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Planning Energy Storage for Power Sector in India: Insights from global and US trends

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Planning Energy Storage for Power Sector in India: Insights from global and US trends

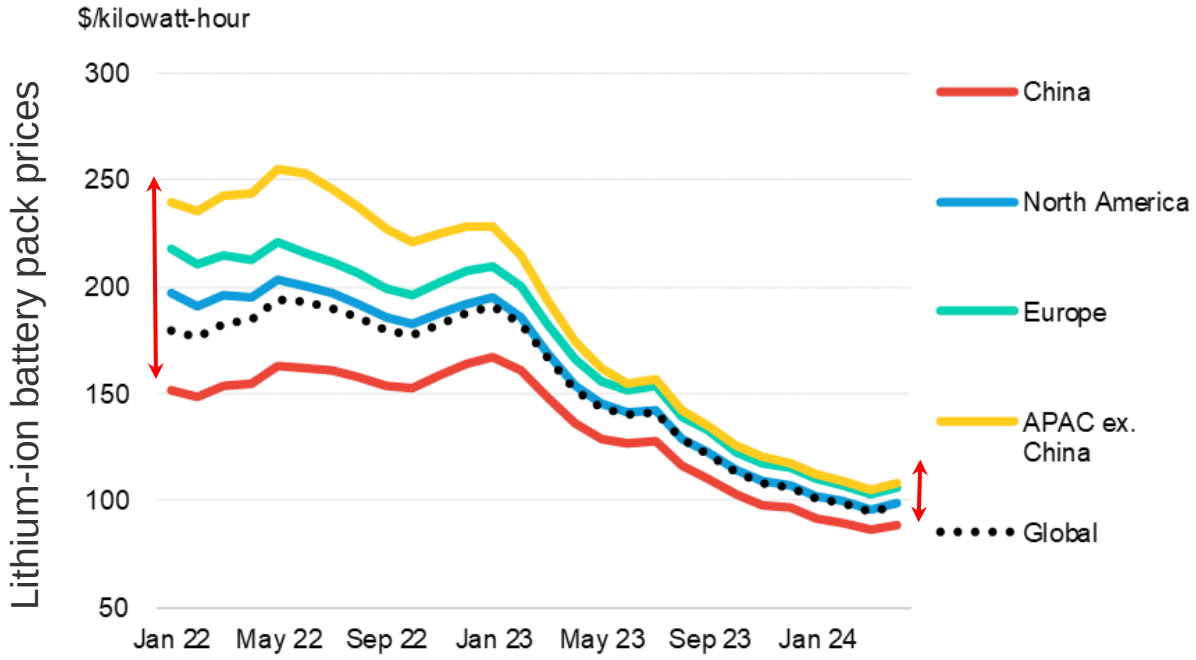
1) Global trends

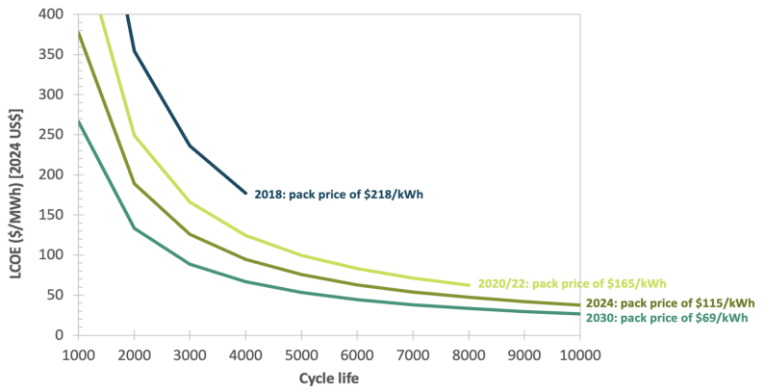
2) US trends

3) Insights of India: Near term a. storage to can help avoid shortages b. Medium to long term: Support affordable and least cost electricity supply

Trends in battery storage

- Similar to solar PV, it is a buyer's market
- Battery storage costs have halved in the last two years, manufacturing capacity has also grown and
- Technology has improved significantly (higher cycle life, higher energy density, improved chemistries)
    - Chinese battery-maker CATL now claims their cells can last **10-15,000 cycles**
- Market-driven deployment is accelerating in California and especially Texas, under liberalized conditions

