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Modeling the Financial and System Benefits of Energy Storage Applications in Distribution Systems

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Hydrogen Energy Storage for Grid and Transportation Services Workshop
Sacramento, California
May 14, 2014

Valuation challenges

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Software Type	Number Reviewed
Electric System Planning Software	
Portfolio Planning	8
Energy Production Cost Simulation	11
Bulk Transmission Planning	7
Distribution System Planning	9
Real-Time Grid Operations	6
Energy Storage Systems	21
TOTAL	**62**

	Energy Storage Industry Stakeholders								
	ISOs/RTOs	Generators / IPPs	Utilities	R&D / Consulting	Project Developers	Technology Providers	End Users	Finance Community	State & Federal Regulators
System Planning									
Portfolio Planning	X	X	X	X	X				
Energy Production Cost Simulation	X	X	X	X	X				
Transmission System Planning	X	X	X	X	X				
Distribution System Planning			X	X	X				
Real Time Grid Operations									
Generation & Transmission System Operation	X	X	X						
Distribution System Operation			X	X					
Energy Storage System									
Estimate & Demonstrate Value		X	X	X	X	X	X	X	X
Calculate System Size		X	X	X	X	X		X	
Control & Operate Installed Systems	X	X	X	X	X	X	X		
Optimize System Performance	X	X	X	X	X	X	X		

- <u>Transmission and Distribution planning</u>

  Models lack standard features that allow the user to properly model energy storage.

- <u>Portfolio planning</u>

  Gaps exist for recognizing storage in planning and energy production cost models

- <u>Energy Storage System Tools</u>

  Despite the variety of tools available, many stakeholders still feel that numerous gaps exists in ES-specific software packages

Source: Lamontagne, C. 2014. *Survey of Models and Tools for the Stationary Energy Storage Industry.* Presentation at Infocast Storage Week. Santa Clara, CA.

Energy storage for Puget Sound Energy region

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

Situation

- 25MVa 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

Approaches used to value energy storage applications

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Num.	Application	Final Assumptions
1	Capacity	Energy storage avoids the incremental cost of a peaker in 2018. Detailed proforma built to estimate revenue requirements for an F-class simple-cycle turbine with peak winter capacity of 221 MW. Line loss gross up, avoided reserve requirements and incremental capacity analysis performed to determine value, which was estimated at $142 per kW-year.
2	Distribution Upgrade Deferral	Deferred costs of proposed distribution upgrades. On Bainbridge Island (BI), value derived from deferring substation costs ($10.5 million) for nine years.
3	Outage Mitigation	Outage time, duration and number of affected customers on relevant circuits obtained using PSE outage data covering multiple years. Customers were sorted into customer classes using PSE data and values were assigned using Lawrence Berkeley National Laboratory outage cost data.[1]

[1]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.

