this does not meet the more stringent CEA reliability benchmark of 0.05 per cent (Central Electricity Authority 2023a), the analysis compares a 3,200-MW coal addition with an equivalent renewable-plus-storage portfolio at the same reliability level to isolate the impact of procurement choices.

Figure 3. Both scenarios, new-coal and new-RE, meet the demand at the same reliability levels



Source: Authors' analysis for BAU scenario.

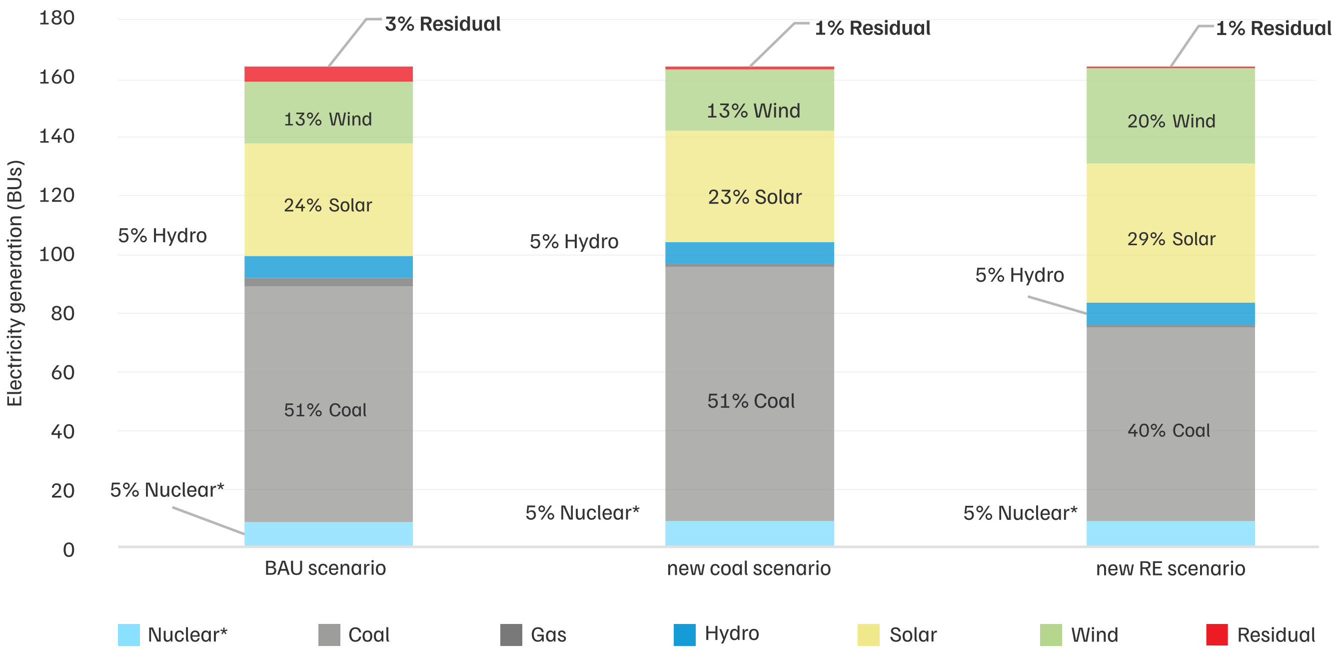
Note: Nuclear* includes nuclear, bio-based energy sources, and small hydro project generation.

11. For reference, between FY22 and FY25, Rajasthan faced shortages ranging from 0.3% to 1.7% of the overall energy requirement (Central Electricity Authority, n.d.).

- **Share of coal will remain high; however, the new capacity will be highly underutilised.** Coal continues to account for a large share of generation across scenarios, contributing 51–53 per cent in the BAU and new-coal cases, and about 40 per cent in the new-RE scenario (Figure 4). However, the additional 3,200 MW of coal capacity is significantly underutilised, operating at an average plant load factor (PLF) of around 34 per cent—well below typical design expectations of 70–80 per cent. At the fleet level, coal PLFs remain broadly similar across scenarios, ranging from 55–59 per cent.

  Solar and wind meet the state's RCO target in the BAU and new-coal scenarios, as planned capacity. In the new-RE scenario, the share of solar and wind generation exceeds the set RCO target, demonstrating Rajasthan's leadership in the energy transition.

Figure 4. Rajasthan discoms can meet and exceed the RCO target by adding new RE



Source: Authors' analysis based on BAU, new-coal, and new-RE scenarios.

- **Rajasthan will require significantly greater system flexibility to manage rising net-load variability.** Net load ramping requirements are projected to increase nearly fourfold between 2022 and 2030 (Agrawal et al. 2023), with ramp rates exceeding ±150 MW per minute for about five per cent of the time. Even if all 14.5 GW of installed coal capacity were to operate at normative ramp rates of ±1 per cent per minute,[12] coal generation would remain structurally inadequate to follow these ramps. Counterfactual analysis indicates that enhanced coal flexibility could address only around one-third of the projected unmet demand of 5.5 BUs (Figure 5).

12. The state-owned coal fleet currently operates at subpar ramping and MTL from the normative ±1 per cent per minute and 55 per cent (Agrawal. 2023) of the installed capacity, respectively. In case this continues, meeting the steep ramping needs will be more challenging for the system operators.

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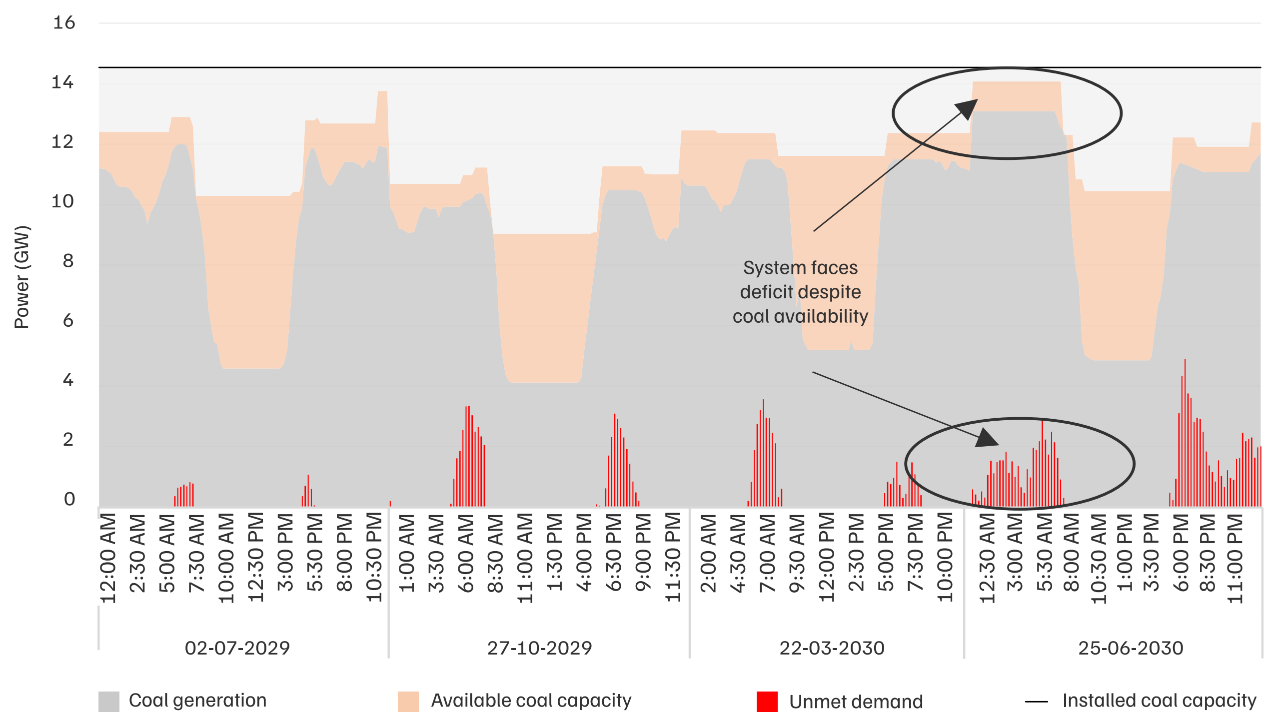
Figure 5. Despite coal availability, Rajasthan will face shortages



