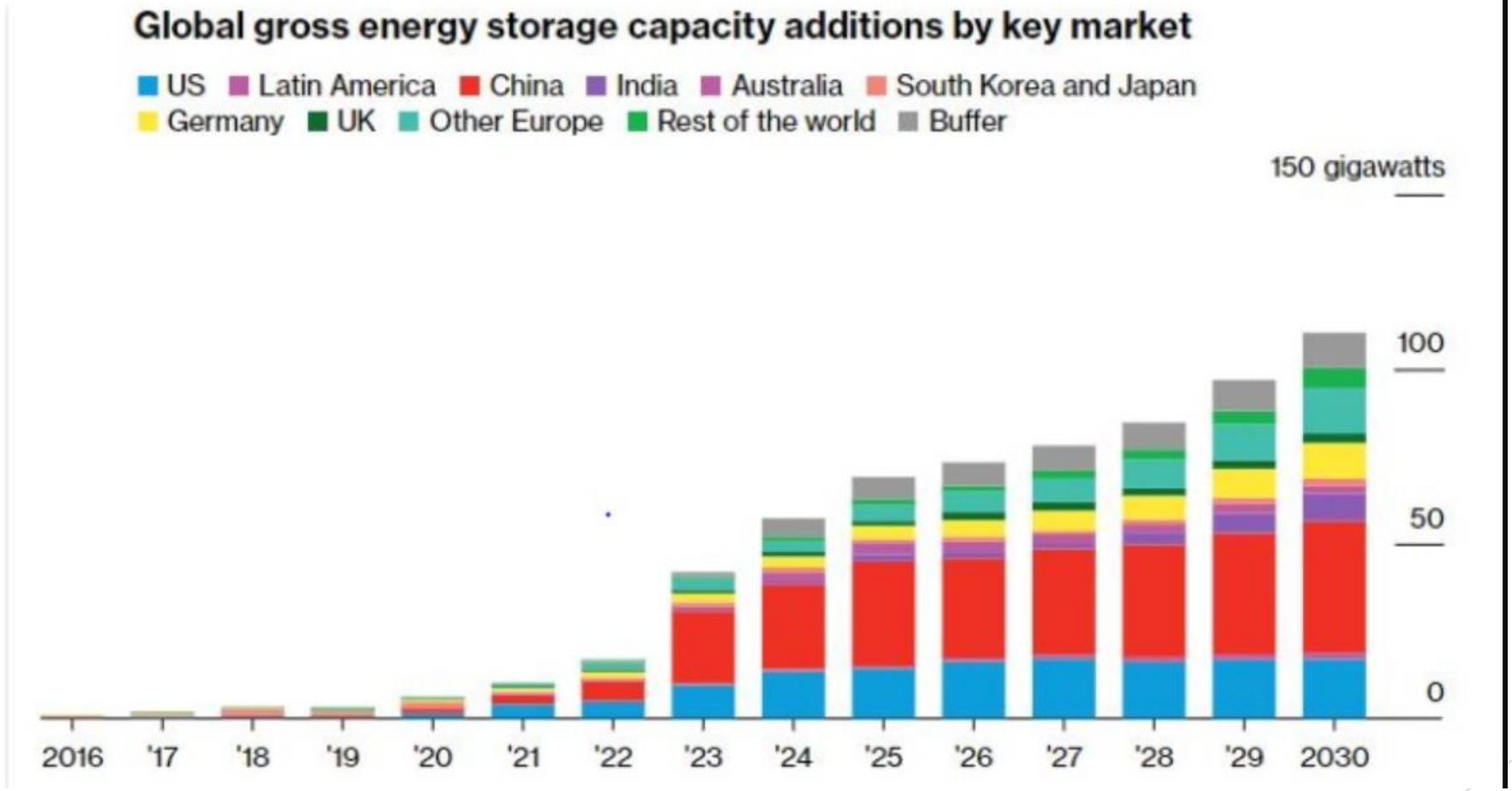
Role of Stationary Storage in Grid Operations

Jaipur

October 23, 2024

How do we Use Storage on the Grid?

BESS is widely used globally for grid stability and renewables integration



Internationally, most storage is 2-4 hours, reflecting peaking needs. However, there is increasingly 8 hour, 24 hour and even 100 hour projects

42 GW/99 GWh of Utility BESS in 2023

Storage is a Capacity-Only Resource

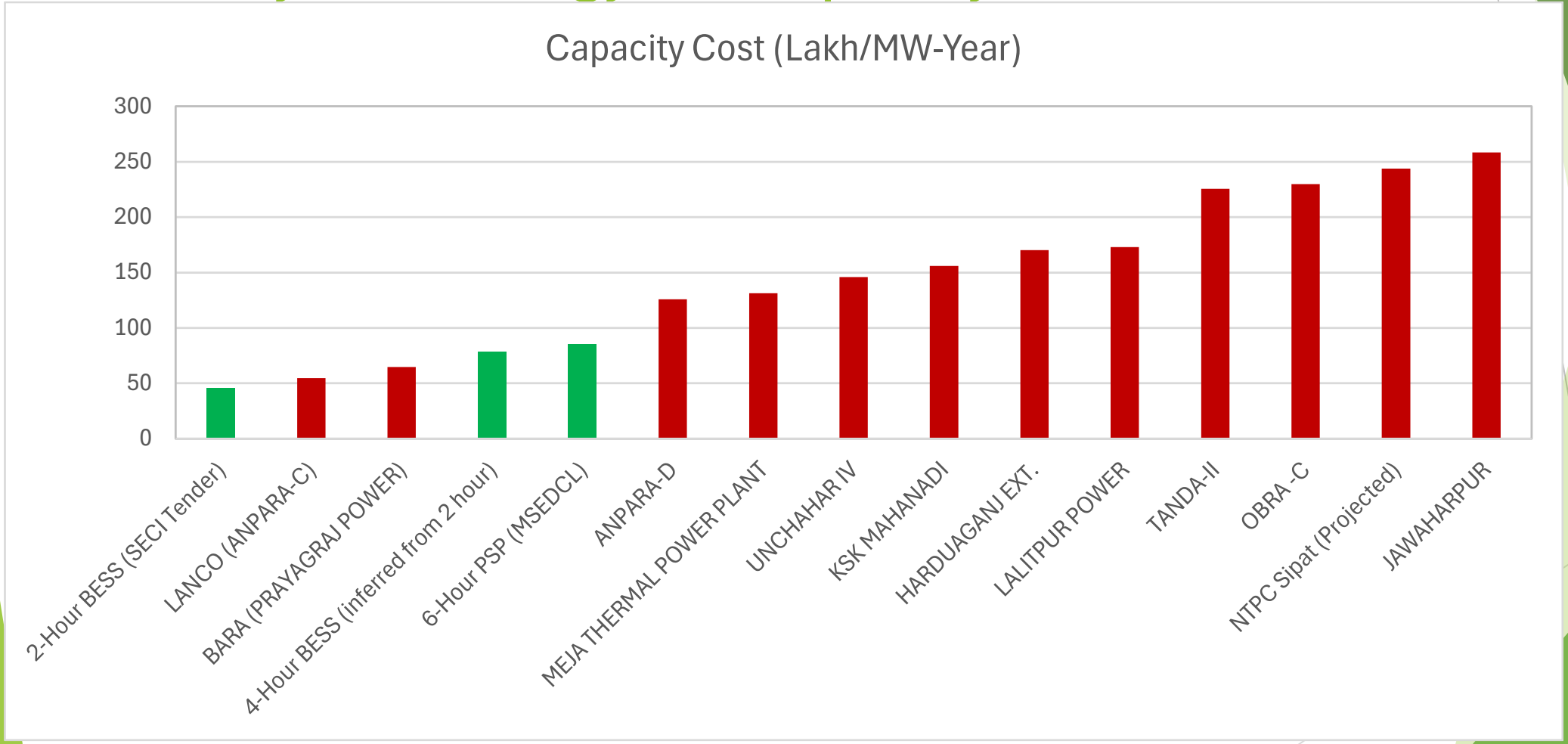
Parameter	Capacity	Energy
Measured In	MW or GW	MWh or GWh aka MU (or TWh)
What is it?	Ability of the System to meet peak demand	Ability of the system to have sufficient energy supply for the whole year
Cost	Fixed Cost	Variable Cost
Cost in	Lakh/MW-year	Rs/kWh (or $/kWh, Takka/kWh)

What exactly is a “Fixed Charge” For?

