Northwest **Power** and **Conservation** Council



October 4, 2016

**MEMORANDUM**

**TO:** **Power Committee**

**FROM:** **Massoud Jourabchi**

**SUBJECT:** **Economics of Utility-Scale Energy Storage Systems (ESS)**

## BACKGROUND:

Presenter: Mr. Patrick Balducci (Chief Economist and Energy and Environment Directorate at Pacific Northwest National Laboratory)

Summary: What are the economic risks and opportunities facing utility-scale ESS?

Mr. Patrick Balducci, will present on some of the PNNL's findings from evaluation of utility owned and operated ESS.

Relevance: Understanding application of utility owned and controlled ESS will help inform Council's ability to model this resource in the future resource plans.

Work plan: B. Maintain Analytical Capability. Action item ANALYS-2 of the 7th Plan calls for tracking and improving long-term load forecast for emerging markets. This presentation focuses on one such market.

Background: Over the past 5 years, staff has been reporting to Council on emerging technologies such as electric vehicles and data centers. This presentation on ESS is an introduction to applications of this emerging field at utility scale.

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# Economics of Utility Scale Energy Storage

Northwest Power and Conservation Council Meeting
October 11, 2016
Portland, OR

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U.S. DEPARTMENT OF
ENERGY

# Monetize Energy Storage Benefits for Multiple Grid Applications

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## Challenge - Over 3,000 utilities

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

## What is needed

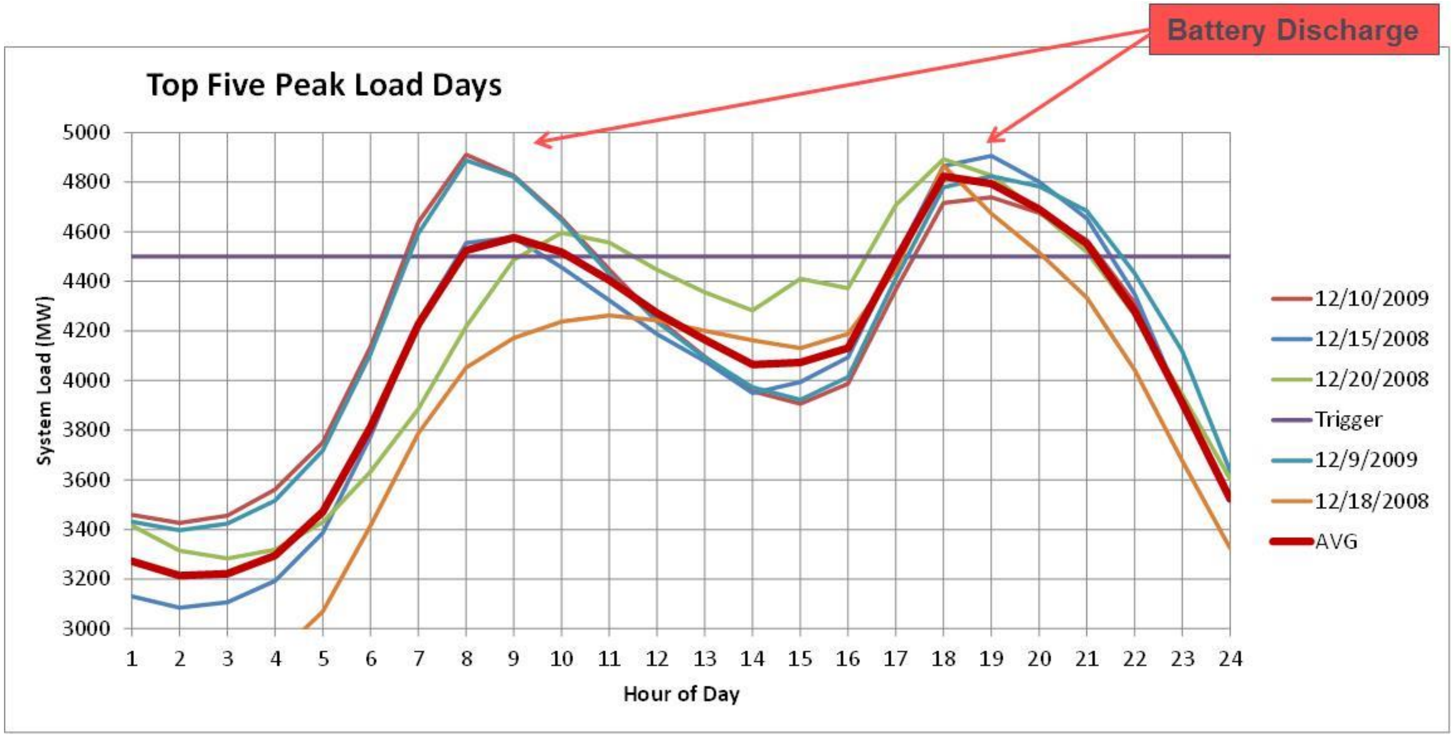
- ✓ Requires regional and local analysis of deployed storage technologies in diverse markets to develop full understanding of monetized and unmonetized benefits
- ✓ Development of industry standard design tools with fidelity to capture the multi-use value of storage in transmission, distribution, and behind the meter applications
- ✓ New business models

# Benefit 1 – Peak Shaving



- Capacity value based on the incremental cost of next best alternative investment (peaking combustion turbine) with adjustments for the incremental capacity equivalent of energy storage and line losses
- Distribution upgrade deferral based on present value benefits of deferring investment in distribution system upgrades

Key Lesson: Values will differ based on presence of markets, local distribution system conditions, and valuation policies.