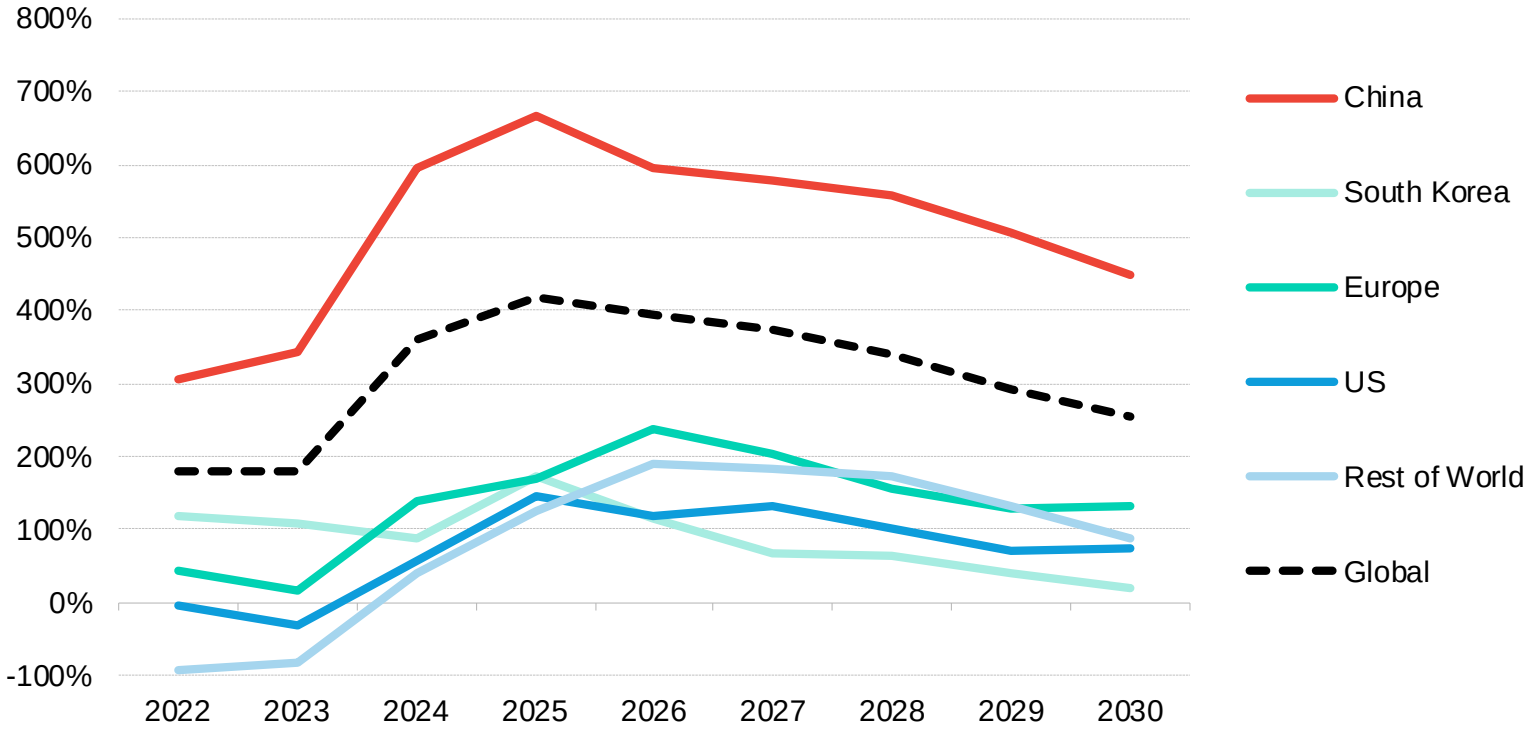




Source: BNEF

Lithium-ion battery cell manufacturing overcapacity will persist at least until 2030 (~ total capacity of 5000 GWh/year in China)

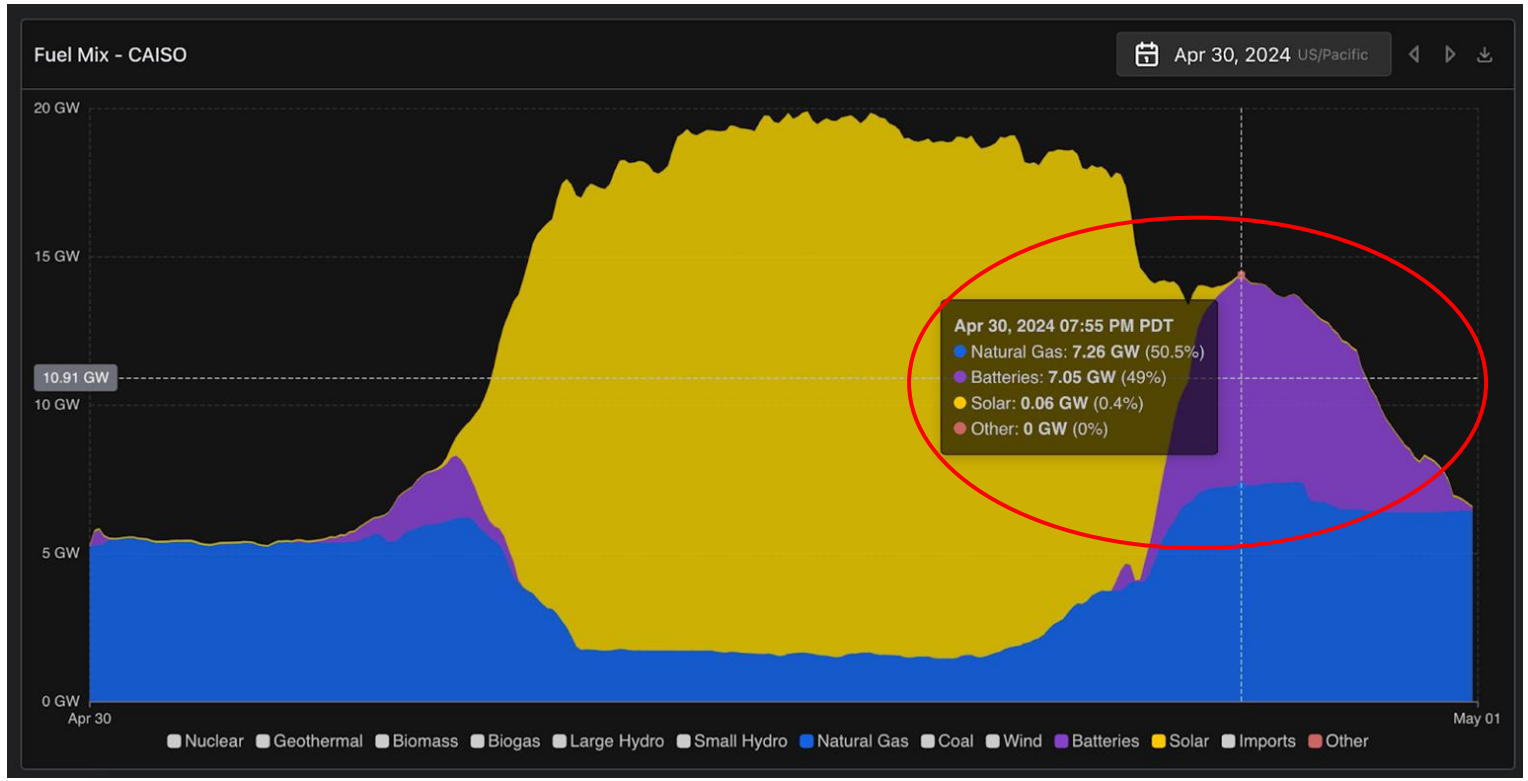
Lithium-ion battery cell manufacturing overcapacity ratio from 2022 to 2030