Parameter	Coal Power	Energy Storage
Ability to meet peak demand	At 85% Availability	Yes, though depends on duration
Ability to ramp up/down to meet demand	~1%/minute	~100%/minute Can actually go “negative” when there is surplus RE
Primary response	Yes, though may suffer efficiency penalty	Yes
Secondary/tertiary response	Warm Start 2-4 hours Cold Start 6-12 hours	Near instantaneous
Blackstart capability	Requires back-up DG	Can “self-start”
Inertia	By default	Requires Smart Inverter
Auxiliary power	5-10%	5-10%

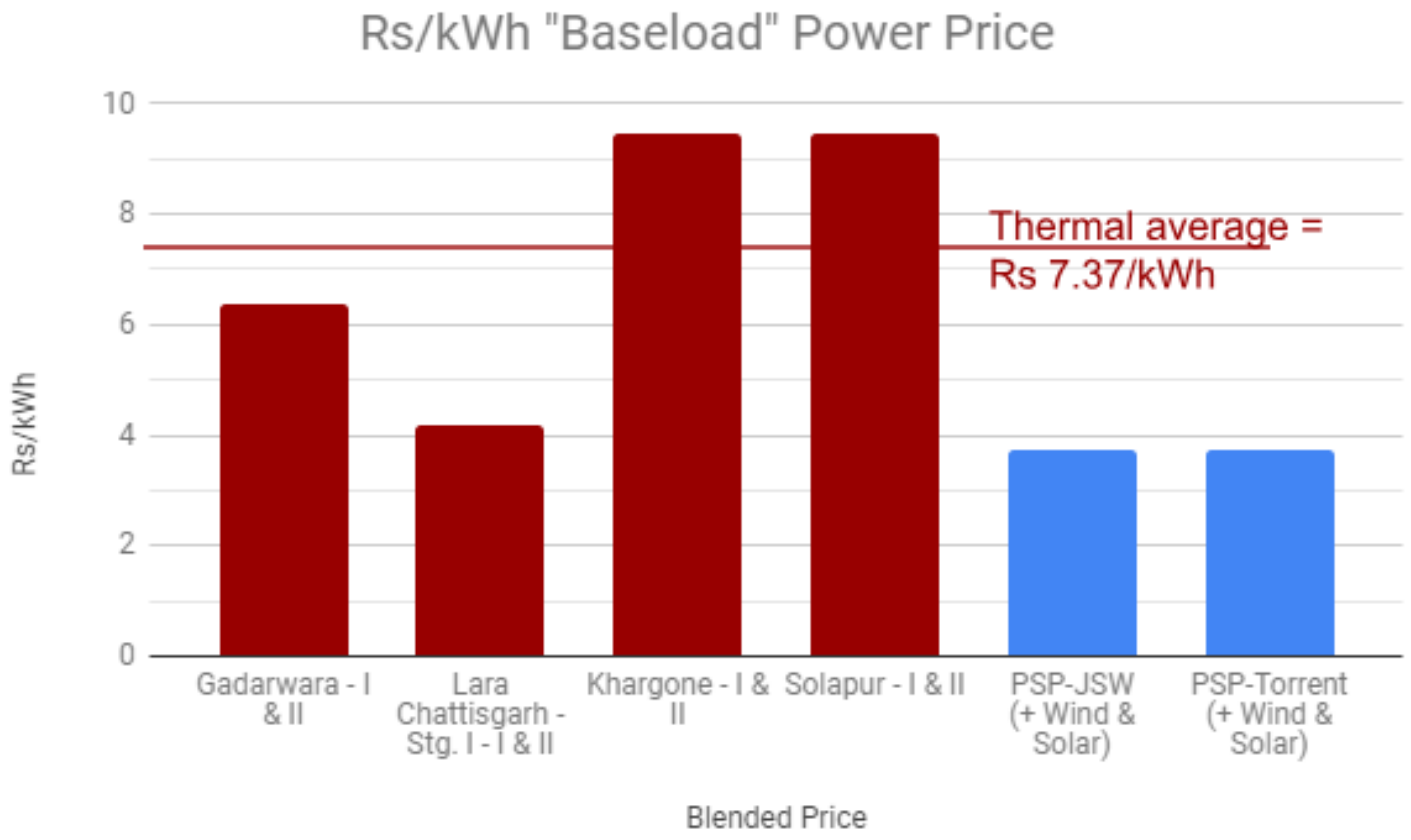
How much does storage cost?

The Misunderstanding that Energy Storage is expensive is caused by the energy vs. capacity confusion



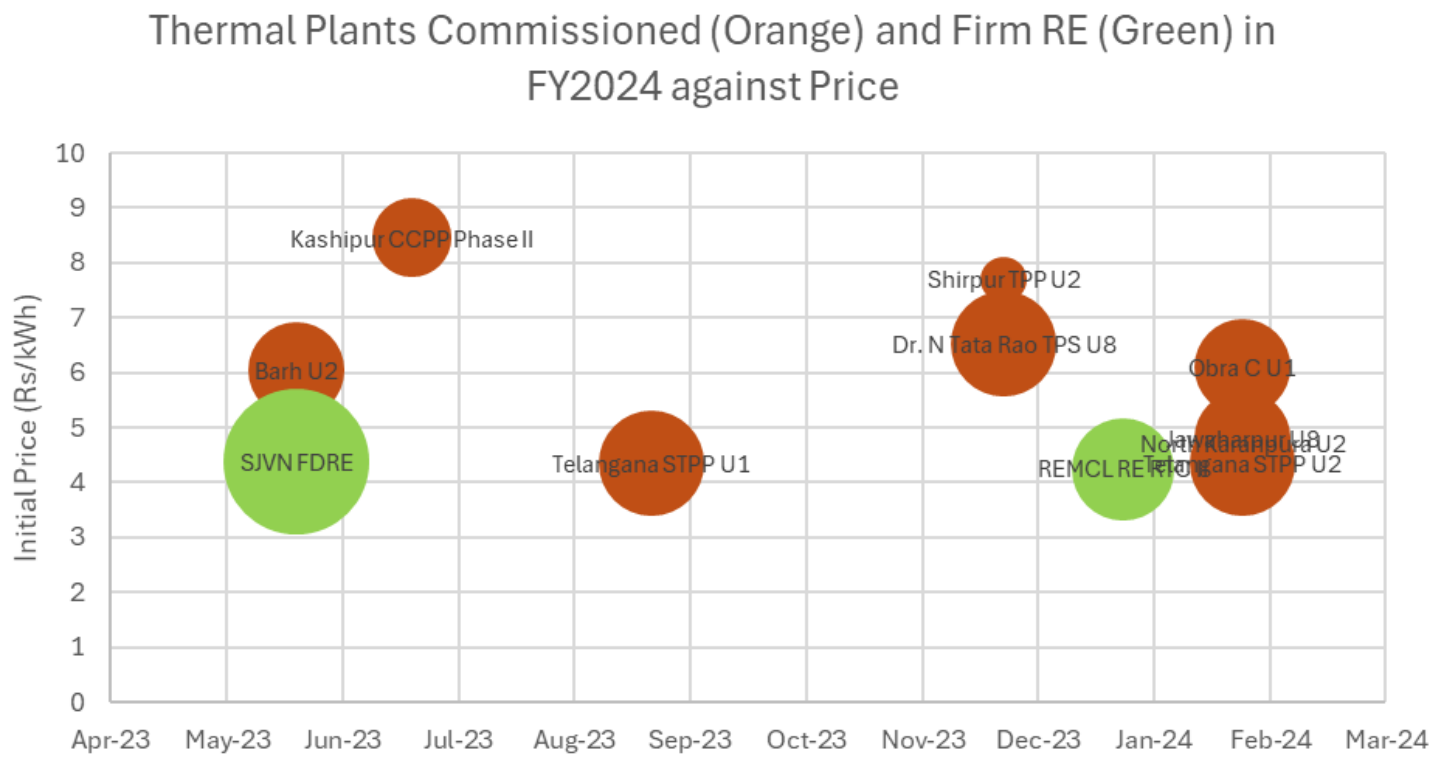
At 75-80 Lakh/MW-year, Energy storage is substantially cheaper than new thermal at 200-250 Lakh/MW-year

Another Way to Compare is to look at the “Baseload” Cost



- This example is from Maharashtra, but similar results hold in other states
- The key is we must compare apples-to-apples. Capacity vs. capacity or energy vs. energy NOT LCOS vs. baseload cost

