Stakeholder Round Table:
Overcoming Market, Regulatory, and Finance Challenges for Long-Duration Storage Technologies

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LONG DURATION ENERGY STORAGE : AN INTRODUCTION

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LONG DURATION STORAGE SHOT TARGET

Reduce storage costs by **90%** from a 2020 Li-ion baseline...

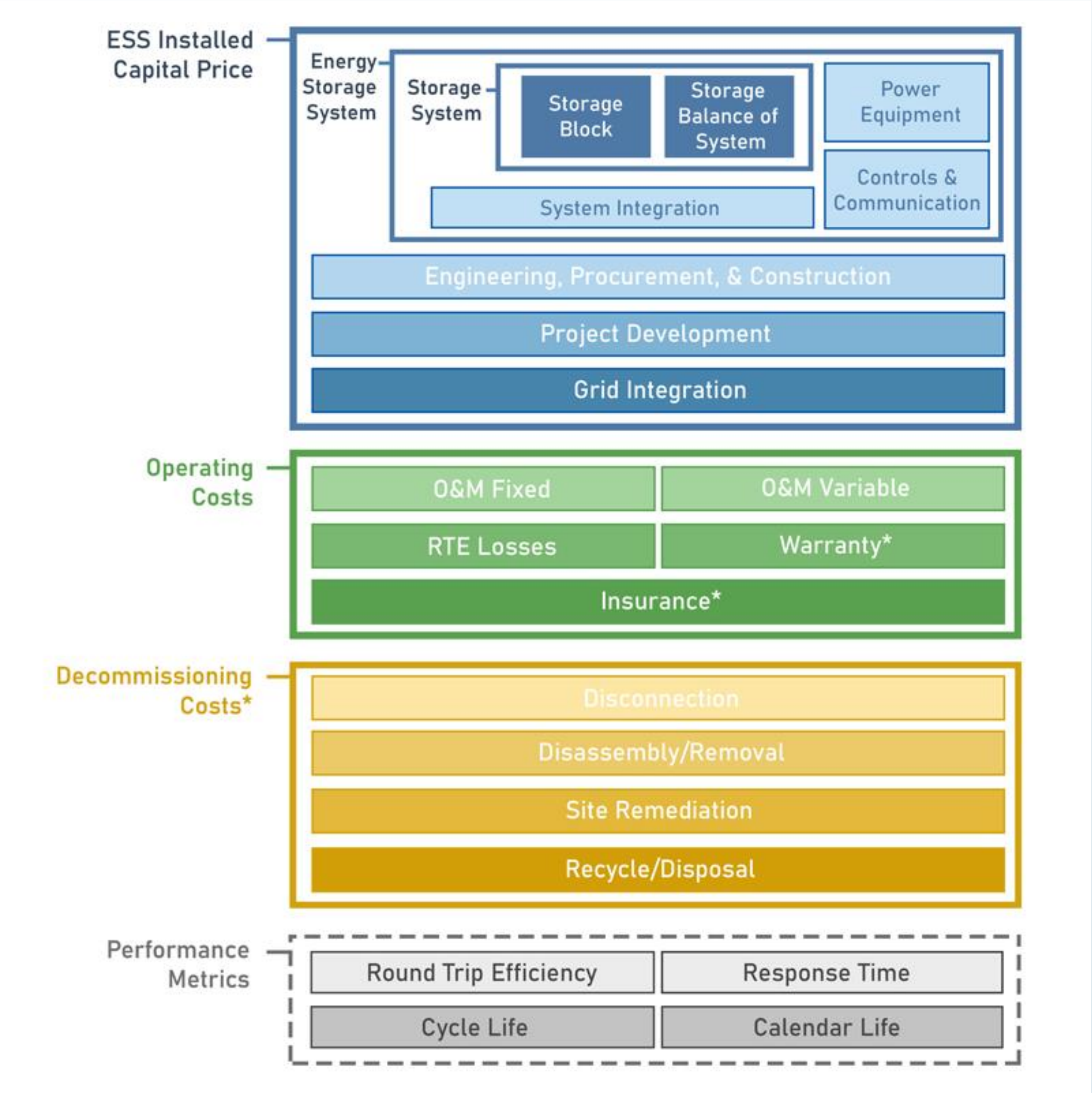
…in storage systems that deliver **10+** hours of duration

