Energy Storage in Long-Term Planning Models

Modeling Practices and Challenges

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Energy Storage in Expansion Plans (1/2)

- In practice, **many utilities and planning entities across the U.S. are including storage in their assessments**, and numerous IRPs incorporate various levels of utility-scale energy storage in their preferred portfolios.
- The forecast need of energy storage for the next 15-20 years is being mostly driven by **renewable energy goals, carbon policies, economic conditions, and the retirement** of conventional generation sources.

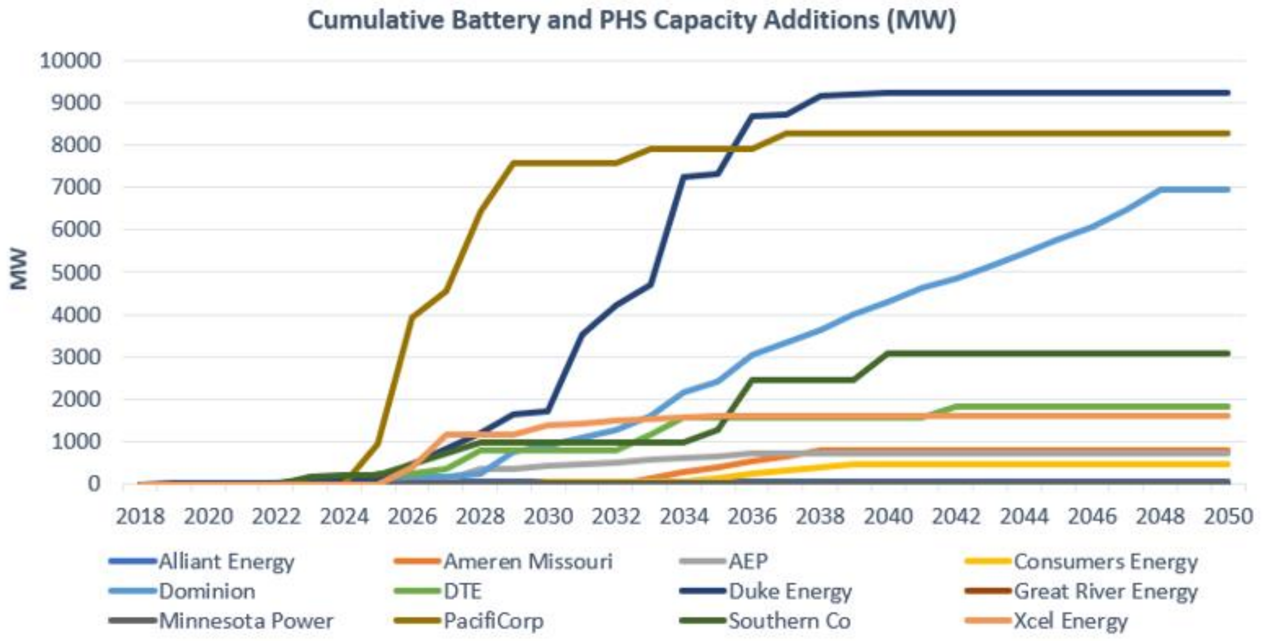


Figure 3: Battery and Pumped Hydro Storage capacity additions through 2050 for a sample of electric companies[6]*.*
Source: EQ Research IRP as a Data Service.

Source: "Energy Storage in Long-Term Resource Planning: A Review of Modeling Approaches and Utility Practices," 2023 EPRI Technical Brief #3002028378

Energy Storage in Expansion Plans (2/2)

- The most common candidate is the Li-ion battery with **durations of 2, 4, 6 and 8 hours.**
- **Hybrid resources** are typically preferred in portfolios, while standalone storage systems selected in scenarios with high decarbonization goals and significant cost reductions.
- Pumped Hydro Storage (PHS) is utilized as long-duration energy storage when available. Additionally, some utilities are **piloting advanced LDES systems.**

