Battery Storage in MISO

How might batteries change the MISO landscape and affect operations?

PRESENTED TO
MISO Advisory Committee Meeting

PRESENTED BY
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Ryan Hledik
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Content

Recent Trend on Battery Costs
Value of Storage
  – Wholesale Market Related Value
  – T&D and Customer Reliability Benefits
Renewable + Storage
Storage in MISO
Some Takeaways
Cost Trends for Battery Storage

- Installed costs for battery storage systems have been decreasing
- NREL forecasts costs of ~$300/kWh ($1,200/kW) by the early 2020s, in line with evidence from recent solicitations by Xcel and NIPSCO.

### Projected Battery Installed Costs

<table>
<thead>
<tr>
<th>Year</th>
<th>Low Cost</th>
<th>Mid Cost</th>
<th>High Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>2025</td>
<td>-10%</td>
<td>-6%</td>
<td>-1%</td>
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<tr>
<td>2030</td>
<td>-9%</td>
<td>-5%</td>
<td>-1%</td>
</tr>
<tr>
<td>2040</td>
<td>-6%</td>
<td>-3%</td>
<td>-1%</td>
</tr>
</tbody>
</table>

**Source:** Bloomberg New Energy Finance (2018) and NREL Annual Technology Baseline with Brattle analysis.

**Notes:** Historical estimate assumes Bloomberg NEF battery pack cost estimate plus a constant non-pack cost estimate of approximately $170/kWh. NREL costs are for a 4-hour, utility-scale lithium ion battery.
Value Proposition for Energy Storage
Conceptually, storage offers a variety of values to a system.

**Customer Services**
- Increased reliability (reduced outages)
- Increased engagement in power supply
- Retail bill savings

**Utility Infrastructure Services**
- Deferred or avoided investments in distribution and transmission infrastructure
- Provision of voltage support

**Wholesale Market Services**
- Traditional value drivers: energy arbitrage, fast-response capabilities, and avoided capacity
- Realizing additional value due to higher quality A/S
- Flexibility and clean-energy products will provide additional revenue opportunities in the future

Subject of FERC Order 841
We have been simulating the power systems with increasing amount of energy storage; we find that storage becomes very valuable when incremental capacity is costly.

Estimated System Benefits and Costs of Storage at Various Deployment Levels in Nevada in 2030

Sources and Notes:
Wholesale Market Services
Energy value: reductions in variable costs of serving customers (fuel and variable O&M costs), e.g. production cost savings.

- Energy storage can reduce production costs by discharging when the marginal cost of supplying power is high and charging when the marginal cost of supplying power is low.
- Private investors capture this energy arbitrage value of
Resource Adequacy

Resource Adequacy Value: savings from the ability of storage to offset the need to build other capacity to meet peak load.

— Energy storage can provide capacity value by reliably **discharging during peak load hours**.

— Storage’s capacity value depends its maximum discharge duration and the nature of peak load events.

**Impact of Energy Storage on Peak Load**

**Sources and Notes:**
The capacity contribution of storage depends on the type of storage, the nature of peak or reliability load events, and the amount of storage deployed.
Flexibility and Ancillary Service

**Flexibility value:** savings from storage’s ability to provide real-time balancing and ancillary services.

- Storage’s near-instantaneous ramp rates can provide a competitive advantage in providing flexibility services
- Storage can also effectively provide other ancillary services (spin, non-spin, blackstart)
Non-Wholesale Services
Transmission and Distribution Value

**T&D value:** savings from the ability of distributed storage to reduce loading on the T&D system by serving local loads during high T&D usage periods, deferring certain T&D investments.

- In some cases, T&D system upgrades are needed to meet anticipated gradual load growth in a local area.

- In these circumstances, distributed storage can sometimes be deployed to shave local peaks, deferring the need for costly and lumpy investments.

- However, storage cannot defer all investments, e.g. circuit breakers, telemetry upgrades, or connecting new customers.
Reliability to the Customer

Customer reliability value: the ability of distributed storage to mitigate end-use customer outages.

- Most customer outages occur due to distribution system issues.
- Distributed storage, when paired with smart switches and microgrid technologies, can be strategically sited to reduce customer outages.

Sources and Notes:
Additional Value and Benefits

Storage may provide additional value by advancing specific objectives of policymakers and regulators.

