Valuation of the benefits and costs of long duration storage

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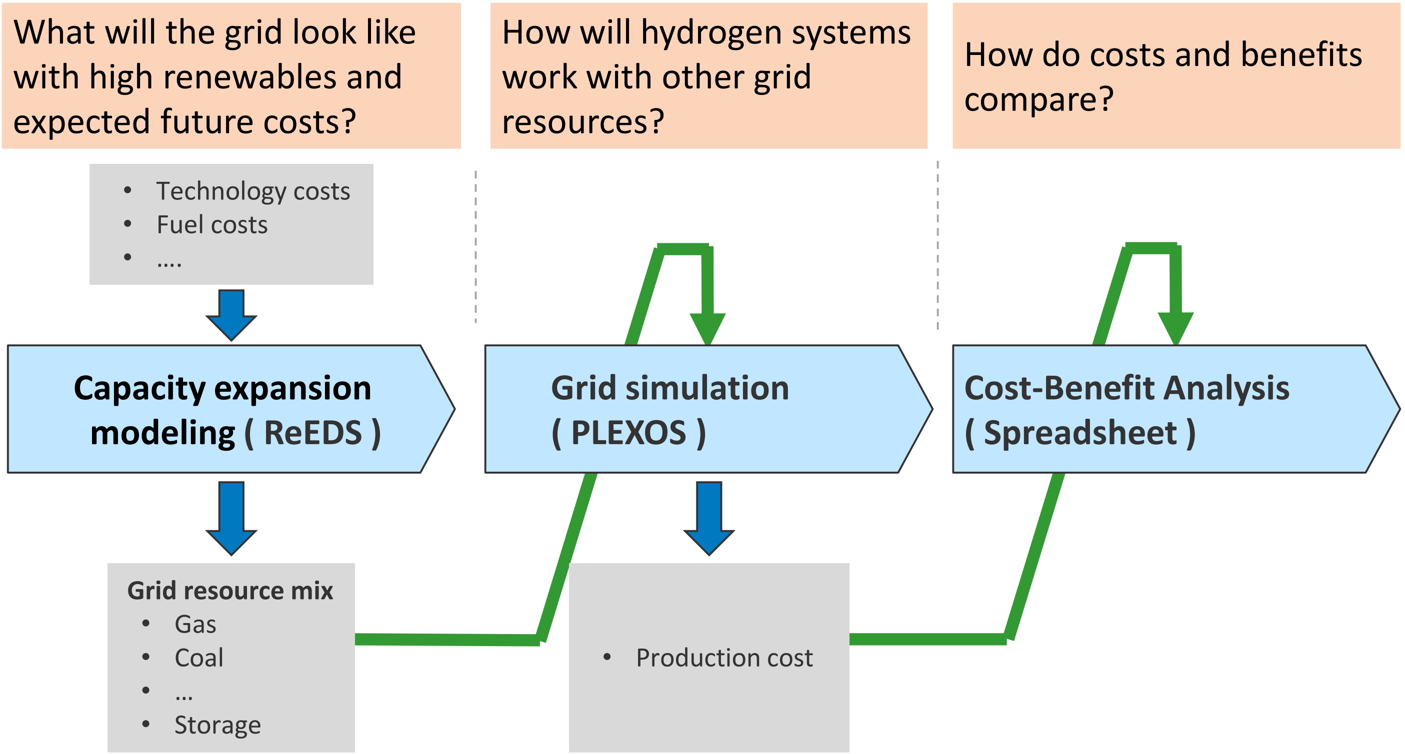
Background

- Existing literature mostly focuses on the levelized cost of long duration energy storage
  - e.g., what is the least expensive technology for a given duration of energy storage
- A critical missing piece to understanding the economic competitiveness of long duration storage is determining the potential system benefit (or avoided cost) and how the benefit changes with increasing renewables
- NREL, EPRI and 5 EPRI member utilities (Xcel, PG&E, SDG&E, NPPD, Southern Company) finished work on a DOE H2@Scale CRADA project titled "Valuation of Hydrogen Technology on the Electric Grid Using Production Cost Modeling"

Research approach: Modeling and analysis workflow



Valuation of Hydrogen Technology on the Electric Grid Using Production Cost Modeling: 2018 Year-End Interim Report. EPRI, Palo Alto, CA: 2019. 3002013731.