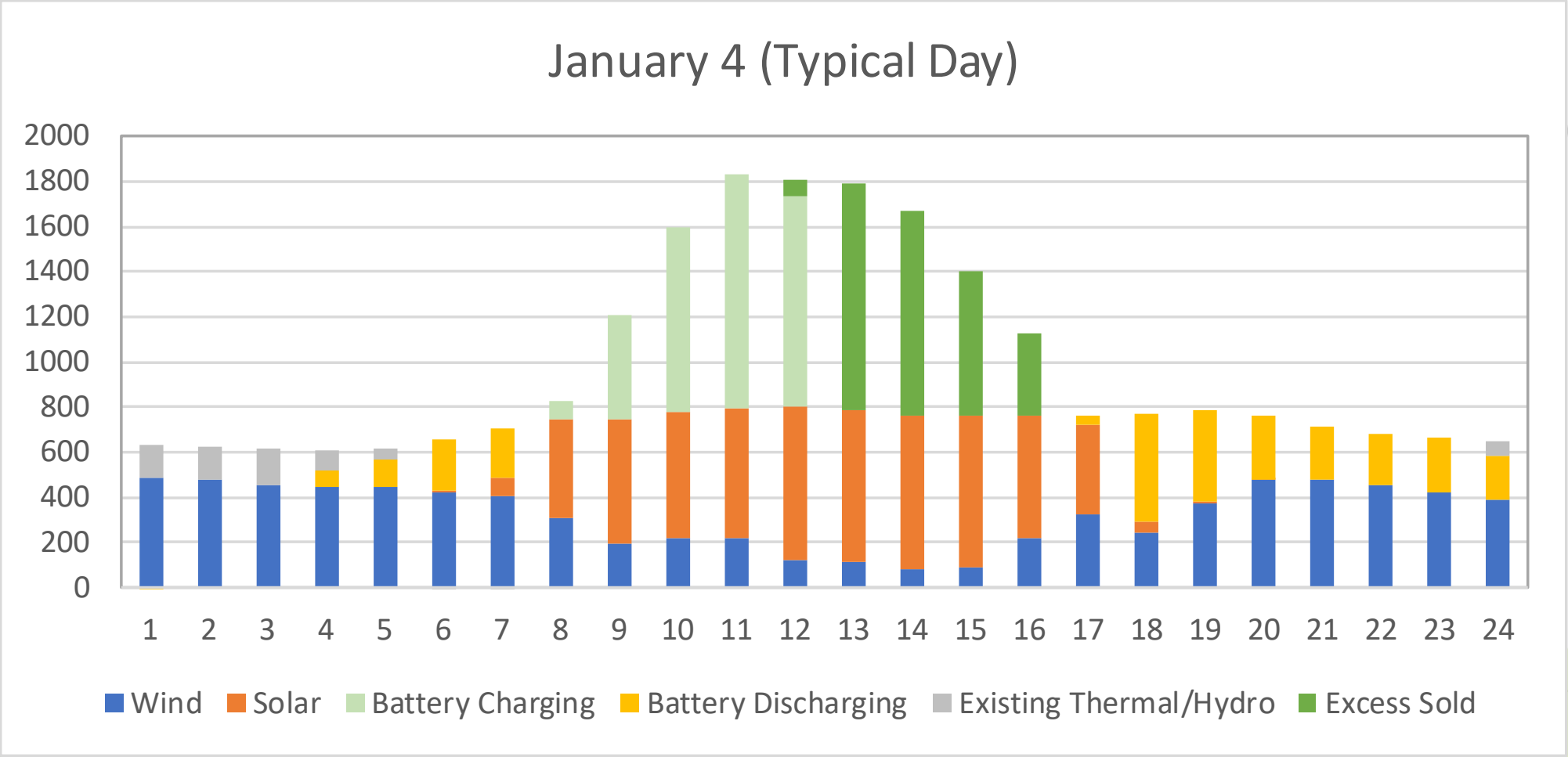
All India, we see FDRE tenders come in lower than New Coal



- FDRE tenders have a penalty for underperformance whereas coal plants do not
- These are thermal plants *commissioned* in FY24. Future plants will be even more

Duration of Storage Required

Storage Provides Firm Power *if* there is sufficient energy resources



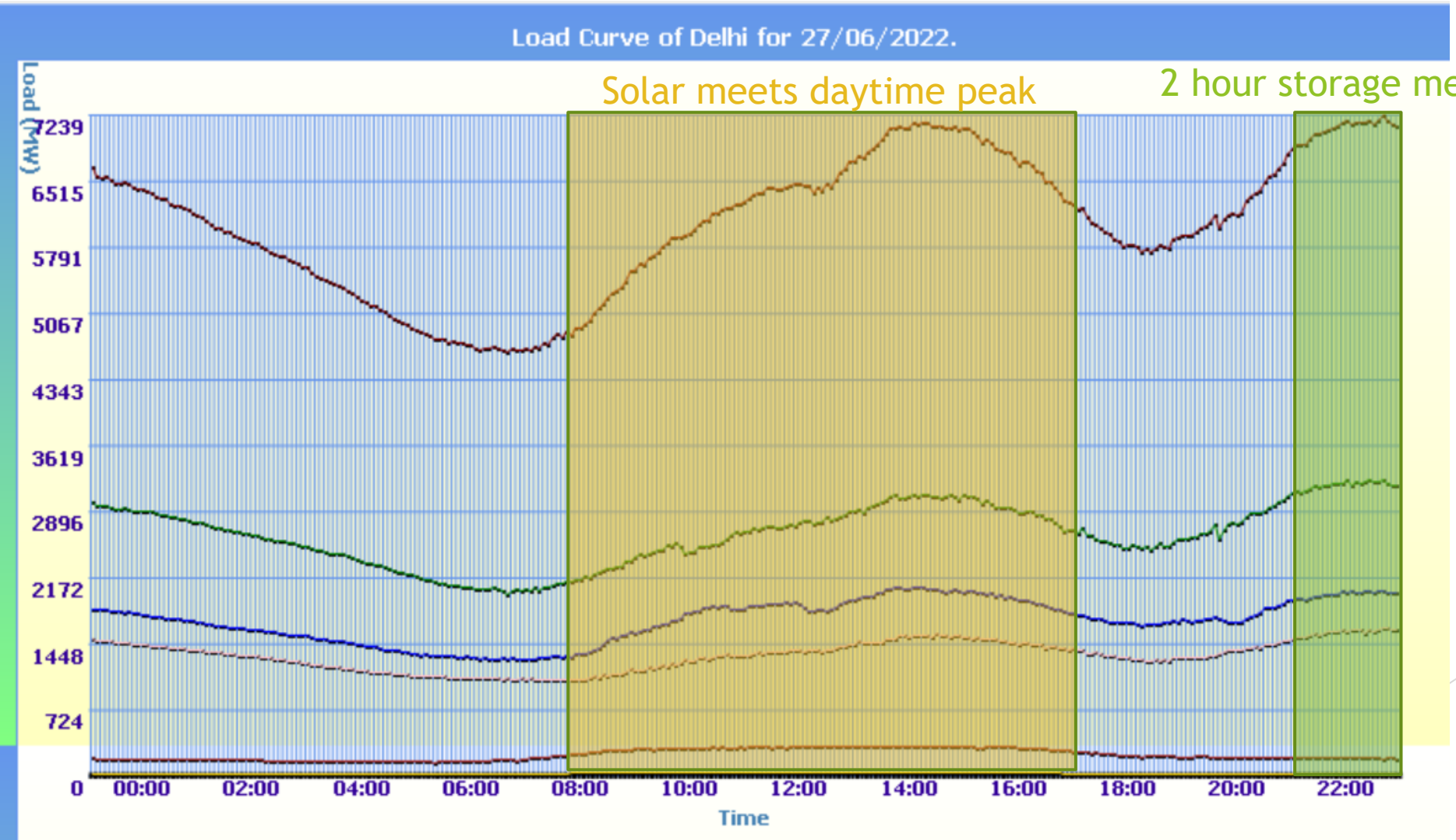
In this example, 1000 MW firm power is provided by:

- 1000 MW BESS
- 2000 MW solar
- 2000 MW wind

Because of the lower CUF, cannot compare wind/solar MW directly with coal!

