



Grid-Scale Battery Storage: Costs, Value, and Regulatory Framework in India

**Webinar jointly hosted by
Lawrence Berkeley National Laboratory and Prayas Energy Group**

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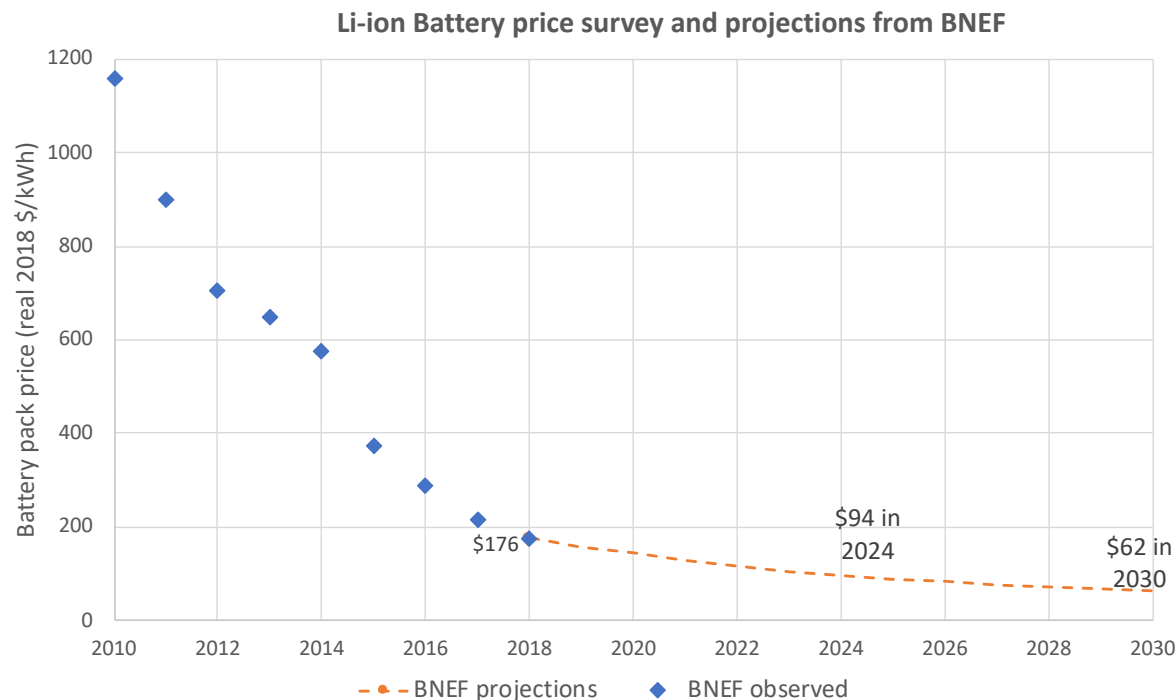
Outline

- Motivation and context
- U.S. trends in cost of grid-scale battery storage
- Methodology for cost estimation in India
- Key Findings on capital costs, LCOS & tariff adder
- Relevance for India
- Policy and regulatory issues
- Key takeaways



Motivation and Context

- Li-ion battery pack prices have dropped by 80-90% since 2010
- Worldwide installation of batteries is expected to increase rapidly – from ~9 GW (17 GWh) in 2018 to ~1,000 GW (2,800 GWh) by 2040, as per Bloomberg New Energy Finance (BNEF)



Recent SECI Tenders on Hybrid Renewables in India

1200 MW Peak power

- Peak tariff: Rs.6.3/kWh
- Off-peak tariff: Rs.2.88/kWh
- Avg levelized tariff: Rs.3.96/kWh
- CUF: 41%
- COD Jun'22