**Additional benefits** include:

- **Reducing carbon emissions**
- **Renewable integration & curtailment reduction**
- **Supporting local economy & job creation**
- **Innovation** and other policy objectives

### Illustrative environmental value of solar+storage facility Online 2023

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>$2,500</td>
<td>$2,000</td>
<td>$1,500</td>
<td>$1,000</td>
<td>$1,000</td>
<td>$2,500</td>
</tr>
</tbody>
</table>

- **Environmental value** (carbon emission reductions valued at social cost of carbon) approximately 30% of total benefits
Renewable + Storage
Renewables + Storage

Recently, Utilities needing capacity are exploring solar+storage or wind+storage to capture the cost advantages, contribution toward resource adequacy, and increased operational flexibility.

Recent examples:

- **NIPSCO, Oct 1**: Released RFP for 2,300 MW of solar and solar+storage
- **Nevada, Dec 4**: PUCN approved NV Energy plan for 1,190 MW of solar + 590 MW storage

Source: Adapted from Direct Testimony of Ryan Hledik on Behalf of Arevia, Public Utilities Commission of Nevada Docket No. 19-06039, Sept 26, 2019.
Solar+storage accounts for over 40% of all capacity in the California ISO interconnection queue. PJM also has seen sizeable growth in applications.
Storage in MISO
Battery Storage in MISO Queue

The MISO queue currently includes >2,500 MW of active battery storage projects across 50 projects (average project size 50 MW).

In-Service Date of Battery Storage in MISO Queue

Source: MISO Generation Interconnection Queue
## Resource Plans of Utilities in MISO

- MISO Utilities’ resource plans are beginning to explore batteries; many pilot projects and technology / cost monitoring.
- When capacity is needed, storage will likely play a big role.

<table>
<thead>
<tr>
<th>Utility</th>
<th>State</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>NIPSCO</td>
<td>Indiana</td>
<td>• 2018 IRP calls for 1,150 MW of solar and solar+storage</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Recently released RFP for 2,300 MW of solar and solar+storage projects</td>
</tr>
<tr>
<td>Xcel Energy</td>
<td>Upper Midwest</td>
<td>• No current plans for battery storage, despite &gt;5,600 MWs of planned solar and wind between 2020 and 2034</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Resource plans note, “while we are confident utility-scale battery storage will be a part of our long-term resource mix, we are also evaluating the potential for near-term battery storage...”</td>
</tr>
<tr>
<td>MidAmerican</td>
<td>Iowa</td>
<td>• 1 MW, 4-hour battery announced in 2018</td>
</tr>
<tr>
<td>Consumers Energy</td>
<td>Michigan</td>
<td>• In 2019, built a 0.5 MW battery co-located with solar</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Consumers IRP plans to add battery storage starting in 2032</td>
</tr>
<tr>
<td>DTE Energy</td>
<td>Michigan</td>
<td>• No plans for battery storage, despite adding ~700 MWs of wind by 2024</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Plan to monitor battery storage development and cost declines</td>
</tr>
<tr>
<td>Duke Energy</td>
<td>Indiana</td>
<td>• Plan to install 15 MWs of battery storage systems in the short-term.</td>
</tr>
<tr>
<td>Entergy</td>
<td>Louisiana</td>
<td>• Plan to monitor cost and performance of storage and other market developments</td>
</tr>
</tbody>
</table>

*Source: Utility Resource Plans*
When look out to 2040, significant amount of renewables and storage additions are expected across MISO.

### 2018-2040 Wind, Solar, and Battery Addition Locations

- **Solar**
- **Wind**
- **Battery**

Size of icon indicates scale of resource type deployment.

