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An Overview of the Techno-Economic Valuations of Select Battery Energy Storage Projects in the Pacific Northwest

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DISCOVERY *in Action*

U.S. DEPARTMENT OF
ENERGY

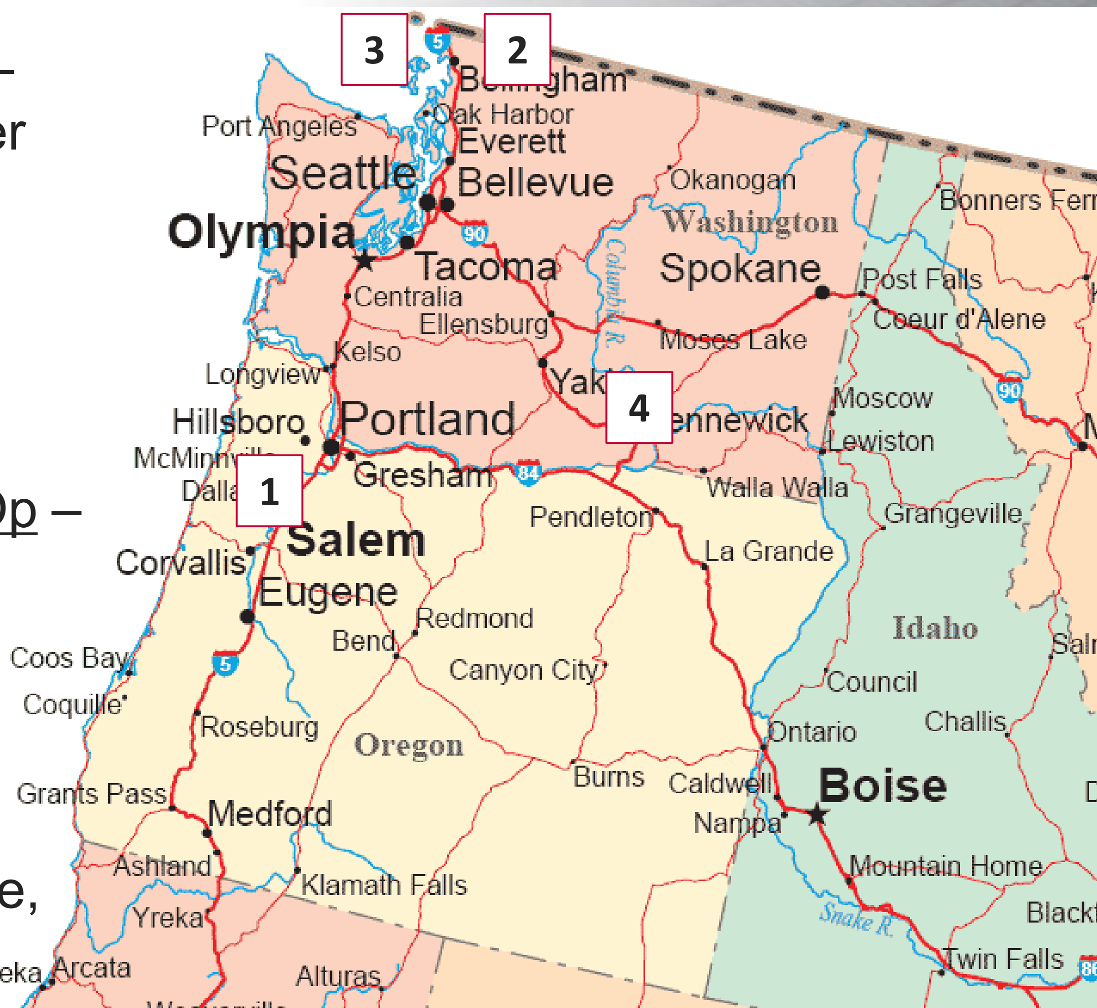
Energy Storage Projects Covered

1. Portland General Electric – Salem Smart Power Center

2. Puget Sound Energy – Glacier Energy Storage Project

3. Orcas Power & Light Co-Op – Decatur Island Energy Storage and Community Solar Project

4. Energy Northwest – Horn Rapids Solar, Storage, and Training Project



Key Concepts in Energy Storage

- Energy storage provides services or functions or values; a use case is an application specific to an installation that provides defined value to the grid and community
- Energy assets come in many forms, and these technologies must be carefully characterized
  - Photovoltaics (PV) (Solar)
  - Wind Turbines
  - Batteries
  - Hydro Resources
  - Diesel Generators
  - Power to Gas (P2G)
- Value comes in many forms
  - Bulk energy – arbitrage and capacity
  - Ancillary services – regulation, spin and non-spin reserve, load following, frequency response, flexible ramping, voltage support, black start
  - Transmission congestion relief and asset deferral
  - Distribution deferral, voltage support, conservation voltage regulation, and outage mitigation/resilience
  - Customer benefits – demand/energy charges, reliability, demand response, resilience