Source: Authors' analysis based on the BAU scenario.

Note: Available coal capacity is the difference between the capacity available on-bar and generation.

In the BAU scenario, Rajasthan's coal fleet is expected to operate under significant operational stress, frequently cycling between minimum and peak output. The system will record over 3,000 warm starts across 37 coal units in 2030,[13] averaging 86 starts per unit. Meeting the demand reliability will further increase the flexibility requirements, to account for the demand and generation variability. Under the new-RE scenario, the cycling stress on the coal fleet will be increased to about 94 per unit. BESS will be despatched optimally — based on the need — and not uniformly across all days. For instance, frequent charge–discharge cycles will be needed in peak winter months, January–February, to meet the steep ramping needs (see Annexure 2 for more details).

In contrast, the new-coal scenario will witness a 32 per cent higher stress (on an average of 124 starts per unit). The new units alone will experience more than 200 warm starts in a single year—levels that can materially shorten plant life and raise operating costs. Expanding storage capacity further will shift flexibility provision away from thermal units, easing operations across both existing and proposed coal plants in Rajasthan.

3.2. RE-plus-storage can reduce Rajasthan discoms' power procurement costs by up to INR 85 billion in 2030

A renewable and storage-based procurement pathway can meet Rajasthan's electricity demand at comparable reliability while lowering system costs. Across a range of technology cost assumptions for solar, wind, BESS, and coal, the RE-plus-storage option delivers net savings of INR 11.4–85 billion in 2030 relative to new coal capacity (Table 2). The RE-plus-storage option remains reliable and cost-effective even on peculiar days such as high-demand days, high-/low-RE-penetration, and high-flexibility days (Annexure 3).

13. We considered coal power plants to operate in a warm-start condition, i.e., once shut down, the unit will come back online in 8 hours.

Table 2. The RE-plus-storage option is cost-effective even with pessimistic assumptions

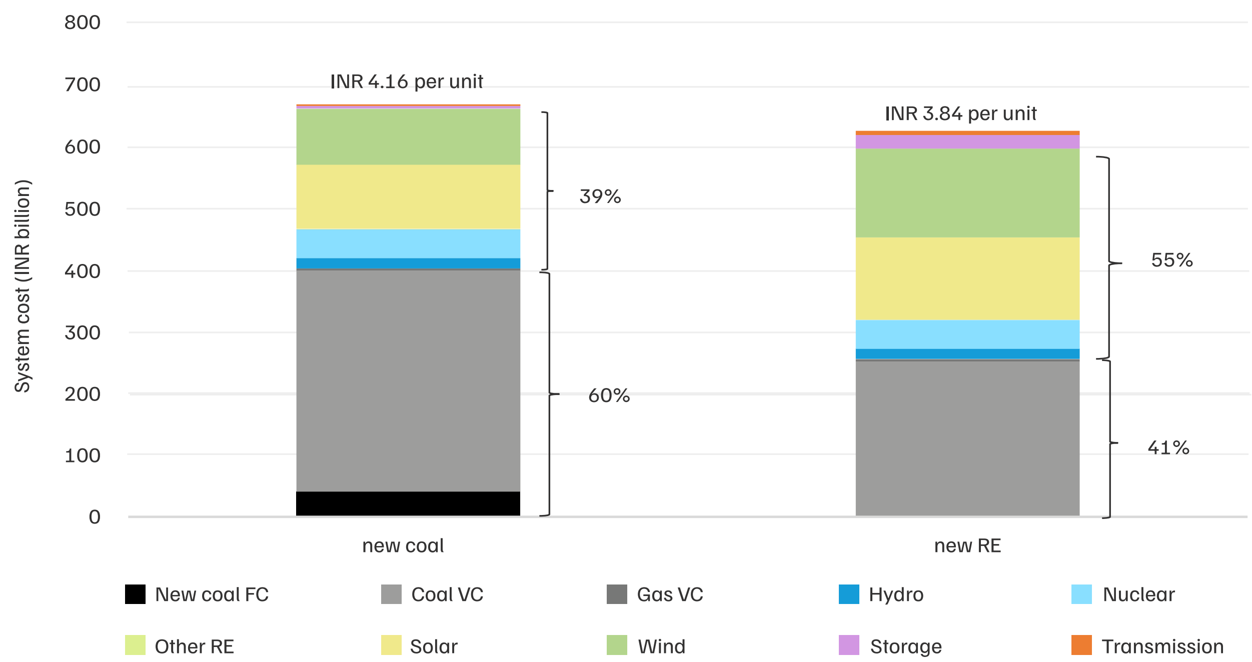
Scenario	System cost (INR per kWh)
New coal	4.16–4.36
New RE	3.84–4.09

Source: Authors' analysis based on scenarios.

Note: 1. Considering real cost numbers as of 2025.
2. The system cost considers variable and operational costs for coal, gas, hydro, nuclear, bio-based energy, small hydro, along with the levelised cost of electricity for solar and wind, and levelised cost of BESS and PSH. It also includes start-up costs for coal and gas power plants, annualised fixed costs for new coal units, and additional transmission costs for new capacities. However, it does not include the existing fixed and transmission costs that are considered sunk costs for the system.
3. We varied the capex, variable cost, and levelised cost of storage assumptions for solar, wind, coal, and BESS, as illustrated in Table 1.

As non-fossil sources rise to around 60 per cent of total generation in the new-RE scenario (Figure 4), they account for roughly 55 per cent of total system costs. This reflects a shift in the power system's cost structure: lower-cost renewable generation increasingly displaces higher-cost fossil-based generation (Figure 6). Even under optimistic cost assumptions, flexible resources—including BESS, pumped storage hydropower (PSH), and associated transmission—contribute only 1–4 per cent of total system costs, while enabling the integration of cheaper energy and reducing overall financial exposure for discoms.

