Battery Storage Evaluation Tool: Assessing the Economic Benefits of Energy Storage and Microgrids

Patrick J. Balducci
Pacific Northwest National Laboratory

Support from DOE Office of Electricity Delivery & Energy Reliability
Energy Storage Program

EESAT Portland, OR
September 23rd, 2015

Pacific Northwest
NATIONAL LABORATORY

Valuation Challenges

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		

- Transmission and Distribution Planning

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

- Portfolio Planning

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

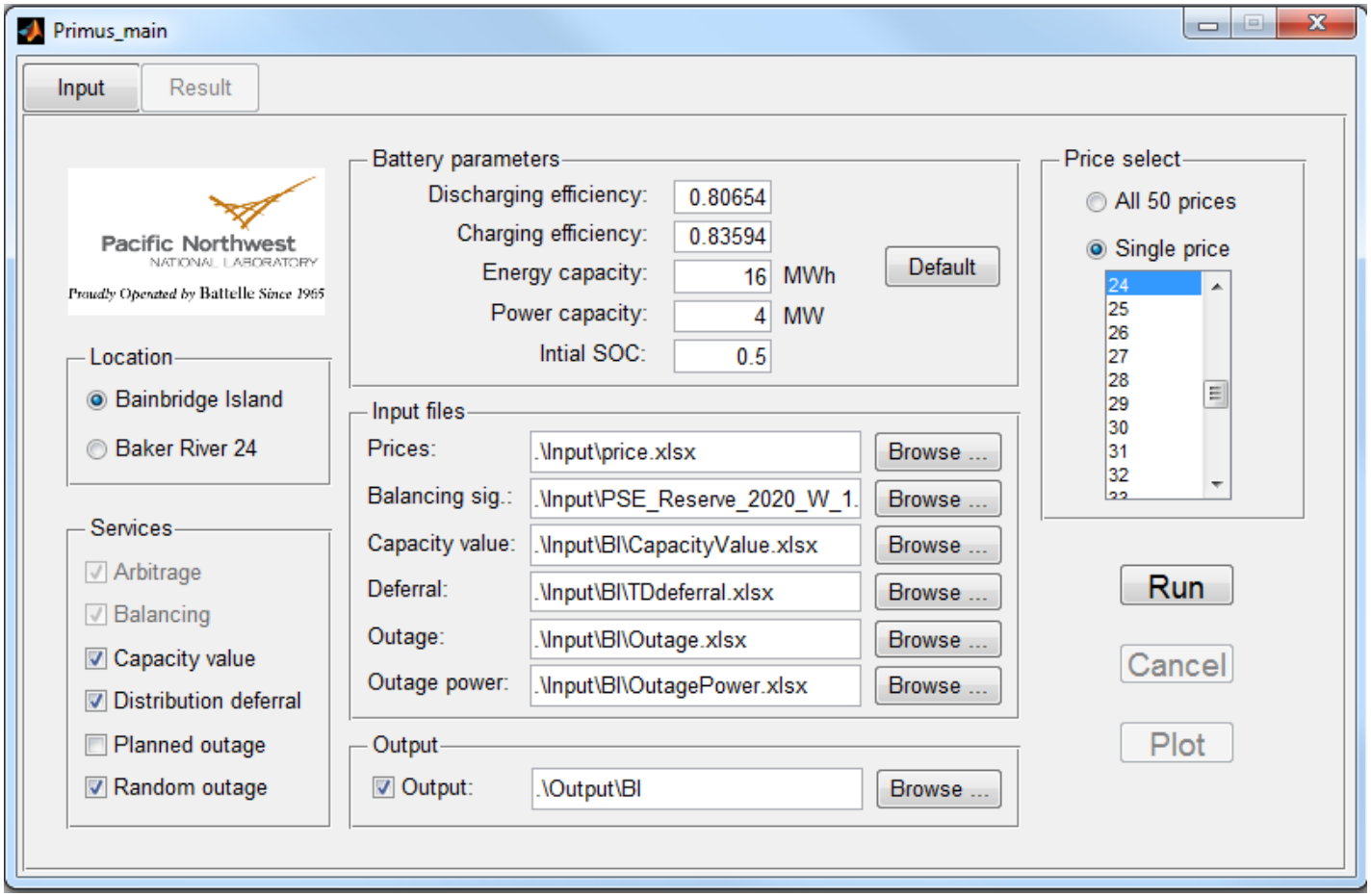
- Energy Storage System Tools

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

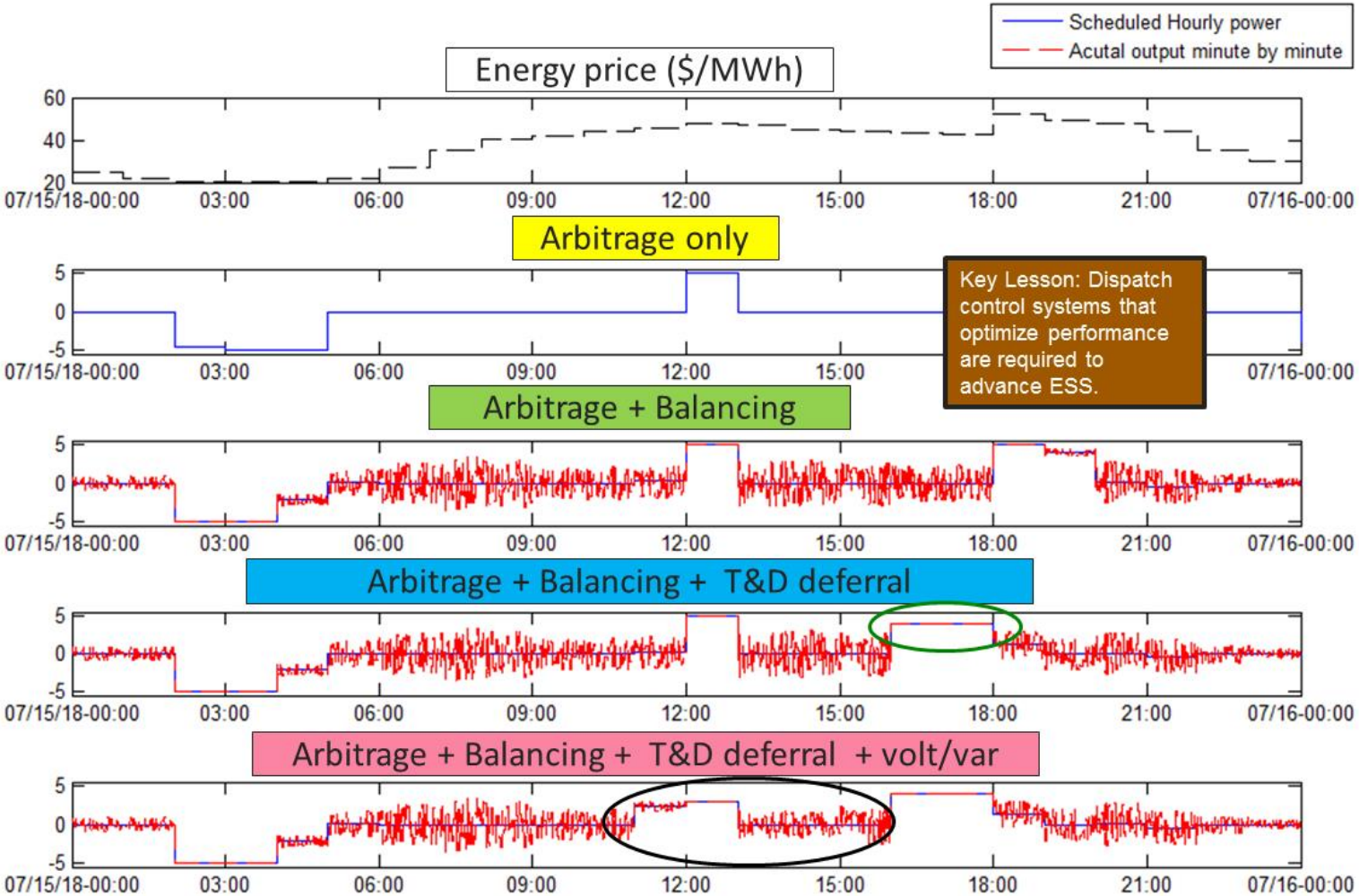
Source: Navigant for Energy Storage Association
Presented: December 2013