Approaches used to value energy storage applications and system capital costs

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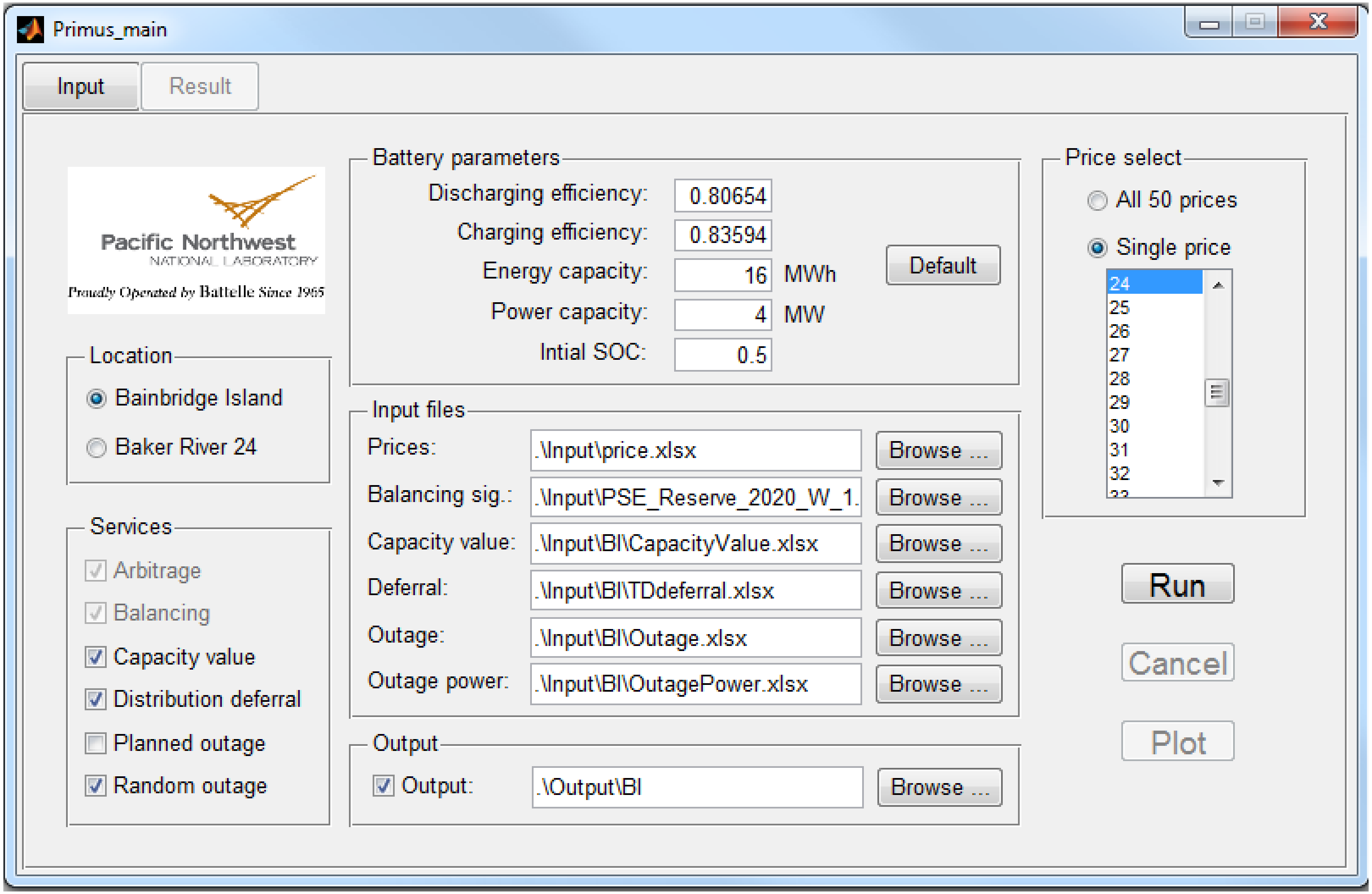
Num.	Application	Final Assumptions
4	Balancing Services	Defined stochastic process was used to generate wind and load forecast error time series with statistical features similar to observed errors. Multiple Monte Carlo runs were then run to determine the balancing reserve requirement. AURORA and a PSE mixed integer linear programming (MILP) model used to determine the inc. and dec. balancing services prices. There were 50 balancing price simulations run and the mid-point was used.
5	Arbitrage	AURORA model used to determine energy price differentials (peak vs. off-peak) minus efficiency losses.
6	Capital Costs	Estimated at $3,690 per kW at BI; $4,384 per kW at BR-24. Estimates include all battery, siting, electrical, thermal management, site/civil, installation, communications, and IT costs, as well as associated overheads.

