Determining the Value of Energy Storage for Multiple Grid Applications

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Challenge - Over 3,000 utilities

- Different grid reliability, resiliency, flexibility, renewable integration challenges
- Different market structures
- Different costs of electricity
- Other competing solution approaches besides energy storage

What is needed

- Requires regional and local analysis of deployed storage technologies in diverse markets to develop full understanding of monetized and unmonetized benefits
- Development of industry standard design tools with fidelity to capture the multi-use value of storage in transmission, distribution, and behind the meter applications
- New business models
What We Have Learned – Need a Detailed Methodology for Assessing Energy Storage System (ESS) Value Proposition

**Siting/Sizing Energy Storage**

Ability to aid in the siting of energy storage systems by capturing/measuring location-specific benefits.

**Broad Set of Use Cases**

Measure benefits associated with bulk energy, transmission-level, ancillary service, distribution-level and customer benefits at sub-hourly level.

**Regional Variation**

Differentiate benefits by region and market structures/rules.

**Utility Structure**

Define benefits for different types of utility (e.g., PUDs, large utilities operating in organized markets and vertically integrated investor owned utilities operating in regulated markets).

**Battery Characteristics**

Accurately characterize battery performance, including round trip efficiency rates across varying states of charge and battery degradation caused by cycling.
Battery Storage Evaluation Tool (BSET)
Energy Storage for the Puget Sound Energy (PSE) Region*


Project objective: Analyze and demonstrate the benefits of electrical energy storage on the distribution grid

Situation

- Bainbridge Island, WA
  - Murden Cove
  - Winslow

Requirements

- Multiple hours of capacity required
- Small footprint to fit within a substation
- Year-round operation capabilities
- Flexibility to perform multiple applications (e.g., balancing svcs., islanding)

Novel technical solution

- Containerized, electrochemical energy storage with a 2nd generation flow battery technology

- 25MVa transformers at radial substations at Murden Cove and Winslow operate at or above target load
Bundling Services: How To Do It Optimally?

Key Lesson: Dispatch control systems that optimize performance are required to advance ESS.
Key Lesson: Capacity value, distribution deferral and outage mitigation represent a small share of ESS usage but a large share of total value.
### Economics and Additional Benefits

**Bainbridge Island, WA**

<table>
<thead>
<tr>
<th>Present value of storage benefits/costs</th>
<th>$M, USD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity value</td>
<td>$22.8</td>
</tr>
<tr>
<td>Dist. upgrade deferral</td>
<td></td>
</tr>
<tr>
<td>Outage mitigation</td>
<td></td>
</tr>
<tr>
<td>Balancing svcs.</td>
<td></td>
</tr>
<tr>
<td>Revenue requirement</td>
<td>$28.6</td>
</tr>
<tr>
<td>Battery - Mid C capacity</td>
<td></td>
</tr>
<tr>
<td>Battery - Peaker capacity</td>
<td></td>
</tr>
<tr>
<td>Revenue requirement</td>
<td>$20.5</td>
</tr>
</tbody>
</table>

Key Lesson: When effectively sited and operated, energy storage can yield positive returns to investors.

- Regardless of capacity assumption economics “pencil out”
- Additional “difficult to quantify” value in
  - Knowledge transfer
  - Institutional know-how
  - Public awareness
Washington Clean Energy Fund (CEF) Energy Storage Analytics Program Synopsis

Objective

- Provide a framework for evaluating the technical and financial benefits of energy storage, and exploring the value that energy storage can deliver to Washington utilities and the customers they serve.

Phases

- **Phase 1: Data and Data Systems**
  - Develop Data Requirements and Data Systems

- **Phase 2: Use Cases / Performance Monitoring**
  - Install Energy Storage Systems (ESS), Run Use Cases, and Document Technical Performance

- **Phase 3: Evaluation**
  - Evaluate Technical and Financial Performance

Team

- **PNNL**: Brings expertise in energy/economics/environment system analysis and modeling
- **PSE, SnoPUD, and Avista**: Bring deep operational experience and required utility data / test sites
- **Washington Dept. of Commerce**: Program management
Washington State Clean Energy Funds