Pacific Northwest
NATIONAL LABORATORY

Battery Storage Evaluation Tool (BSET) User Interface

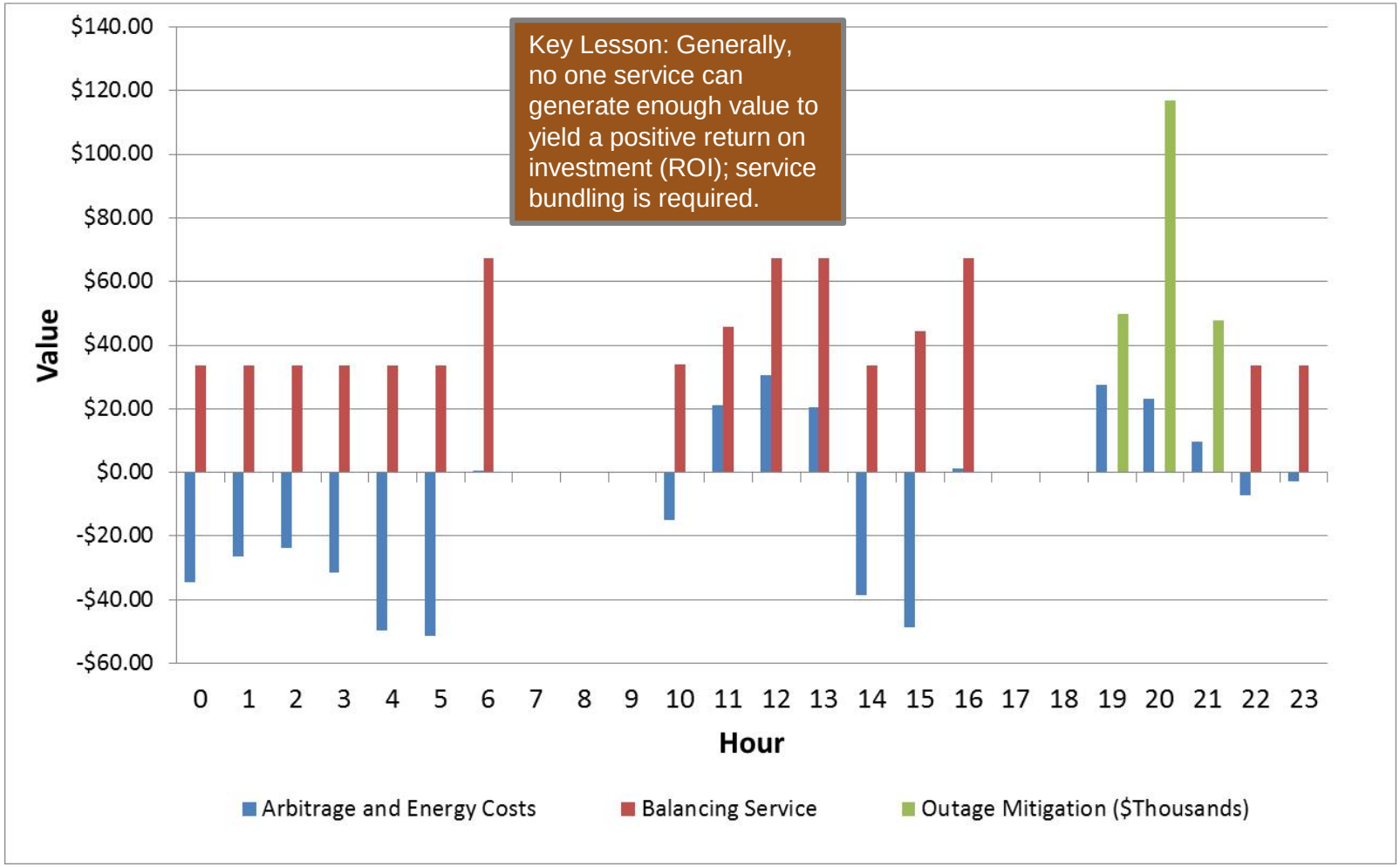


Bundling Services: How To Do It Optimally

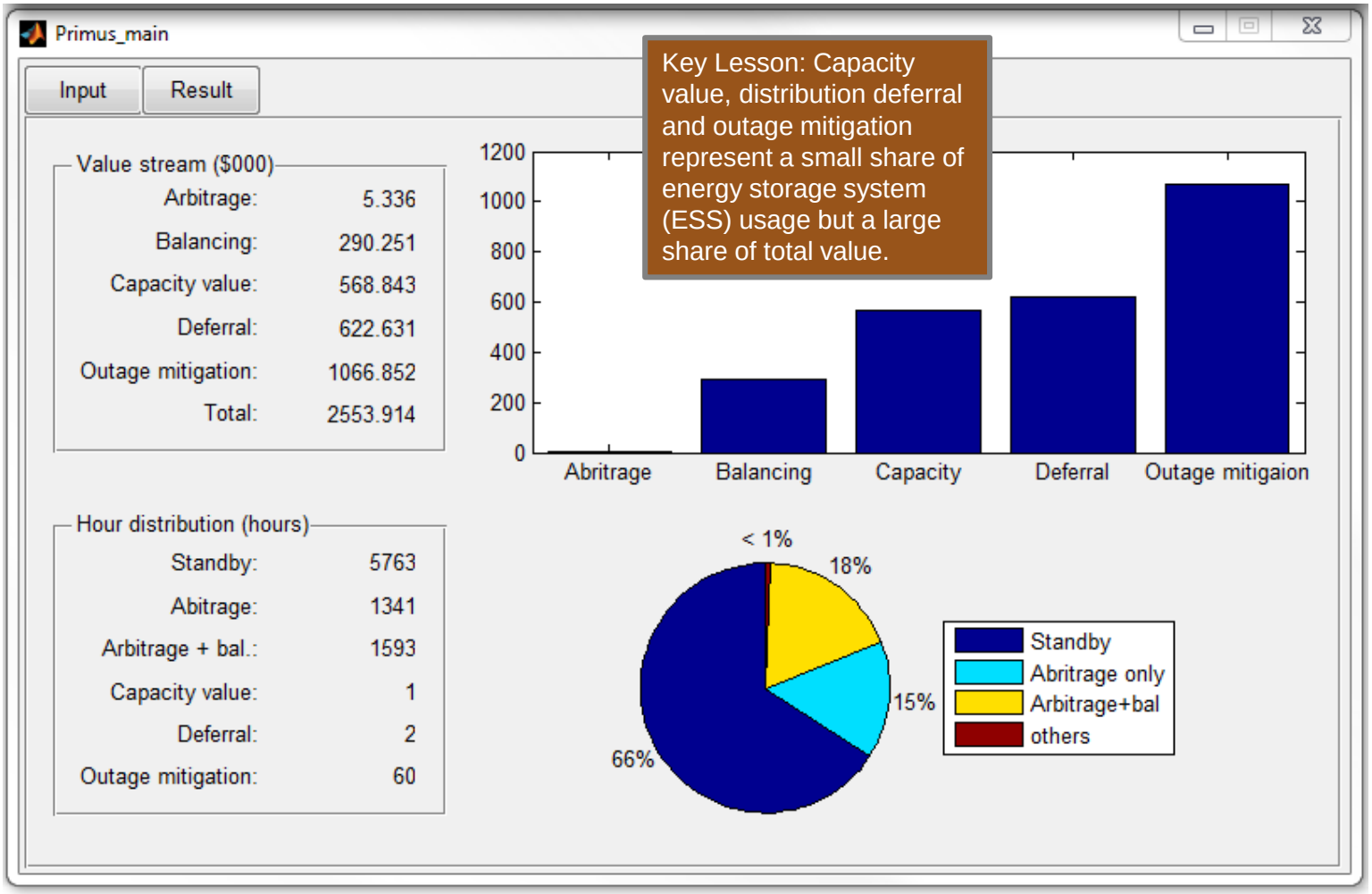


Key Lesson: Dispatch control systems that optimize performance are required to advance ESS.