Energy Storage Service Values

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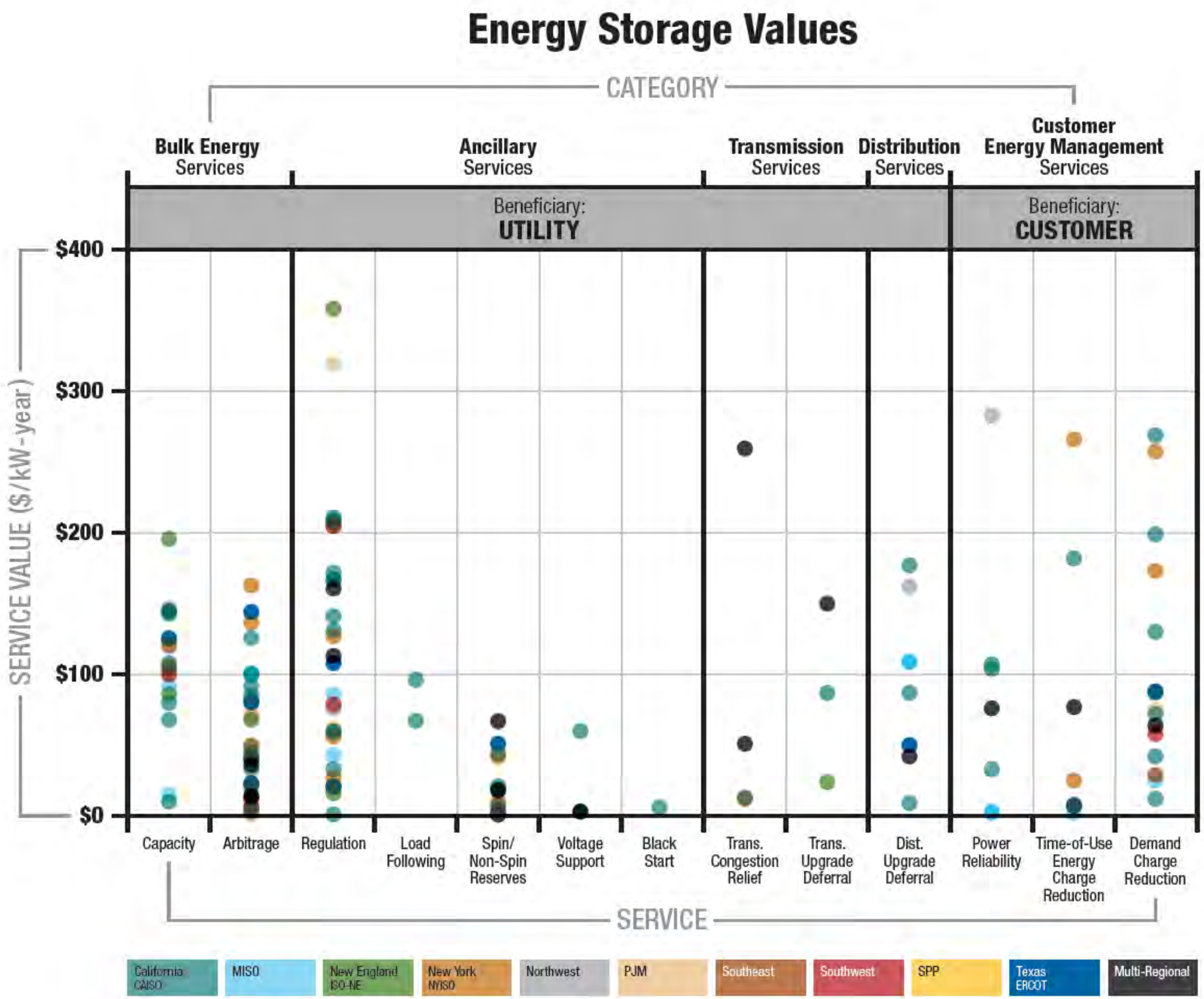

Key Lesson: The value of distributed energy resources can accrue at multiple levels of the electric grid.

Individual Benefits vs. Cost Optimized Benefits

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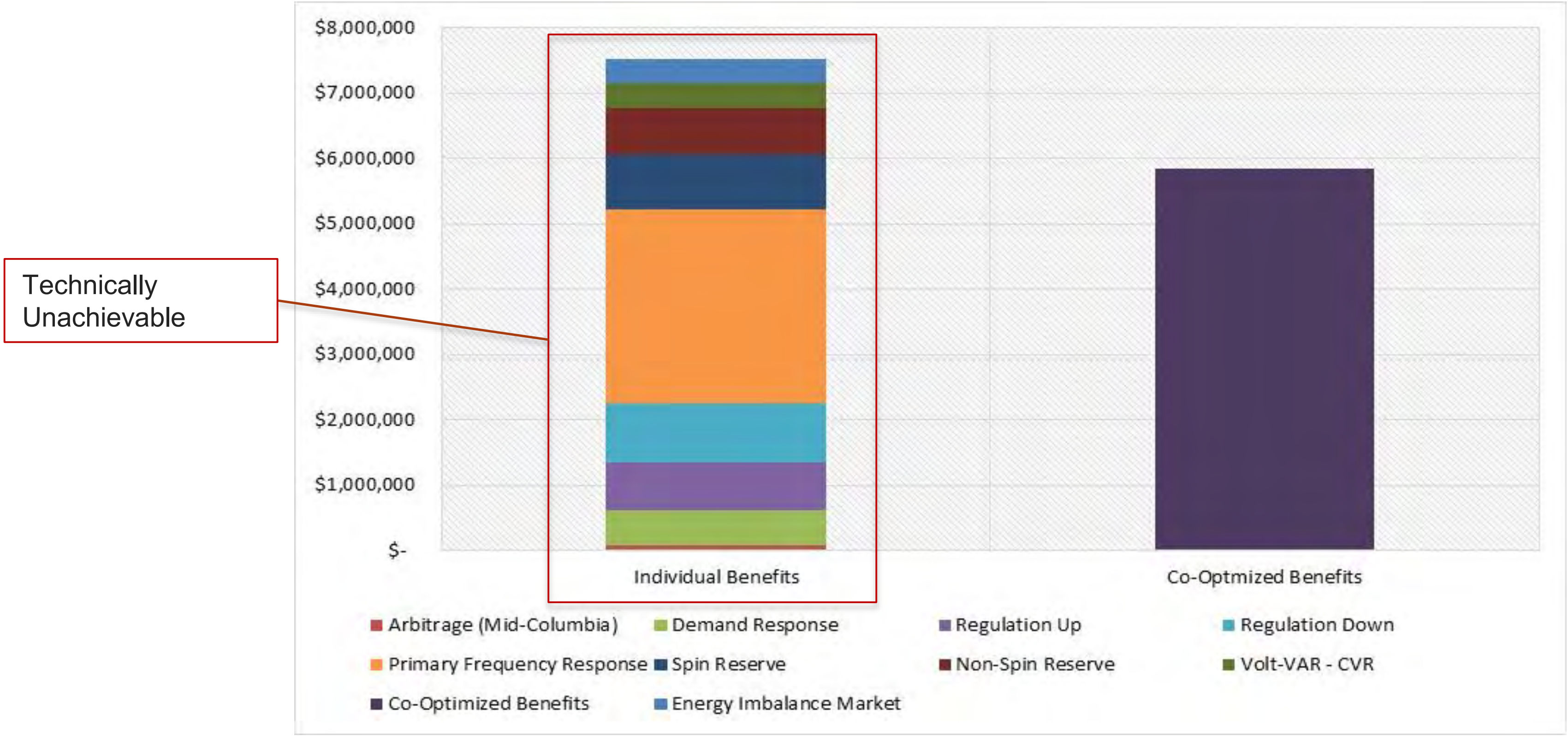
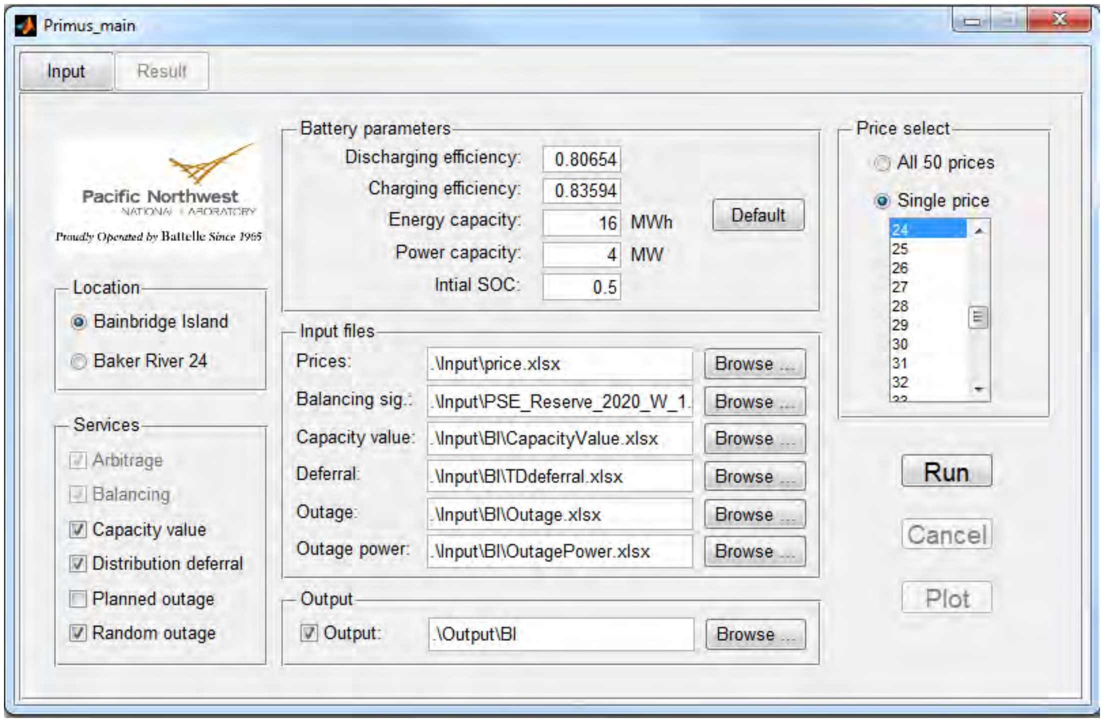
- Energy in the battery is competed for on an hourly basis
- Example: evaluated individually, the total 20-year value of Salem Smart Power Center operations exceeds $7.5 million in present value (PV) terms. When co-optimized, revenue falls to $5.8 million