…in **1** decade

Affordable grid storage for clean power – any time, anywhere

Energy Storage Cost and Performance

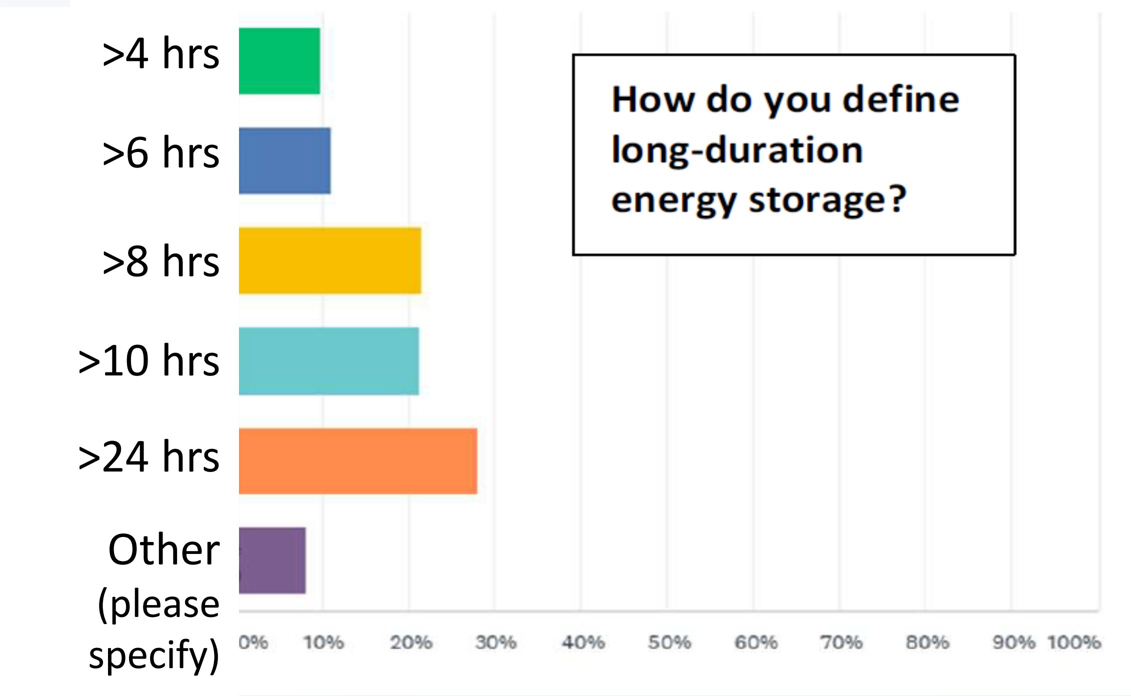
Technology	Durations Considered
Lithium-ion	2, 4, 6, 8, 10
Lead-acid	2, 4, 6, 8, 10
Vanadium Redox Flow Battery	2, 4, 6, 8, 10
Pumped Storage Hydropower	4, 10
Compressed Air Energy Storage	4, 10
Hydrogen	4, 10



LDES: Duration

LDES Shot Duration Floor: 10 hours

LDES Duration Literature Review[1]		
Duration (Hours)	Total #	Greatest citation count
≥4	**13**	Journal (tech. focus)
≥6	1	U.S. Dept. of Energy
≥8	2	Utility/ Trade/ Consultant & Other
≥10	**15**	Journal (grid focus)
Beyond diurnal	**7**	Journal (grid focus)



DAYS Advanced Research Projects Agency–Energy (ARPA-E) defines LDES as 10–100 hours[2] → growing use, and support, of the >10 hours definition[1]