Figure 6. Cheaper non-fossil generation displaces higher-cost fossil-based sources



Source: Authors' analysis based on scenarios new coal and new RE.

Note: FC: fixed cost, VC: variable cost and other RE includes small hydro and bio-energy based generation.

In addition to these system-level savings, Rajasthan discoms can monetise surplus generation through power exchanges, earning up to INR 35 billion in 2030. Surplus energy is available across thermal, solar, wind, and other renewable sources (Table 3), with the highest volumes occurring between March and May during solar transition hours. This surplus not only improves discom revenues but also supports system balancing for other utilities. The surplus energy is sold at the exchange for every 15 minutes, when it is economically viable to sell. For instance, in the new-coal scenario, only 22 out of 26 BUs of surplus energy in 2030 traded at the exchange as the variable cost of surplus coal power is less than the anticipated exchange price, which will yield profits for the state discoms.

Table 3. Rajasthan discoms can earn up to INR 35 billion in 2030 from the sale of surplus power

Source of surplus	Option 1: New 3,200 MW coal (INR billion)	Option 2: New Solar + wind + storage (INR billion)
Solar + Wind	12.9–13.3	17.6–18.3
Coal	5.9–6.8	4.6–4.8
State hydro, small hydro, and bio-energy	14.2–14.7	19–19.8
Overall	27.5–29.2	34–35.2

Source: Authors' analysis based on simulation results and power exchange price between 1 July 2023 and 30 June 2025.

Note: Surplus power is sold at 15-minute intervals only when the market-clearing price exceeds the variable cost of generation. Average exchange prices over the past two years are discounted by INR 0.50 per unit to account for future market prices.

3.3 Renewable-plus-storage delivers employment, investment, and emissions benefits for the people of Rajasthan

Beyond meeting the electricity demand reliably and affordably, power procurement choices shape the broader development outcomes for the state. We assess the employment, investment, and emissions implications of the two procurement pathways (Table 4).

The new-RE scenario is expected to generate substantially higher socio-economic benefits for Rajasthan. By 2030, it will create nearly 11 times as many full-time equivalent (FTE) jobs as the new-coal pathway. The RE-plus-storage pathway is also expected to attract higher investment, around INR 600 billion in clean energy technology.

At the same time, the transition will reduce the power system's environmental footprint. Annual CO_2 emissions under the new-RE scenario will reduce to 52 million tonnes—around 24 per cent lower than the new-coal pathway and equivalent to 78 per cent of Rajasthan's power sector emissions in FY24.[14] These outcomes indicate that a renewables-led procurement strategy can support a reliable power supply while advancing employment, investment, and emissions-reduction objectives of the state.

14. Rajasthan's power sector emissions for FY24 were 66 million tonnes (MT) (NITI Aayog, n.d.)

Table 4. Renewable-plus-storage delivers stronger socio-economic outcomes for the people of Rajasthan

Parameter	New-coal scenario	New-RE scenario
FTE jobs (till 2030)	2,560	26,967
Investment attracted (INR billion)	400	600
CO_2 emissions of state's power system (MT/year)	68	52 (24% lower)

Source: Authors' analysis.

Note: 1. Considering the 0.8, 1.68, 1.15 and 4.29 full time equivalent (FTE) coefficient for new coal, new utility solar, wind and BESS as discussed in (Agarwal et al. 2025; Council on Energy, Environment and Water, n.d.).
2. Considering the emission factor as 0.727 tonnes/MWh (Central Electricity Authority, n.d.-a).
3. Considering transmission investment along with generation will result in INR 420 billion of investment in Rajasthan under new-coal scenario, and INR 650 billion under new-RE scenario.

4. How should states align planning and procurement to ensure a reliable, affordable, and secure power supply?

India and its states, like many other emerging economies in the Global South, are caught in a trilemma—meeting rising electricity demand reliably, keeping tariffs affordable, and reducing exposure to fuel and supply risks. This challenge is most acute in fast-growing, renewable-rich states, where demand growth coincides with a changing generation portfolio.

The Rajasthan case highlights that the state's power shortage is not primarily driven by inadequate capacity, but the capacity available at the time of need. Despite a capacity addition of 3,200 MW, which is designed to generate over 20 BUs, as opposed to 5.5 BUs of deficit, the state will continue to face deficits during critical hours, suggesting gaps in planning.[15] Adding new resources without a robust, system-level evaluation risks locking discoms into higher costs without resolving reliability concerns.

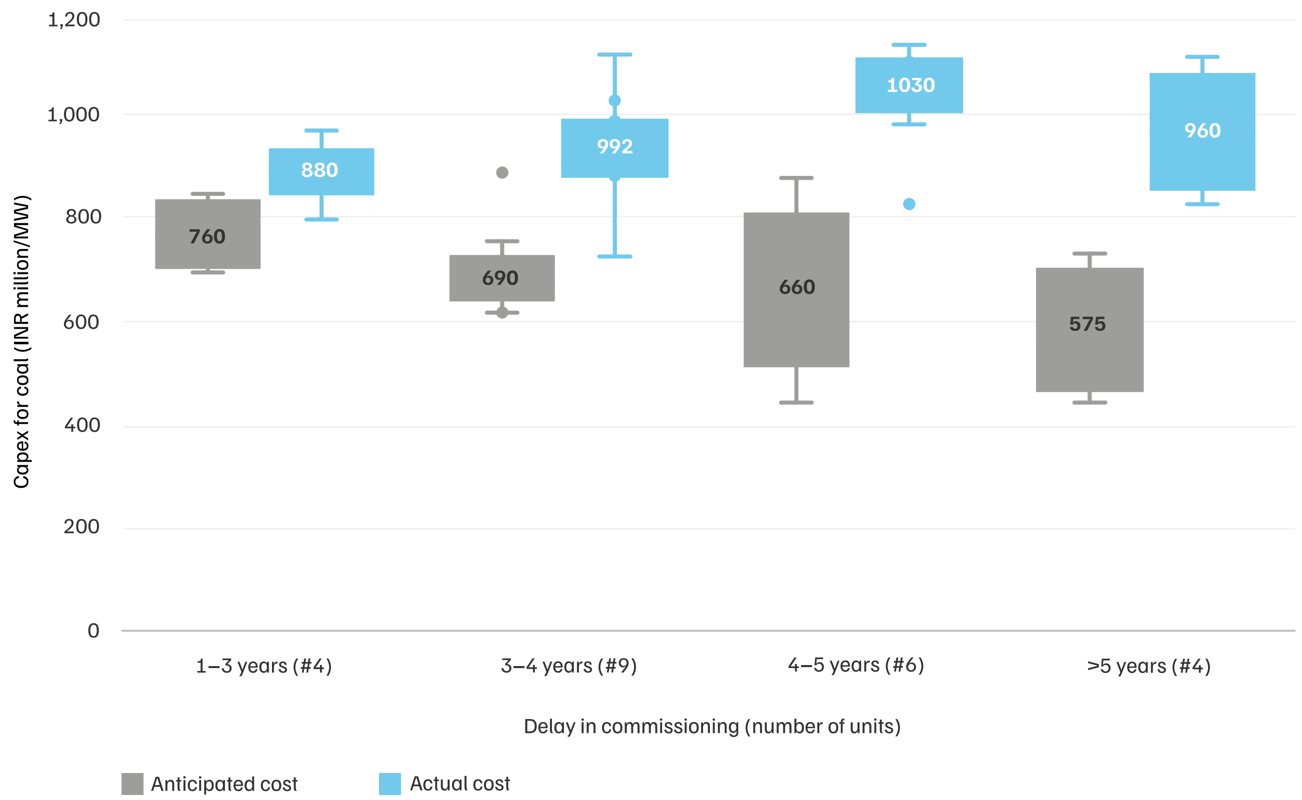
4.1 Planning must move away from project-level costs to reflect the least-cost outcomes for the system and consumers