Round-the-Clock (RTC) 400 MW RE

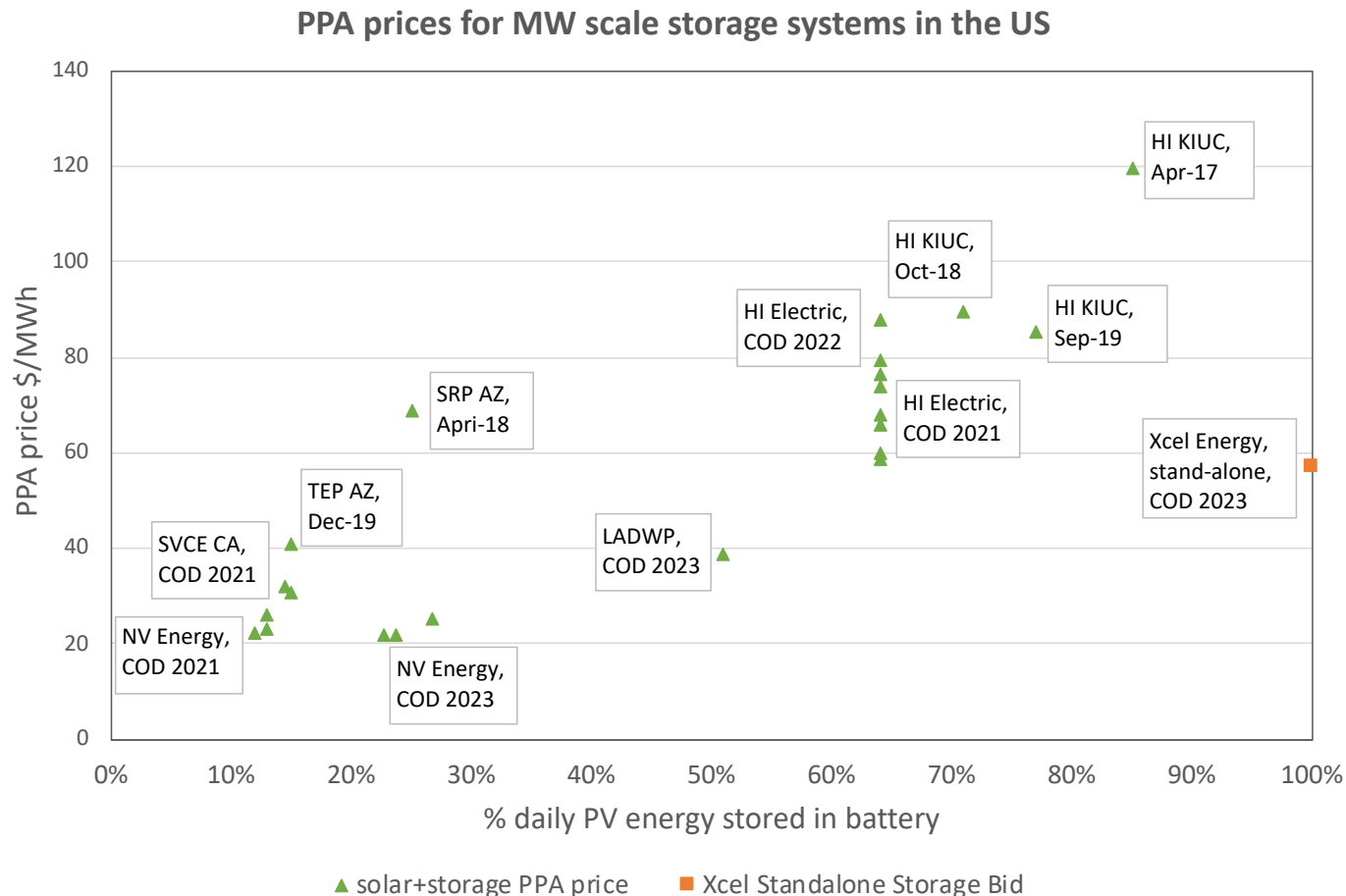
- Tariff Rs.2.91/kWh + 3% esc p.a. for 15 yrs
- Levelized tariff: Rs.3.59/kWh
- CUF: min 80% annually, 70% monthly

RE+Thermal RTC 5000 MW

- Tariff: yet to be discovered
- 80% min annual availability, 51% RE

In the US, PV-plus-storage deployment is rapidly growing as costs decline

- ~70 GW of the planned RE capacity over the next few years is paired with >30 GW of storage



- By 2021, incremental PPA adder of \$5/MWh for 12-13% of storage (NV Energy)
- By 2023, incremental PPA adder of ~\$20/MWh for 52% storage (LADWP)