Research approach: Modeling and analysis workflow

Major focus

	Capacity expansion modeling (ReEDS)	Grid simulation (PLEXOS)	Cost-Benefit Analysis (Spreadsheet)
This research	• Generate 85% renewable scenario	• Significant methods development • Many, many scenarios run	• Establish uniform framework • Integrate grid benefit outcomes with other factors

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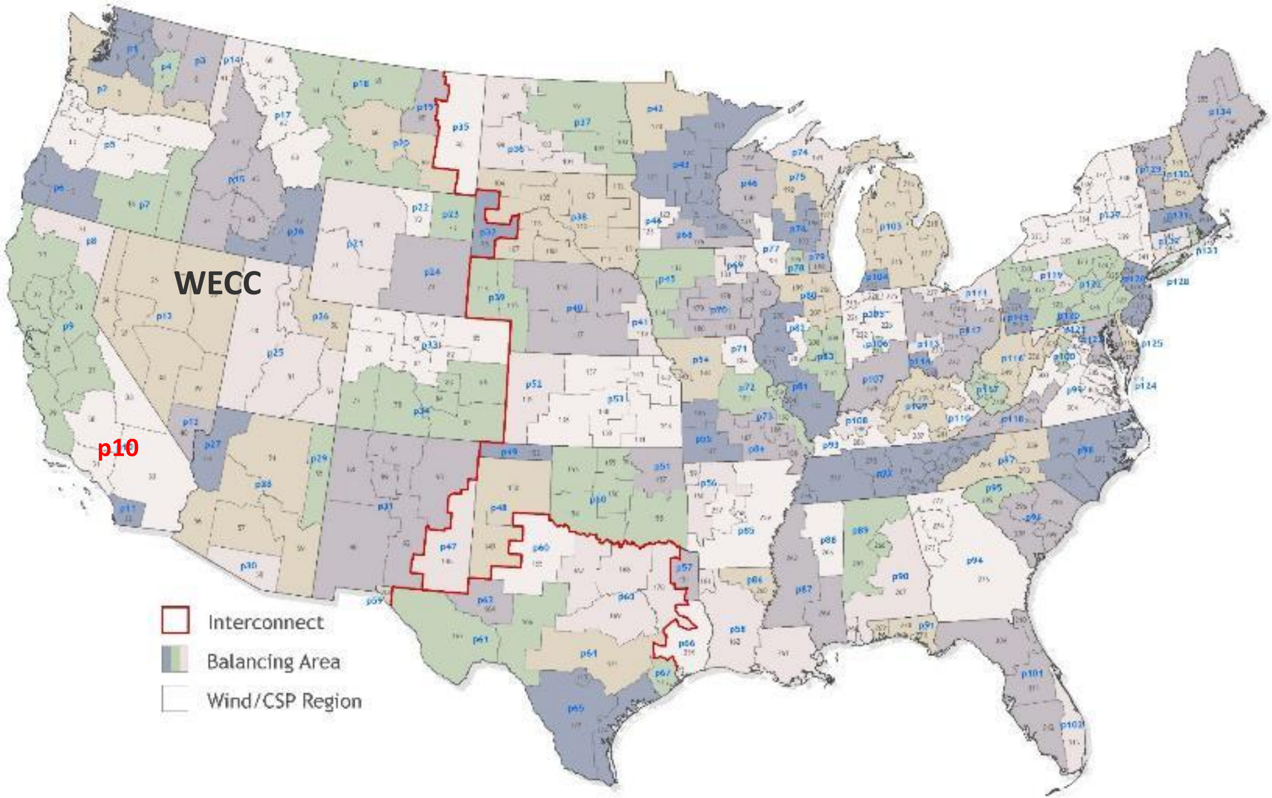
Modeling Scope