Energy Storage Projects

2 MW / 4.4 MWh lithium-ion/phosphate battery – Glacier, WA

1 MW / 3.2 MWh UET vanadium-flow battery – Pullman, WA

2 MW / 1 MWh Li-ion system
2 MW, 8.8 MWh UET vanadium-flow- Everett, WA

Total – 7 MW / 15 MWh; $14.3 million state investment / $43 million total investment for energy storage systems
## DOE OE and Washington Dept. of Commerce Funding PNNL to Analyze Broad Set of Use Cases

<table>
<thead>
<tr>
<th>Category</th>
<th>Services</th>
<th>Avista</th>
<th>PSE</th>
<th>SnoPUD</th>
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<tbody>
<tr>
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<td>Electric Energy Time Shift (Arbitrage)</td>
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<td>Y</td>
<td>Y</td>
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<tr>
<td></td>
<td>Electric Supply Capacity</td>
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<td>Y</td>
<td>Y</td>
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<tr>
<td><strong>Transmission Infrastructure Services</strong></td>
<td>Transmission Upgrade Deferral</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Transmission Congestion Relief</td>
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<td></td>
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<tr>
<td><strong>Distribution Infrastructure Services</strong></td>
<td>Distribution Upgrade Deferral</td>
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<td>Y</td>
<td></td>
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<tr>
<td></td>
<td>Voltage Support</td>
<td>Y</td>
<td></td>
<td>Y</td>
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<tr>
<td></td>
<td>Load Shaping Service</td>
<td>Y</td>
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<tr>
<td><strong>Ancillary Services</strong></td>
<td>Regulation Services</td>
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<td>Y</td>
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<td>Load Following Services</td>
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<td>Y</td>
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<td>Real-World Flexibility Operation</td>
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<td>Y</td>
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<td></td>
<td>Black Start Capability</td>
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<td></td>
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<tr>
<td><strong>Customer Energy Management</strong></td>
<td>Power Reliability</td>
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<td>Y</td>
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<td></td>
<td>Demand Management</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Retail Energy Time Shift</td>
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<td></td>
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</tr>
<tr>
<td></td>
<td>Power Quality</td>
<td></td>
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</tbody>
</table>
Discharging at 520 kW and 400 kW changes duration to 6 and 8 hour battery system.

Modeled energy schedule based on historic data and applied to battery system.

Variation in RTE may be due to:
- Change in initial SOC
- Change in temperature

<table>
<thead>
<tr>
<th>Date</th>
<th>RTE</th>
<th>RTE No Aux</th>
<th>Charge Power (kW)</th>
<th>Discharge Power (kw)</th>
<th>Strings Active</th>
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<td>83%</td>
<td>600</td>
<td>520</td>
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<tr>
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<td>82%</td>
<td>600</td>
<td>400</td>
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<tr>
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<td>400</td>
<td>2</td>
</tr>
<tr>
<td>2016/01/22 02:00:00</td>
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<td>78%</td>
<td>600</td>
<td>400</td>
<td>2</td>
</tr>
<tr>
<td>2016/01/19 18:00:00</td>
<td>67%</td>
<td>76%</td>
<td>600</td>
<td>520</td>
<td>2</td>
</tr>
</tbody>
</table>

![Graph showing power vs. time](image)
The potential market opportunity for energy storage is significant with two main challenges

- Reduce cost
- Determine value for multiple grid applications across multiple utilities with varying grid challenges

Take advantage of all Field Demonstrations by developing and sharing “use-case” analysis

- Ability to aid in the siting of energy storage systems by capturing/measuring location-specific benefits
- Differentiate benefits by region and market structures/rules
- Define benefits for different types of utility
- Accurately characterize battery performance
Acknowledgments

Dr. Imre Gyuk - Energy Storage Program Manager, Office of Electricity Delivery and Energy Reliability, U.S. Department of Energy

More Information

▶ PNNL:

- National Assessment of Energy Storage:
  http://energyenvironment.pnnl.gov/pdf/National_Assessment_Storage_PHASE_II_vol_1_final.pdf

- Energy Storage Valuation for Distribution Systems

- Codes and Standards for Performance Measurements

- Optimization Tool

▶ DOE/EPRI Storage Handbook
2016 ENERGY NORTHWEST PUBLIC POWER FORUM: 
UTILITY OF THE FUTURE – BATTERY STORAGE

OCTOBER 28, 2016

Virgil Lee Beaston
Senior Vice President & CTO
Powin Energy Corporation
Deep Decarbonization of the U.S. Energy System: A Driver for Change