# Benefit Example 2 – Energy Arbitrage

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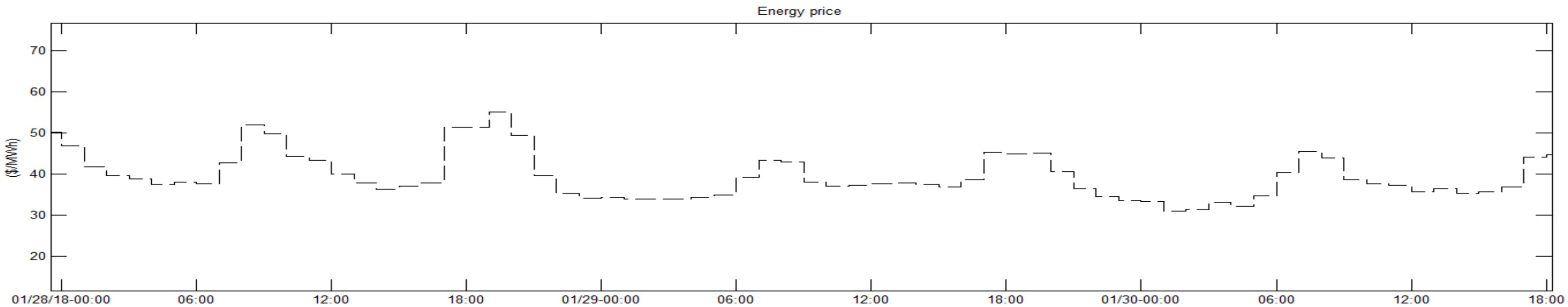
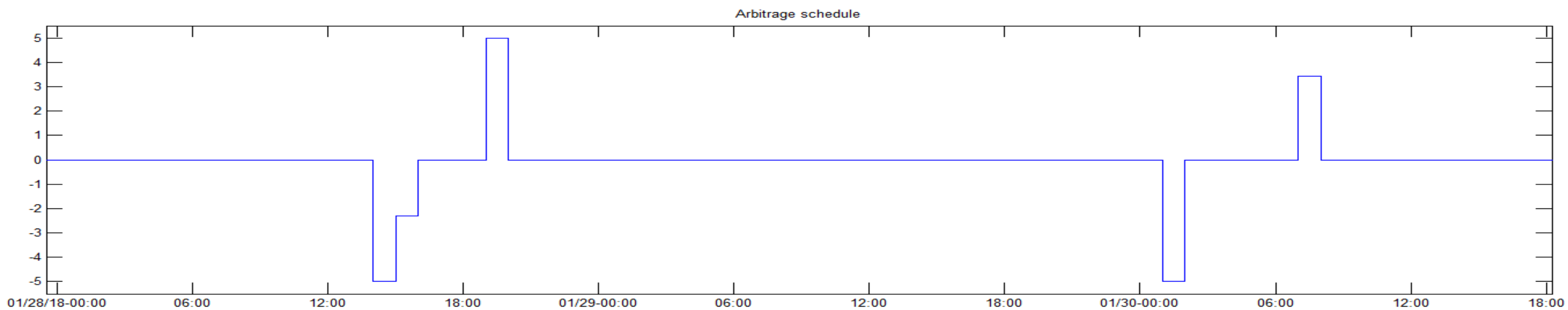
- Hourly indexed day-ahead or real-time energy market used to determine peak / off-peak price differentials
- Value obtained by purchasing energy during low price hours and selling energy at high energy price hours – efficiency losses considered

Key Lesson: Profitability differs significantly by region; profit also affected by round trip efficiency of the ESS.



# Benefit Example 3 – System Flexibility

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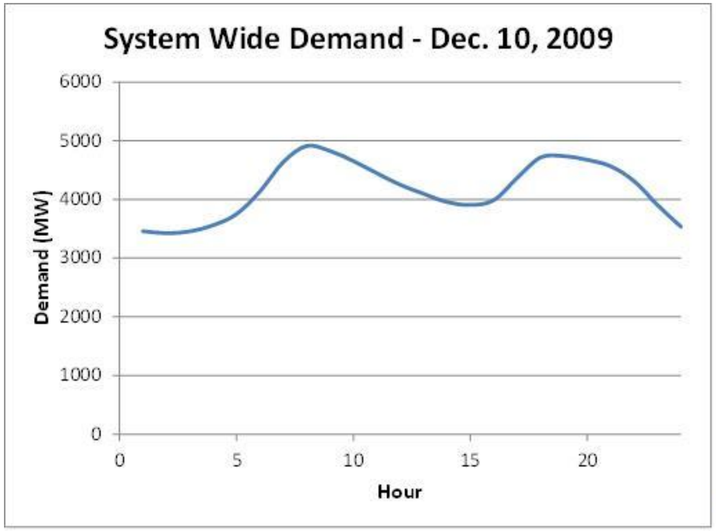
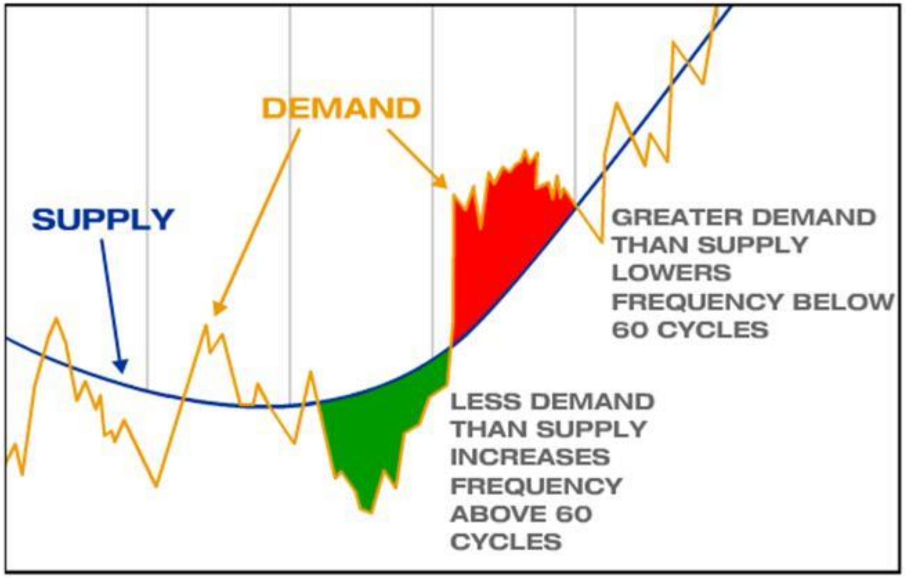
- Battery fills the short-term gaps between supply and demand
- Reduces cost and emissions associated with idling fossil-fuel burning plants



# Benefit Example 4 – Outage Mitigation



- Outage data
  - Outage data obtained from utility for multiple years
  - Average annual number of outages determined and outages randomly selected and scaled to approximate average year
  - Outage start time and duration

| Duration | Cost per Outage ($2008)* | | |
|---|---|---|---|
| | Residential | Small C + I | Large C + I |
| Momentary | $2 | $210 | $7,331 |
| Less than 1 hr | $4 | $738 | $16,347 |
| 2-4 hours | $7 | $3,236 | $40,297 |
| 8-12 hours | $12 | $3,996 | $46,227 |

Source: Sullivan, M., Mercurio, M., and J. Schellenberg. 2009. "Estimated Value of Service Reliability for Electric Utility Customers in the United States." Prepared for U.S. Department of Energy by Lawrence Berkeley National Laboratory. Berkeley, CA.