The Indian Electricity Grid Code mandates each discom, in consultation with the state and central transmission utility, to conduct integrated resource planning (IRP) — including (i) demand forecasting; (ii) generation; and (iii) transmission adequacy—to meet projected requirements (Central Electricity Regulatory Commission 2023). However, in practice, implementation remains inconsistent. For instance, 42 out of 62 Indian discoms use simple CAGR extrapolations to estimate future power needs. Only a few discoms conduct trend analysis or evaluate demand at a higher granularity (monthly) (Pandey and Shweta Kulkarni 2024). These methods often underestimate peak requirements while overstating baseload demand, skewing procurement decisions towards building an inflexible mix.

Planning gaps extend beyond demand forecasting. Although regulations mandate integrated generation -transmission planning, multiple states have recently procured large, long-term capacities without exploring realistic least-cost alternatives. For instance, Bihar and Assam procured 5,600 MW of new long-term capacity in 2025 (Bihar Electricity Regulatory Commission 2025; Assam Electricity Regulatory Commission 2025), with fixed costs ranging between INR 4.17–4.54 per unit. However, the underlying planning studies assumed a capital cost of INR 115 million per MW (INR 11.5 crore per MW), implying a fixed cost of less than INR 2.55 per unit for the same technology (Central Electricity Authority 2025e, 2025d).[16] In contrast, the capex considered for RE is mostly reflected in the discovered tariffs.

Further, these assumptions rely on commissioning the coal unit within a four-year timeline. Historically, coal plants in India have taken 7-9 years to commission (Agarwal et al. 2025). Delays significantly increase the project costs (Figure 7). For instance, the Bhusawal thermal power station unit six in Maharashtra saw a 40 per cent cost escalation following a nearly 3-year delay. A similar trend holds for other conventional technologies, where consumers bear the impact of the escalated fixed costs due to delayed commissioning.

Figure 7. Capex increases by 30% with 3-4-year delay, a common trend



Source: Authors' analysis based on Central Electricity Authority data.

Note: Representing coal units commissioned between FY22 and FY25.

Locking into long-term take-or-pay contracts under these conditions exposes discoms to substantial financial risk particularly in a rapidly changing demand scenario.

If plants operate below the normative 85 per cent utilisation level, the effective per-unit fixed costs increase further.

15. The 3,200 MW of new coal capacity or equivalent RE-plus-storage capacity is designed to generate ~20 BUs annually (considering 70 per cent PLF). These 20 BUs will still not satisfy the CEA's reliability criteria at 15-minute granularity of limiting the NENS to 0.05 per cent of the demand annually.

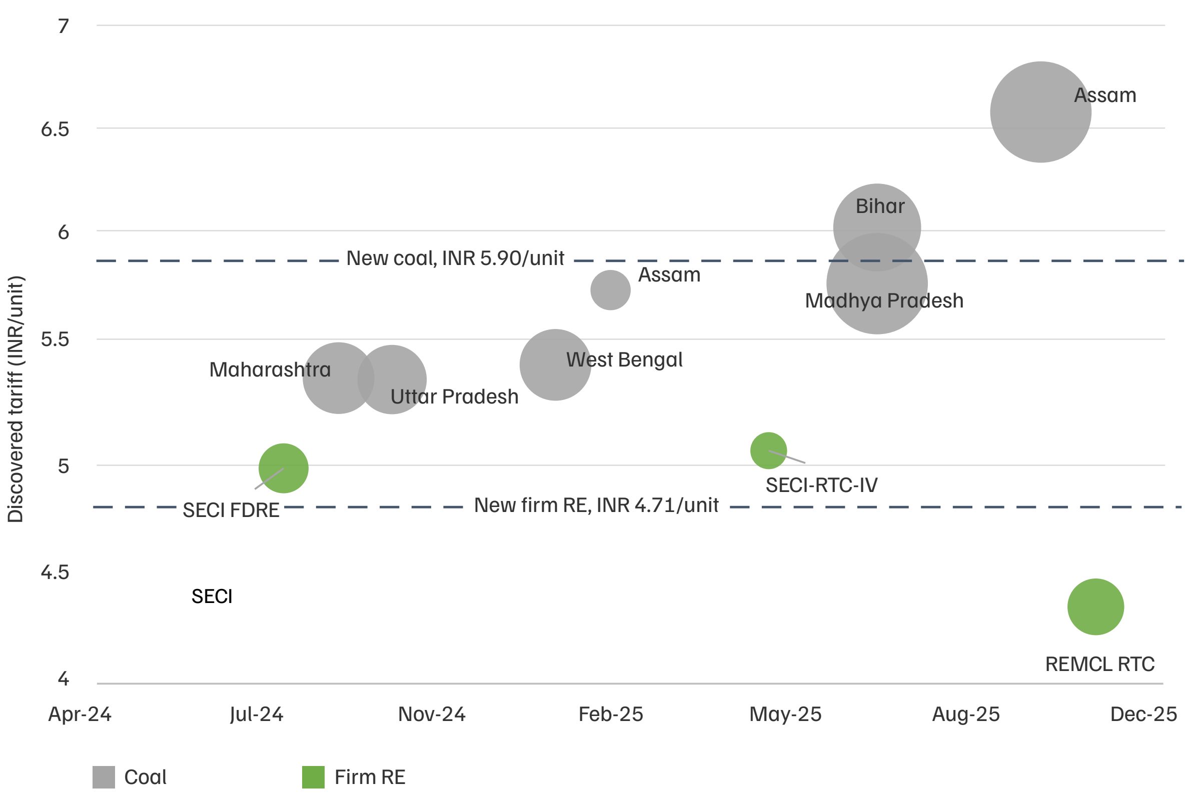
16. We considered capex recovery makes 80–85 per cent of the overall fixed tariff. With INR 110–130 million per MW capex at 85% availability and 10.8 per cent weighted average cost of capital (WACC), the fixed cost should be INR 2.16–INR 2.55 per unit.