Source: BloombergNEF. Note: Overcapacity ratio based on the manufacturing capacity over the same year's demand. Demand is based on BNEF's EVO 2024. Nameplate manufacturing capacity as of May 9, 2024. Includes plants that are fully owned by battery makers, as well as joint ventures with automakers, however, pack assembly plants are excluded. 2023 manufacturing capacity includes only fully commissioned capacity. Future capacity is based on non-de-risked capacity tracked by BNEF's battery manufacturing database based on commissioning date before December 31 of respective years.

BloombergNEF

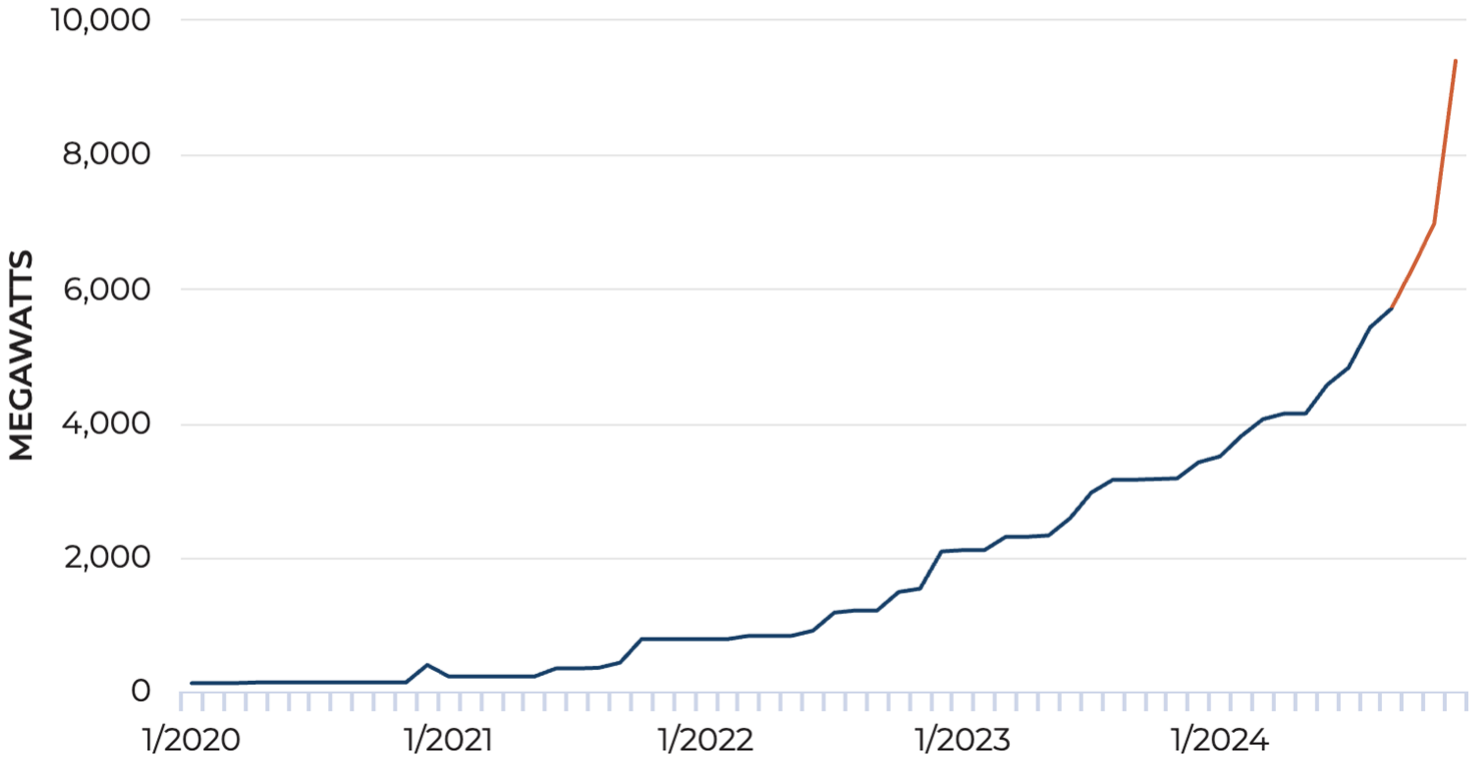
Storage is playing a key role in California (CAISO)