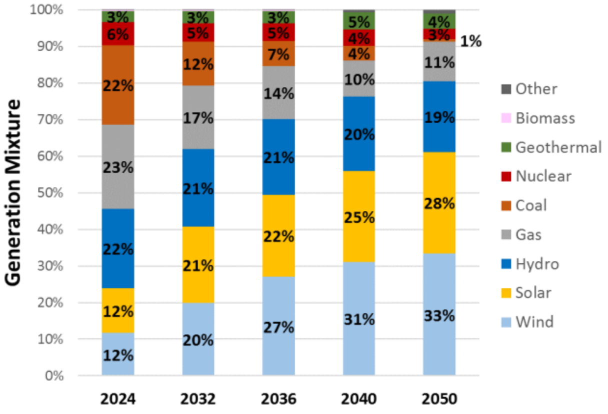
- Renewable penetration scenarios were drawn from the ReEDS Standard Scenarios, "National RPS 80%"
  - Up to 85% RPS for the WECC



The WI grid in ~2050 with 85% renewables

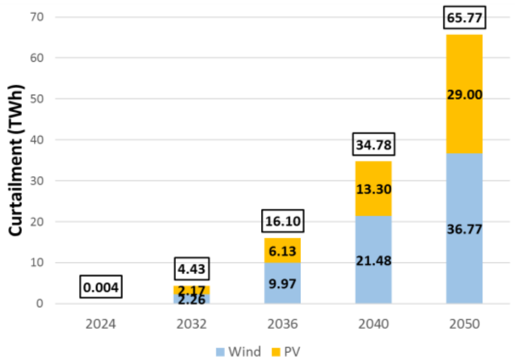
Generation mix

Wind and solar grow, some gas remains



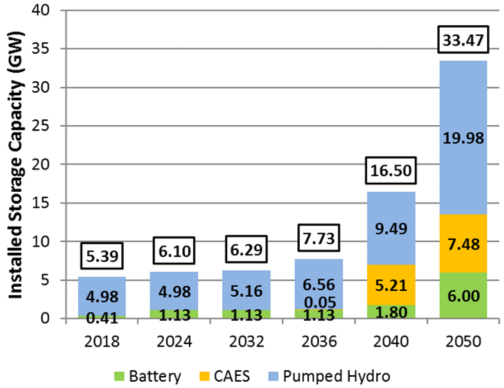
Curtailment

Grows dramatically from 2036 (74%) onwards



Grid storage

Grows dramatically from 2036 (74%) onwards – about half PHS



Long duration storage modeling approach

- Explored methods for implementing long duration storage in large-scale power system models
  - Heuristic optimization
    - Summary: Use price points to determine when to charge or discharge (e.g., if shadow price is less than $10/MWh charge and if greater than $10/MWh discharge)
    - Pros: Simple, computationally efficient
    - Cons: Needs to be tuned to maximize benefit (sub-optimal)
  - Two-stage optimization
    - Summary: Use one optimization to determine the seasonal planning/operation and a second to dispatch on the daily timeframe
    - Pros: Potential to generate optimal results if information is passed between each stage
    - Cons: Complex to implement, computationally expensive