Hourly Value at Bainbridge Island for 24-Hour Period



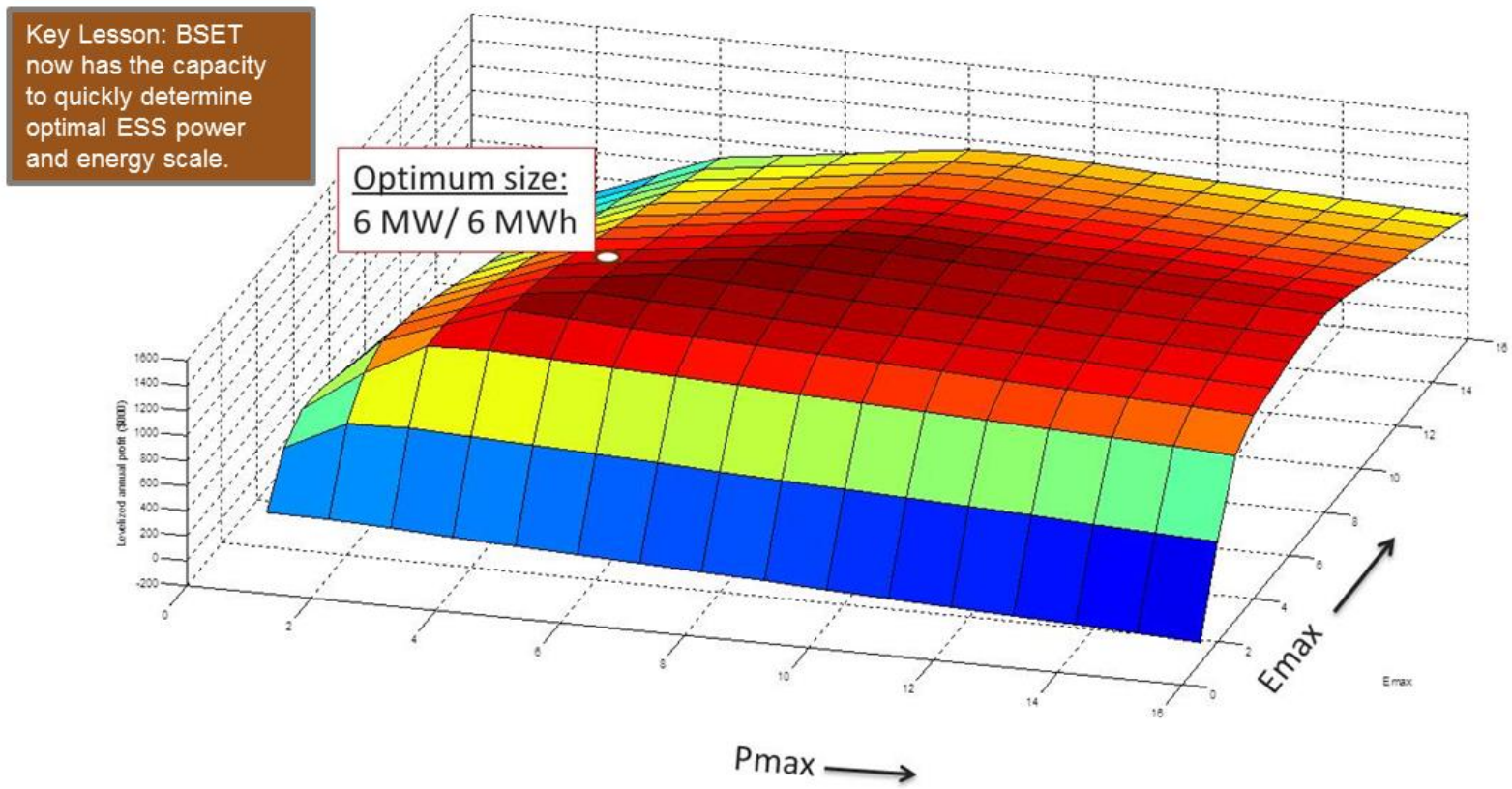
BSET Output



Key Lesson: Capacity value, distribution deferral and outage mitigation represent a small share of energy storage system (ESS) usage but a large share of total value.