- **Batteries are complementing natural gas** as solar ramps down in the afternoon
- This eases California's duck curve, improving grid stability
- At the end of 2024, California had **11.5 GW** of installed utility-scale storage capacity
- In 2025, California will add another **3 GW** of utility-scale storage capacity
- This is primarily driven by large **solar+storage hybrid** projects

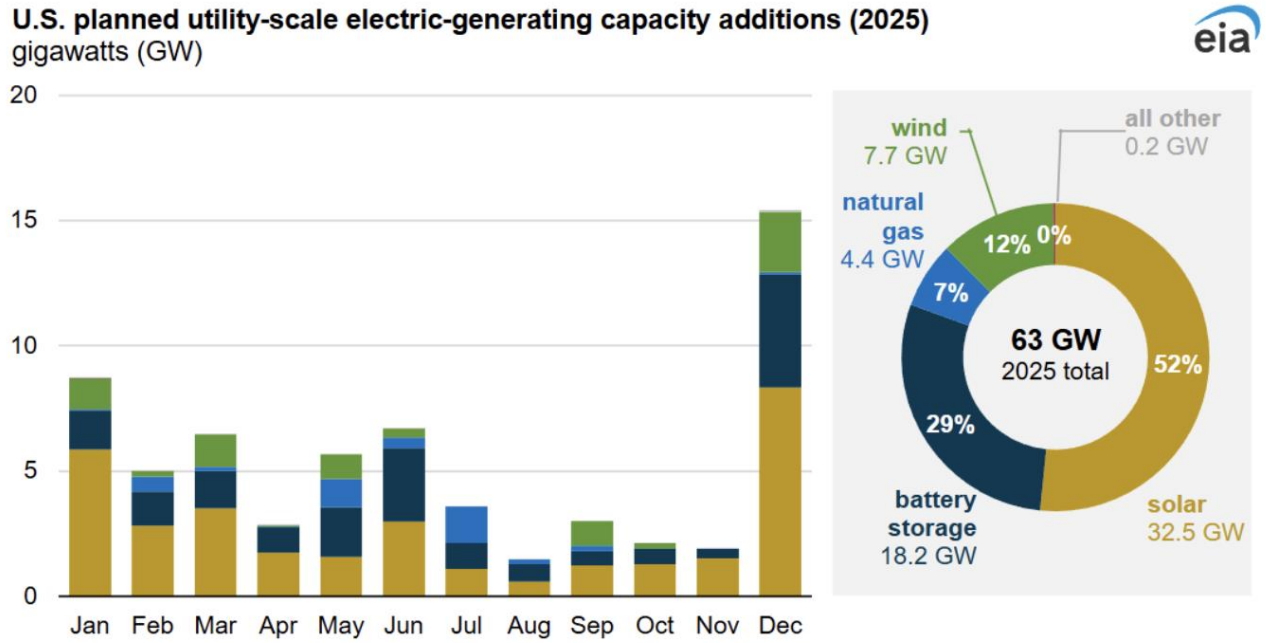
Storage is playing a key role in Texas (ERCOT)

EXHIBIT 1: CUMULATIVE OPERATIONAL BESS CAPACITY BY RATED POWER IN ERCOT, IN MEGAWATTS (MW)



- Similar to California, **batteries increasingly pivotal role in electricity generation**
- At the end of 2024, Texas had **9.4 GW** of installed utility-scale storage capacity
- **In 2025, Texas will add another 12 GW of utility-scale storage capacity, overtaking California, to total 21 GW**

Together, solar & storage lead US electric generating capacity additions



- Hybrid solar+storage projects combine low-cost RE with firm capacity of storage, optimizing delivery
- **Over 500 GW of solar+storage projects have applied for grid connection in US interconnection queues**

Battery Storage Deployment Policy and Market Drivers by Region

Region	Market Structure	Key Revenue Sources	Policy / Planning Drivers
California (CAISO)	IRP + RA mandates	RA payments, energy arbitrage, ancillary services, long-term contracts	CPUC IRP, SB100 mandate, state procurement orders (~14.8 GW)
ERCOT (Texas)	Energy-only market	Real-time arbitrage, FFR, ancillary services	No central planning; market-driven with ERCOT protocols
PJM	Capacity market (RPM)	RPM capacity payments, arbitrage, ancillary services	FERC Order 841, state clean energy mandates (e.g., NJ, MD)