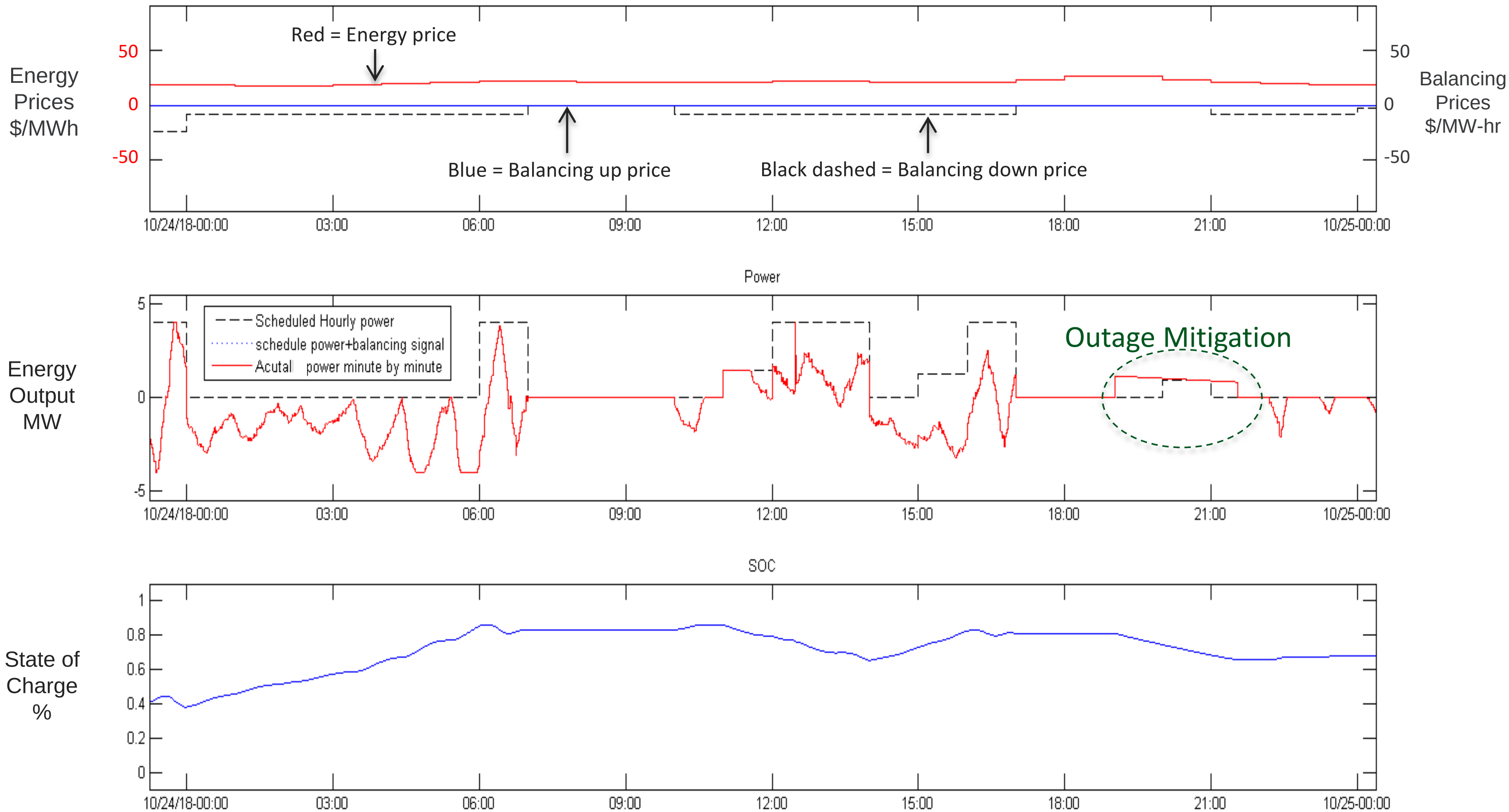
Battery Storage Evaluation Tool (BSET)