- Customer and load information
  - Number of customers affected each outage obtained from utility
  - Customer outages sorted into customer classes using utility data and assigned values
  - Load determined using 15-minute SCADA information
- Alternative scenarios
  - Perfect foreknowledge – energy storage charges up in advance of inclement weather
  - No foreknowledge – energy on-hand when outage occurs is used to reduce outage impact

Key Lesson: Benefits, which can be very large, accrue primarily to the customer and are largely dependent on the effective placement of the ESS. If focused on utility benefits, we would focus on violation costs, lost energy sales, and avoided equipment purchases.

# Existing Planning Efforts and Models Fail to Capture All Energy Storage Benefits

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| Components | Planning Processes | | |
|---|---|---|---|
| | Integrated Resource Planning | Transmission Planning | Distribution Planning |
| Generation | = Primary | = Rarely | = Not considered |
| Energy Efficiency | = Primary | = Rarely | = Rarely |
| Demand Response | = Primary | = Rarely | = Rarely |
| Transmission | = Sometimes | = Primary | = Not considered |
| Distribution | = Rarely | = Not considered | = Primary |

- = Primary
- = Sometimes
- = Rarely
- = Not considered

*Alternatives matter but are often ignored.*

| | Location/Service | Analysis Tools |
|---|---|---|
| | Transmission System | |
| 1 | Arbitrage | Production cost modeling |
| 2 | Balancing Regulation | Stochastic model w. & w/o valuation, KERMIT |
| 3 | Capacity | Financial models |
| | Distribution System | |
| 4 | Transformer Deferral and Volt/VAR Control | GridLab-D, OpenDSS |
| 5 | Upgrade Deferral | Financial Models |
| 6 | PV Integration | Gridlab-D, OpenDSS |
| 7 | Outage Mitigation | |
| | Customer Side | |
| | Industry, School, Multifamily | Optimization tools |
| | Bundled Services | Energy Storage Evaluation Tool (E3/EPRI), Battery Storage Evaluation Tool (PNNL), ESWare™ (24M), ES-Select™ (DNV-KEMA) |

*Grid functions typically require several tools to estimate values.*

# What We Have Learned – Need a Detailed Methodology for Assessing Energy Storage System (ESS) Value Proposition



| | |
|---|---|
| **Siting 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 **varying 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. |

# 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


- 25 MVa transformers at radial substations at Murden Cove and Winslow operate at or above target load

### Requirements

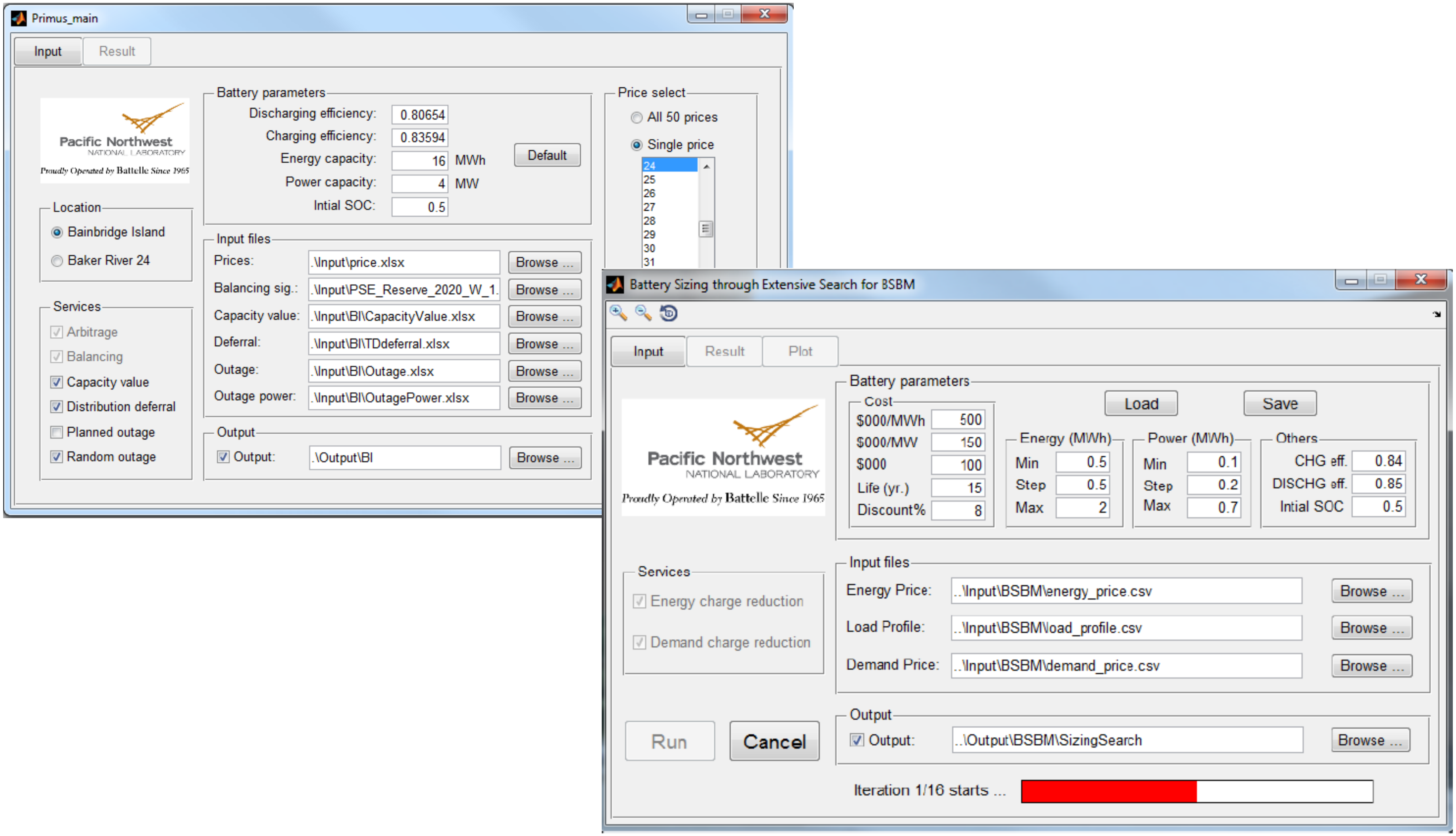
- ❑ Multiple hours of capacity required
- ❑ Small footprint to fit within a substation
- ❑ Year-round operation capabilities
- ❑ Flexibility to perform multiple applications (e.g., balancing svcs., islanding)