<u>We chose a two-stage iterative approach</u>

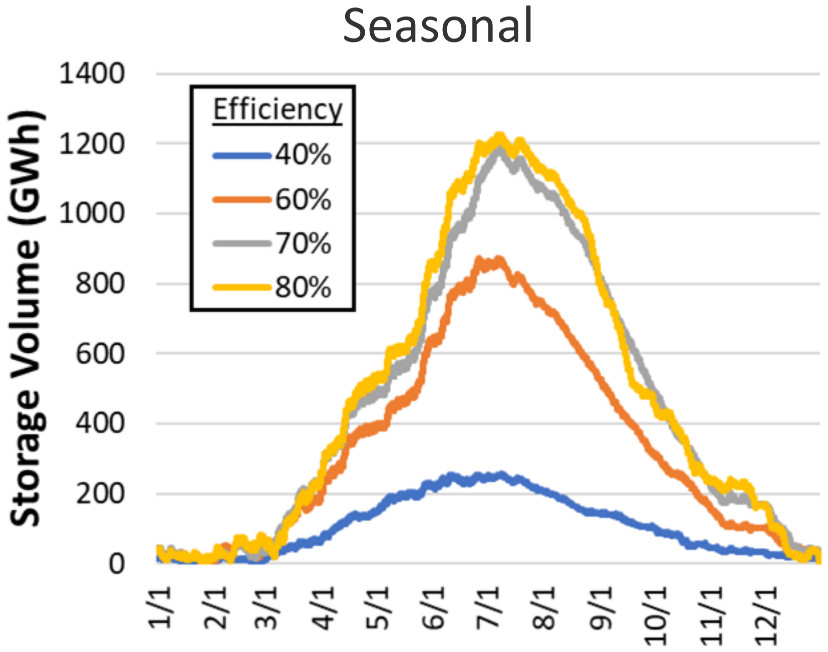
Technologies considered

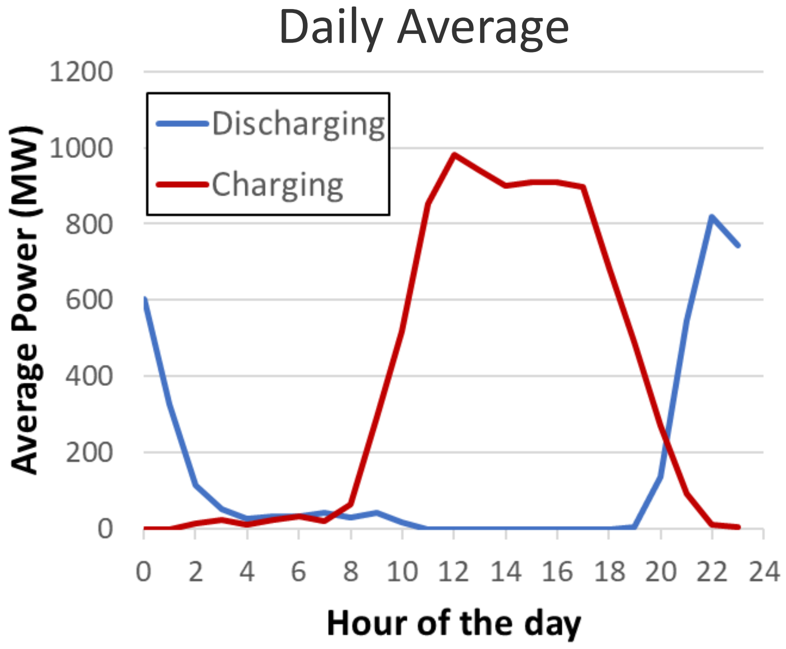
- This study considered both energy storage and demand response
- Storage technologies are uniquely defined by their round-trip efficiencies

Technologies
Compressed air energy storage (CAES)
Pumped hydro
Flow battery
Power-to-gas-to-power (P2G2P)
Power-to-gas (P2G)

Storage Operation Profile

- An example storage operation profile shows seasonal behavior as well as optimal daily behavior