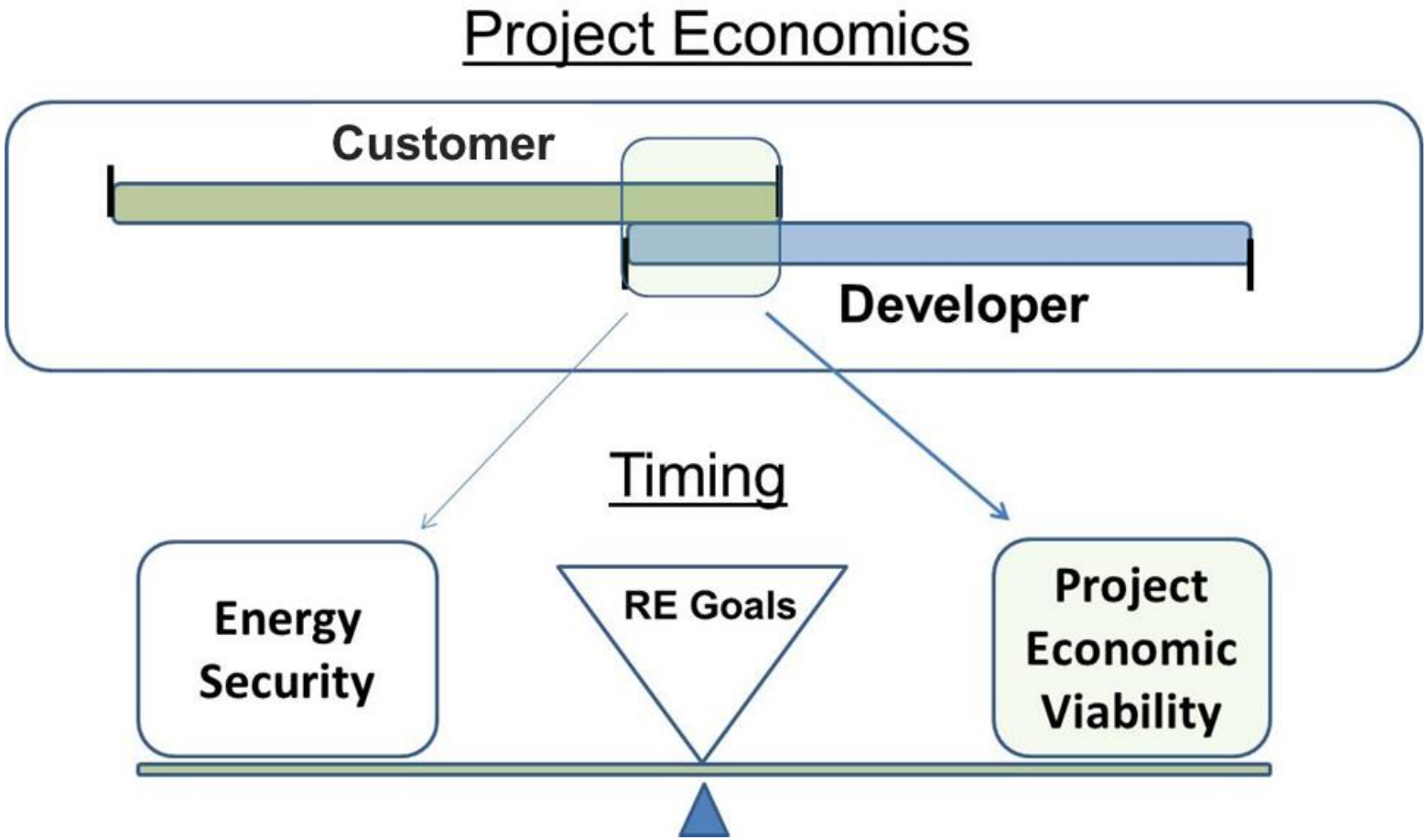
Pacific Northwest
NATIONAL LABORATORY

Sizing Energy Storage Optimally to Maximize Net Benefits

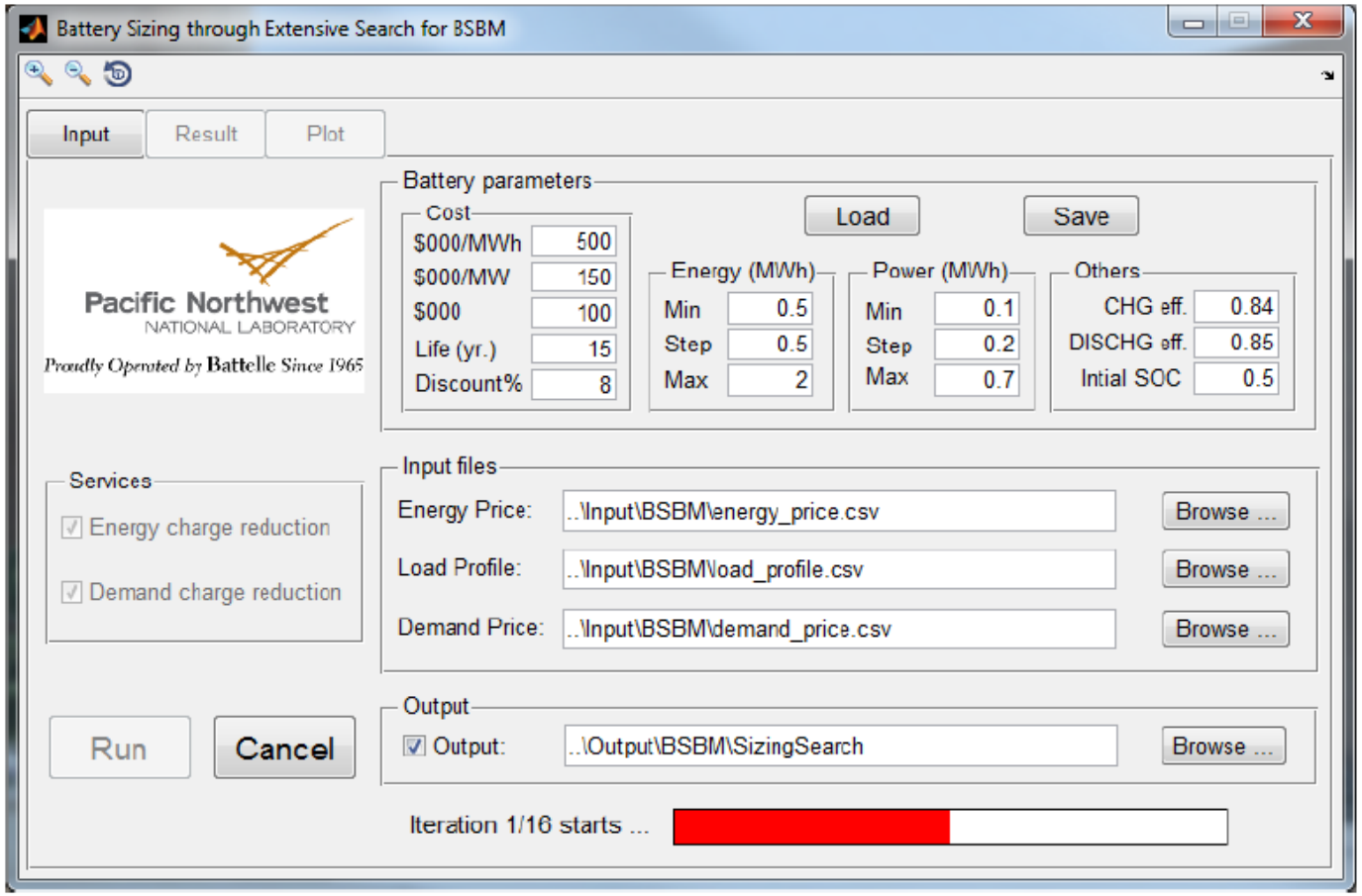


Pacific Northwest
NATIONAL LABORATORY

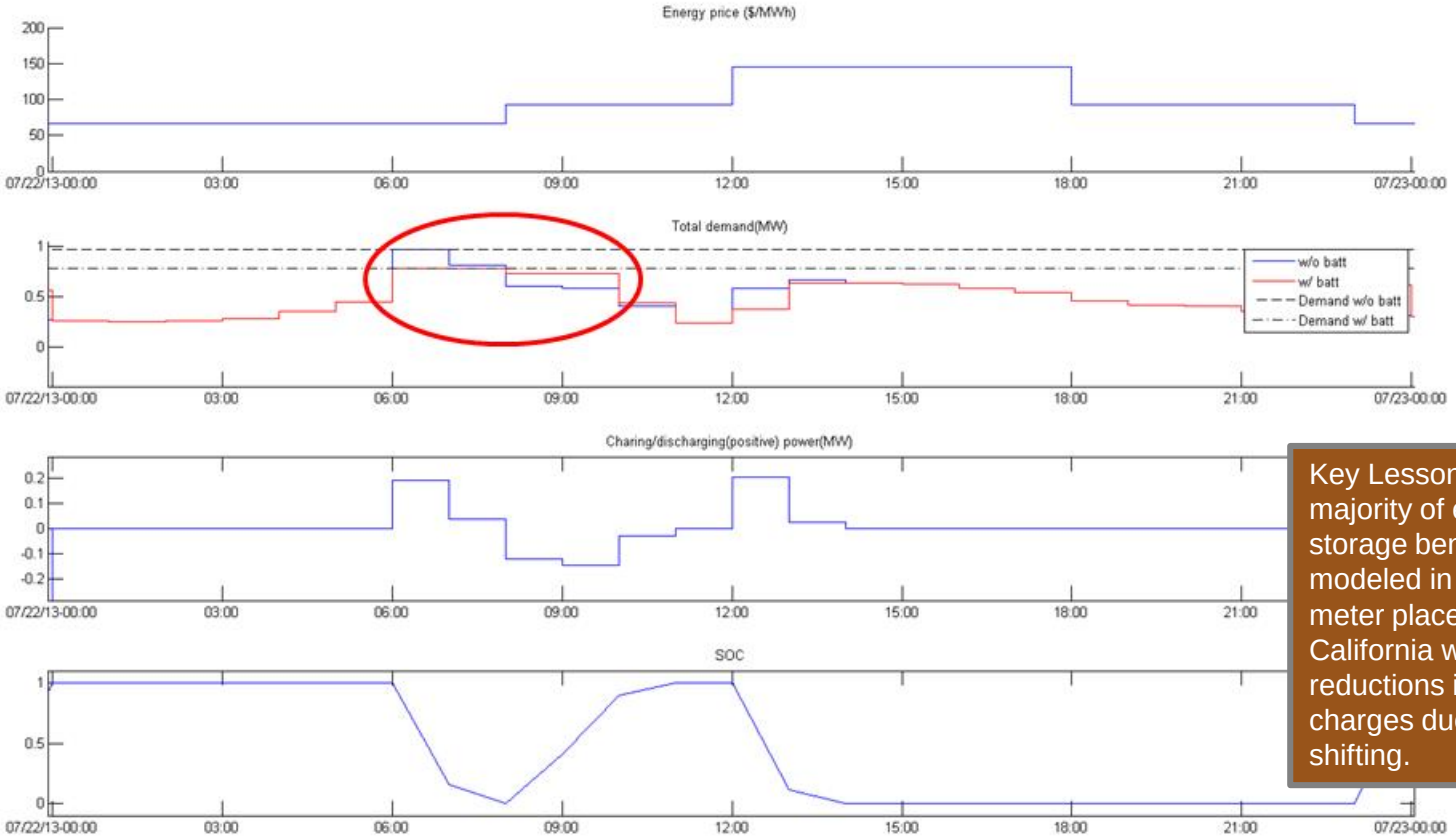
Microgrids


Project Economics
Customer
Developer
Timing
Energy Security
RE Goals
Project Economic Viability

Battery Storage Evaluation Tool – Behind-Meter User Interface



Battery Operation for An Illustrative Day



Key Lesson: The vast majority of energy storage benefits we modeled in behind-the-meter placements in California were tied to reductions in demand charges due to energy shifting.