### Novel technical solution


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

# Battery Storage Evaluation Tool (BSET) and Optimization Tool





# Bundling Services: How To Do It Optimally?

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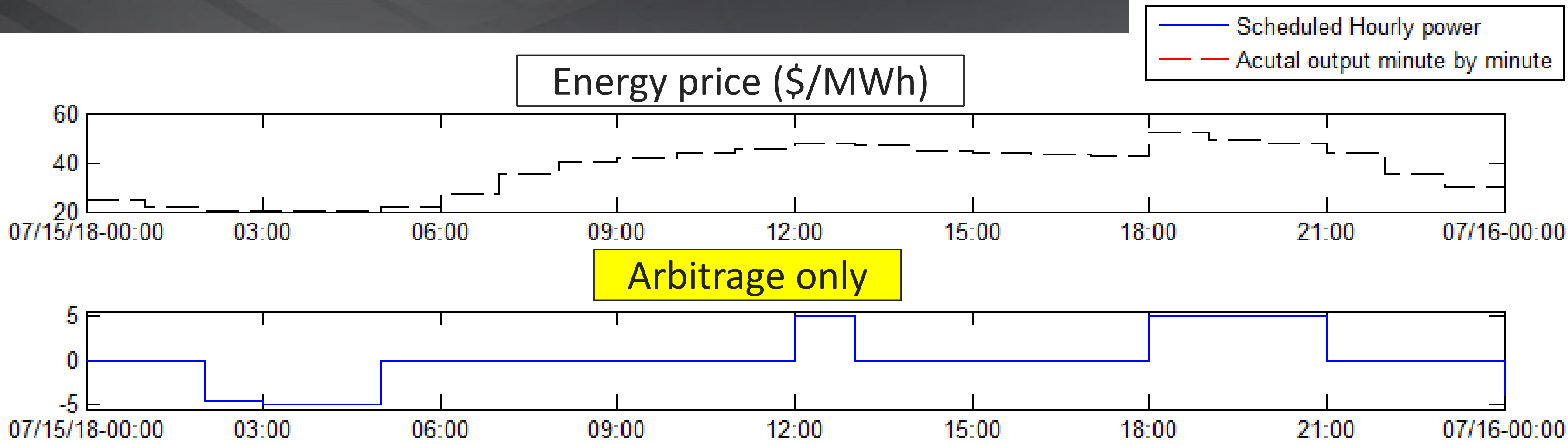

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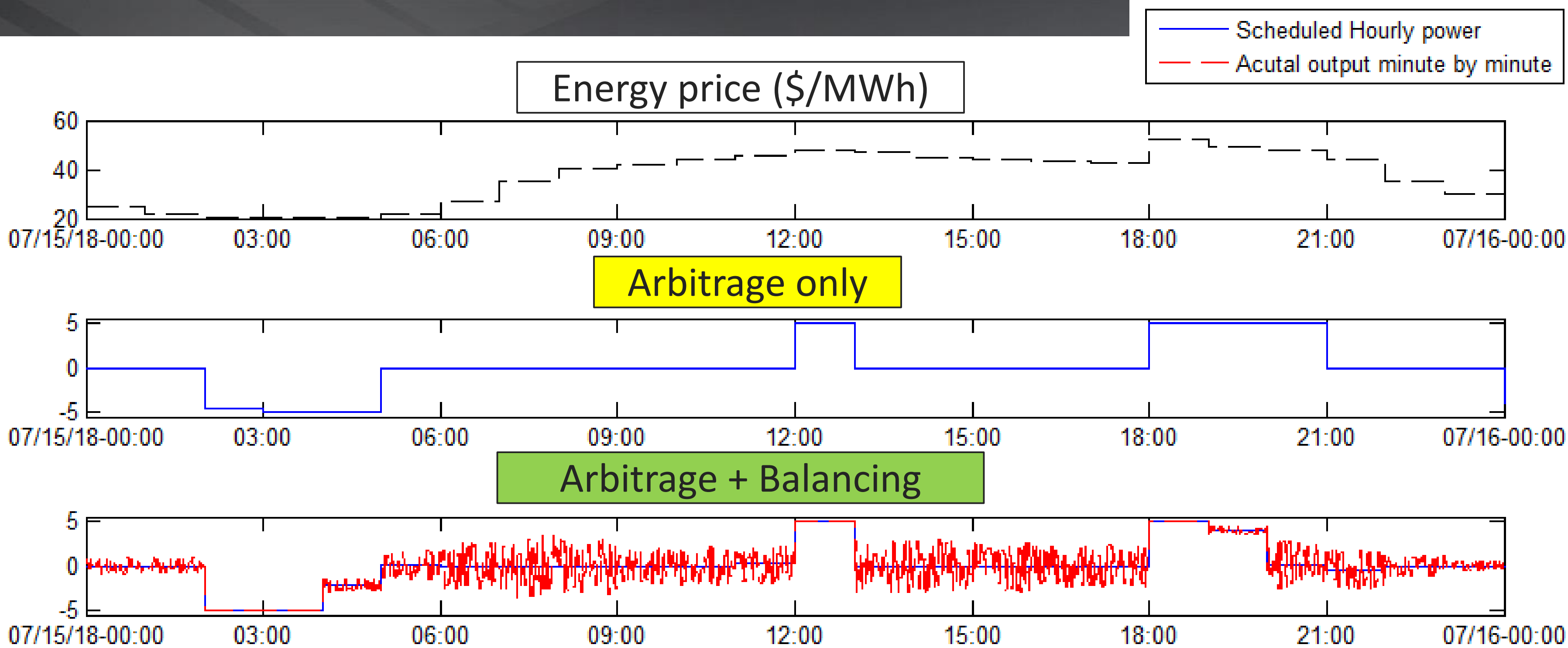