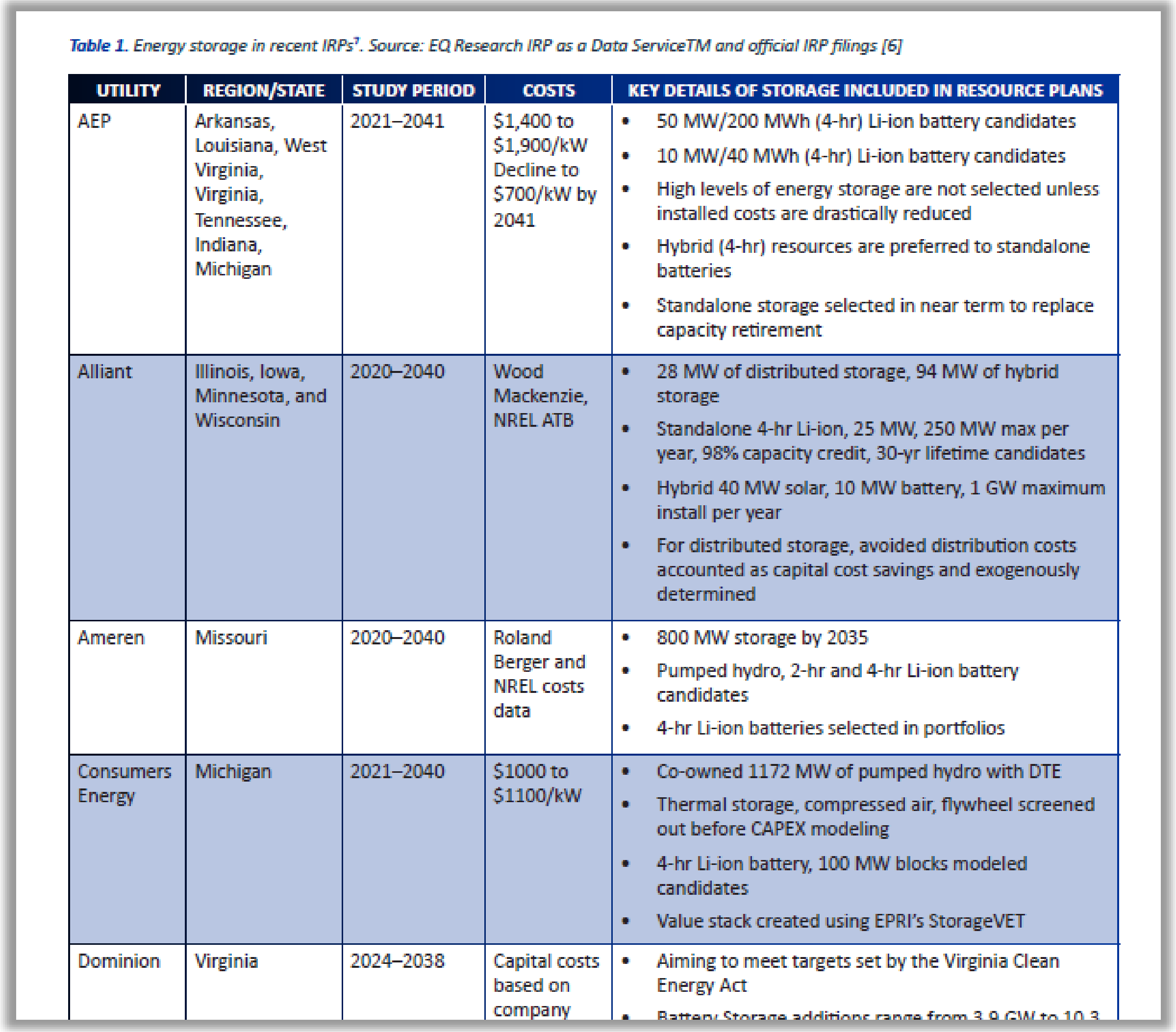


Table 1. *Energy storage in recent IRPs[7]. Source: EQ Research IRP as a Data ServiceTM and official IRP filings [6]*