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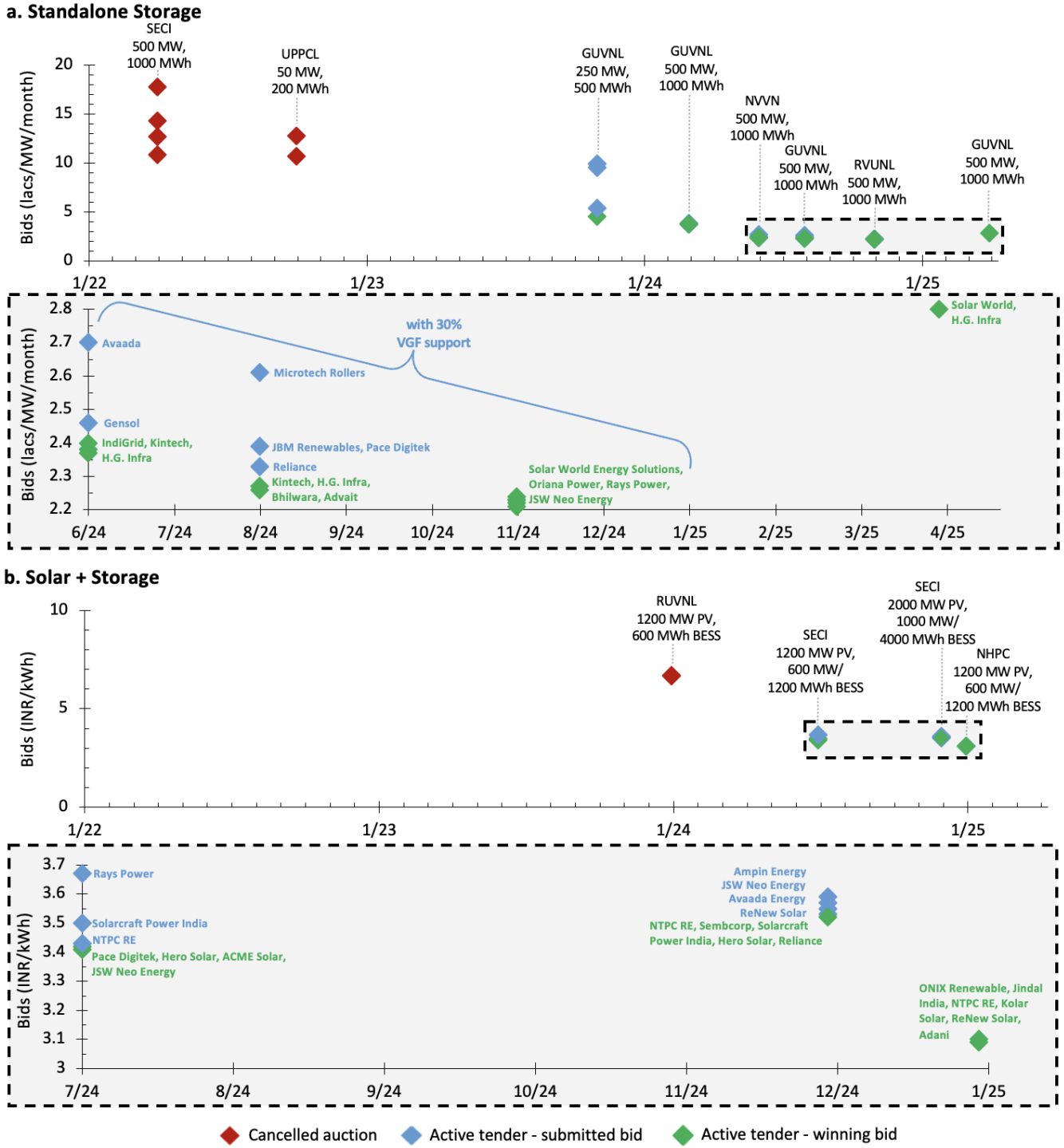

Dramatic decline in storage and hybrid bids in India

Imply under $100/kWh battery cost

If electricity demand grows beyond 6% p.a., significant evening shortages by 2027-2028 are likely

	Formula	Demand growth = 6% p.a.	Demand growth = 7.5% p.a.	Demand growth = 10% p.a.
Evening Peak in 2024	A	234	234	234
Evening Peak in 2027	B	279	291	311
Net Addition to the Evening Peak	**C = B-A**	**45**	**57**	**77**
New Firm Capacity (Under Construction)	D	41	41	41
Net Firm Capacity Shortfall in 2027	***E = C-D***	***4***	***16***	***36***

Note: All numbers in GW. This is a simplistic exercise for developing an intuitive understanding. These are NOT simulation results. An implicit assumption behind this simplistic calculation is that the maximum firm capacity support by the existing generation capacity cannot go beyond 2024 summer levels (~221 GW). Also, RE generation is not given any evening peak capacity credit. Finally, all new hydro capacity, including ROR plants have been generously given full capacity credit. No delays are assumed in commissioning the under-construction power plants.