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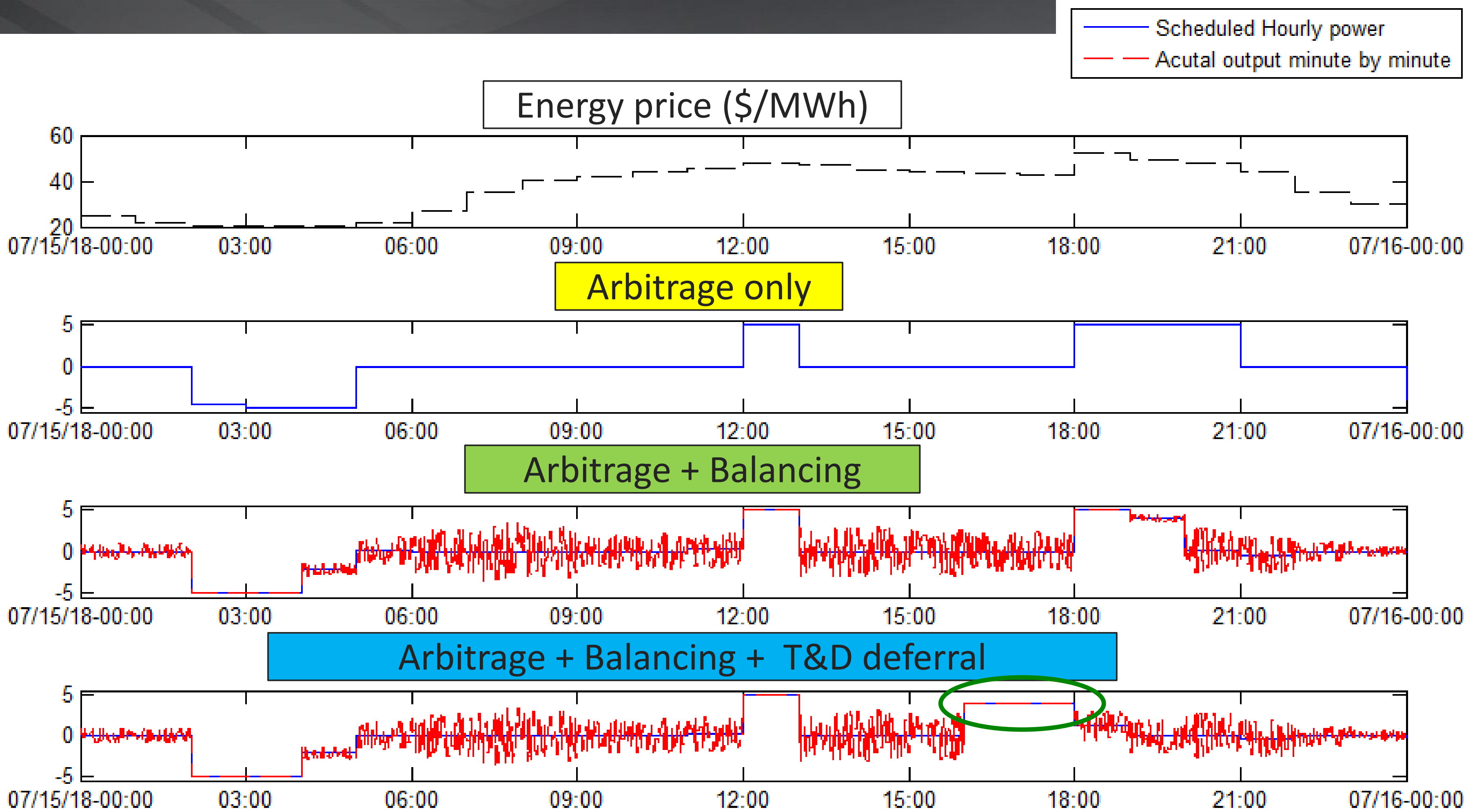
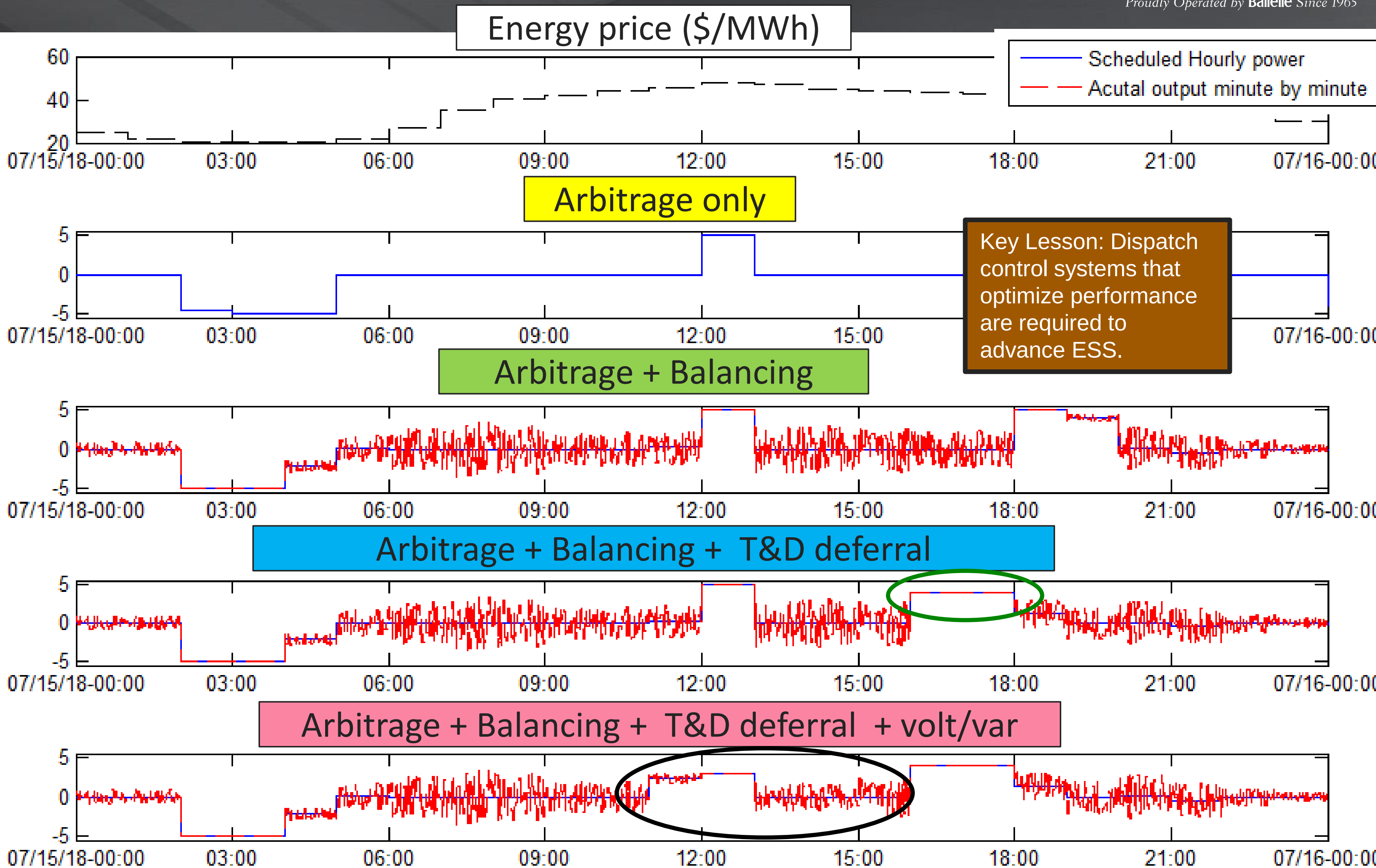