- There are losses associated with charging/discharging operations, which are modeled and considered in the optimal scheduling formulation in order to obtain the maximum obtainable profit

- Services/functions/values have to be co-optimized to avoid double counting
- BSET is used to run a one-year simulation of battery storage operations
- The formulation can consider the different operation modes of a hydro battery system, including:
  - Pumping (charging)
  - Generating (discharging)
  - Spinning reserve, and
  - Standby modes
- Increasing discharging power for one energy service decreases the battery's capability for other services

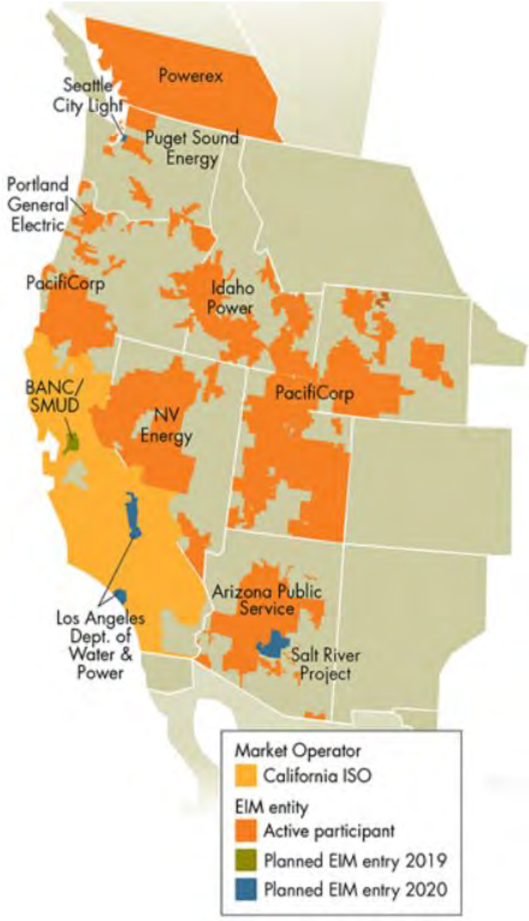
24-hour Energy Storage Schedule Example



(1) Portland General Electric Salem Smart Power Center (SSPC)

- Developed as an R&D project under the Pacific Northwest Smart Grid Demo as part of the American Recovery and Reinvestment Act of 2009
- The U.S. Department of Energy (DOE) provided half of the funding ($20 million)
- 5 MW – 1.25 MWh lithium-ion battery system built and managed by PGE

- Potential energy storage benefits:
  - Energy arbitrage
  - Participation in the Western Energy Imbalance Market (EIM)
  - Demand response
  - Regulation up and down
  - Primary frequency response
  - Spin reserve
  - Non-spin reserve
  - Volt-VAR control
  - Conservation voltage reduction



(1) Portland General Electric Salem Smart Power Center (cont.)

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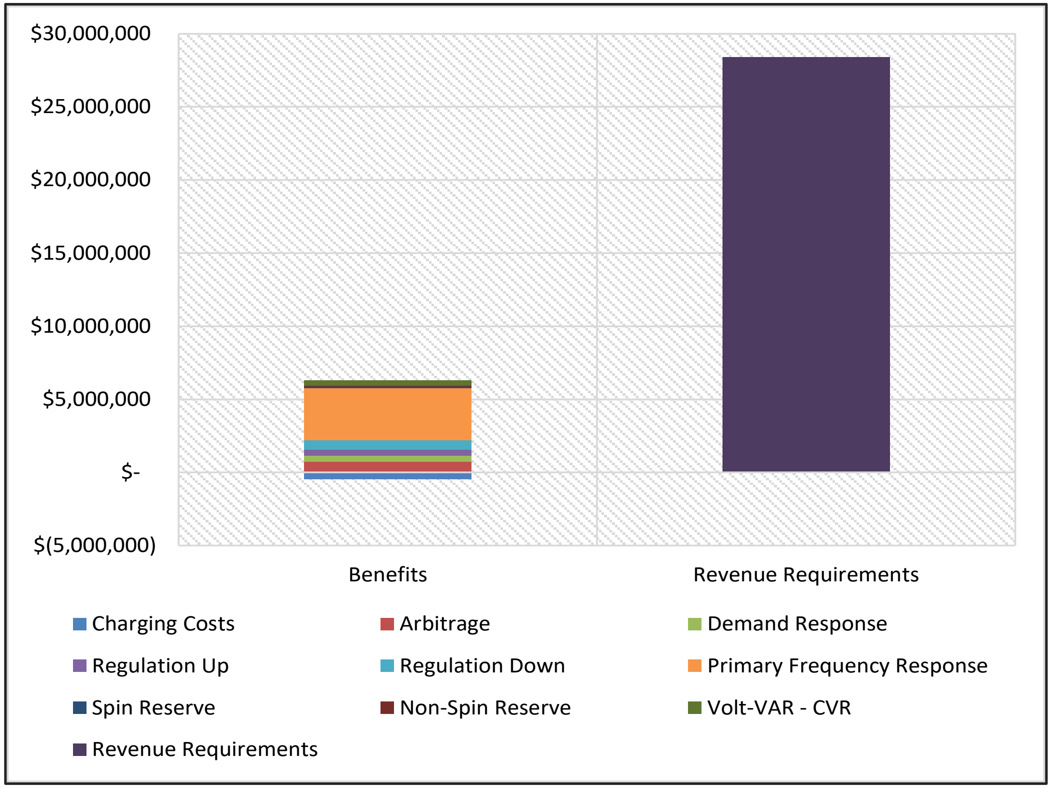
- SSPC benefits for the base case (**$5.8 million**) fall far short of the revenue requirements as originally designed and built (**$28.4 million**); however, the SSPC was originally designed as an R&D project with a goal of establishing a high reliability zone
- Benefit cost ratio of 0.20