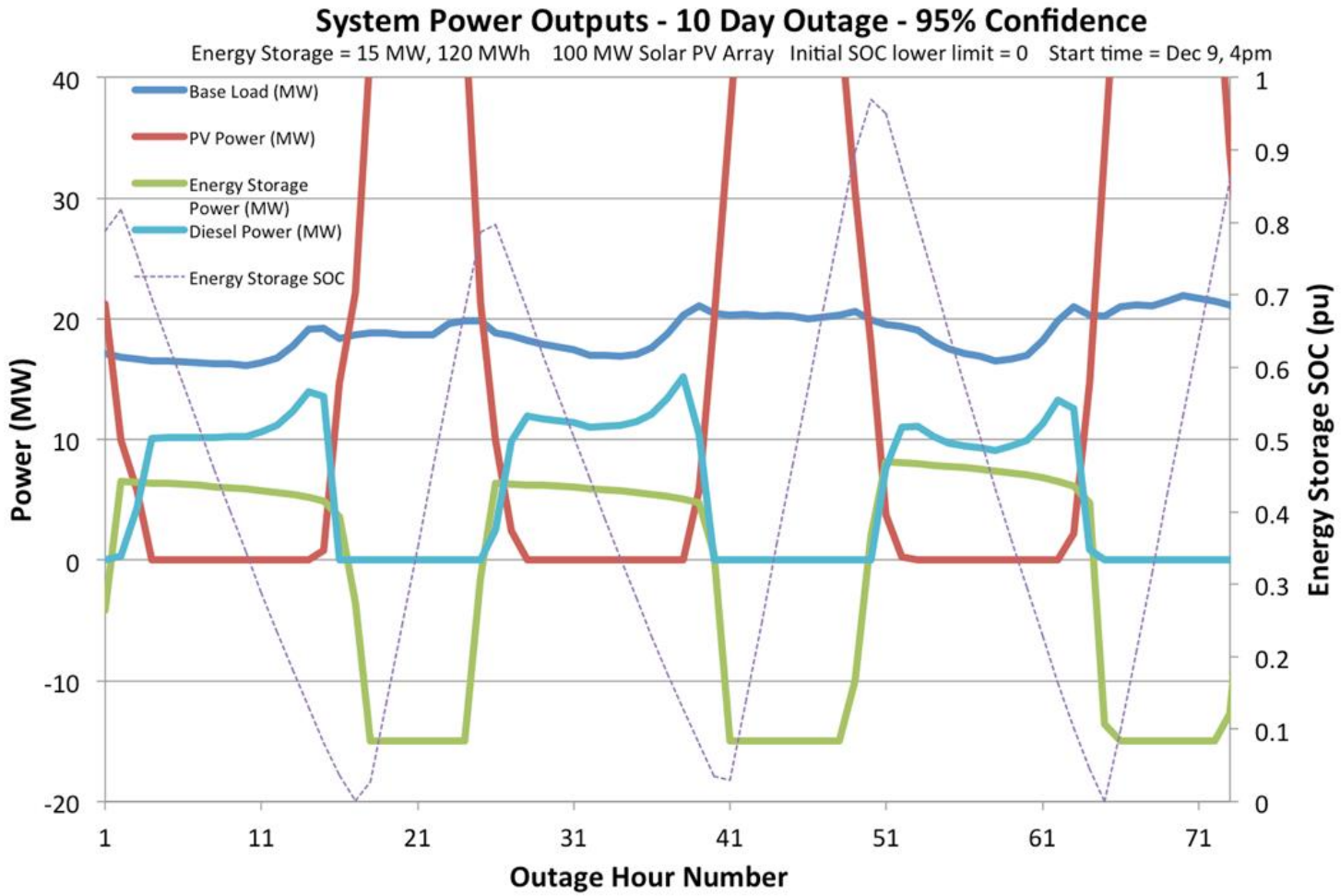
Outage Survivability Analysis

- Repeated analysis using randomized test conditions allows for exploration of performance for a given set of system specifications (photovoltaic [PV] and energy storage sizes)

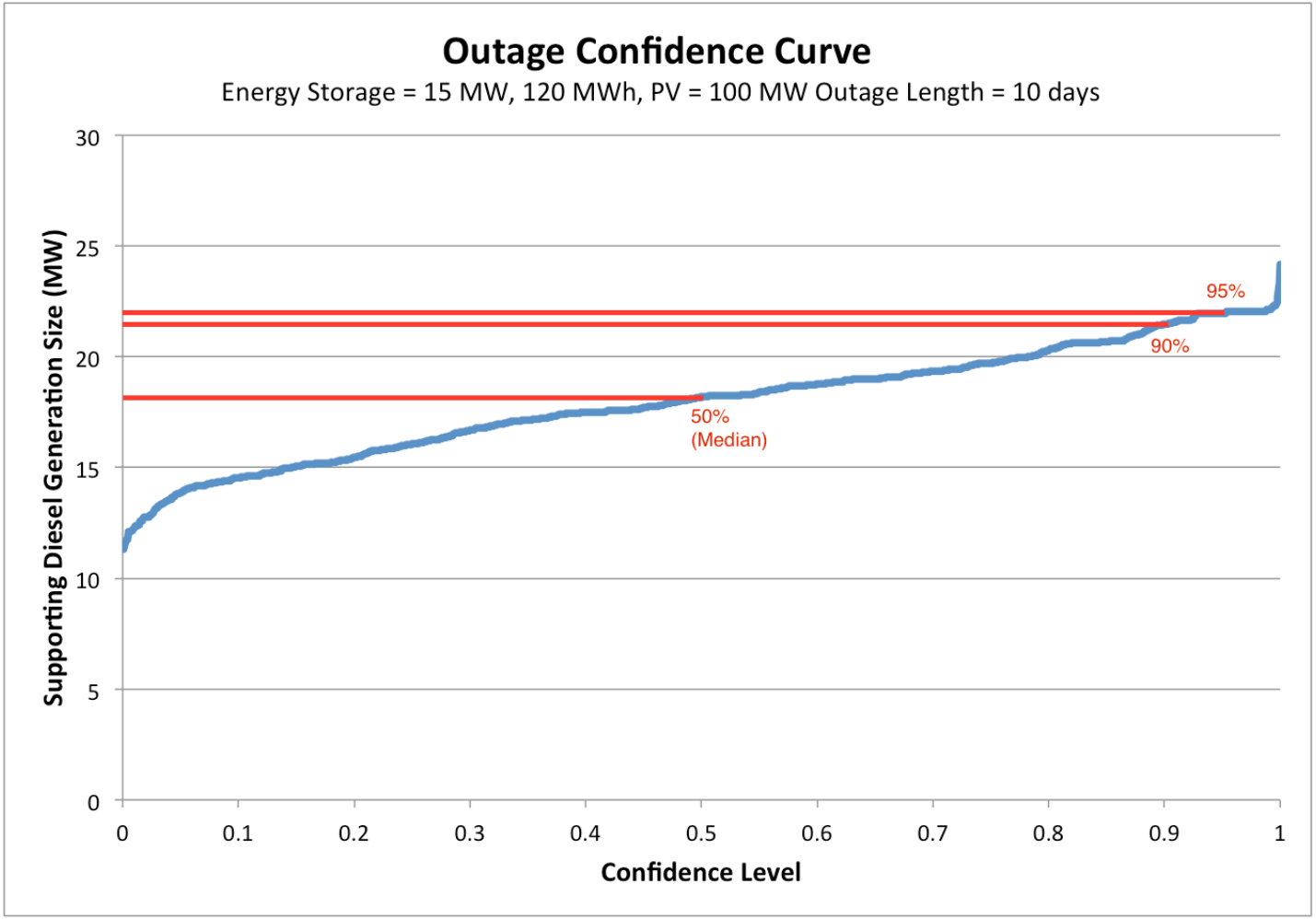
- Randomized inputs:
  - Analysis period start time
  - Hourly solar profile based on typical meteorological year (influenced by start time)
  - Energy storage initial state of charge

- We ran 1,000 cases for each system specification and reported diesel generation power required to meet load for 90%, 95%, 99%, and 100% of the cases.