Battery Storage Cost Estimation Methodology

- We use a two-pronged approach to estimate Li-ion battery LCOS / PPA prices in India:
 1. **Market Based:** We scale the most recent US bids and PPA prices (only storage adder component) using appropriate interest rate / financing assumptions
 2. **Bottom-up:** For battery pack prices, we use global forecasts; For Balance of System (BoS) costs, we scale US benchmark estimates to India using comparison with component level solar PV system costs
 - Using the bottom-up capital costs, LCOS is estimated using the following assumptions: Project life = 20 yrs, battery pack life = 10 yrs, depth of discharge = 90%, Interest rate = 11% (nominal), O&M cost = 1% of capex, daily cycling, battery pack performance degradation = 1% per year

India Estimates for Storage PPAs Derived by Scaling U.S. Market Data

Offtaker (COD)	Solar MW	Battery MWh	% of PV MWh Stored in Battery	PPA price (\$/MWh, 2018 dollars)	Unsubsidized (\$/MWh, 2018 dollars)	India Estimate (\$/MWh, 2018 dollars)	India Estimate (Rs./kWh)
NV Energy (Dec 2021)	200	200	13%	23.1	33.0	44.1	3.1
TEP AZ (Dec 2019)	100	120	15%	40.7	58.1	77.0	5.4
LADWP (2023)	400	1,200	51%	38.9	55.6	73.2	5.1
Xcel Energy - standalone (2023)	N/A	variable	N/A	56.9	81.3	104.1	7.3

- India estimates are ~34% higher than the US mainly due to the interest rate differences (5.5% in the US vs 11% in India)
- Estimated solar+storage PPA prices in India are
 - ~Rs.3/kWh for 13% energy stored in battery, 2021 delivery
 - ~Rs.5/kWh for 50% energy stored in battery, 2023 delivery