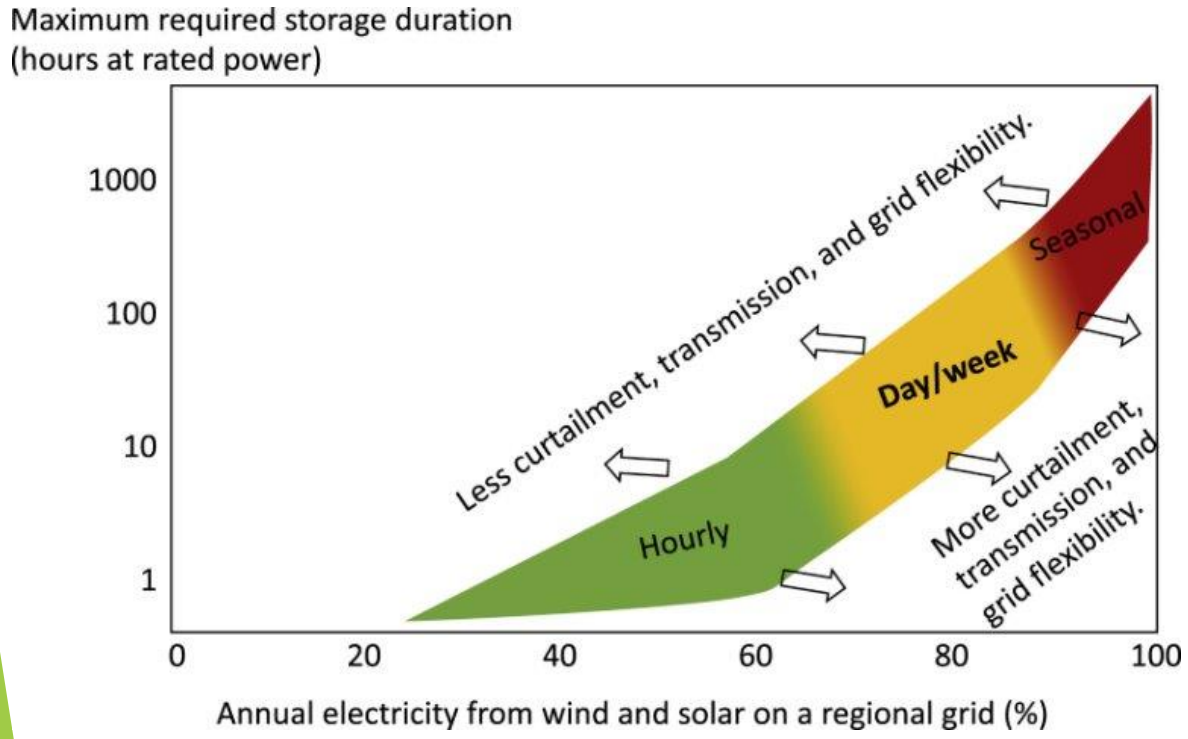
- Coal provides “blocks” of power. Storage “fills up” the gaps”
- In this example, a 3-Hour Battery can provide 97.5% reliability.
  - If peak load is 1000 MW, battery is 1000 MW/3000 MWh. But the peak discharge is 480 MWh, and average discharge over night hours is 300 MWh, so a “3 hour” battery can “complement” wind for 10 hours

It is Crucial to “Right-Size” Storage. About 10% can be met with 2-hour storage

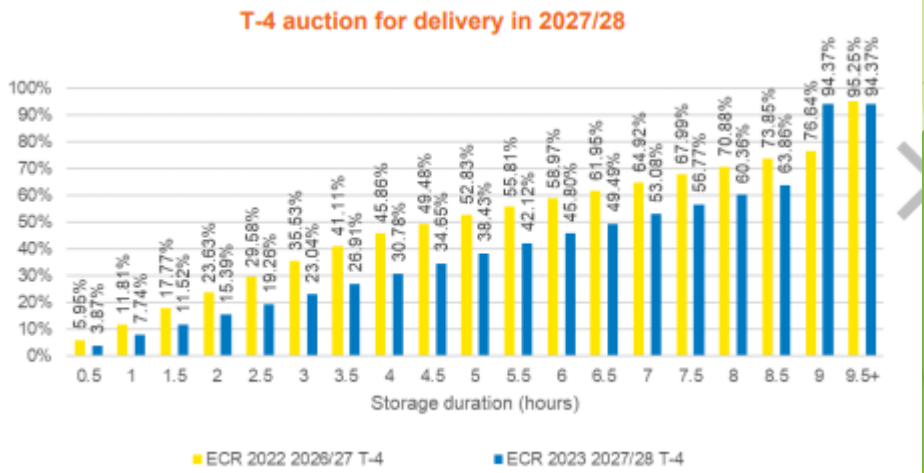


If/when there is sufficient solar to meet daytime load, 2-hour storage can meet the top ~5-10% of peak (~500 MW in this example of Delhi)

What Duration of Storage is Required?



Generation Sources	Capacity Credit(p.u.)
Coal	0.7-0.8
Nuclear	0.6-0.7
Gas	0.7-0.8
Hydro#	RoR- 0.25-0.3, With Storage- 0.6-0.7
Biomass#	0.3
PSP@	0.9-1
BESS@	0.5-1



In India (CEA), with ~12% VRE, 2 hour can be considered at 50% and 6-hour at 90%

In UK (National Grid) with ~40% VRE, 9 hour is required to be worth 90%

Procurement of Storage

Regulatory Models for Storage Adoption

Resource Planning	Capacity Market	Energy-Only Market
California, China	*Ontario, PJM, UK, Chile*	*Texas, Germany*
Regulator determines amount of energy and capacity resources based on demand forecast Storage mandates (usually co-located with RE) based on need for peaking demand	Annual Capacity auction for future *capacity* (MW) needs, usually at least 3-5 years in the future “Capacity credit” for various durations of storage (and other technologies) determined by ELCC	No explicit separate requirement for capacity No (or at least very high) maximum market price in energy market Energy storage expected to earn market returns based on a handful of volatile/”peaky” hours

Many Discuss "Value Stacking"; in India, but only Two Things are Paid for: Capacity and Energy

TABLE 6-30: GENERATING STATION-WISE POWER PURCHASE COST SUBMITTED BY PETITIONERS FOR FY 2023-24

Sl. No.	Source of Power (Station wise)	FY 2023-24			
		Units (MU)	Annual Fixed Charges (Rs. Cr.)	Annual Energy/ Variable charge (Rs. Cr.)	Total Cost (Rs. Cr.)
A	Long term Sources				
a	Power procured from own Generating Stations (if any)				
b	From State Generating Stations Thermal				
1	ANPARA-A	3,550.43	260.80	793.05	1,053.85
2	ANPARA-B	6,719.49	311.15	1,493.80	1,804.95
3	PANKI	0.00	0.00	0.00	0.00
4	PARICHHA	0.00	0.00	0.00	0.00
5	PARICHHA EXT.	1,192.92	337.21	484.15	821.36
6	OBRA-A	0.00	0.00	0.00	0.00
7	OBRA-B	3,742.73	325.07	1,094.56	1,419.62
8	HARDUAGANJ	0.00	0.00	0.00	0.00
9	HARDUAGANJ EXT.	856.66	487.51	379.99	867.50
10	PARICHHA EXT. STAGE-II	989.66	504.09	401.65	905.74

- Sample from UPPCL Tariff Order, but all utilities in India are similar
- Simplest way is likely to separate Fixed from variable energy charges, and pay storage and wind + solar separately