With 16 GW/62 GWh of storage shortages could be avoided

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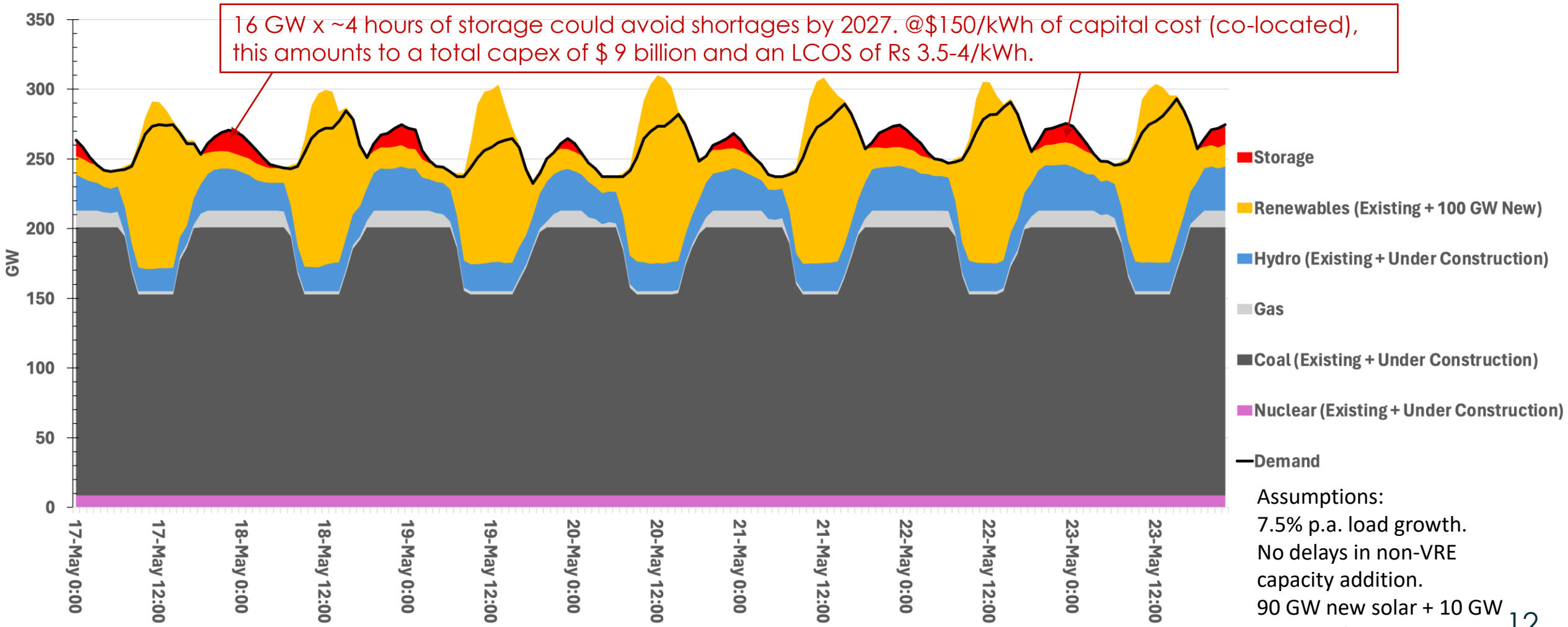
Simulated hourly system dispatch (national) between May 17 and 24, 2027

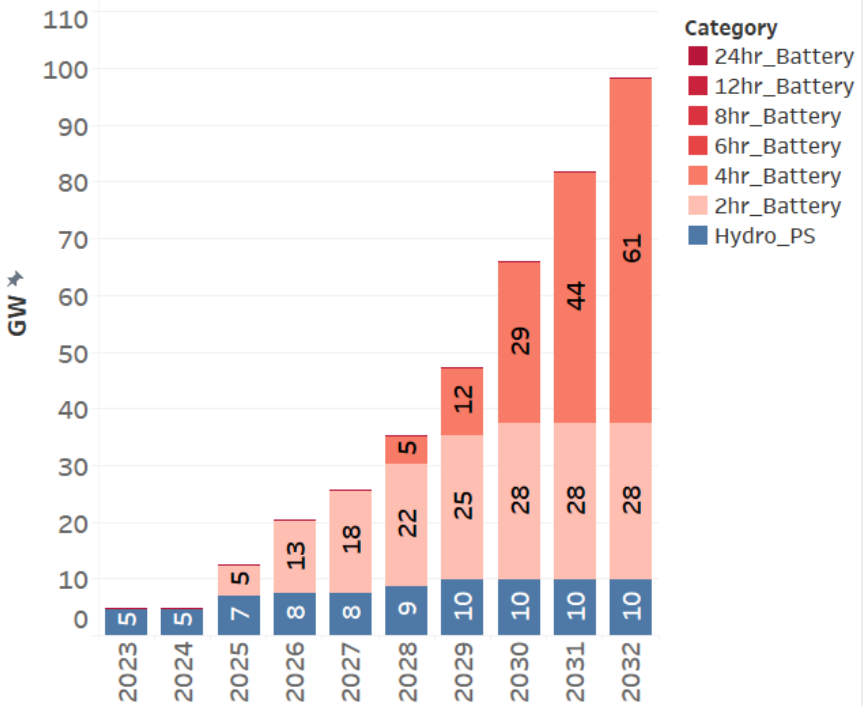


Assumptions:
7.5% p.a. load growth.
No delays in non-VRE capacity addition.
90 GW new solar + 10 GW new wind.