- ~20 GW of renewable additions
- >20 GW of renewable additions

### 2018-2040 Wind, Solar and Battery Addition by Zones (MW)

<table>
<thead>
<tr>
<th>Zone</th>
<th>Solar</th>
<th>Wind</th>
<th>Total Renewables</th>
<th>Battery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone 1</td>
<td>10,700</td>
<td>10,350</td>
<td>21,050</td>
<td>260</td>
</tr>
<tr>
<td>Zone 2</td>
<td>5,000</td>
<td>1,200</td>
<td>6,200</td>
<td>86</td>
</tr>
<tr>
<td>Zone 3</td>
<td>4,200</td>
<td>3,750</td>
<td>7,950</td>
<td>91</td>
</tr>
<tr>
<td>Zone 4</td>
<td>900</td>
<td>450</td>
<td>1,350</td>
<td>67</td>
</tr>
<tr>
<td>Zone 5</td>
<td>4,700</td>
<td>3,600</td>
<td>8,300</td>
<td>296</td>
</tr>
<tr>
<td>Zone 6</td>
<td>5,350</td>
<td>8,550</td>
<td>13,900</td>
<td>600</td>
</tr>
<tr>
<td>Zone 7</td>
<td>8,881</td>
<td>1,921</td>
<td>10,802</td>
<td>450</td>
</tr>
<tr>
<td>Zone 8</td>
<td>4,400</td>
<td>600</td>
<td>5,000</td>
<td>124</td>
</tr>
<tr>
<td>Zone 9</td>
<td>5,000</td>
<td>900</td>
<td>5,900</td>
<td>173</td>
</tr>
<tr>
<td>Zone 10</td>
<td>3,800</td>
<td>0</td>
<td>3,800</td>
<td>91</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>52,931</strong></td>
<td><strong>31,321</strong></td>
<td><strong>84,252</strong></td>
<td><strong>2,238</strong></td>
</tr>
</tbody>
</table>

Sources and notes:
Brattle analysis; DTE IRP Team PACE Reference Case.
MISO’s Flexibility Needs

- Flexibility is becoming increasingly important as wind & solar deployment grows in MISO
- MISO’s 2019 “MISO Forward” report highlights the growing need for flexible resources.

Source: MISO Forward, 2019
Impact of Resource Mix Change on Flexibility Needs

Illustrative Example shows:

1. The growing level of renewables increases net load variability, uncertainty, and ramping, requiring more flexibility from the system.

2. The increase in renewables pushes down minimum net load levels, which puts pressure on dispatchable generators to operate at lower levels or go offline.

Source: The Brattle Group.
Simulated Pumped Storage in MISO

Pumped storage’s operations can shift considerably based on net load shapes, for example, in a solar-heavy region:

- Storage shifts its charging from night to mid-day
- Storage shifts discharging from late afternoon to evening peaks

As renewable deployment increases, pumped storage tends to operate at higher charging and generating capabilities

Source: The Brattle Group.
Potential Challenges When Operating a System with Significant Storage

- How to **reliably operate** many small and distributed battery storage systems across all wholesale market products?

- How to evaluate the **capacity value** of storage as increasing amounts of storage is deployed on the system?

- How to ensure sufficient **visibility** into operations and control?

- How to **monitor and mitigate** offers from storage?

- How to **coordinate control** across wholesale and non-wholesale uses?
Main Takeaways

- Battery storage will likely become an increasingly important part of MISO’s system

- **Deployment of battery storage is likely to grow**
  - Interconnection queue indicates growing interest in storage by developers
  - Renewable+storage and batteries becoming increasingly competitive with new gas plants
  - Increasing need for flexibility due to growing renewable energy will encourage the development of storage

- **Clear rules of interconnection, transparency of owners’ usage, and controllability** are challenges MISO may need to consider

- Overall, we anticipate that battery storage can add **significant value** to the MISO system, but new systems will be needed to ensure visibility and controllability
Ms. Judy Chang is an energy economist and policy expert with a background in electrical engineering, and has over 20 years of experience in advising energy companies on regulatory and financial issues, with a focus on power sector investment decisions in clean energy, electric transmission, and energy storage. Ms. Chang has submitted expert testimonies to the U.S. Federal Energy Regulatory Commission, and U.S. state and Canadian provincial regulatory authorities on topics related to resource planning, power purchase and sale agreements, and transmission planning, access, and pricing. She has authored numerous reports and articles on the economic issues associated with generation and transmission investments, clean energy development, energy storage investments, and systems planning. In addition, she has led teams of energy company executives and board members in comprehensive organizational strategic and business planning.

Ms. Chang holds a Bachelor of Science in Electrical Engineering and Computer Science from University of California, Davis and a Master of Public Policy from Harvard Kennedy School. She co-manages the power sector practice at Brattle and is the founding board member of the New England Women in Energy and the Environment.
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