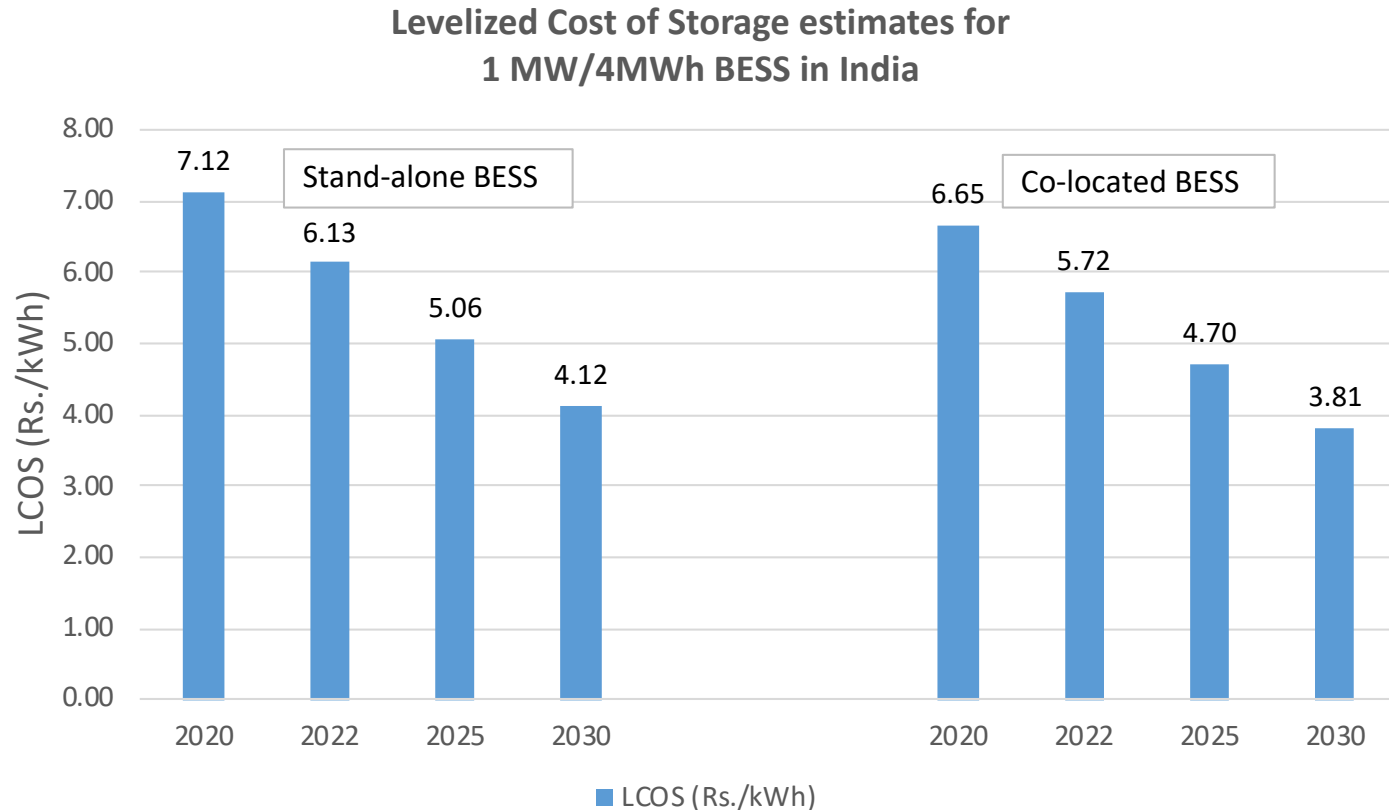
Bottom-up estimates for BESS in India

CapEx Estimates for 1 MW/4 MWh BESS in India	Standalone Year/Cost (\$/kWh)		
Components	2020	2025	2030
Battery pack	143	88	62
BoS hardware	22	17	15
BoS inverter	16	13	11
Soft costs	7	5	5
EPC	14	11	10
Total CapEx (\$/kWh)	203	134	103

PV Co-located Year/Cost (\$/kWh)		
2020	2025	2030
143	88	62
13	10	9
10	8	7
7	5	5
14	11	10
187	122	92

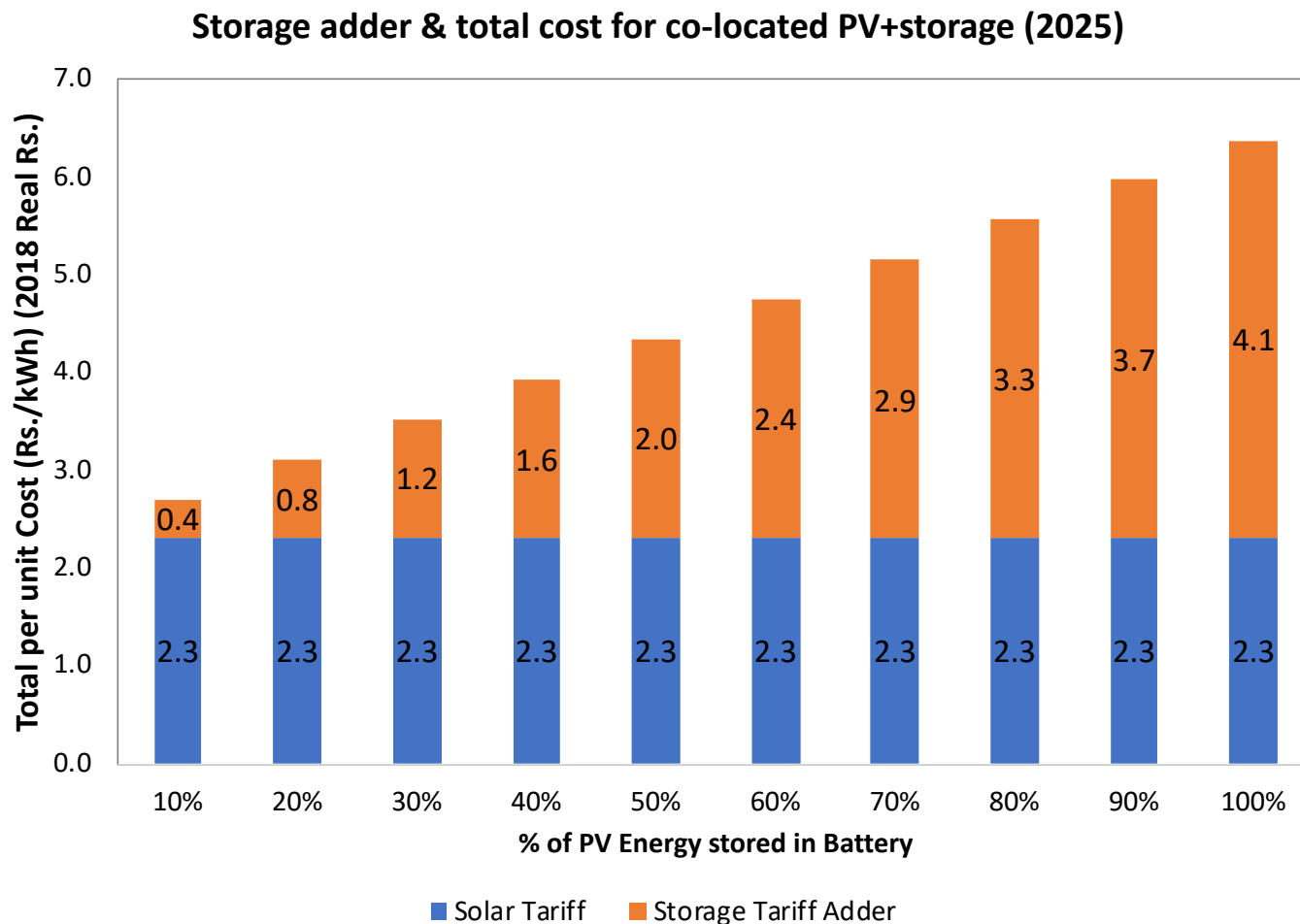
Battery CapEx is expected to halve over the next decade