Energy storage optimization tool inputs



Energy storage optimization tool output

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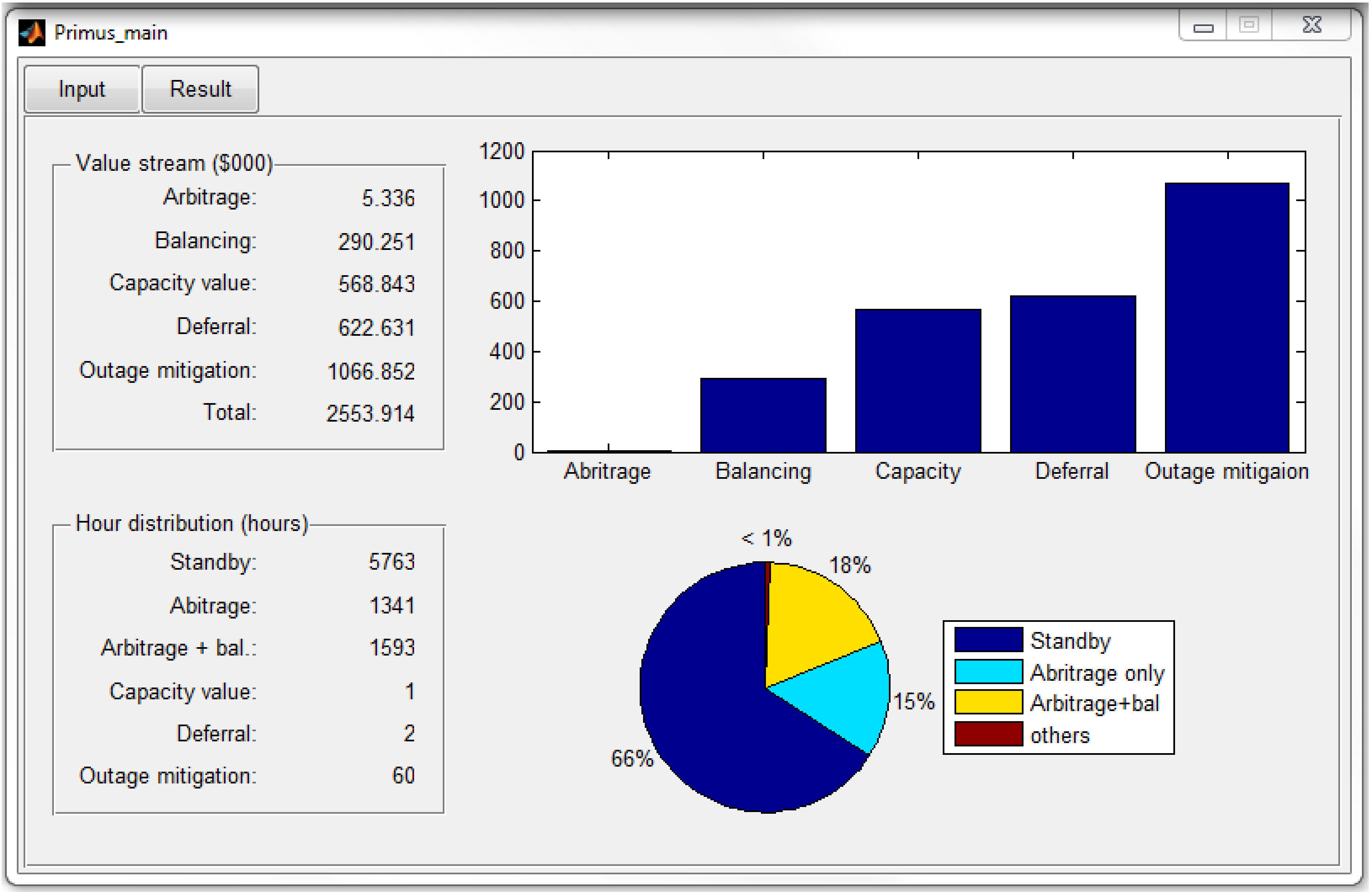
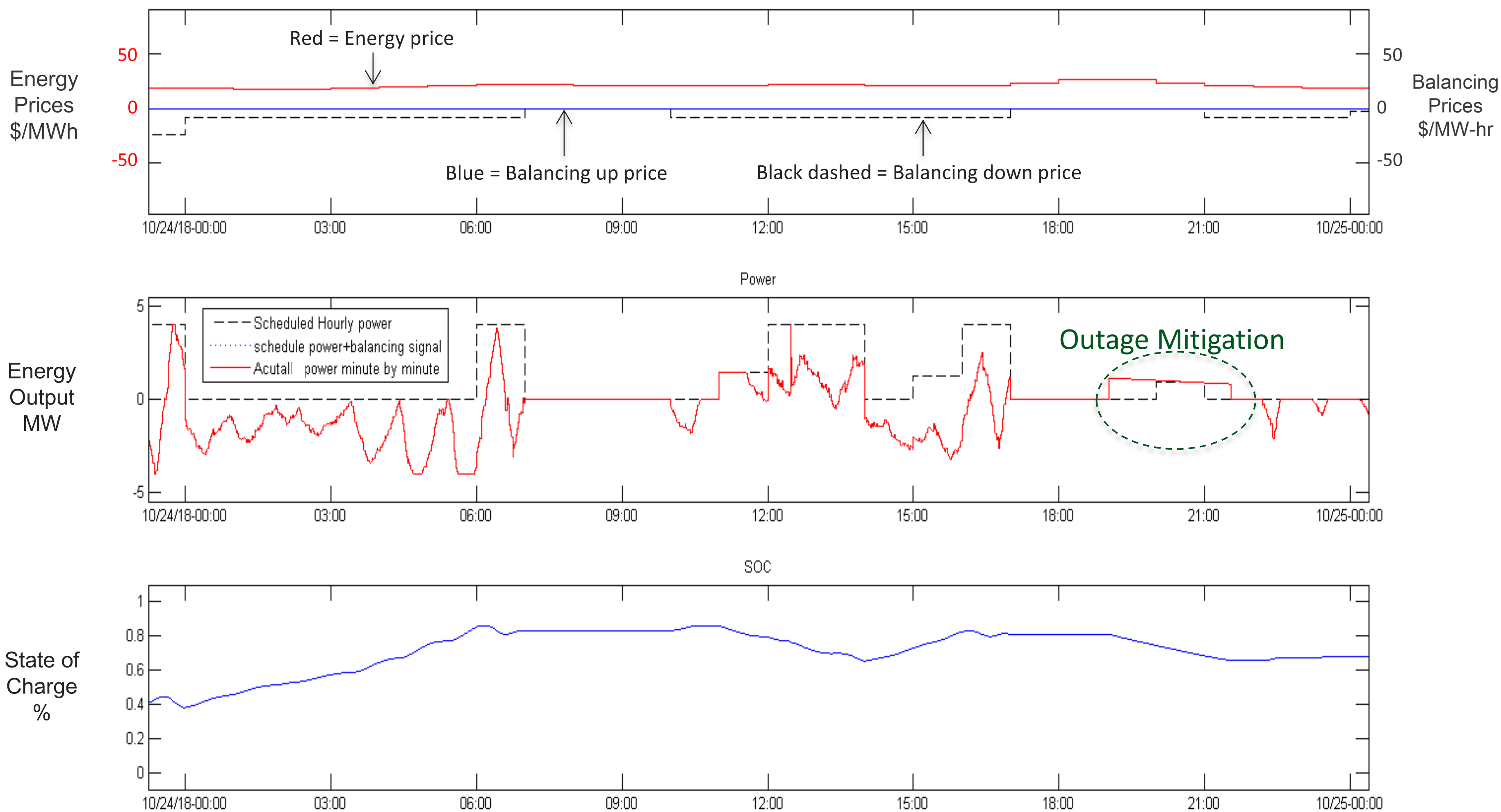
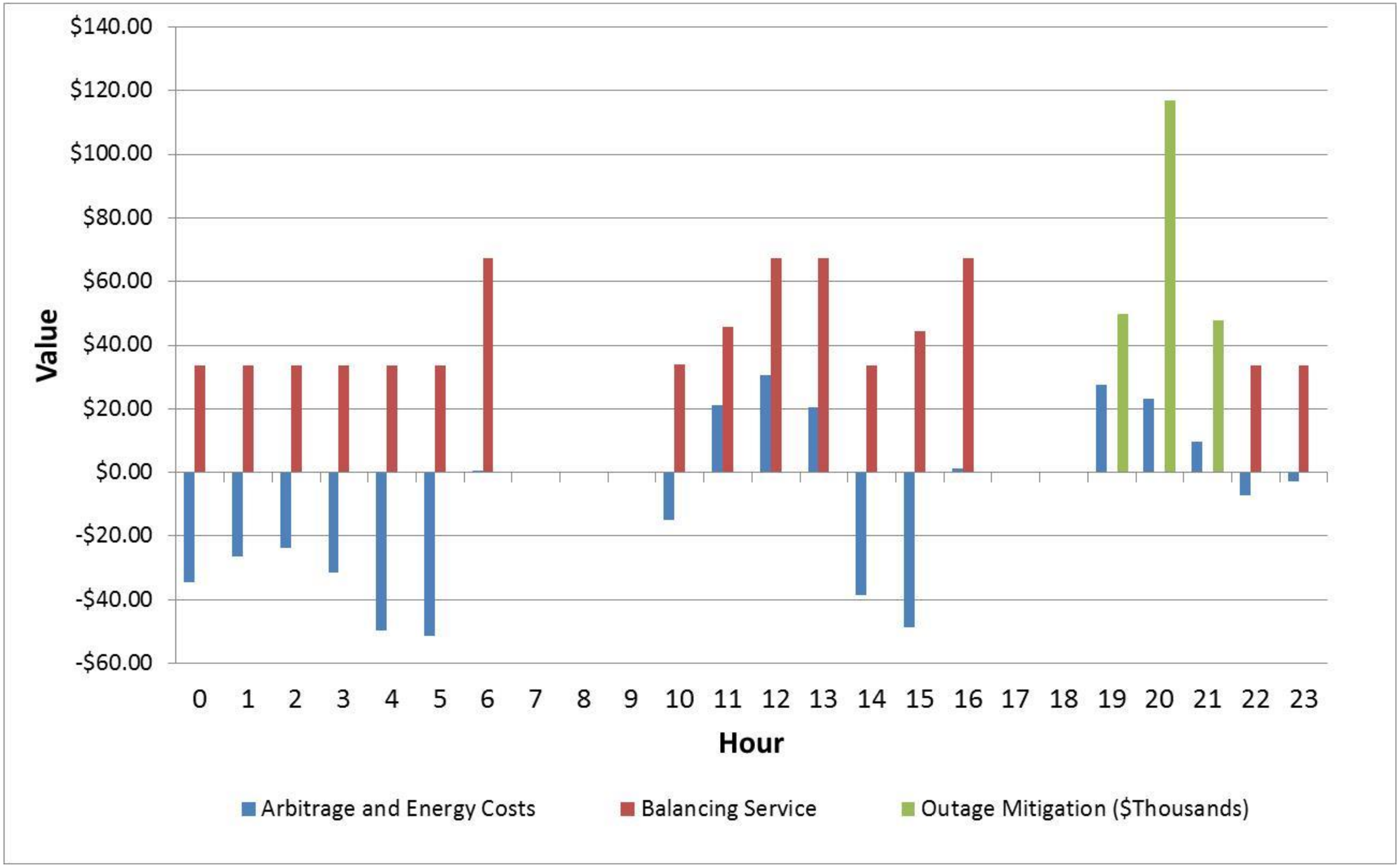