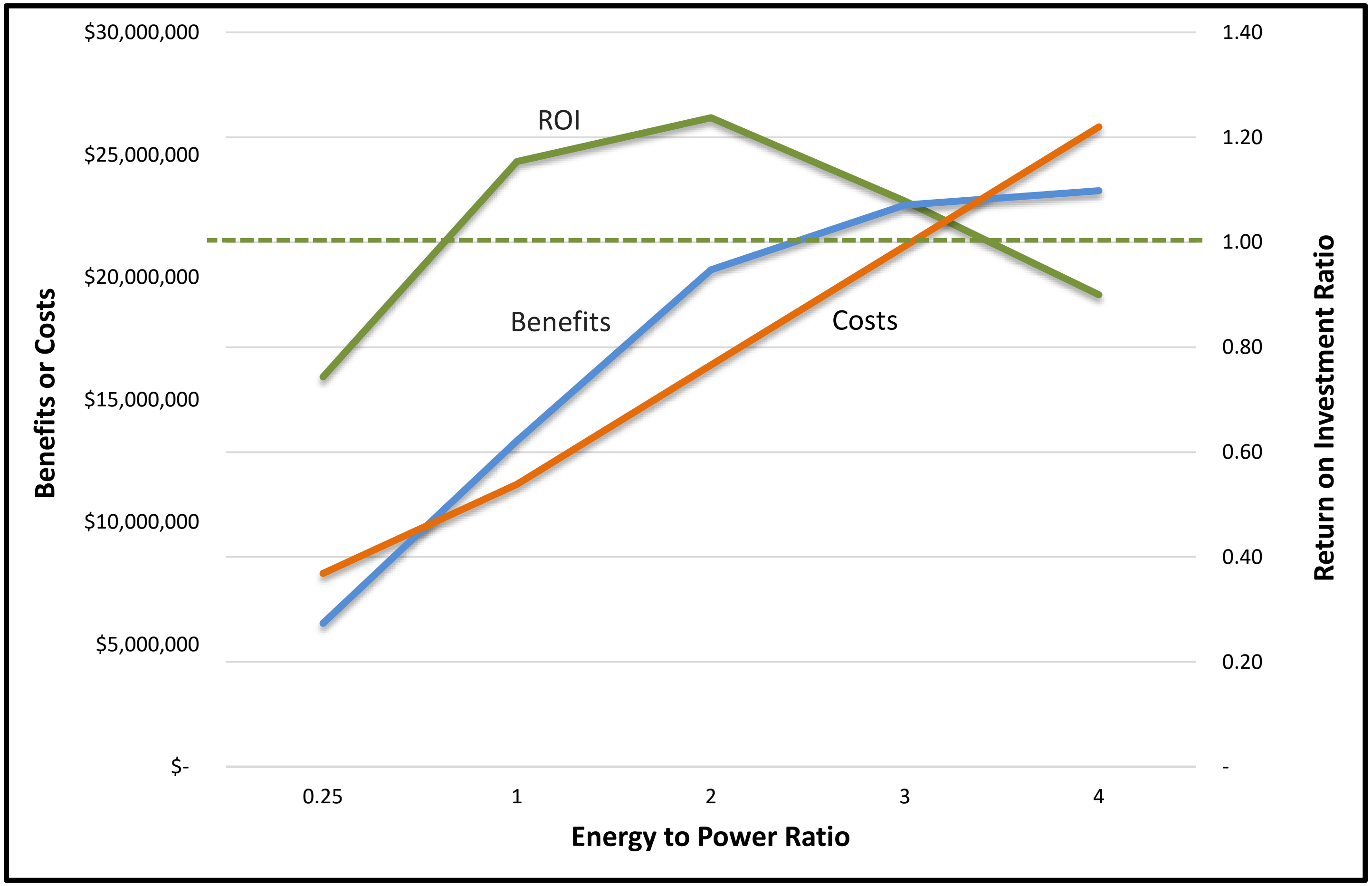
Sensitivity Analyses:

- SSPC currently being used only for primary frequency response; optimal operation could generate an additional $170,068 in value annually
- Using current day prices (Lahiri 2017)*, the loss is reduced to $2 million overall
- Modifying the energy storage capacity greatly affects the overall return on investment ratio

*Lahiri, S. 2017. Assessing CAPEX for Storage Projects. Presentation at Storage Week. Oakland, CA.

(1) Portland General Electric Salem Smart Power Center (cont.)

- By upsizing the energy storage capacity to 10 MWh, the return on investment ratio yields a positive result at 1.24



(2) Puget Sound Energy – Clean Energy Fund I Glacier Energy Storage System

- Frequent transmission-line outages in Glacier, WA due to vegetation
- $3.8 million grid modernization grant awarded to Puget Sound Energy as part of Washington Clean Energy Fund (CEF) I
- 2 MW – 4.4 MWh lithium-ion battery near Glacier substation to provide (temporary) backup power to distribution circuit

With DOE support, PNNL modeled battery operations to determine the long-term financial benefits and costs to Glacier, WA

- **Benefits Explored:**
  - Flexibility services
    - Energy arbitrage
    - Regulation up/down
  - Primary Frequency Response
  - Capacity
  - Outage Mitigation

(2) Puget Sound Energy – Clean Energy Fund I Glacier Energy Storage System (cont.)