Estimated LCOS for standalone and co-located BESS in India



- By 2030, the LCOS for standalone BESS system would be Rs 4.1/kWh and that for co-located system would be Rs 3.8/kWh.
- This implies that adding diurnal flexibility to ~20-25% of the RE generation would cost an additional Rs 0.7-0.8/kWh by 2030.

Tariff adder for 25% PV energy routed via battery drops to Re.1/kWh by 2025



By 2025-2030,

- cost of extending solar generation into evening peak hours would be Rs.3-3.5/kWh
- cost of extending solar generation to 12-15 hours would be Rs.4-5/kWh

RELEVANCE FOR INDIA

What is the value of energy storage in India?

How would it be dispatched?

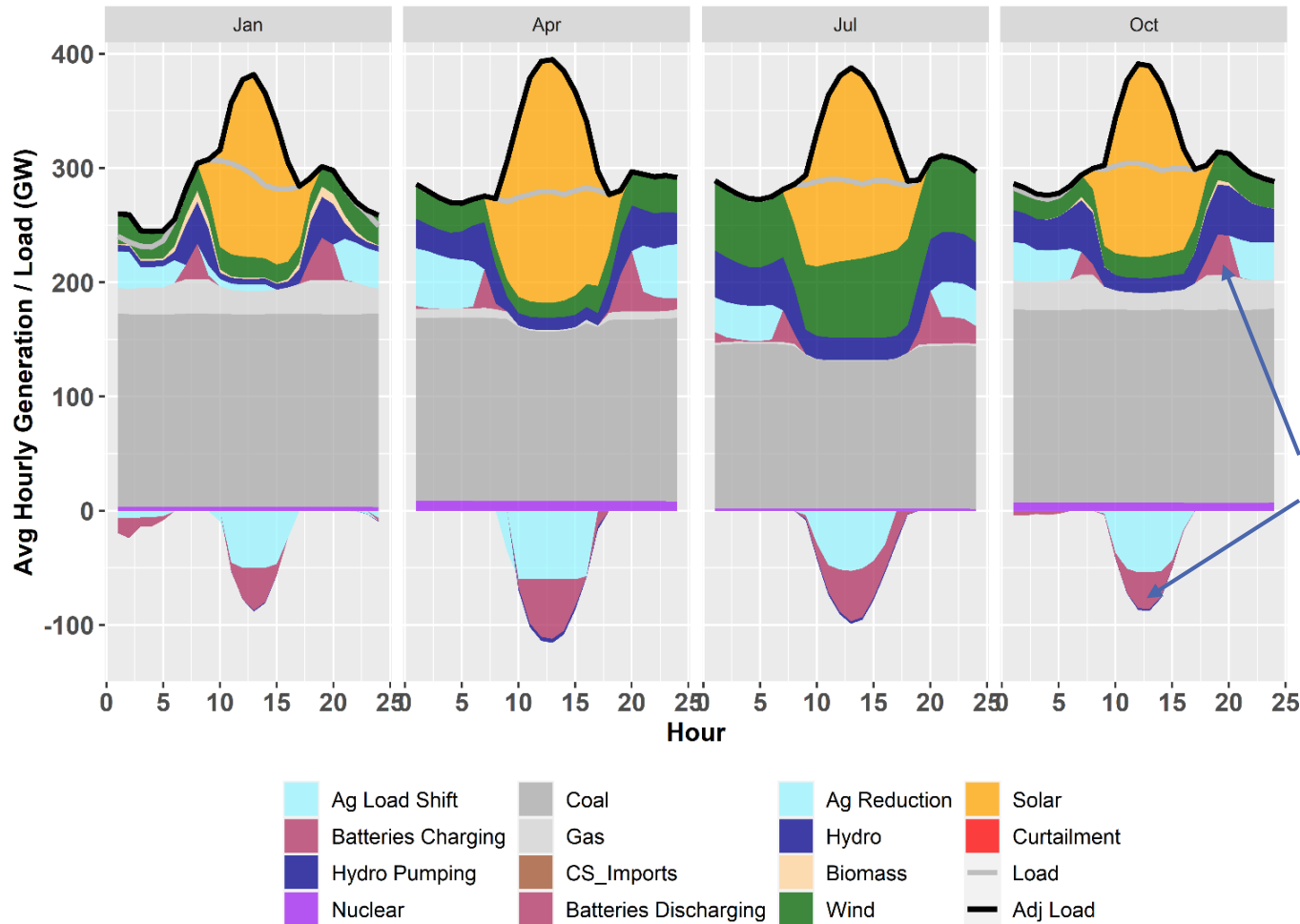
How much storage is required?