UTILITY	REGION/STATE	STUDY PERIOD	COSTS	KEY DETAILS OF STORAGE INCLUDED IN RESOURCE PLANS
AEP	Arkansas, Louisiana, West Virginia, Virginia, Tennessee, Indiana, Michigan	2021–2041	$1,400 to $1,900/kW Decline to $700/kW by 2041	• 50 MW/200 MWh (4-hr) Li-ion battery candidates • 10 MW/40 MWh (4-hr) Li-ion battery candidates • High levels of energy storage are not selected unless installed costs are drastically reduced • Hybrid (4-hr) resources are preferred to standalone batteries • Standalone storage selected in near term to replace capacity retirement
Alliant	Illinois, Iowa, Minnesota, and Wisconsin	2020–2040	Wood Mackenzie, NREL ATB	• 28 MW of distributed storage, 94 MW of hybrid storage • Standalone 4-hr Li-ion, 25 MW, 250 MW max per year, 98% capacity credit, 30-yr lifetime candidates • Hybrid 40 MW solar, 10 MW battery, 1 GW maximum install per year • For distributed storage, avoided distribution costs accounted as capital cost savings and exogenously determined
Ameren	Missouri	2020–2040	Roland Berger and NREL costs data	• 800 MW storage by 2035 • Pumped hydro, 2-hr and 4-hr Li-ion battery candidates • 4-hr Li-ion batteries selected in portfolios
Consumers Energy	Michigan	2021–2040	$1000 to $1100/kW	• Co-owned 1172 MW of pumped hydro with DTE • Thermal storage, compressed air, flywheel screened out before CAPEX modeling • 4-hr Li-ion battery, 100 MW blocks modeled candidates • Value stack created using EPRI's StorageVET
Dominion	Virginia	2024–2038	Capital costs based on company	• Aiming to meet targets set by the Virginia Clean Energy Act • Battery Storage additions range from 3.9 GW to 10.3

Source: "Energy Storage in Long-Term Resource Planning: A Review of Modeling Approaches and Utility Practices," 2023 EPRI Technical Brief #3002028378

Modeling Challenges for Energy Storage in Planning

Technological Representations

- Different technology configurations, costs and technological parameters
- Operational-related performance (efficiency, degradation)

Value and Market Participation

- Wide range of applications: energy time shifting, firm capacity, ancillary services, transmission and distribution services, and customer services
- Service value with deployment changes

Temporal resolution

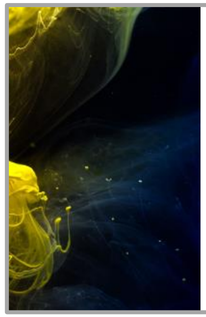
- State-of-charge dependencies
- Short-term (sub-hourly) variability
- Approaches impact the valuation of storage services

Spatial resolution

- System variability depends on geographical coverage
- A reduced system misses regional characteristics
- Lower or no congestion in simplified systems

Policies and incentives

- Several policies and incentives at national and sub-national levels



Others

- Uncertainty about technology costs and performance, and policies
- Forecast errors, load profiles and growth
- Emerging technologies, etc.

Source: Adapted from J. Bistline et al 2020 Prog. Energy 2 032001

Energy Storage Modeling in Practice - Common Approaches

- The **assessment of energy storage is more complex** than other technologies.
- To **manage the tractability issues** that quickly arise when modeling energy storage in capacity expansion models, resource planners relay on simplifications that may result in inaccurate estimations of benefits and costs.

Energy storage additions are pre-screened to determine those eligible to include in more detailed modeling

Energy storage is added exogenously to pre-optimized resource portfolios and evaluated for feasibility and economics using hourly operations models

Costs and benefits associated with sub-hourly flexibility of energy storage are evaluated using engineering-based storage technology model

Optimal energy storage additions are identified endogenously within a **Capacity Expansion Planning Model (CEM)**

Source: "Energy Storage in Long-Term Resource Planning: A Review of Modeling Approaches and Utility Practices," 2023 EPRI Technical Brief #3002028378

Energy Storage Modeling in Practice - Common Simplifications

Temporal simplifications include on-peak and off-peak days with a limited number of hours per day; typical weeks; one or two chronological weeks per month.

Regional network aggregation (copper plate) seems to be the preferred approach, with or without a link to outside markets. For large-scale models, hourly interregional energy limits between balancing areas are also used.

Capacity value for storage is normally determined exogenously for various levels of deployment. Resource adequacy models are employed to determine effective load carrying capability (ELCC) curves for each storage tier which are later used as inputs.

All approaches and simplifications have disadvantages, and modelers need to weigh the tradeoffs between fidelity (i.e., improved representation) and model tractability

Trade-offs in Spatiotemporal Resolution vs. Complexity (1/2)

- Key common simplification methods to reduce the planning model's temporal dimension, optimization period, and representation of the transmission network **result in significant variation in storage portfolios.**

- These simplifications (aimed at reducing lengthy run times in capacity expansion models) may lead to inaccurate evaluations, potentially resulting in **either underestimation or overestimation of storage resources** and even other generation technologies in planning studies.