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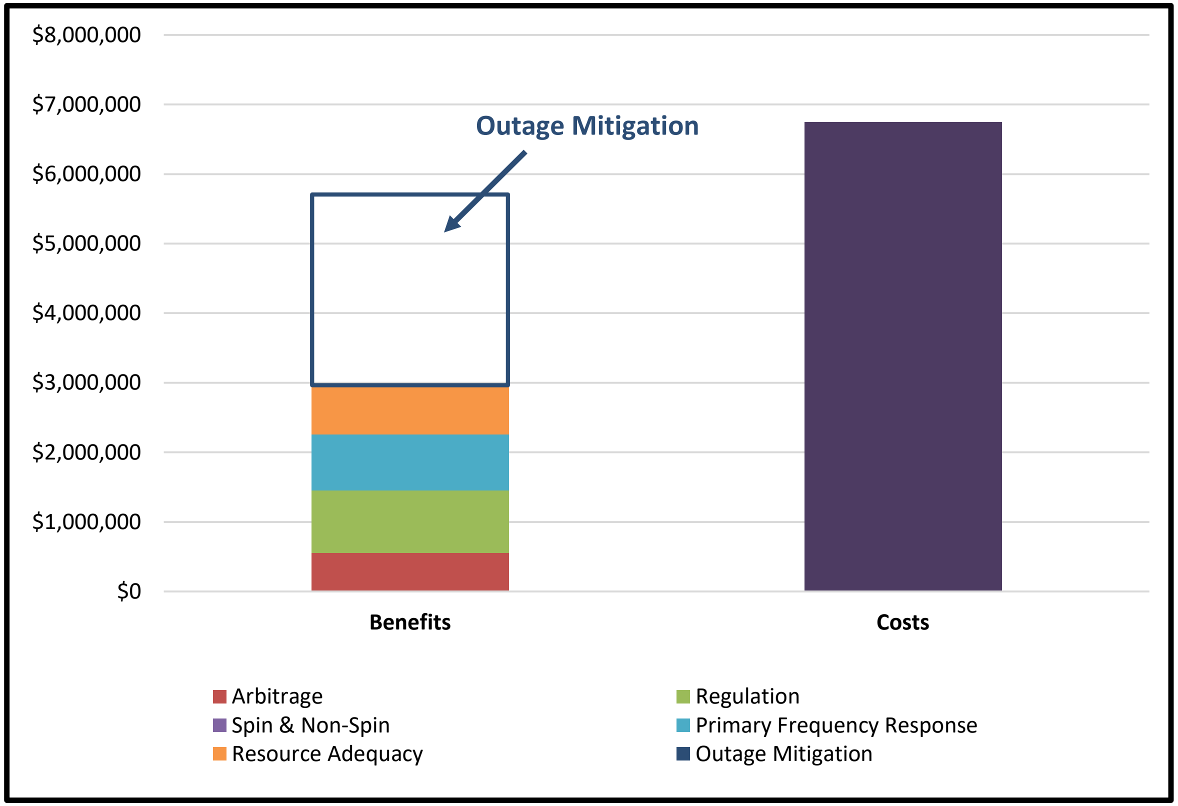
- Total 10-year benefit value of ESS operations is **$2.9 million** in present value terms, while costs are **$6.7 million**, inclusive of CEF grant
- Benefit-cost ratio of 0.44



Sensitivity Analyses:

- Outage Mitigation not included in base case due to utility perspective analysis. Including it increases benefits by $2.8 million, giving a return on investment of 0.85
- Extending analysis for a 20-year battery increases benefits by $1.3 million over the life of the asset and a BCR of 0.65

(3) Orcas Power & Light Co-Op – CEF II Energy Storage & Community Solar

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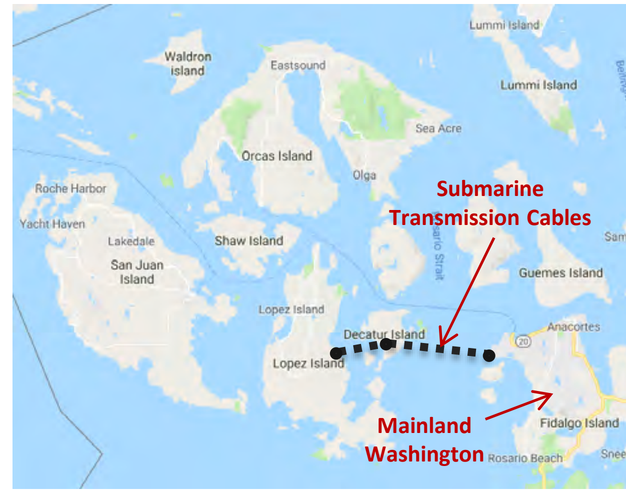
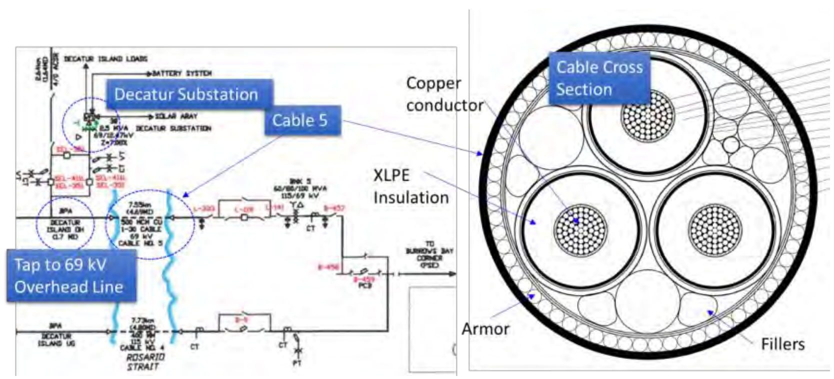
- $1 million grid modernization grant awarded to Orcas Power & Light Co-Op (OPALCO) as part of Washington CEF II
- 0.5 MW / 2 MWh UniEnergy Technology (UET) Vanadium Redox Flow Battery
- 504 kW LG Community Solar Array from Puget Sound Solar



Transmission Cable Map from Fidalgo Substation in Anacortes to Decatur and Lopez Islands