How do battery storage costs compare with pumped hydro?



Average hourly dispatch in 2030 (w/ 300 GW solar + 140 GW wind)

Average Hourly Dispatch (India Total) for HighRE_Flex2 (FY 2030)



RE provides little evening peak power.

Utilities are shifting Agri load to solar hours; but their peak contribution is limited.

Batteries charge during the day & discharge during evening & morning peak hours (~4-6 hrs/day).

~300-400 GWh of battery storage (~10-15% of average daily RE generation) is found to be cost effective by 2030.

Comparative Economics of 4-hrs Pumped Hydro and Battery Storage (2030)

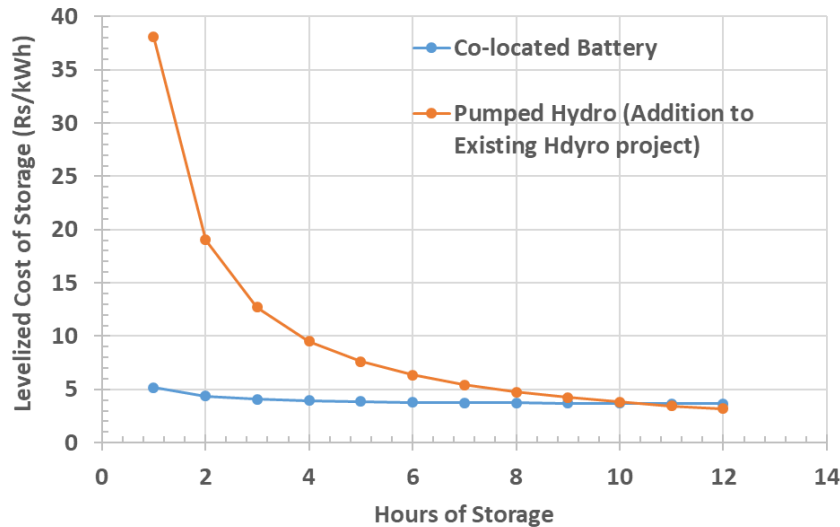
	Pumped Hydro	
	Addition to existing hydro stations	New build
Storage Capacity	1 MW / 4 MWh	1 MW / 4 MWh
Capital Cost	Rs 8 Cr/MW	Rs 12 Cr/MW
Life (years)	30	30
Days of operation per year	365	365
Levelized Cost of Storage Rs/kWh	9.5	14.9
Construction time	3-4 years	8-10 years
Land requirement	~2-5 Acres/MW (Assuming ~300 m net head)	

Battery Storage	
Co-located with Solar	Stand-alone
1 MW / 4 MWh	1 MW / 4 MWh
\$122/kWh	\$134/kWh
20 (replacement of battery pack considered)	20 (replacement of battery pack considered)
365	365
3.8	4.1
~6 months	~6 months
~0.1 Acres/MW	