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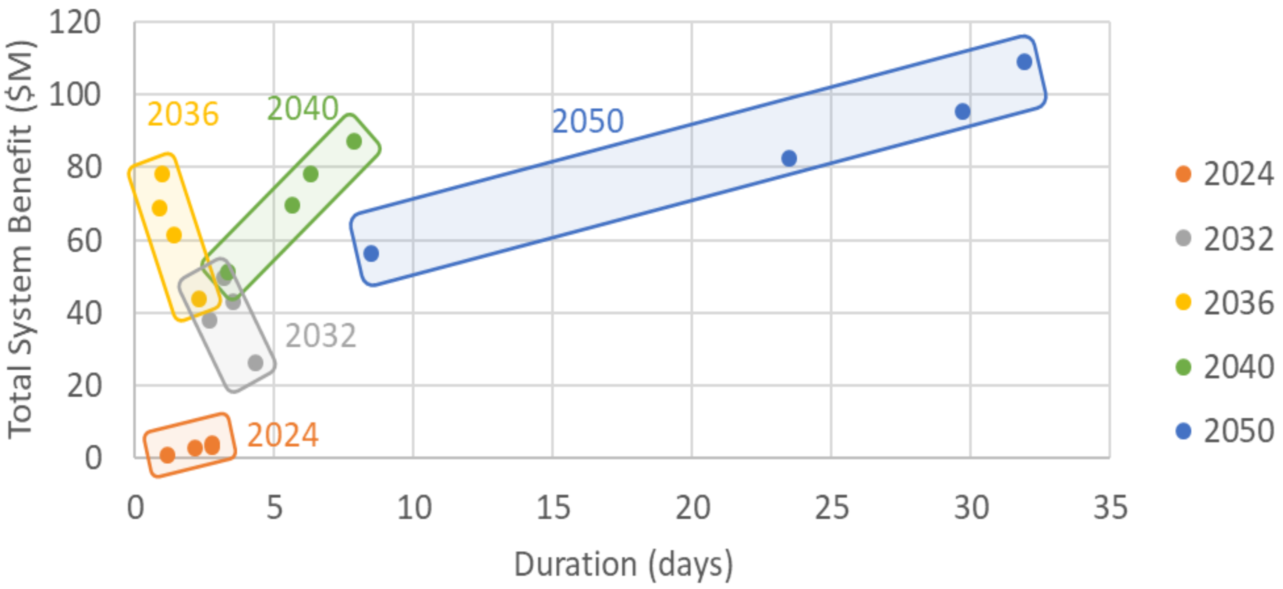
Maximum avoided cost for storage and the corresponding duration

- Longer duration storage becomes more valuable at higher shares of renewable generation
- Storage costs are not considered at this stage



Each point corresponds to a round-trip efficiency (i.e., 40%, 60%, 70%, or 80%)

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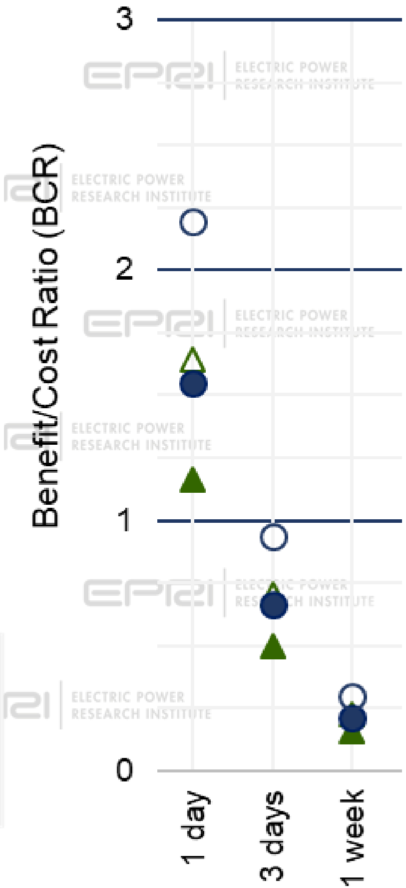
Compare the benefit to the cost

- Results show that some long duration storage can be competitive.
- However, durations that are economically competitive are much lower than the durations that yield the maximum avoided system cost (previous slide)
  - e.g., max duration from previous slide is over 30 days versus 1 day for the benefit/cost comparison



Conclusions

- Power systems are likely to benefit from long duration storage.
- This benefit increases as the amount of renewables on the system increases and as the duration increases.
- With 85% renewable shares, the WECC could benefit from systems with over 30 days of storage (80% round-trip efficiency)
- While system benefit (avoided cost) was identified, the additional equipment costs must be offset.
- When costs are considered, the preferred duration of storage will be much lower than the maximum identified.

Future Work

- Analyze other system-wide values, e.g., ancillary services, congestion management, sub-hourly response, etc.
- Further consider how the capacity value might change when provided by long duration storage.
- Explore even higher renewable penetration levels.
- Further improve methods and grid models used.
- Perform sensitivity analysis for important properties (e.g., potential technology capital cost reduction).
- Evaluate the system-value of long-duration storage in other countries/regions.

Thank you

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