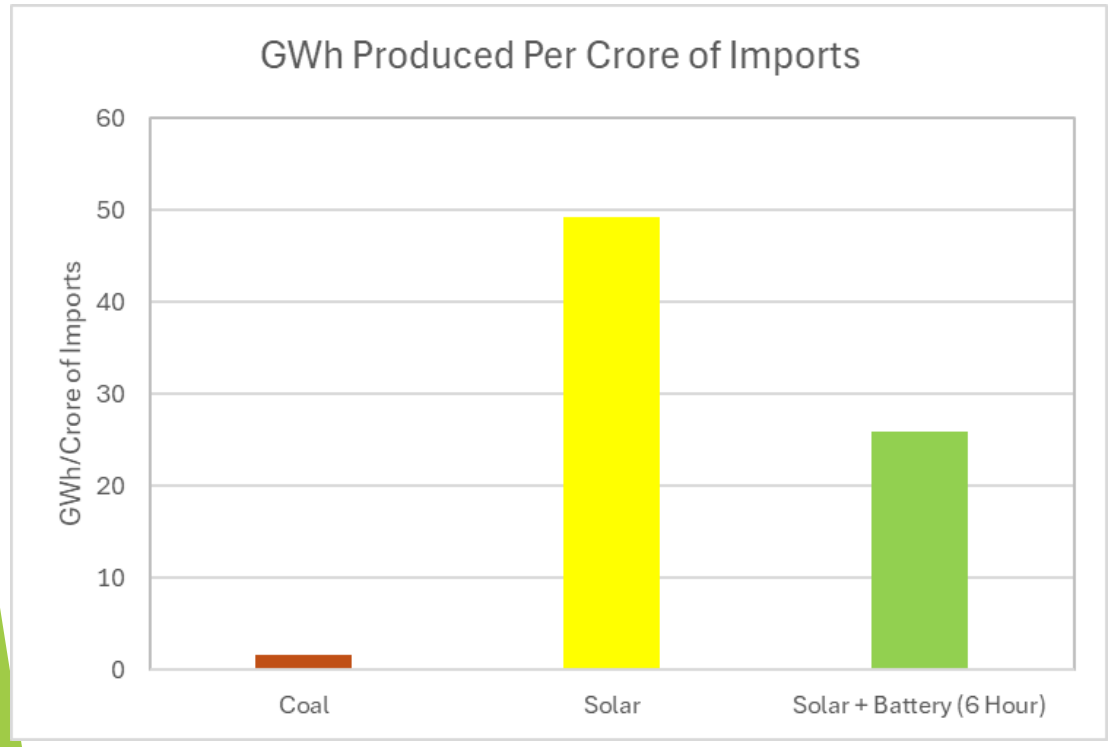
Three Main Approaches

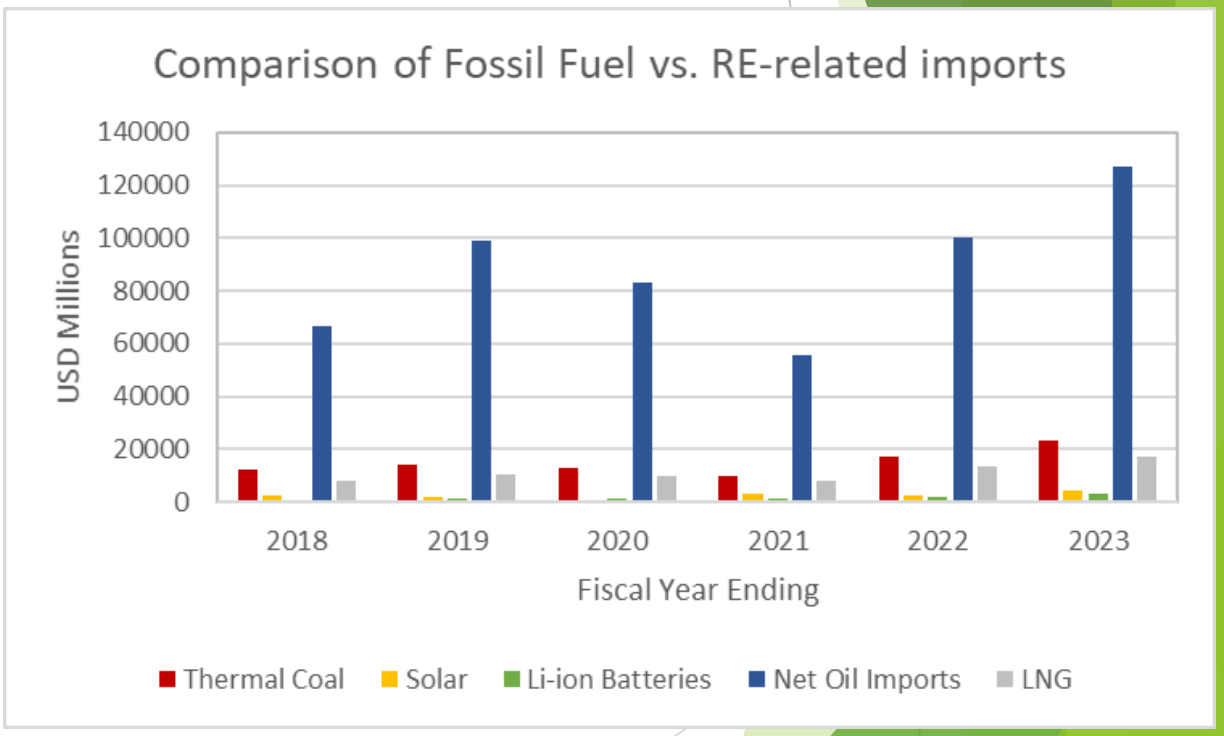
Firm, Dispatchable Renewable Energy	Solar + Storage	Vanilla wind, Solar, Standalone Storage
Single Blended Price-directly comparable to coal	Single blended price but not directly comparable to coal Meet peaking needs affordably	Energy price for wind/solar (comparable to VC) Capacity price for storage (comparable to FC)
Awarded based on LCOE	Awarded based on LCOE	Awarded based on Rs/kWh (solar/wind) and Lakh/MW-year (storage)
Less risk on buyer-seller responsible for supply	Buyer or seller can be responsible for real-time discharging	Buyer responsible for real-time charging/discharging
Dispatch primarily by seller		Dispatch controlled by buyer
Project sizing determined by seller	Requirement/sizing determined by buyer	Requirement/sizing determined by buyer

Procuring wind/solar/storage separately will lead to a lower overall cost *if*
Load Dispatch Center is trained to Manage It

Other Considerations

Use of Energy Storage (even if imported) can drastically improve energy security

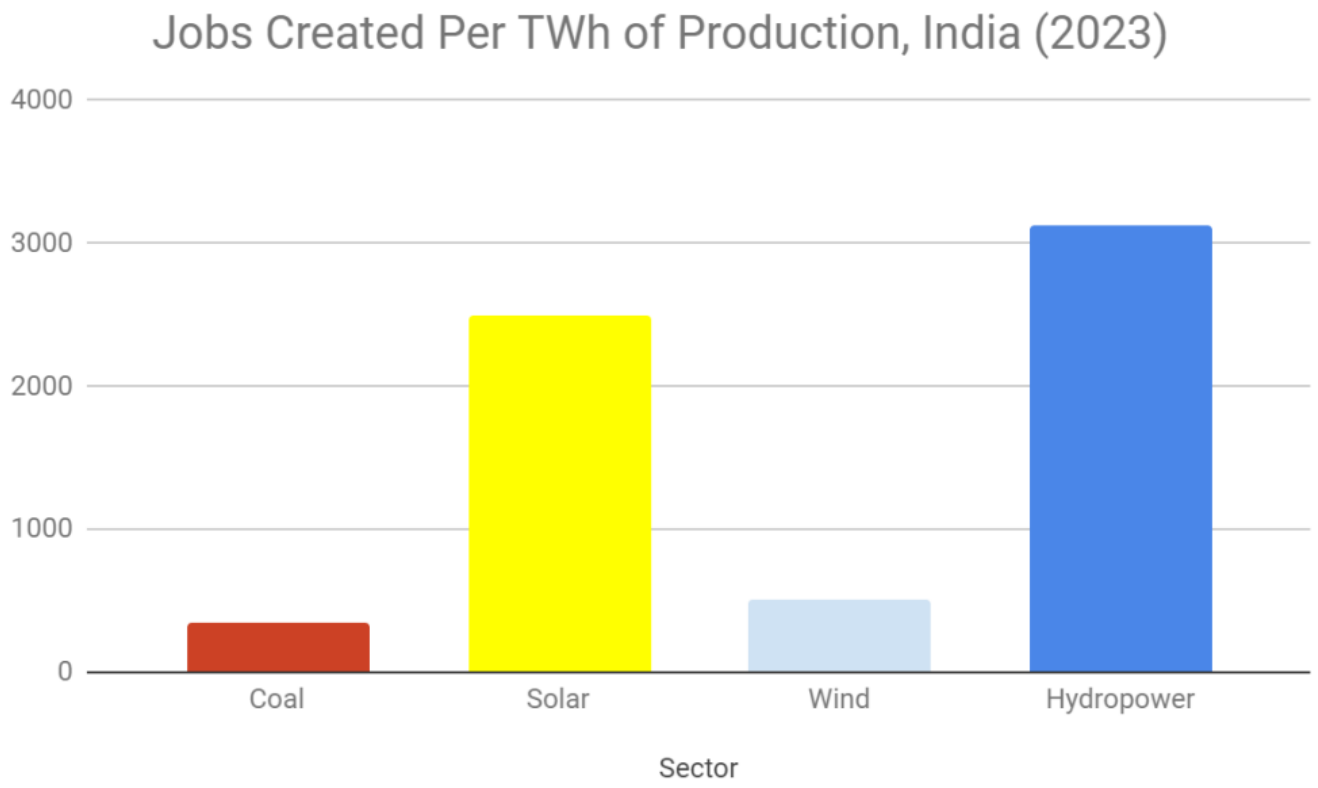




Fact: In a **Worst-Case** Scenario (0 domestic production), Solar + battery provides 15x the energy per Crore of Imports. This is even higher when compared to diesel generators