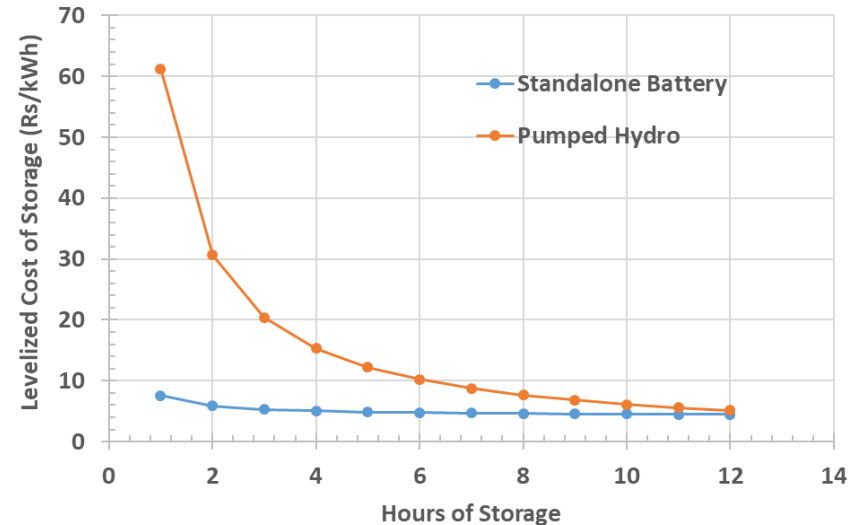
For 4-6 hours of storage, batteries are much cheaper than pumped hydro systems
Pumped hydro becomes cheaper than batteries for >10-12 hours of storage

Pumped hydro is MW-constrained, while battery is MWh-constrained

For low storage hours (up to 6-8 hours or so), batteries are more cost-effective. As hours of storage increase, pumped hydro becomes more cost-effective.



Co-located battery storage systems are cost-effective up to 10 hours of storage, when compared with adding pumped hydro to existing hydro projects.



For new builds, battery storage is always cost-effective irrespective of the hours of storage.

Over the next 10-15 years, 4-6 hour storage system is found to be cost-effective in India, if agricultural (or other) load could be shifted to solar hours

Key considerations for regulatory framework in India..1

- Resource Adequacy requirement mandate
 - Time of day/Seasonal demand assessment and corresponding least cost dependable power procurement plan

- Valuing storage and providing guidelines for procurement
 - Develop cost-effectiveness criteria so that all value chains provided by storage / other flexible capacity are counted for e.g. capacity value, energy value

- Develop rules for market participation
 - Allow market participants to change direction instantaneously in the day-ahead/real-time market

Key considerations for regulatory framework in India..2

- Technology neutral deployment mandate
 - E.g. CA requires utilities to procure ~5 GWh of storage capacity by 2020

- Reserves requirement assessment – Exploring alternatives (including storage as an option) for replacement of high cost ‘Reliability must run’ resources– need for cost benefit analysis.

- Rewarding fast response through ancillary services market – enabling all resources including storage to compete for this segment. (Can/should the system operators be asked to procure part of such services requirement?)

Summary and Key Takeaways

- ❑ Capital cost of 1 MW/4 MWh battery storage co-located with solar PV in India is estimated at \$187/kWh in 2020, falling to \$92/kWh in 2030
- ❑ Tariff adder for co-located battery system storing 25% of PV energy is estimated to be Rs. 1.44/kWh in 2020, Rs. 1.0/kWh in 2025, and Rs. 0.83/kWh in 2030
- ❑ By 2025-2030,
 - cost of extending solar generation into evening peak hours would be Rs.3-3.5/kWh
 - cost of extending solar generation to 12-15 hours would be Rs.4-5/kWh
- ❑ Adding diurnal flexibility to ~20-25% of RE generation would cost an additional Rs 0.7-0.8/kWh by 2030
- ❑ 4-6 hours of storage system is found to be cost-effective in 2030
- ❑ These cost estimates warrant a closer examination of future investments in the power sector
- ❑ However, significant regulatory interventions would be needed for cost-effective deployment of grid-scale battery storage