Perceptions of LDES duration varied considerably, from >4hrs to >24 hrs. >24hrs identified most often (~30%)[3]

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[1]: Paul Denholm et al., National Renewable Energy Laboratory
[2]: DAYS (Duration Addition to electricitY Storage) https://arpa-e.energy.gov/technologies/programs/days

[3]: Clifford K. Ho, Sandia National Laboratories, https://www.sandia.gov/ess-ssl/ldes/

Necessity: Storage Enables Grid Decarbonization

Phase 0 23 GW, 8-12 hrs
- Providing flexibility to the nuclear fleet
- Mostly pumped storage

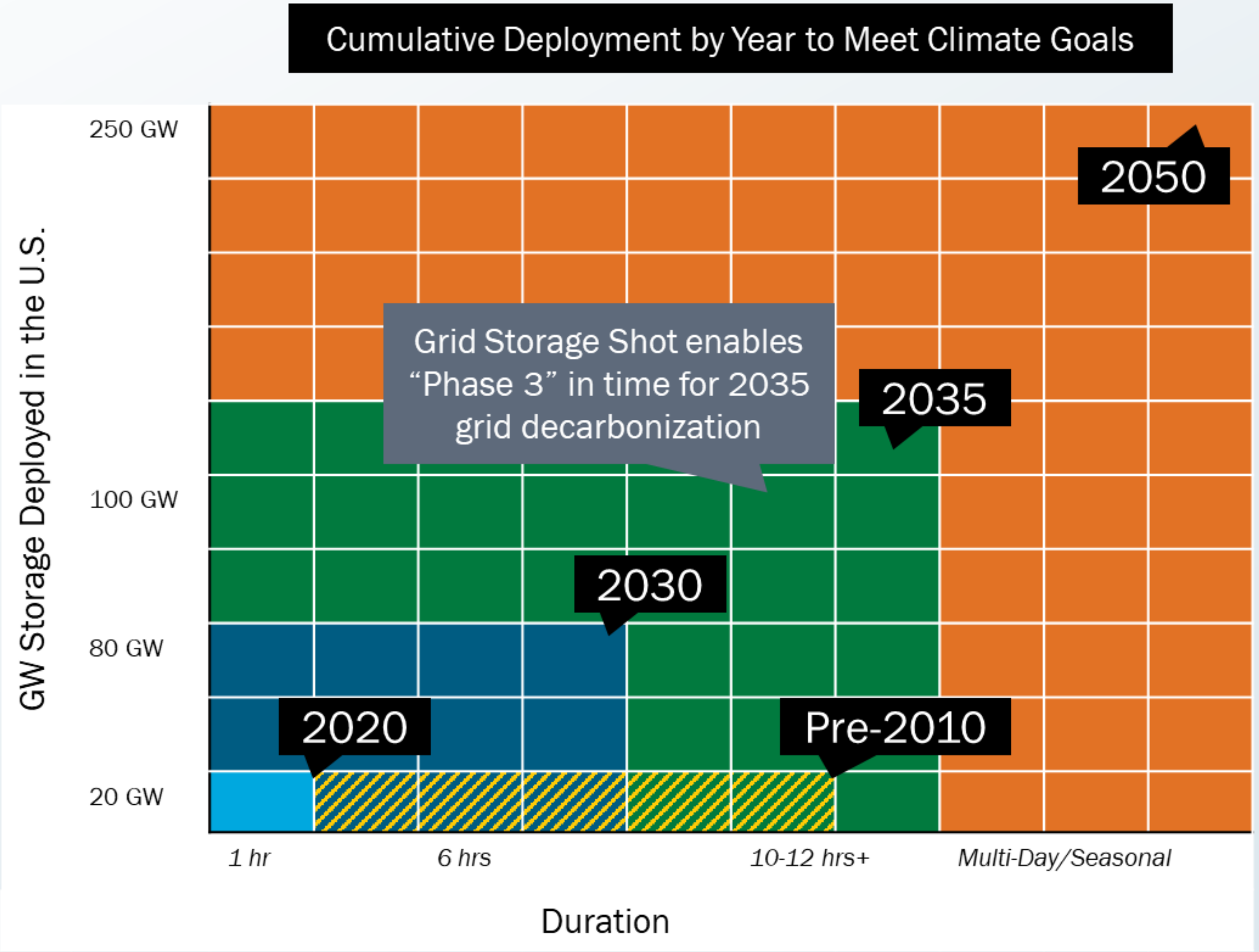
Phase 1 >30 GW, 1 hr
- Displace fossil generators to provide Essential Reliability Services
- Mostly Li-Ion
- 5¢/kwh LCOS @ ~$200/kwh Li battery equivalent capex