“Deep decarbonization” refers to the reduction of greenhouse gas (GHG) emissions over time to a level consistent with limiting global warming to 2°C or less

- This is based on the scientific consensus that higher levels of warming pose an unacceptable risk of dangerous climate change

- To do this, the US Government has set a target of reducing net U.S. GHG emissions (CO2e) 80% below the 1990 level by the year 2050

- This requires the U.S. to reduce CO2 from fossil fuel combustion to 1.7 metric tons per capita in 2050, an order of magnitude below recent levels
Three pillars of decarbonization

There are "three pillars" to decarbonization that must be in place by 2050 to reach the U.S. goals:

- Highly efficient end use of energy in buildings, transportation, and industry
- Nearly complete decarbonization of electricity, and reduced carbon in other kinds of fuels
- Electrification where possible and switching to lower-carbon fuels otherwise
THREE PILLARS OF DECARBONIZATION

Highly efficient end use of energy in buildings, transportation, and industry requires:

• Energy intensity of GDP to decline by 70% from now to 2050 – a final energy use reduced by 20%

• This is despite a forecast population increase of 40% and a 166% increase in GDP.
THREE PILLARS OF DECARBONIZATION

Nearly complete decarbonization of electricity, and reduced carbon in other kinds of fuels requires:

• Carbon intensity of electricity to be reduced by at least 97%

• This is from more than 500 g CO2/kWh today to 15 g CO2/kWh or less in 2050.
THREE PILLARS OF DECARBONIZATION

Electrification where possible and switching to lower-carbon fuels otherwise requires:

• The share of end-use energy coming directly from electricity or fuels produced from electricity, such as hydrogen, to increase from less than 20% in 2010 to over 50% in 2050, displacing fossil fuel combustion
Deep Decarbonization & its Impact on the Utility of the Future

• Deep decarbonization will profoundly transform the U.S. energy economy, in terms of what money is spent on and where investment will flow.

• Change in consumer costs for energy goods and services however is likely to be small.

• Electricity will become a much larger share of final energy, due to fuel switching away from fossil fuels toward electricity and the increased use of electricity-derived fuels such as hydrogen and synthetic natural gas.

• Decarbonized forms of primary energy will be dramatically increased, as wind, solar, biomass, and nuclear become the dominant share of primary energy supply.
Utility of the Future & Battery Storage

• Energy storage of all types and forms will be needed in the future to balance electricity supply with demand – Batteries will certainly be one of the forms of energy storage to be used

• Batteries will start appearing everywhere, and many of these batteries will be connected to the internet and will be dispatchable

• Utilities of the future will be in the best position to aggregate and dispatch these batteries along with other forms of energy storage

• This is already happening in the U.S. as demonstrated by the increased interest in and use of demand response, and the number of companies now developing products for this purpose
GRAND JOHANNA PROJECT  
(2MW - 9MWH)

Batteries Housed in a 13,500 SF Warehouse In Irvine California
GRAND JOHANNA PROJECT

- 2MW Eaton Power Converter & Switchgear
- 9MWH Powin Energy Li-Ion Battery System
  - 16 Battery Arrays + 2 Spares for Future Use
  - 9 Battery Strings/Array
  - 17 Battery Packs/String
GRAND JOHANNA PROJECT
(2MW - 9MWH)
Battery System Architecture is a Network of Smart, Scalable, Plug & Play Battery Packs
The bp-OS has many features:

- Balancing Manager
- Battery Odometer
- Warranty Tracker
- Operating History Monitor
- Alarms, Warning, Errors (AWE) Manager
- Maintenance Manager
- Calibration Manager
- Plug & Play Configuration Manager
- Communication Manager
- Software Update Manager
BPA & Energy Northwest Project
INTEL CAR CHARGER PROJECT
Utility of the Future

StorEdge™ for On-grid Applications and Backup Power
Utility of the Future
Utility of the Future
Utility of the Future
DEEP DECARBONIZATION REPORT
(FOR THE UNITED STATES)
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