# Bundling Services: How To Do It Optimally?

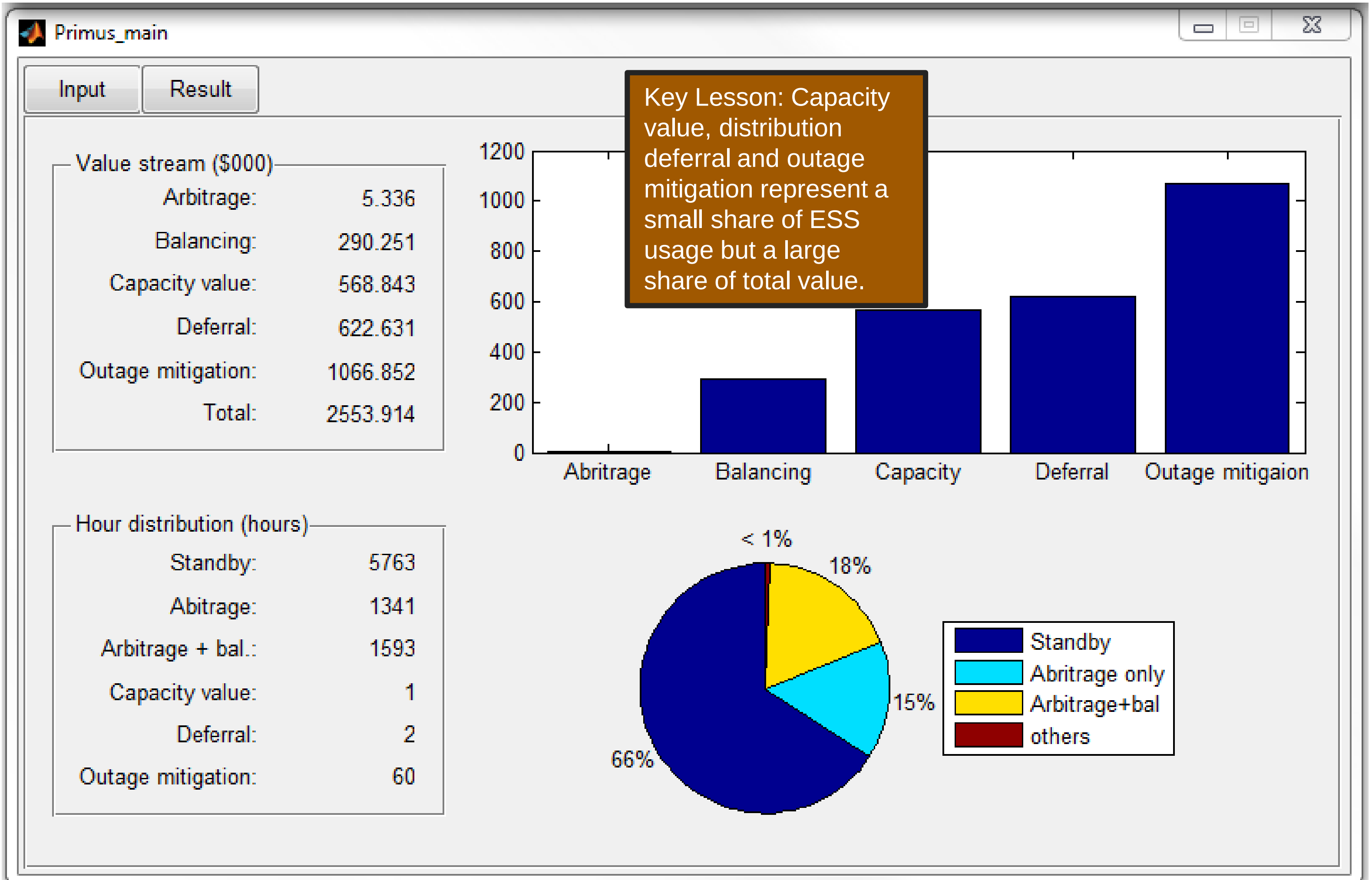





Key Lesson: Dispatch control systems that optimize performance are required to advance ESS.