4.2 Clean technologies make an increasingly compelling choice to reduce system costs

Globally, the cost of the BESS pack has declined by 82 per cent over the last decade (Ember 2025). With declining costs and technological development, RE combined with storage now delivers firm power at a lower cost. In 2024 and 2025, bids for firm RE were at least INR 1.2/unit lower than those for recently procured coal capacity (Figure 8). Multiple system-level simulations reinforce this finding. Our analysis for Rajasthan shows that a RE-plus-storage pathway can meet demand at comparable reliability levels while reducing overall system costs by more than 50 paise per unit relative to new coal additions (section 3.2).

Additionally, power from RE plants is inflation-proof for the consumers. Our consultations with developers and renewable energy implementation agencies (REIAs) indicate that utility-scale solar projects have been commissioned in 16 months, wind farms in 20-45 months—significantly faster than coal plants. While transmission build-out (typically 3-5 years) remains a constraint, recent amendments to the CERC's General Network Access (GNA) regulations have enabled solar and non-solar hour-specific connectivity, promising better transmission utilisation and faster renewable integration.

Figure 8. New RE bids are at least INR 1.20 per unit cheaper than newly bid coal units



Source: Authors' analysis based on recent bid results for new coal and firm RE procurement.

Note: 1. The size of the bubble indicates the capacity.
2. Grey colour represents new coal bids, and green colour represents the new firm RE bids.
3. To maintain consistency, we did not consider the peak assured firm and despatchable renewable energy (FDRE) tenders, as that is not comparable with the round-the-clock (RTC) bid for coal power.
4. The differential will increase, as the actual built cost for coal is always higher than the bid (Figure 7).

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4.3 Clean energy presents an enormous opportunity to reduce India's electricity imports

India spends heavily on energy imports. For instance, between FY19 and FY23, India spent approximately USD 82 billion on importing non-coking coal, majorly used for power generation (Ministry of Coal, n.d.). Concurrently, India also spent about USD 24 billion on importing RE and storage technologies.

However, the nature of this expenditure differs fundamentally. Coal imports represent recurring fuel payments tied to electricity generation. In contrast, RE and storage investments create domestic generation assets with negligible fuel risk over their operational life. India has also strengthened its domestic manufacturing capacity. The country has over 170 GW of module manufacturing capacity, more than 25 GW of cell manufacturing capacity, and surplus wind manufacturing capacity alongside rapidly expanding BESS manufacturing capabilities (Ministry of New and Renewable Energy 2026). Scaling renewable and storage deployment can therefore reduce reliance on imports in the long run, stabilise the power costs, and stimulate domestic industrial growth.

4.4 Procurement must be anchored in robust system planning

The examples above point to a structural gap between planning and actual procurement decisions across states. Often, procurement decisions are not driven by robust, transparent, system-level assessments that evaluate multiple demand-and-supply scenarios. States typically prefer choosing selective technologies, resulting in a sub-optimal solution for the consumers. The National Tariff Policy, 2016, emphasises competitive bidding to deliver consumer benefits through cost reduction and efficiency gains (Ministry of Power 2016). In practice, however, technology-specific competitive bidding determines the price of a selected capacity rather than whether that capacity is the most cost-effective way to meet system needs. Strengthening the link between planning and procurement, therefore, requires procurement decisions to follow from system-level planning outcomes. When planning compares multiple scenarios and a wider set of technology options, procurement can focus on addressing the identified reliability gap, instead of defaulting to capacity-specific solutions.

While this case study focused on evaluating the procurement decision for the proposed 3,200 MW of new coal capacity in Rajasthan, similar studies must be conducted to set the state's plans and meet the future demand. According to the regulations, these studies must include robust medium- and long-term demand forecasting to assess the least-cost planning, meeting system adequacy needs.

Procurement frameworks must internalise these strategic considerations. Choices made today will determine not only near-term system adequacy, but also long-term fiscal resilience and energy sovereignty.

To address the misalignment between planning and procurement, we propose three key interventions.

1. **State discoms must institutionalise robust, scenario-based integrated resource planning.** State discoms must build an ecosystem within the institution to conduct regular planning studies. For instance, Gujarat Urja Vikas Nigam Limited (GUVNL) has an autonomous institute called Green Energy Transition Research Institution (GETRI). It is equipped with full-time members with expertise in the power sector across generation, transmission, distribution, regulatory, IT, finance and commerce. GETRI supports GUVNL in conducting deep research such as creating resource adequacy plans for GUVNL and training the GUVNL officials across its six departments including, generation company, four discoms, and the transmission company (GETRI, n.d.).

   IRPs should move beyond single-point demand forecasts and comprehensively assess generation, storage, transmission, and flexibility options using sub-hourly simulations. Planning outputs must identify the type, timing, and duration of capacity and flexibility required, rather than pre-selecting technologies. The regulators must:

- Standardise IRP methodologies and minimum analytical requirements across discoms.
- Mandate periodic updates to IRPs aligned with procurement cycles, while assessing the annual revenue requirements for discoms.
- Ensure the availability of IRP assumptions and scenario results in the public domain to allow for independent evaluation and enhance credibility.

Evidence from Rajasthan and other states shows that simplified forecasting and siloed planning have led to procurement choices that increase fixed costs without addressing peak shortages or operational stress.

2. **The Forum of Regulators should anchor procurement in technology-neutral, system-defined requirements.** The Forum of Regulators (FoR), in collaboration with the Government of India and the Central Electricity Regulatory Commission (CERC), should design technology-neutral procurement frameworks that allow all resources to compete to meet defined system needs.

Procurement guidelines should specify the system services required, such as bids for reliability, which includes meeting desired firm energy, base capacity or peak support; or bids for meeting flexibility, like steep ramping capability and seasonal adequacy capacity, as identified in the IRP. For example, U.S. utilities such as Xcel Energy (Colorado) and Salt River Project (Arizona) use all-source procurement processes that specify the capacity, reliability and operational services required, while allowing competing technologies—including renewables, storage and conventional generation—to compete on equal footing to meet those needs (Paul Ciampoli 2025).
Various international markets consider evaluating all eligible resources using common reliability metrics (e.g., effective load carrying capability), without embedding technology-specific attributes or compliance tags where not relevant. Indian regulators must:

- Develop technology-neutral tender guidelines with defined standard metrics and evaluation templates for such procurements.
- Pilot technology-neutral tenders for identified needs of the system.
- Periodically review procurement outcomes against system performance.

Competitive bidding determines the price of a chosen capacity, but not whether that capacity represents the least-cost solution for the system. Technology-neutral tenders enable discoms to respond to evolving system needs without locking into inflexible capacity choices.

3. **State electricity regulatory commissions must strengthen in-house technical capacity to independently evaluate procurement proposals.** State electricity regulators must build internal technical capacity to independently evaluate system needs and critically assess procurement proposals submitted by discoms.