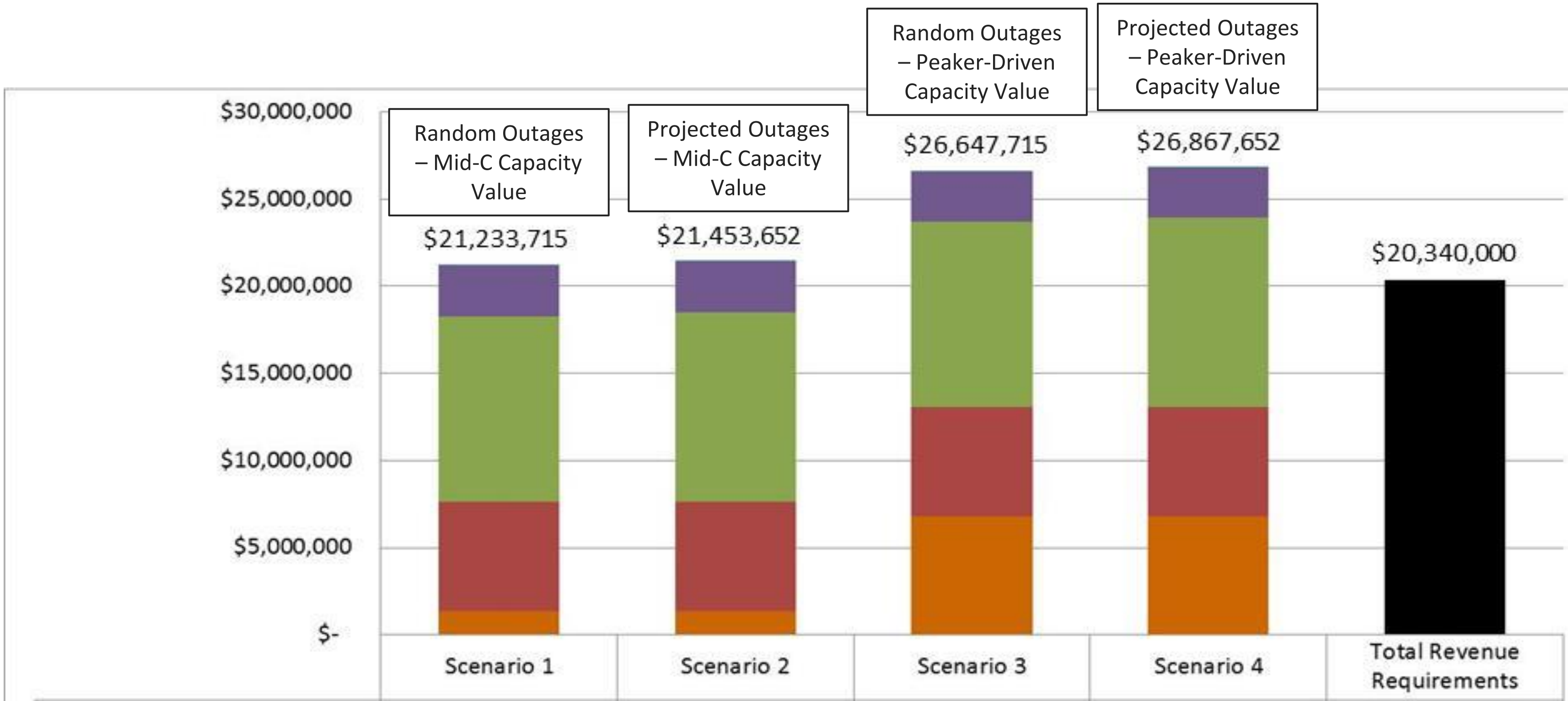
24-hour energy storage schedule for Bainbridge Island



