Valuation of the benefits and costs of long duration storage

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• 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

What will the grid look like with high renewables and expected future costs?
- Technology costs
- Fuel costs
- ...

Capacity expansion modeling (ReEDS)

How will hydrogen systems work with other grid resources?

Grid simulation (PLEXOS)
- Production cost

How do costs and benefits compare?

Cost-Benefit Analysis (Spreadsheet)

Grid resource mix
- Gas
- Coal
- ...
- Storage

Research approach: Modeling and analysis workflow

Major focus

- Capacity expansion modeling (ReEDS)
  - Generate 85% renewable scenario

- Grid simulation (PLEXOS)
  - Significant methods development
  - Many, many scenarios run

- Cost-Benefit Analysis (Spreadsheet)
  - Establish uniform framework
  - Integrate grid benefit outcomes with other factors

This research

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

We chose a two-stage iterative approach
Technologies considered

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

<table>
<thead>
<tr>
<th>Technologies</th>
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<tbody>
<tr>
<td>Compressed air energy storage (CAES)</td>
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<td>Pumped hydro</td>
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<td>Flow battery</td>
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<td>Power-to-gas-to-power (P2G2P)</td>
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<td>Power-to-gas (P2G)</td>
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• An example storage operation profile shows seasonal behavior as well as optimal daily behavior.

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%)
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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