Regulatory commissions should ensure that technical staff are trained to (a) assess system requirements, including peak adequacy, ramping, flexibility, inertia, and reactive power needs; (b) distinguish whether projected demand growth reflects energy, peak, or flexibility requirements, and identify suitable resource options accordingly; and (c) evaluate whether proposed resources (coal, RE, storage, or hybrids) are the least-cost and most appropriate means of meeting the identified system need, based on planning and operational evidence. The regulatory commissions must:

- Introduce targeted training on system planning, resource adequacy, and flexibility assessment.
- Establish standard analytical questions for reviewing procurement proposals by discoms.
- Create internal technical cells or expert panels for examining large or long-term procurements.

While discoms are responsible for demand forecasting and proposing procurement plans, regulators must be able to independently test whether these proposals address the underlying system needs and consumer interests. Strengthening regulatory capacity is essential to avoid long-term procurement lock-ins that respond to demand projections without resolving system constraints.

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Annexure 1. Role of wind and a balanced renewable mix in reducing power shortages

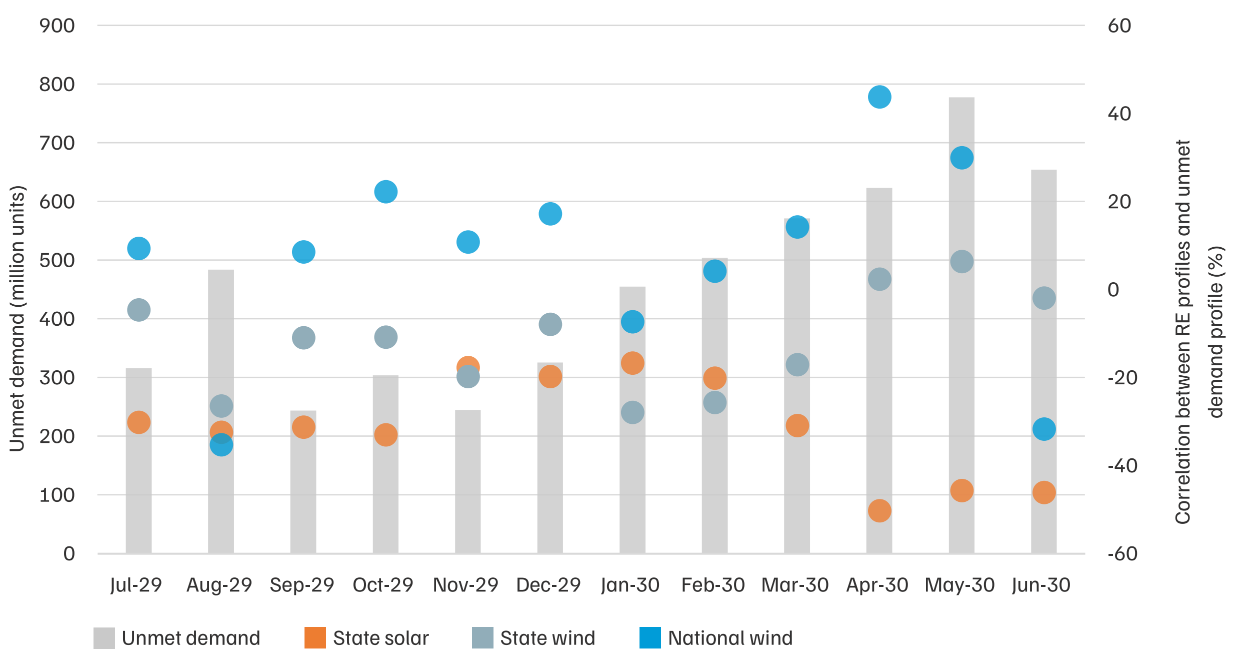
This annexure examines how Rajasthan’s unmet demand in 2030 can be mitigated with a more balanced mix of solar, wind, and storage, while reducing system costs.

Our analysis shows that a significant share of unmet demand in the BAU scenario arises not from insufficient installed capacity, but from the system’s limited ability to respond to steep ramping needs. As solar penetration increases, net-load ramps become sharper during early morning and evening transition hours, increasing the need for flexible resources.

Under current plans to meet the RCO targets, solar generation is expected to contribute approximately 2.2 times the energy generated from wind. This skewed renewable mix exacerbates flexibility requirements. A more balanced renewable portfolio can moderate these challenges. Wind generation profiles in Rajasthan are better aligned with periods of system stress—particularly during evening, night-time, and early morning hours—when shortages are most likely to occur.

Figure A1 shows that wind availability is more closely correlated with the timing of unmet demand in the BAU scenario than solar generation. This alignment improves further when geographically diversified wind capacity across multiple states is considered, highlighting the role of spatial diversification in enhancing system reliability.

Figure A1. State-level and geographically diversified wind profiles align with the timing of expected power shortages

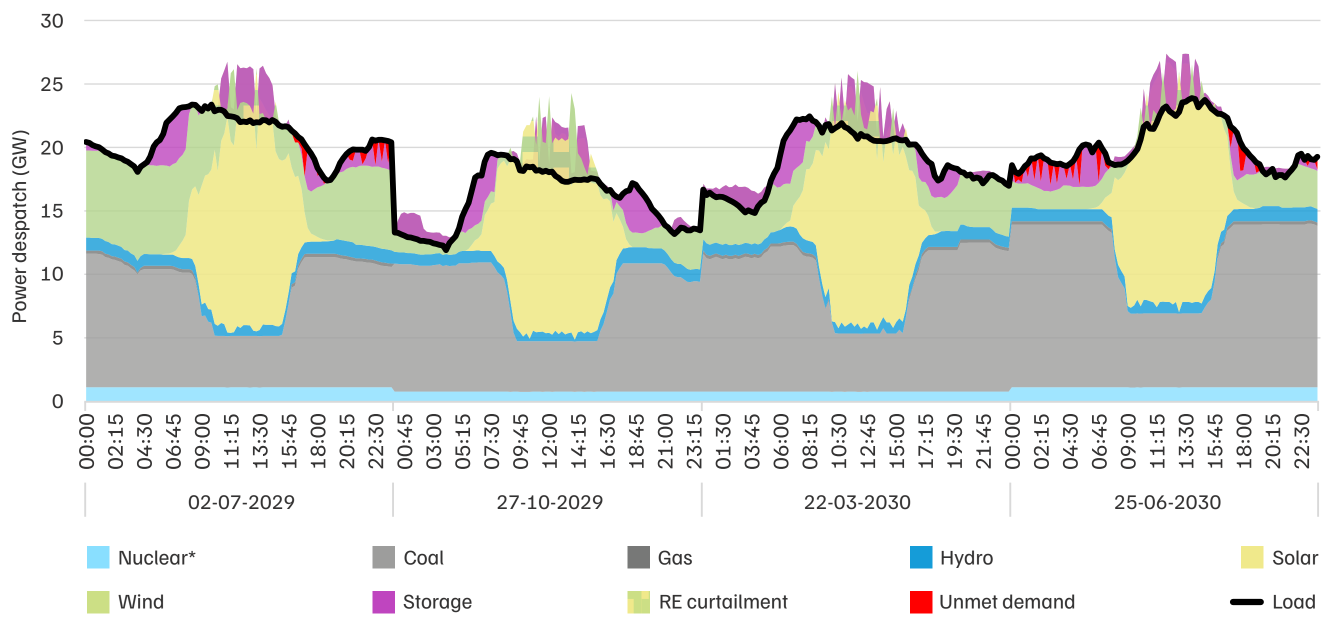


Source: Authors’ analysis of BAU scenario.