THANK YOU

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ADDITIONAL MATERIAL

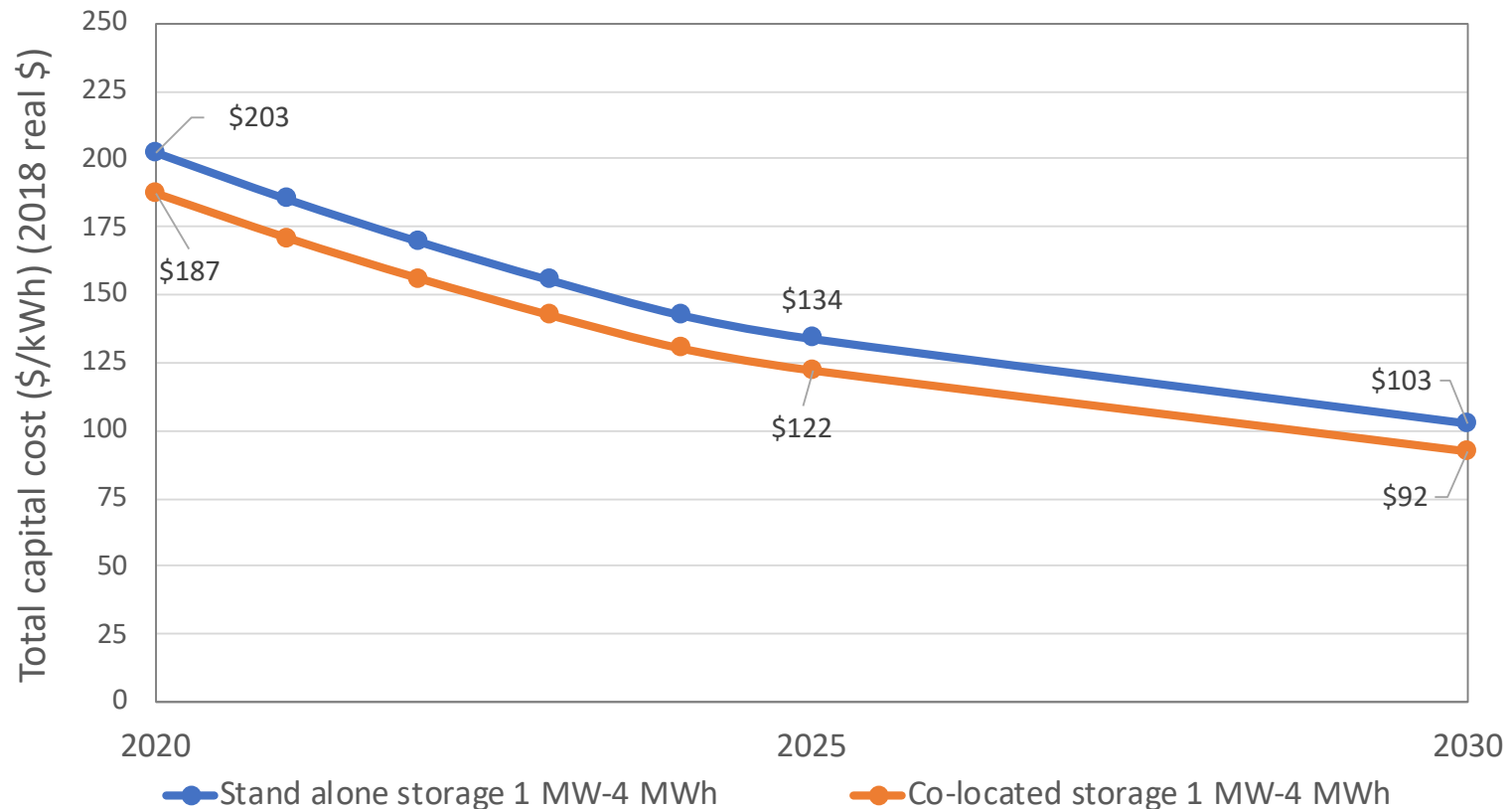


ENERGY TECHNOLOGIES AREA

ENERGY ANALYSIS AND ENVIRONMENTAL IMPACTS DIVISION

Estimated capital cost of battery systems in India

Estimated capital cost of (stand-alone & co-located) storage in India



Standalone : \$203/kWh in 2020 to \$103/kWh in 2030

Co-located: \$187/kWh in 2020 to \$92/kWh in 2030