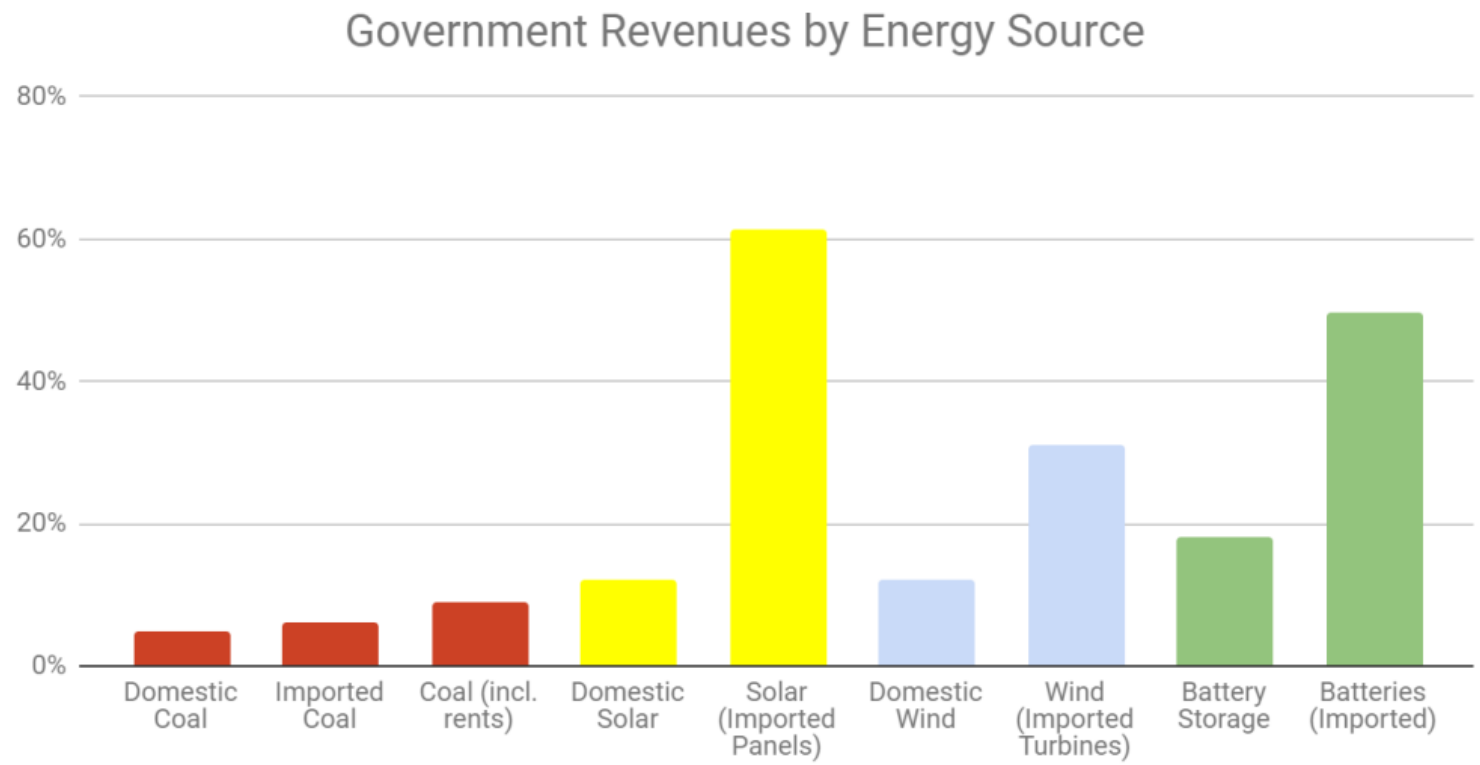
From an energy access perspective, BESS can be deployed in 3 months vs. 50 months for thermal

Deployment of Renewable Energy and Storage will Create Jobs On Net



- Yes coal employs more people now because it is 75% of the generation (vs. just 6% for solar). If solar generates as much as coal, it will create more jobs

Government Revenues *Per Dollar Invested* are actually higher for RE + Storage than Coal

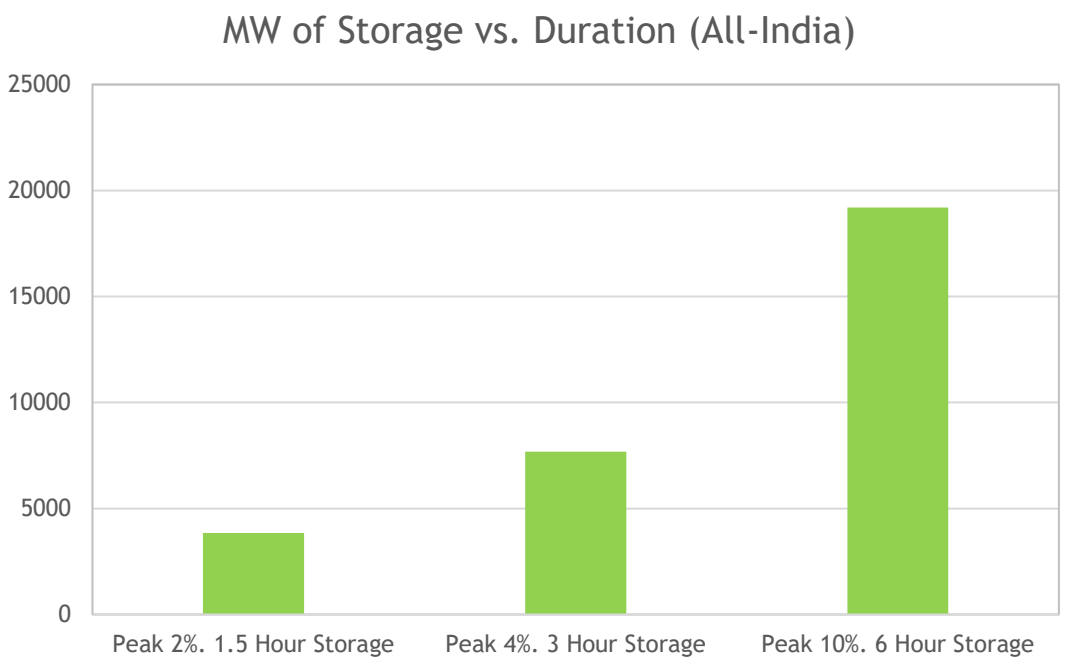


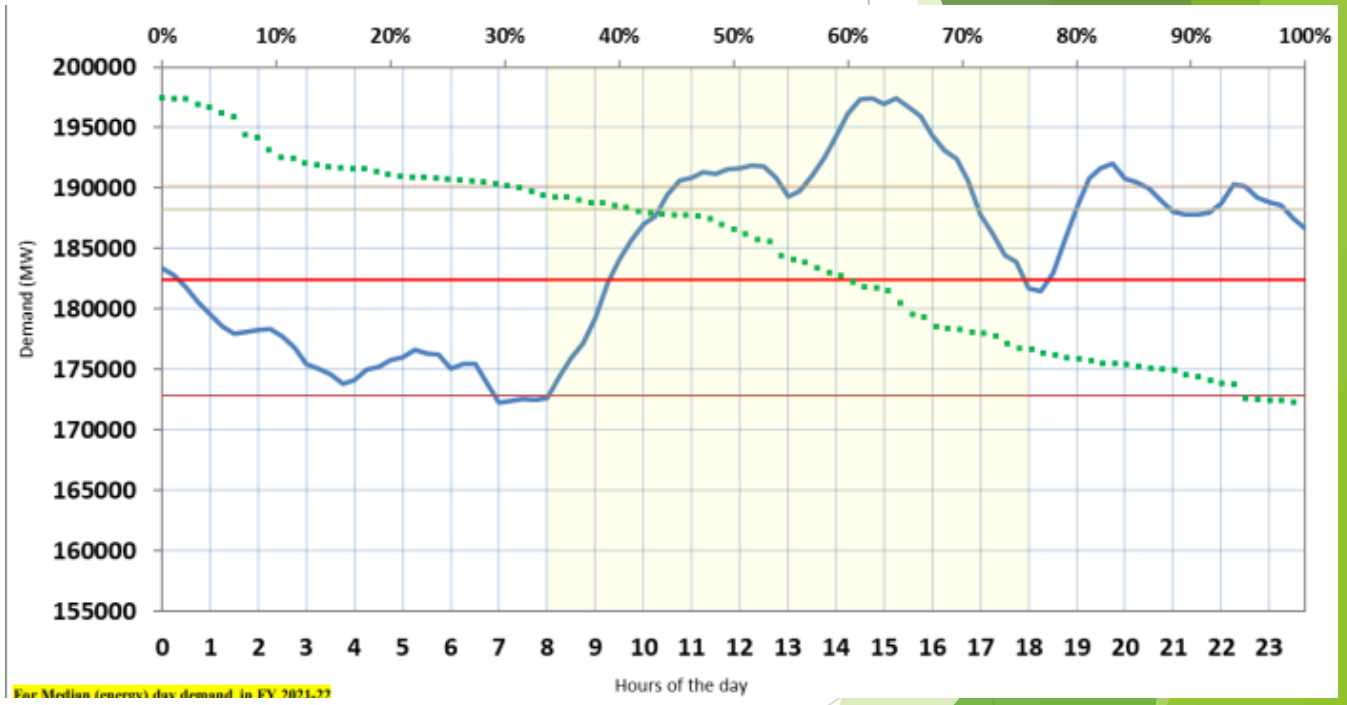
- Because coal is 75% of India's power it provides a larger source of revenue in absolute terms. But if wind and solar are scaled, the government revenue would actually increase

Appendix

- Old Slides

Peak 10% (~20 GW) can be met with 6-Hour Storage





- Note: This analysis ignores wind. If wind is added, storage requirement is further reduced