Phase 2 30-100 GW, 4-6 hrs
- Displace thermal generators to provide peaking capacity
- Larger opportunities for thermal, flexibility, flow batteries
- 5¢/kwh LCOS @ ~$100/kwh Li battery equivalent capex

Phase 3 100+ GW, 10 hrs
- Diurnal energy time shifting for very high renewable generation
- Continued opportunities for flow, chemical (e.g. H_2)
- 5¢/kwh LCOS @ ~$10-$35/kwh Li battery equivalent capex

Phase 4 250+ GW, 12+ hrs
- Multiday to seasonal energy time shifting for economy-wide decarbonization
- Non-battery architectures likely
- Exceptionally low capex required to achieve 5¢/kwh LCOS

Adapted from https://www.nrel.gov/analysis/storage-futures.html



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LDES: Valuation Approaches

Two main approaches for valuation of energy storage:

1. **Price-taker approach:** typically applied for small ES installations, assuming that they are not likely to affect market prices
2. **System analysis approach:** typically applied for larger ES projects whose operation may affect market prices. Often referred to as a price-influencer, or price-maker approach.

The challenge is how to properly estimate the value for the use cases and services LDES can provide.

Valuation Gaps:

Temporal Resolution	Value Streams	Valuation Strategy and Quantification	Non-Market Cost Evaluation
Varying time scales of costs, benefits, and generation	Selection of streams vastly impacts results, with limited guidance on selection → limited consistency	Selection of methods impacts ease of use and accuracy with similar challenges to value stream selection	Often evaluated with custom analysis techniques → prevents comparison and limits decision-making

Vladimir Koritarov et al., *Pumped Storage Hydropower Valuation Guidebook – A Cost-Benefit and Decision Analysis Valuation Framework*, Water Power Technologies Office, March 2021. https://www.energy.gov/eere/water/pumped-storage-hydropower-valuation-guidebook-cost-benefit-and-decision-analysis

LDES: Transmission

As a dual-use (transmission and generation) asset, energy storage will likely have significant opportunities to provide energy services in the market, thereby generating offsetting revenue that can be shared with customers to reduce system costs[1]

Reliability/Resilience Storage Support[2]

Storage may be deployed as transmission or in place of transmission

- ES can maintain voltage, manage power flows, and absorb excess power
- Alleviate thermal overloading on transmission lines
- Extend the life of existing assets

Dual-Use Storage Implementation Needs[2]

- Establish clear, transparent processes for the proposal and study of energy storage as a dual-use asset
- Prepare a reasonable forecast of future market revenues to quantify the net present cost of the asset to transmission customers
- Establish market participation windows in advance
- Create flexible market products and resource definitions
- Balance cost recovery mechanisms to incent market participation

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[1]: FERC Policy Statement on Dual-Use Storage (2017), https://www.ferc.gov/sites/default/files/2020-04/E-2_34.pdf
[2]: Twitchell J.B. 05/26/2021. "Energy Storage as a Transmission and Dual-Use Asset." Presented by J.B. Twitchell at Wisconsin Public Service Commission Workshop, Online Conference, United States. PNNL-SA-162957.

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Any Questions?

Thank you!

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