# BSET Output






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

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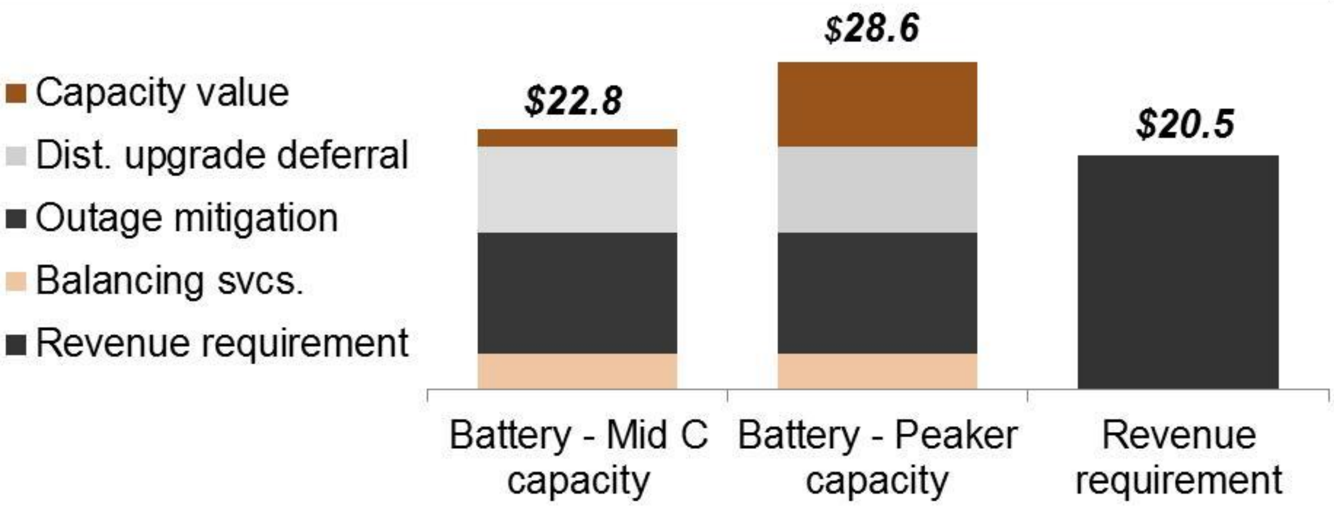
**Present value of storage benefits/costs**
*$M, USD*




- Regardless of capacity assumption economics “pencil out”
- Additional “difficult to quantify” value in
  - Knowledge transfer
  - Institutional know-how
  - Public awareness

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

Key Lesson: Traditional cost metrics, such as levelized cost of energy, are not effective for evaluating energy storage.

# Washington State Clean Energy Funds Energy Storage Projects

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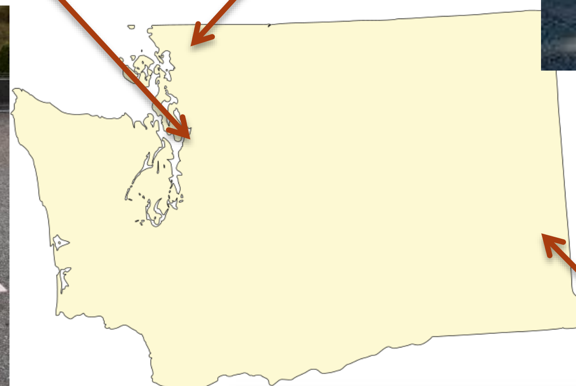
SNOHOMISH COUNTY PUD PUBLIC UTILITY DISTRICT NO. 1

PSE PUGET SOUND ENERGY

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



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

AVISTA

Total – 7 MW / 15 MWh; $14.3 million state investment / $43 million total investment for energy storage systems

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

# DOE OE Funding PNNL to Analyze Broad Set of Use Cases

| Category | Services | Avista | PSE | SnoPUD |
|---|---|---|---|---|
| Bulk Energy Services | Electric Energy Time Shift (Arbitrage) | Y | Y | Y |
| | Electric Supply Capacity | Y | Y | Y |
| Transmission Infrastructure Services | Transmission Upgrade Deferral | | | |
| | Transmission Congestion Relief | | | |
| Distribution Infrastructure Services | Distribution Upgrade Deferral | Y | Y | |
| | Voltage Support | Y | | Y |
| | Load Shaping Service | Y | Y | Y |
| Ancillary Services | Regulation Services | Y | Y | Y |
| | Load Following Services | Y | Y | Y |
| | Real-World Flexibility Operation | Y | Y | Y |
| | Black Start Capability | Y | | |
| Customer Energy Management | Power Reliability | Y | Y | |
| | Demand Management | | | |
| | Retail Energy Time Shift | | | |
| | Power Quality | | | |