Hourly value at Bainbridge Island for 24-hour period



Summary of results (NPV benefits and revenue requirements over 20-year time horizon) – Bainbridge Island



	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Total Revenue Requirements
Revenue Requirements					$20,340,000
Arbitrage and Energy Costs	$53,299	$40,833	$53,299	$40,833	
Balancing Services	$2,899,171	$2,898,352	$2,899,171	$2,898,352	
Outage Mitigation	$10,656,246	$10,889,467	$10,656,246	$10,889,467	
Distribution Upgrade Deferral	$6,252,000	$6,252,000	$6,252,000	$6,252,000	
Capacity Value	$1,373,000	$1,373,000	$6,787,000	$6,787,000	

Key lessons and implications of this assessment

- We developed procedures to site and size ESS
- Several energy storage applications were defined and examined
  - Capacity, outage mitigation, and distribution deferral values largely drive results
  - Balancing service and arbitrage values less significant in Pacific NW due to presence of low-cost hydro
- Site-specific non-battery costs could be significant ($750-$1,500 per kW)
- The proposed ESS generates positive net benefits to PSE on Bainbridge Island but not for the Baker River site; thus, location matters
- Any single use would not yield positive returns on investment; services must be bundled
- A tool for optimizing energy storage deployment was developed, as was an executable file and primer to guide users
- Final Phase I findings and the executable file / primer were submitted to BPA in mid-December 2013 and will be made available more widely in the coming months