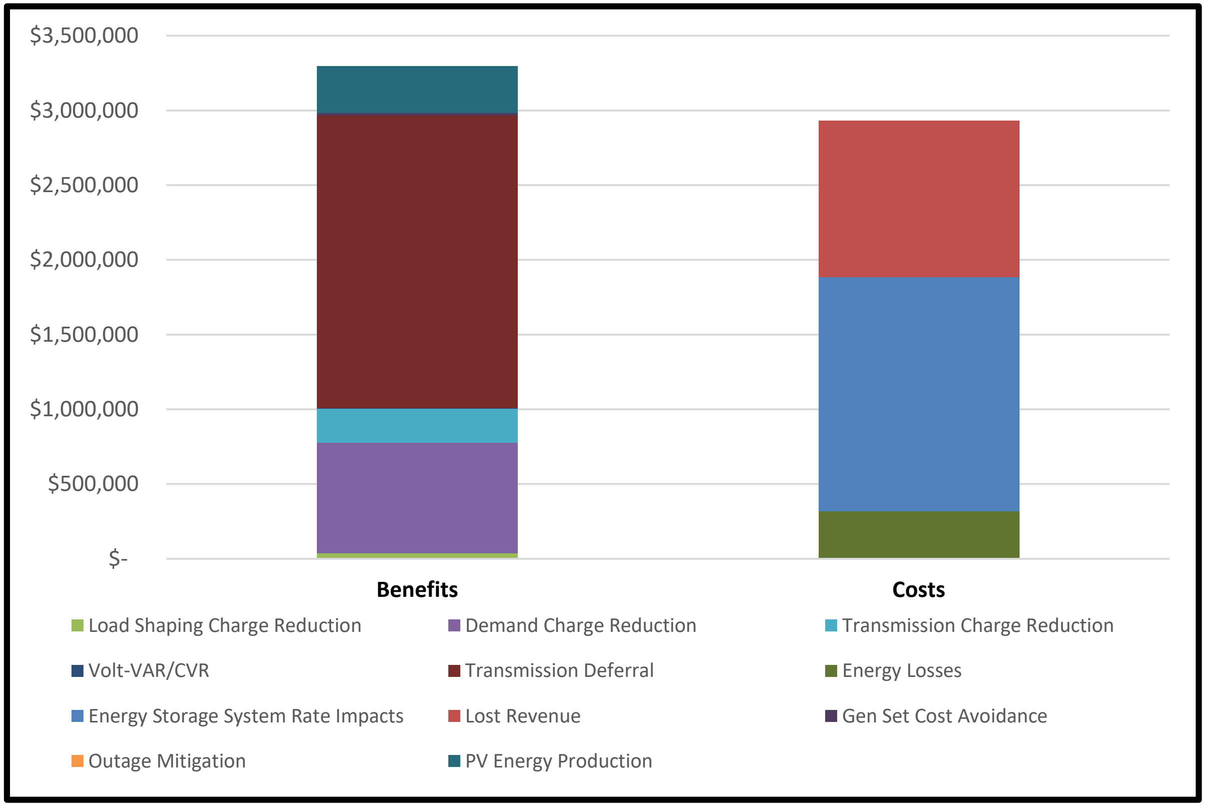
- Potential PV and energy storage benefits:
  - Demand charge reduction
  - Load shaping charge reduction
  - Transmission charge reduction
  - Transmission submarine cable replacement deferral
  - Volt-VAR/CVR
  - Outage mitigation



Cable 5 and ESS site at Decatur Substation in the OPALCO Single Line Diagram (left); Cable 5 Cross Section (right)

(3) Orcas Power & Light Co-Op – CEF II Energy Storage & Community Solar (cont.)

- Total 20-year value of PV and ESS operations at **$3.3 million** in present value terms, while costs are **$2.9 million** for a benefit-cost ratio of 1.13
- Benefits largely driven by transmission deferral benefit at $2.0 million in present value terms
- Cable replacement deferral estimated to be 3.65 years on a 40-year cable



Sensitivity Analyses:

- Outage Mitigation not included in base case due to utility perspective analysis. Adding in the additional use case increases benefits by $2.8 million and provides a BCR of 1.25

(4) Energy Northwest – CEF II
Horn Rapids Solar, Storage, and Training Project

- $3 million grid modernization grant awarded to Energy Northwest as part of Washington CEF II
- 1 MW – 4 MWh UniEnergy Technology Vanadium Redox Flow Battery
- 4 MW Solar Array from Potelco/Quanta Services

- Potential PV and energy storage benefits:
  - Demand charge reduction
  - Load shaping charge reduction
  - Transmission charge reduction
  - Volt-VAR/CVR
  - Outage mitigation
  - Solar Energy Production
  - Renewable energy credits

(4) Energy Northwest – CEF II Horn Rapids Energy Storage Evaluation (cont.)