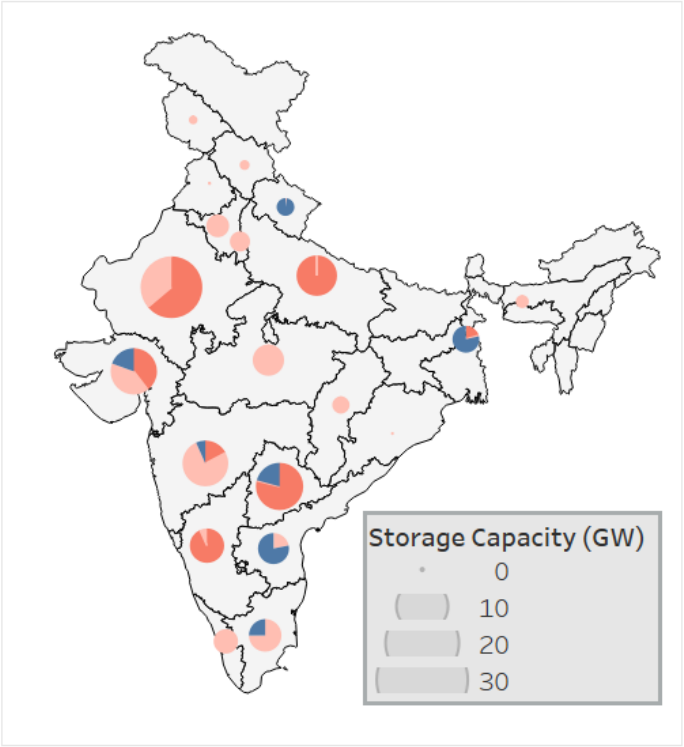
Least Cost Study - Energy Storage Requirement: 61 GW by 2030 and 96 GW by 2032

Demand_Growth	PHS_Cost	Battery_Cost	Storage Goal	National RPO
(●) Base	(●) Base	(●) Base	(●) Yes	(●) Yes
( ) High	( ) Low	( ) CEA	( ) Restrict	( ) Restrict
		( ) High	( ) No	( ) No

Storage Installed Capacity



Storage Locations (States) - 2030



Note: Totals may not match due to rounding

By 2030, 61 GW / 218 GWh of energy storage is found to be cost-effective to support 500 GW clean power.

As PHS plants under construction (~2.7 GW) get built, total PHS capacity by 2030 will be ~9 GW.

Given the deep reduction in battery pieces, battery storage is found to be more cost effective than new PHS plants.

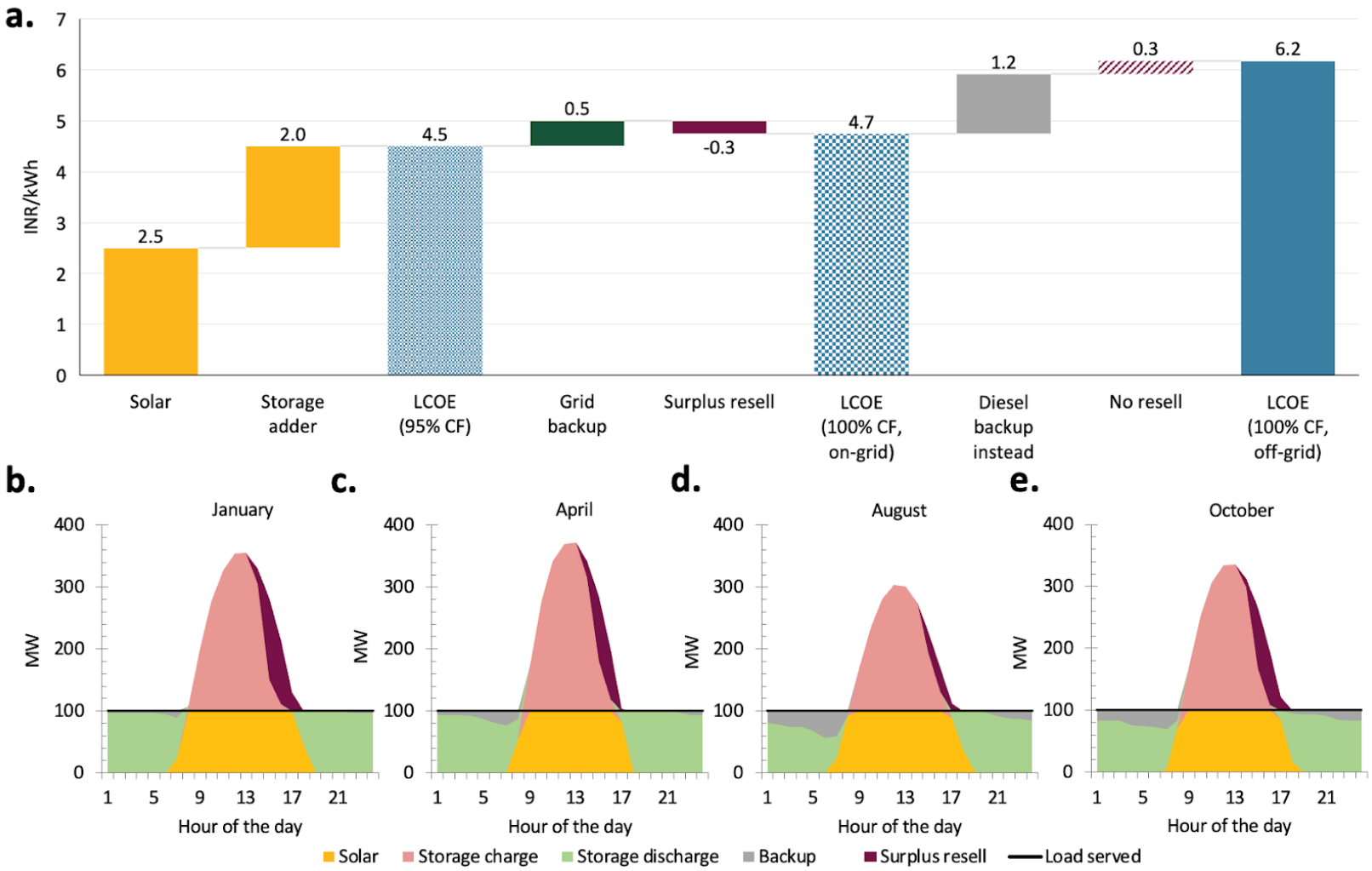
By 2030, 51 GW / 164 GWh of battery storage (20 GW x 2 hours, 31 GW x 4 hours) is found to be cost-effective.