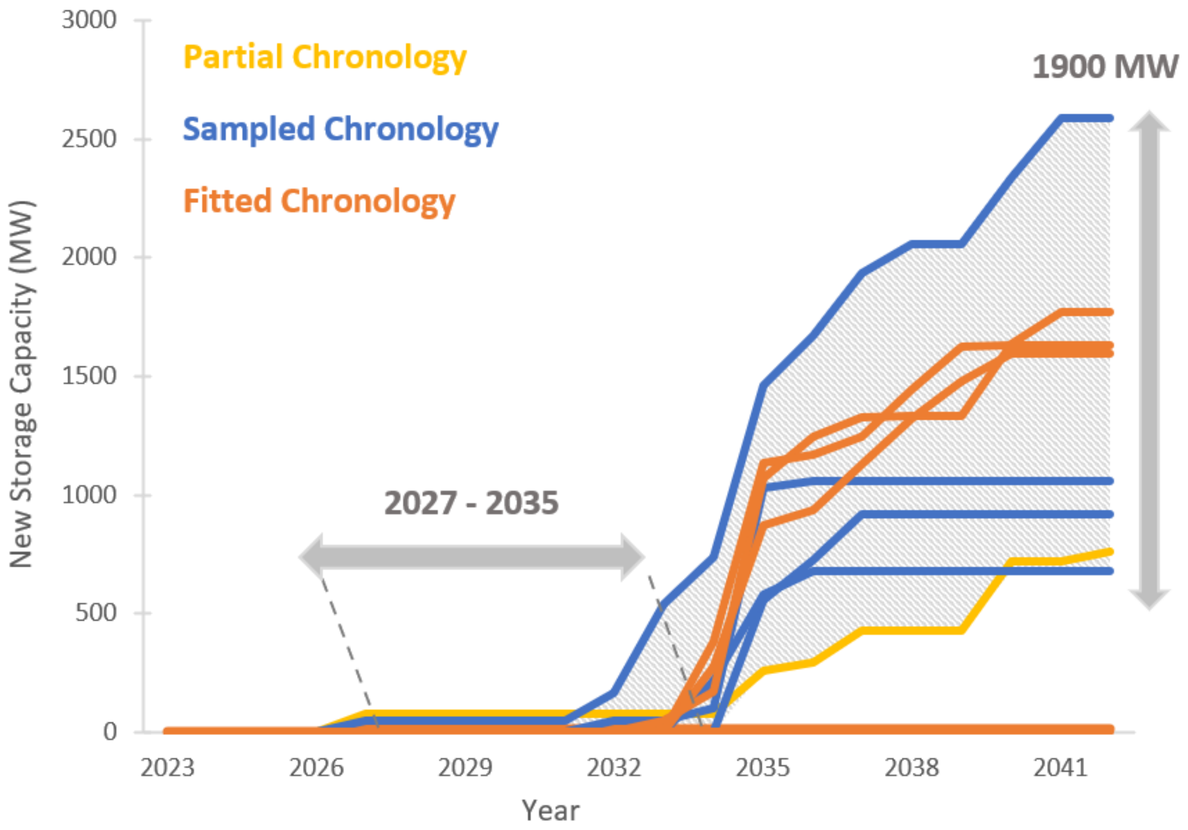


Figure1. Comparison of new storage capacity (MW) across three low-carbon resource portfolios, using different temporal resolution modeling strategies

Source: "Assessing Temporal and Spatial Modeling Choices for Energy Storage in Long-Term Resource Plannings," Product ID 3002028963

Trade-offs in Spatiotemporal Resolution vs. Complexity (2/2)

- **Finer temporal granularity —with chronology— drives higher storage deployment**; temporal simplifications may overlook peak and off-peak pricing periods crucial for accurately valuing energy storage.
- **Simultaneously modeling the transmission network can help mitigate future congestion** issues by identifying optimal storage locations and deployment timing.
- **Myopic models with shorter optimization periods may result in lower storage deployment**. These models miss anticipating later carbon targets and thus the need to retire fossil and build more renewables and storage.