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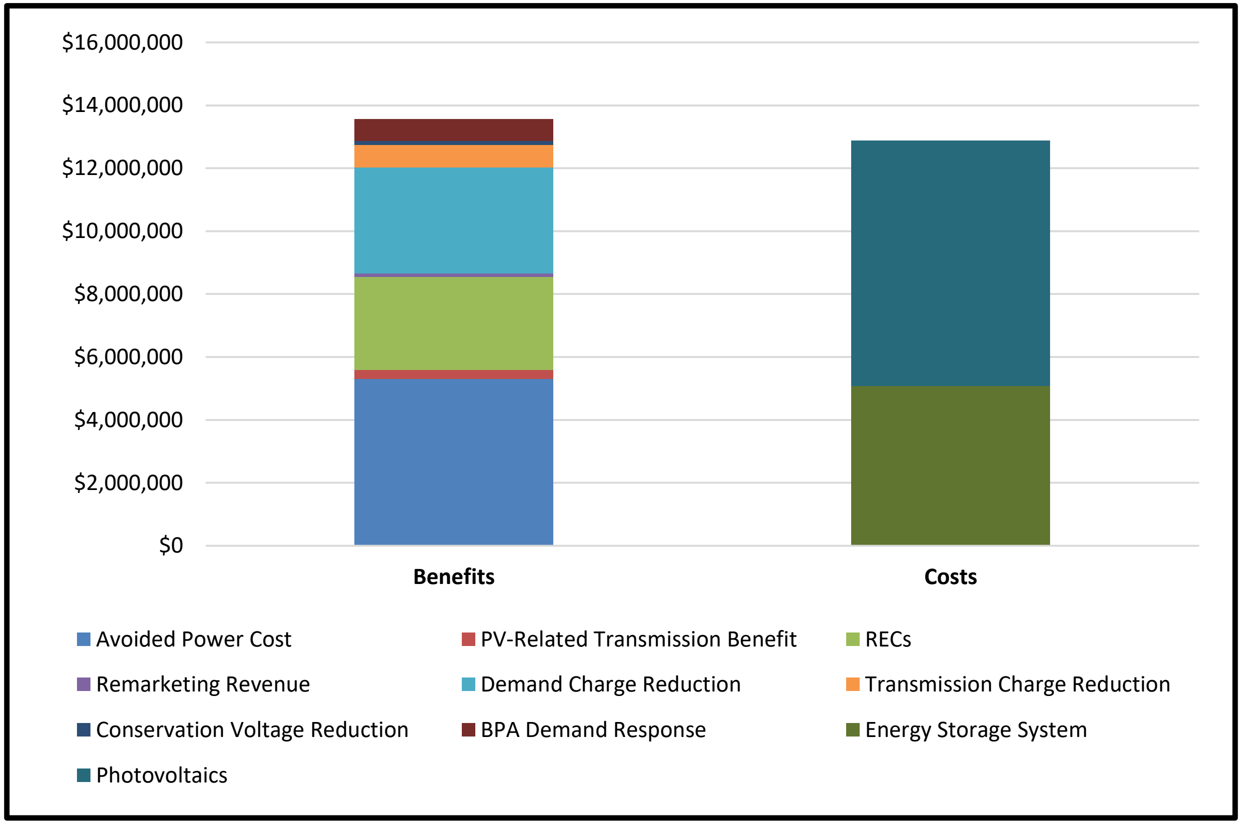
- Total 20-year value of PV and ESS operations at **$13.56 million** in present value terms, while costs are **$12.87 million**
- Benefit-cost ratio of 1.05

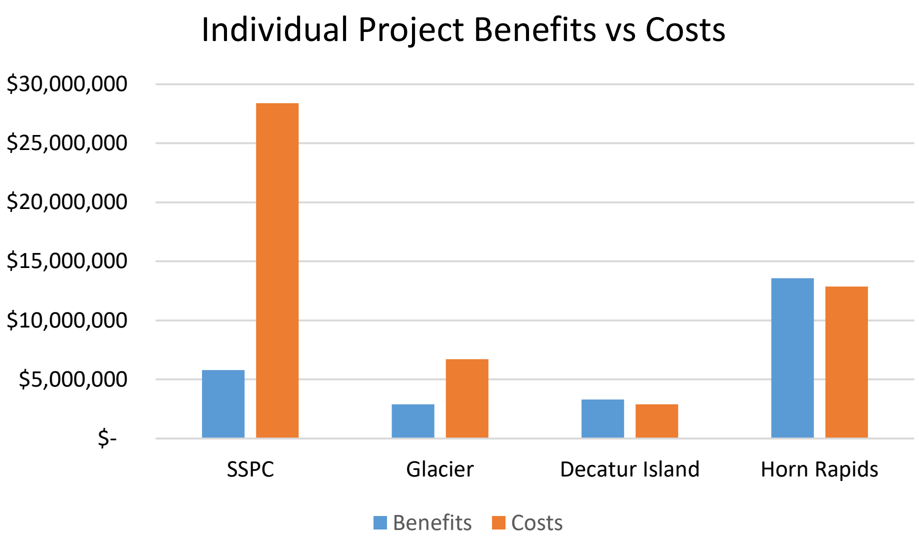


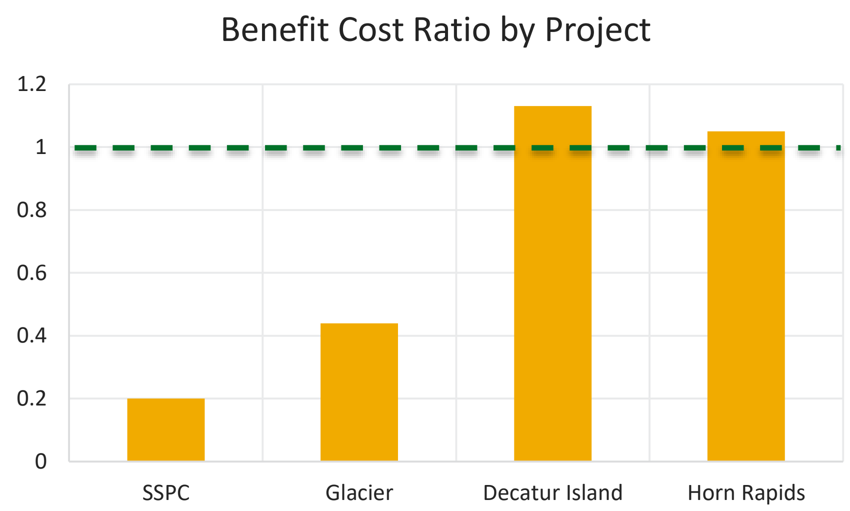
Sensitivity Analyses:

- Outage mitigation benefits are estimated at $4.8 million in present value terms; including outage mitigation improves the benefit-cost ratio to 1.43
- Net benefits of energy storage in isolation estimated at roughly ($160k); benefit-cost ratio of .97

Comparison of Economic Results

	SSPC	Glacier	Decatur Island	Horn Rapids
Benefits	$ 5.8 million	$ 2.9 million	$ 3.3 million	$ 13.56 million
Costs	$ 28.4 million	$ 6.7 million	$ 2.9 million	$ 12.87 million
BCR	0.2	0.44	1.13	1.05





Conclusions

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- Correctly valuing energy storage assets requires the optimal stacking of benefits. Not all benefits can be provided simultaneously, making co-optimization necessary
- Value gained from an energy storage asset can be highly dependent on site-specific factors
  - Assets that yield a positive return on investment in one location may not be economically viable in another
  - Opportunities to obtain specific benefits may not be available in all areas (i.e. arbitrage in the Pacific Northwest)
  - Technological limitations can dictate what use cases and values the asset is capable of providing
- Energy storage has the potential to provide a wide range of valuable benefits to the electric grid and the customers it serves and accurately capturing them continues to be a developing process

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