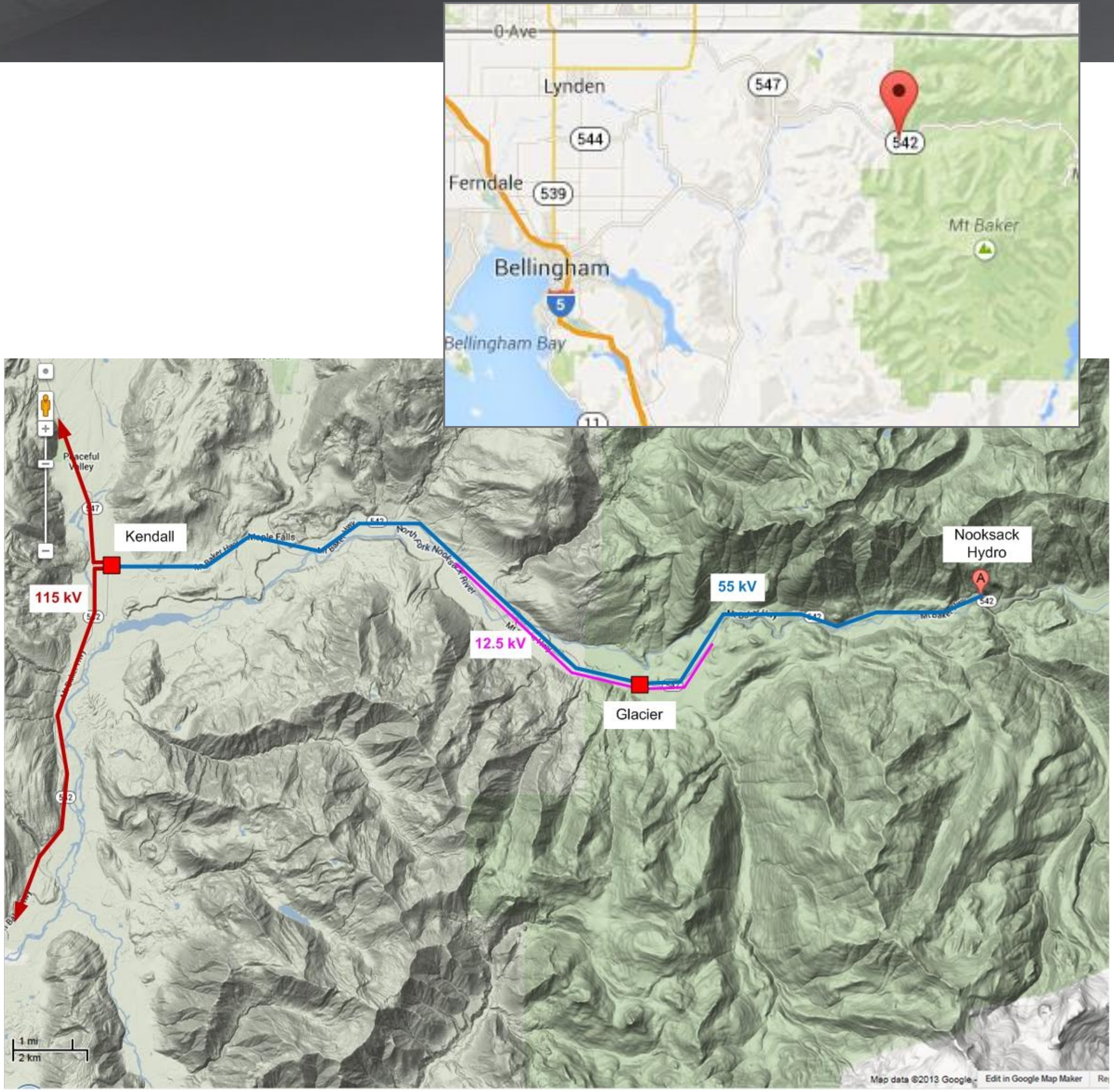
# Puget Sound Energy Glacier Project



**Issue**:
Frequent transmission-line outages due to vegetation.

**Solution**:
Locate 2.0MW – 4.4 MWh lithium-ion battery near Glacier substation to provide (temporary) backup power to distribution circuit.

**Benefits**:
1. Provide backup power to Glacier substation during outages
2. Provide energy during high demand reducing the need for new peaking power plants
3. Fill short-term gaps between supply and demand



# Eugene (OR) Water and Electric Board



## Microgrid Project

- 500kW energy storage + 125kW PV + diesel gen sets at three aggregated sites
- Benefits of energy storage:
  - Peak shifting
  - Transmission congestion relief
  - Minimizing balancing service payments to BPA
  - Energy arbitrage
  - Volt-VAR control
  - Outage mitigation
  - Capacity / resource adequacy.
- EWEB working with Sandia National Laboratories and PNNL:
  - Define and monetize value of use cases
  - Evaluate design of planned microgrid.
- Energy storage at the three sites can be aggregated to provide grid benefits.

**Partners**

Sandia National Laboratories

CleanEnergy States Alliance

Oak Ridge National Laboratory

EWEB

# Salem (OR) Smart Power Center

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- Salem Smart Power Center is comprised of a 5 MW – 1.25 MWh lithium-ion battery system built and managed by Portland General Electric (PGE)
- Recent demonstrations of value
  - Integration of renewables onto the grid (reduce intermittency of local 114-kW solar array)
  - Stabilization of grid frequency during recent power sag
  - Simulation of local microgrid, establishing a high-reliability zone
- Potential energy storage benefits:
  - Energy arbitrage
  - 400 kW of demand response capacity
  - 2-4 MW of real-time frequency and voltage regulation
  - kVAr support and control on the distribution feeder
  - Renewables integration
  - 5 MW of load response to under-voltage
  - Adaptive conservation voltage reduction
  - Emergency power for OR National Guard command
  - Intra-hour load balancing.

*With DOE support, PNNL will model battery operations to determine the long-term financial benefits or value to PGE.*

**Partners**

CleanEnergy States Alliance

PGE

Sandia National Laboratories

# Conclusions



- Resource adequacy requirements and penetration of renewable, intermittent power are driving the need for investment in ESSs
- We have developed procedures to site and size ESSs and have made our tool (BSET) available for use; DOE has demonstrated a willingness to provide analytical support for proposed and existing ESS projects
- Any single use would rarely yield positive returns on investment; services usually must be bundled and co-optimized
- Maximizing the value of energy storage requires optimal siting, sizing, control and design of the ESS
- We are evaluating a broader set of use cases through our Washington CEF engagement; use case values differ significantly by utility
- Dispatch control systems that optimize performance are required to advance energy storage
- Traditional resource planning approaches do not provide visibility into energy storage system benefits

# Acknowledgments

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

**Bob Kirchmeier** - Senior Energy Policy Specialist, Clean Energy Fund Grid Modernization Program, Washington State Energy Office

# More Information



- PNNL:
  - National Assessment of Energy Storage:
    http://energyenvironment.pnnl.gov/pdf/National_Assessment_Storage_PHASE_II_vol_1_final.pdf
    http://energyenvironment.pnnl.gov/pdf/National_Assessment_Storage_PHASE_II_vol_2_final.pdf
  - Energy Storage Valuation for Distribution Systems
    http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-23040.pdf
  - Codes and Standards for Performance Measurements
    http://energyenvironment.pnnl.gov/pdf/PNNL_22010_ESS_Protocol_Final.pdf
  - Optimization Tool
    http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-23039.pdf
- DOE/EPRI Storage Handbook
  http://www.sandia.gov/ess/publications/SAND2013-5131.pdf