Storage Costs Will Continue to Decline

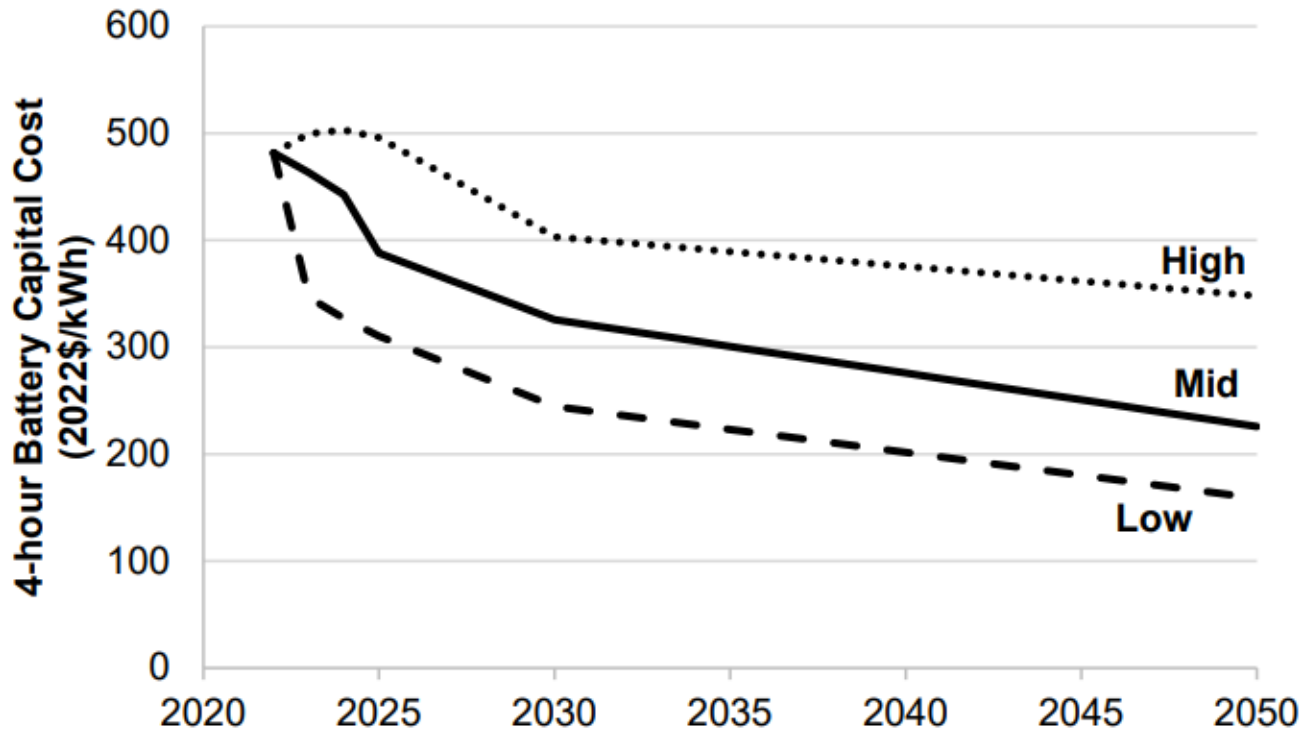


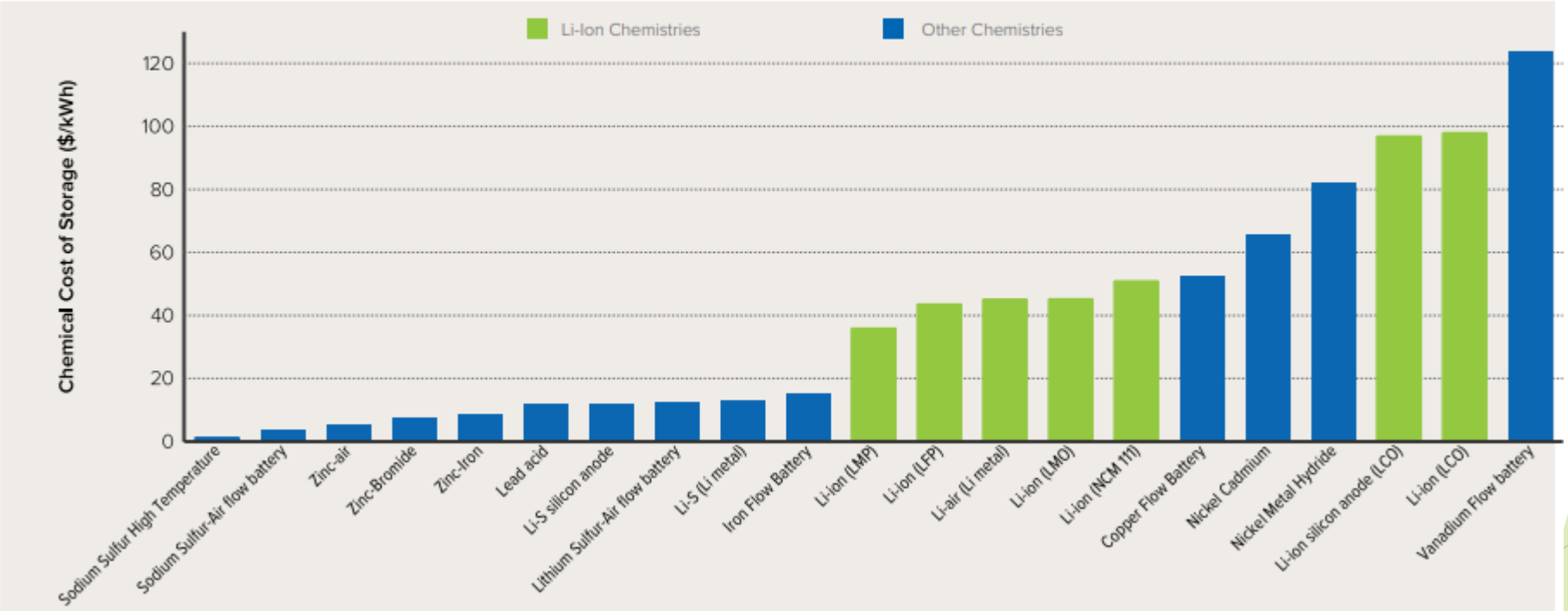
Figure 2. Battery cost projections for 4-hour lithium-ion systems.

Note: Crucial to consider system, not just cell cost (which is now well below $100/kWh)