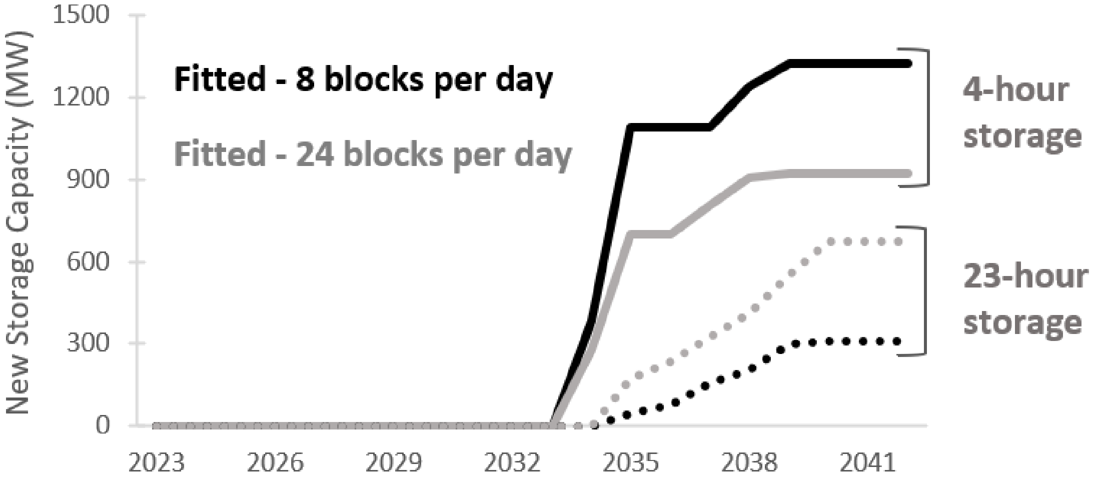


Figure 2. Comparison of storage deployment by capacity (MW) under different temporal resolutions

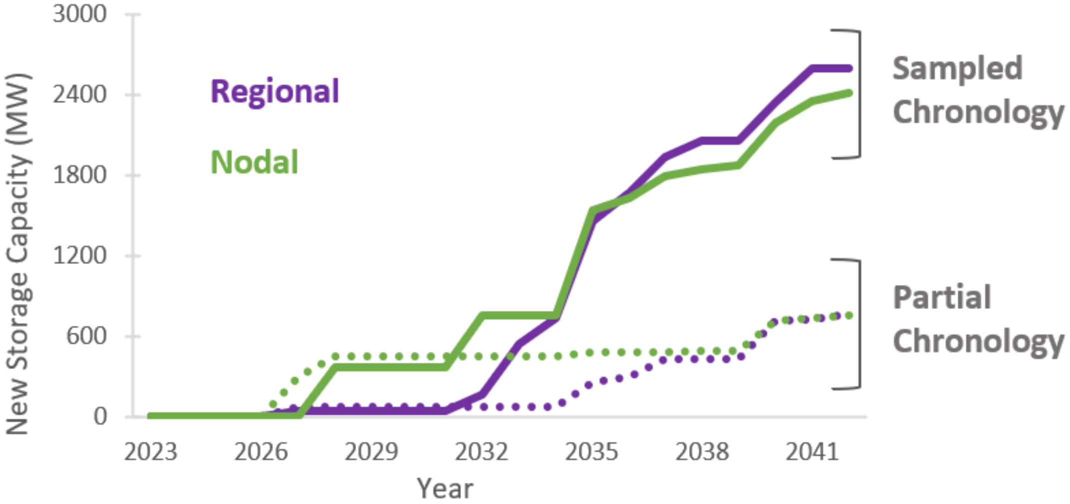


Figure 3. Comparison of storage deployment by capacity (MW) between nodal and regional approaches

Source: "Assessing Temporal and Spatial Modeling Choices for Energy Storage in Long-Term Resource Plannings," Product ID 3002028963

Long Duration Energy Storage (LDES) is Amplifying the Existing Complexities of Storage Modeling

How to configure LDES if information is limited?

Substantial uncertainty exists for new storage technologies regarding capital cost trajectories, storage capabilities, and operational use, which can be used to benchmark the outputs of the models used by resource planners.

How to implement longer chronologies necessary for evaluating LDES effectively?

Computationally expensive temporal models are needed to capture multi-day and multi-month charging dynamics, especially when capturing a wide range of weather and load conditions over extended horizons.

How to determine LDES capacity contribution to meet planning reserve margins?

LDES may provide firm capacity during periods of high stress in the grid, but adequacy values are highly dependent on the resource mix, especially their interaction with other storage and renewable resources.

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