By 2032, storage requirement will be as high as ~97 GW / 362 GWh. Out of this, battery storage capacity will be 87 GW/308 GWh – with nearly 67 GW x 4-hour batteries and 20 GW x 2-hour batteries.

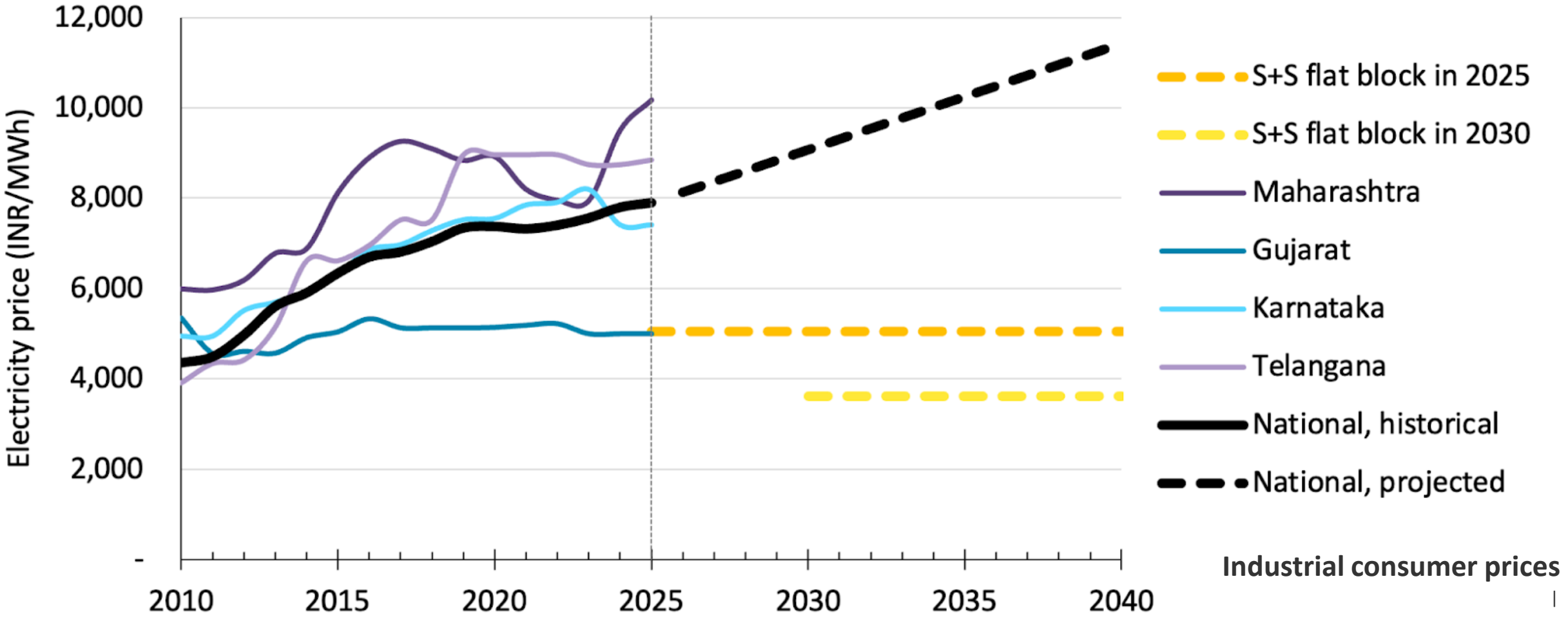
Note that the economical choice between battery storage and pumped hydro depends on cost assumptions.

Meeting 24 by 7 Clean Power Needs from Data Centers and other industrial consumers

India can offer highly competitive solar + storage flat block power



Solar + storage flat block with 95% CUF can be achieved under 5 Rs/kWh – inflation proof for 25 years, lower than industrial tariffs, attractive to data centers



Industrial consumer prices