As part of a sensitivity analysis, we assessed the impact of increasing wind capacity by 10 per cent, i.e., 850 MW, over planned levels and coupling it with 3.6 GW of three-hour BESS, while keeping all other assumptions unchanged.

The results show that this balanced wind-plus-storage configuration reduces unmet demand to around 1.7 per cent of total electricity requirement in 2030. The reduction is most pronounced between September and March, when wind availability is relatively higher. At an intra-day level, the additional wind and storage substantially reduce the magnitude of shortages during early morning hours (6–8 a.m.), when solar generation begins to ramp up, and during evening transition hours (5–7 p.m.), when solar output declines (Figure A2).

Figure A2. Additional wind and storage reduced power shortages across seasons



Source: Authors’ analysis based on simulation results for sensitivity.

Note: 1. Nuclear* includes nuclear, bio-based energy sources and small hydro project generation.
2. Representative days in each quarter.

The reliability achieved under the balanced renewable mix is comparable to that obtained by adding approximately 1,600 MW of new coal-based capacity. However, unlike coal additions, the wind-plus-storage pathway avoids long-term fixed-cost commitments and delivers system savings of up to INR 62 billion in 2030, driven by lower fuel costs and reduced reliance on inflexible capacity.

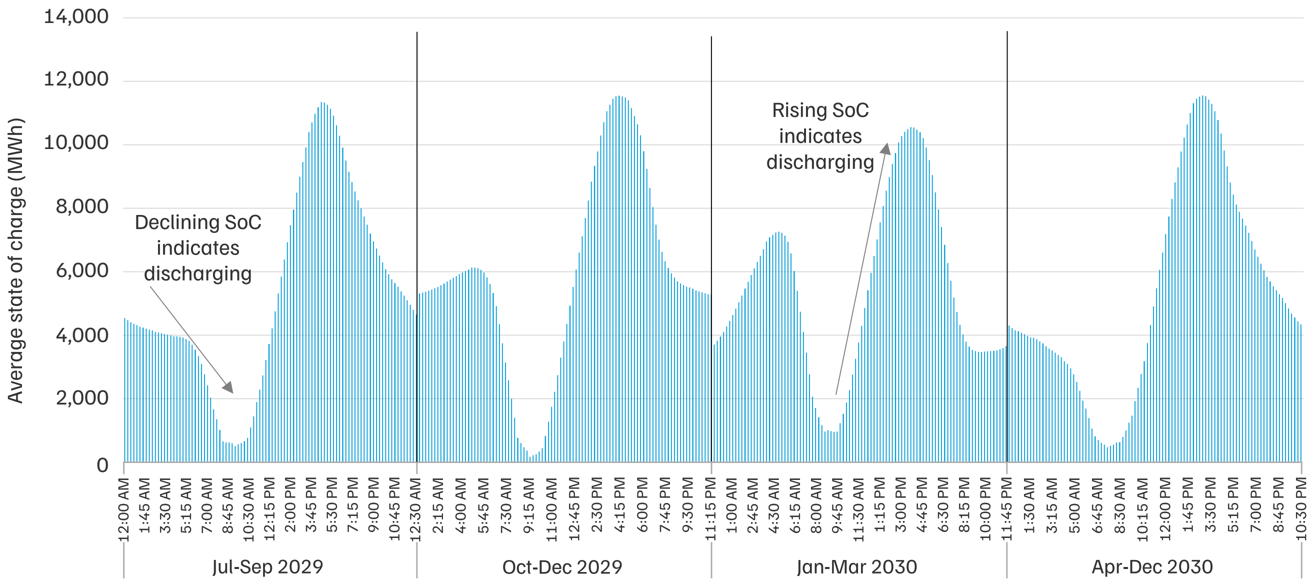
These findings underscore that addressing Rajasthan’s power shortages requires not only additional capacity but a careful alignment of resource profiles with system flexibility needs. A balanced mix of solar, wind, and storage can meet demand reliably while lowering costs and operational stress.

Annexure 2. Optimal despatch of battery storage eases the grid operation

In our simulations, BESS improves system reliability by energy arbitrage, by shifting electricity from surplus generation periods to deficit periods. Their value, however, depends not only on installed capacity but also on how they are dispatched across seasons and operating conditions.

We consider 24-hour visibility to decide when to charge and discharge battery, minimising the overall system cost and while maintaining supply reliability. Figure A3 illustrates the seasonal variation in the battery state of charge (SoC). During months with abundant solar generation, batteries primarily charge during mid-day hours using surplus renewable energy and discharge during the evening peak. During winter months, when wind is also available and system flexibility requirements are higher, batteries charge in the night hours, meeting the early morning steep ramps, swiftly absorbing the solar generation and ramp to meet the evening peak demand.

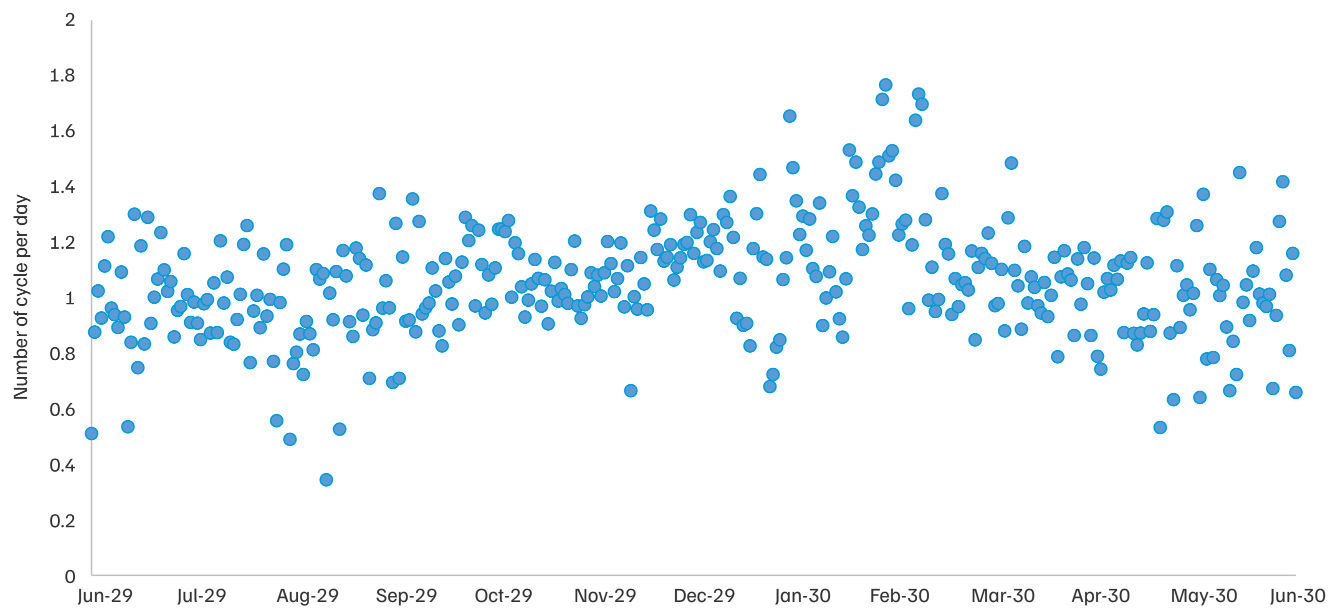
Figure A3. State of charge pattern varies across seasons