While Lithium will dominate in near-term, R&D on alternatives is crucial

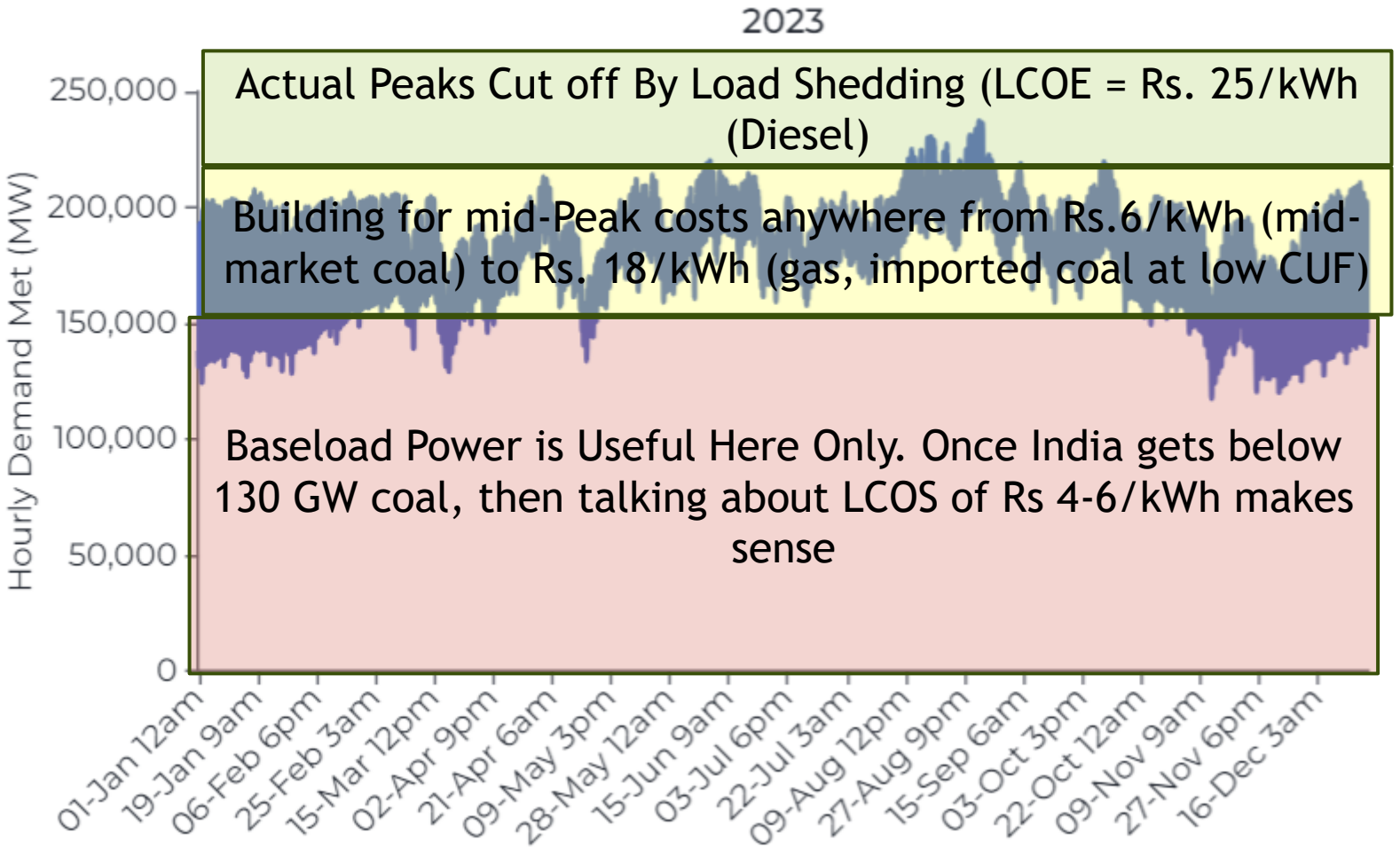
EXHIBIT 20

Estimated Cost of Raw Materials for Different Battery Chemistries[24]

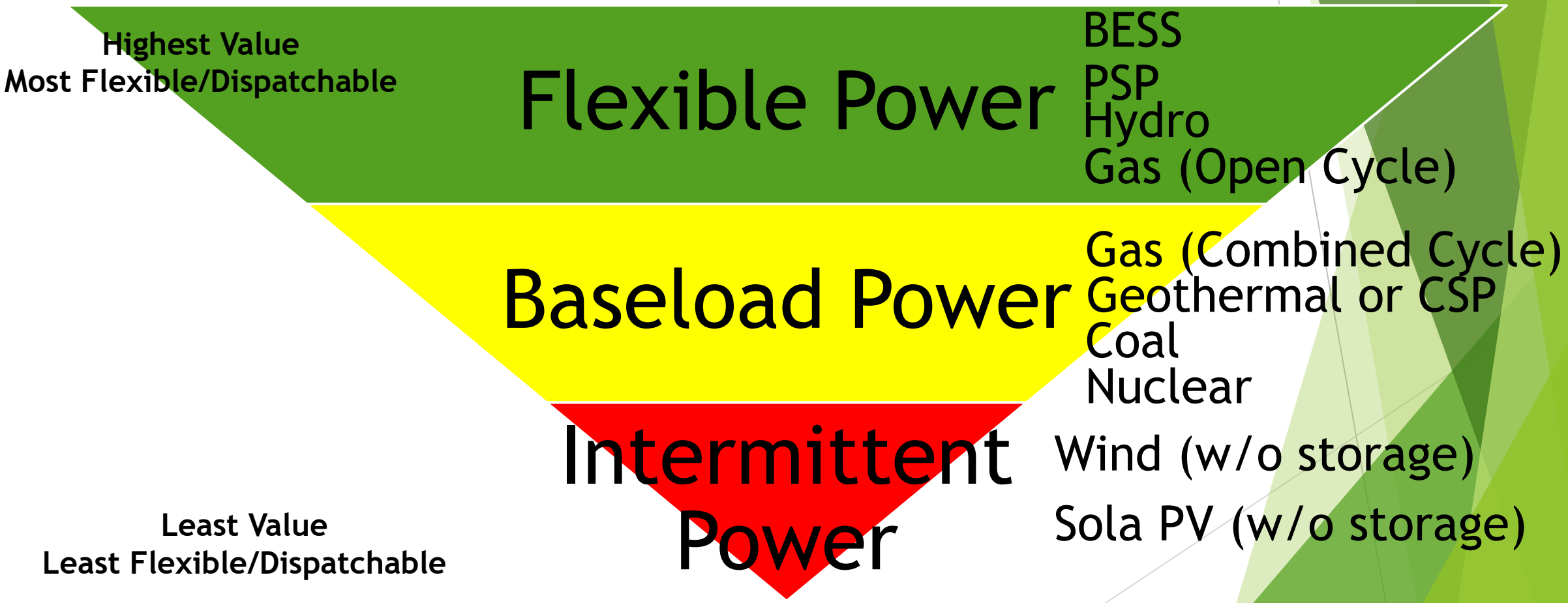


- Sodium-ion and zinc-air already being commercialized

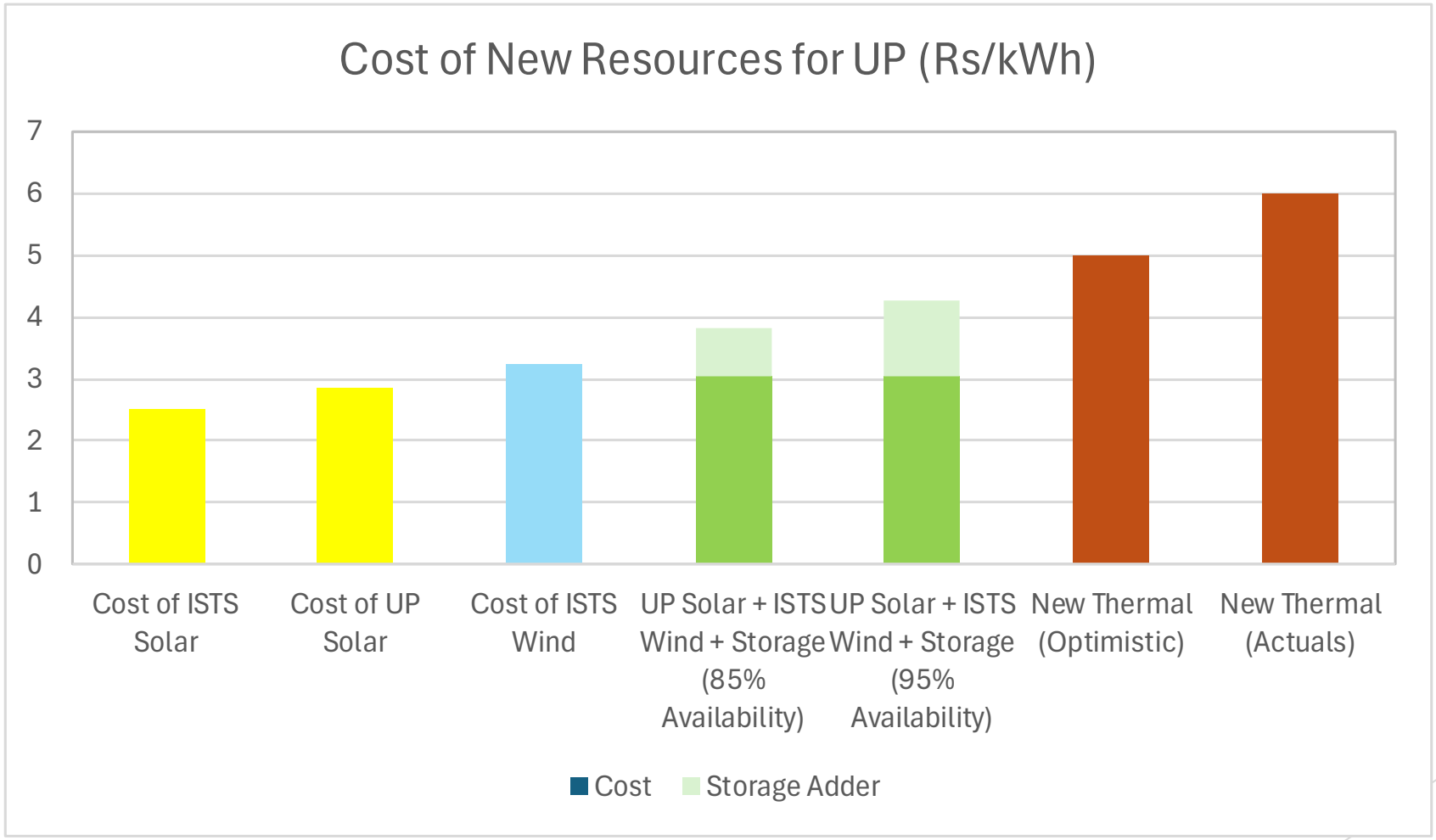
Load Duration Curves and “Baseload” Power



Value of Generating Resources



Most Regulators Think in terms of Rs/kWh rather than Lakhs/MW-Year, but Story is the Same



- Must do apples to apples comparison! Either Compare blended cost of wind + solar + storage vs. blended cost of coal OR compare FC of coal to FC of energy storage.
- Comparing LCOS to blended cost of coal is nonsense!
- A coal plant running for just 3-4 hour peak would cost Rs 15-18/kWh