Source: Authors' analysis based on new-RE scenario.

Battery utilisation also varies throughout the year. Figure A4 shows that batteries experience the highest number of charge-discharge cycles during January and February, when Rajasthan faces frequent flexibility requirements arising from peak demand, increased wind generation and steeper net-load ramp periods. Under these conditions, storage provides balancing services multiple times within a day, reducing the need for thermal generators to cycle frequently or operate at part load.

Figure A4. BESS operates at higher cycle per day during January and February 2030



Source: Authors' analysis.

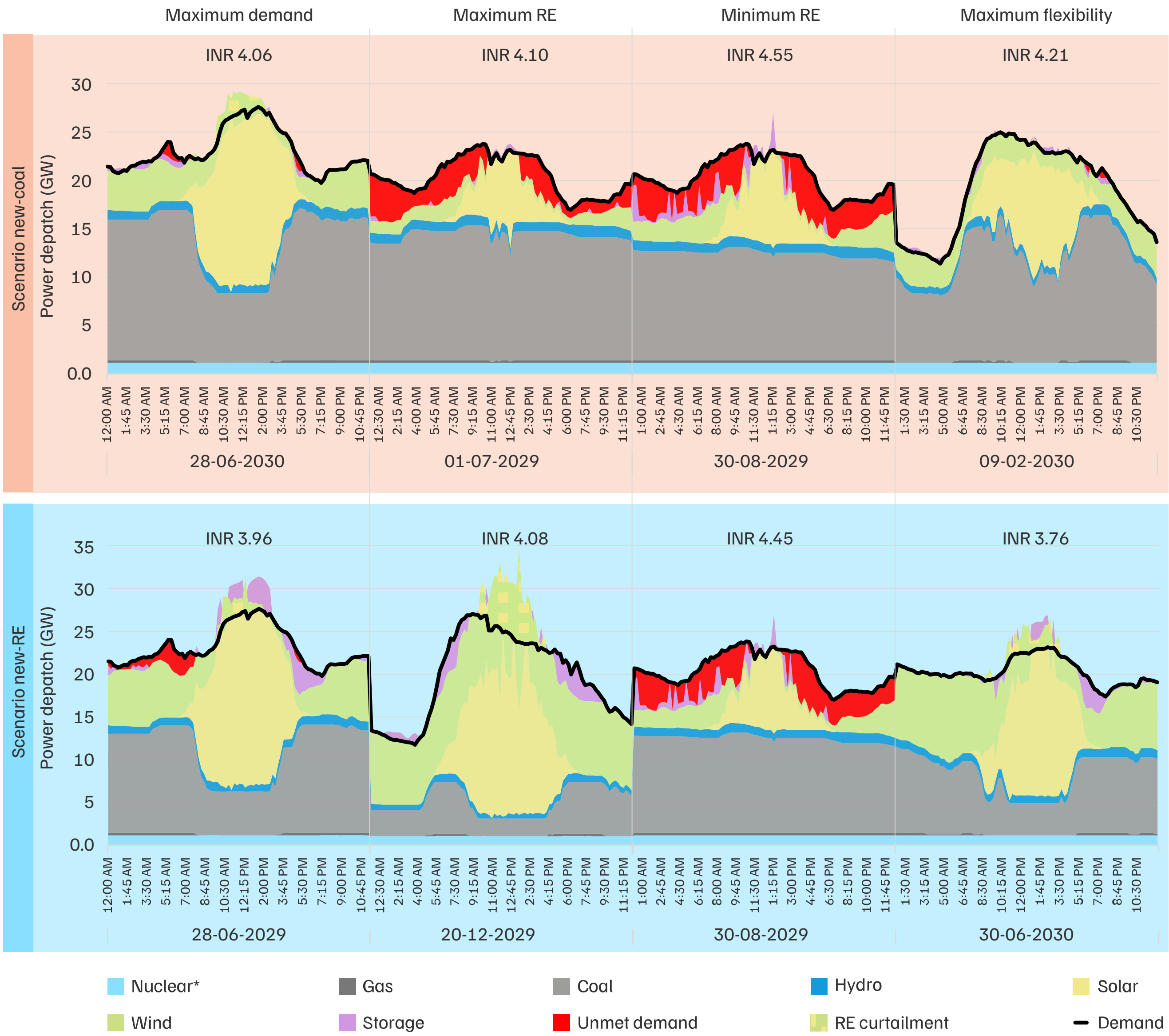
Annexure 3. Renewable plus storage will deliver power at lower cost throughout the year

Choosing an RE-plus-storage pathway could reduce Rajasthan's average system cost by up to INR 0.52 per unit of electricity generated in 2030. This annexure compares system operations and costs under the new-RE and new-coal scenarios across four representative system conditions: (i) maximum demand, (ii) maximum RE penetration, (iii) minimum RE contribution, and (iv) maximum flexibility requirement.[17]

Our analysis shows that the new-RE scenario results in lower system costs across all representative days. The cost advantage is most pronounced during high-flexibility conditions, when the system experiences steep net-load ramps. On such days, the new-RE scenario delivers power at INR 3.76 per unit, while the new-coal scenario is approximately INR 0.46 per unit more expensive due to increased cycling and ramping requirements for coal plants (Figure A5).
The cost differential is lowest on the day with the highest RE contribution, when RE accounts for 47–71 per cent of total generation. This indicates that higher renewable absorption can lower overall system costs while maintaining reliability.

17. A high-flexibility day is defined as a day with the highest occurrence of steep net-load ramps, where the ramp between consecutive time blocks exceeds the 90th percentile of absolute net-load ramps.

Figure A5. New-RE scenario results in lower system costs across all days



Source: Authors' analysis.

Note: Here, for the daily system costs, we considered the cost of generation, start-up cost, and INR 10 per unit (power exchange cap) for the residual unmet demand. We do not consider the annualised fixed cost for coal or transmission, which will result in an even higher differential.

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