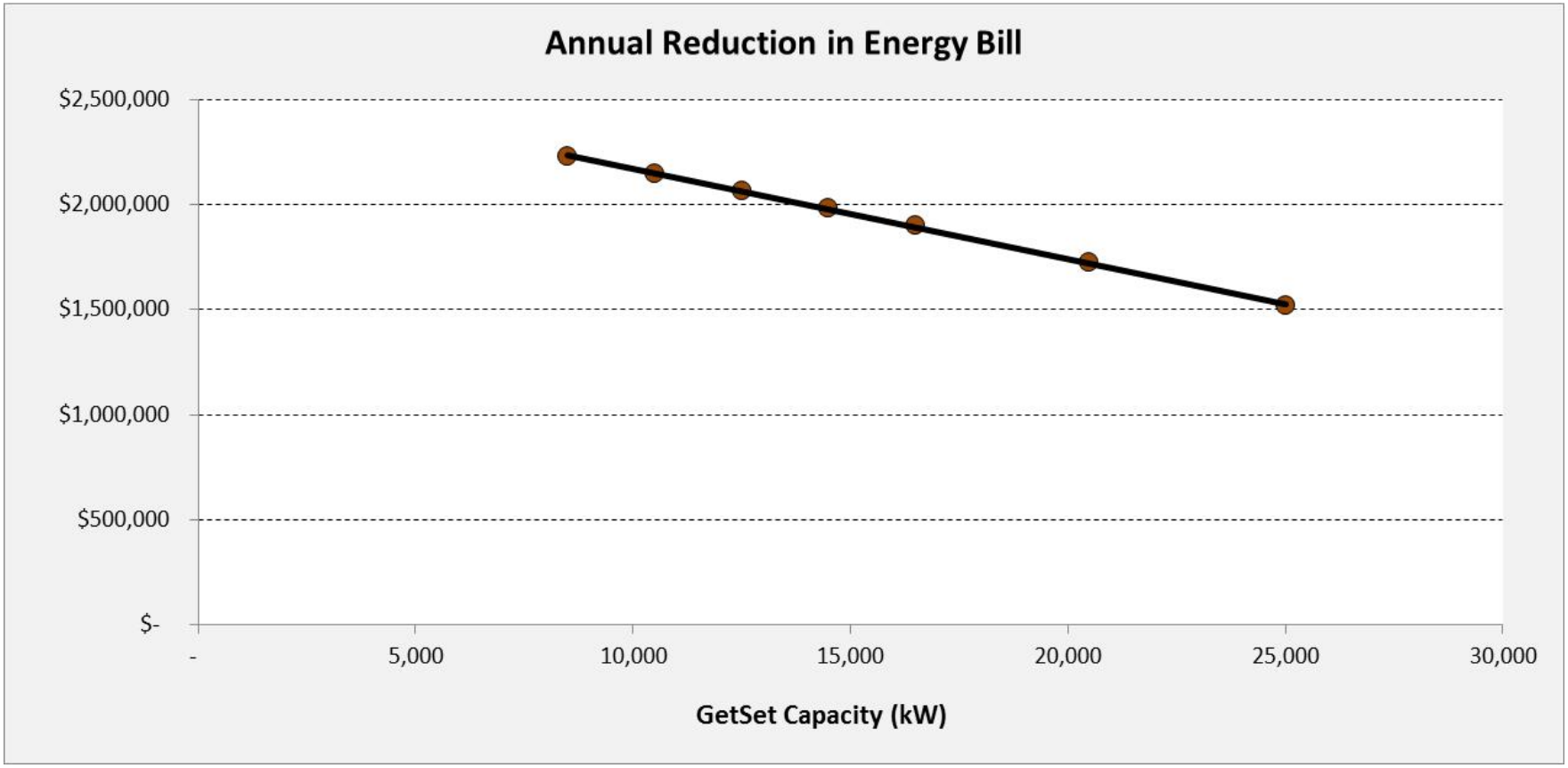
Prioritized Dispatch



Results – Ordered Minimum Generator Sizing



Reducing Gen Set Capacity to Upsize Energy Storage and PV Investment



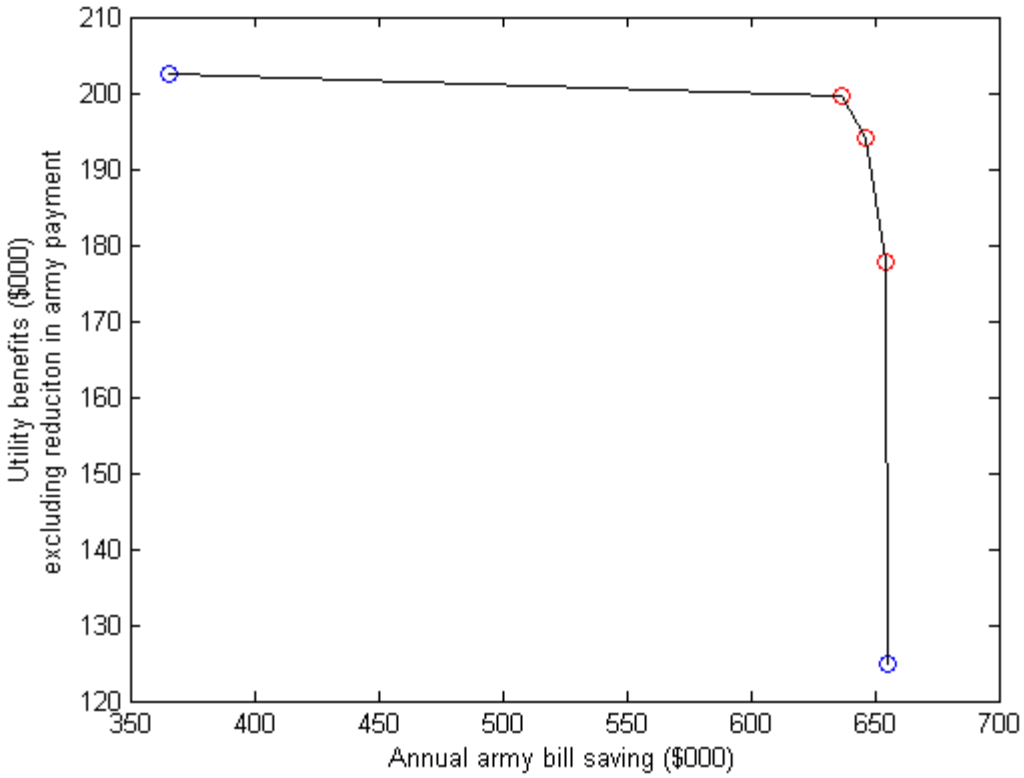
Methodology for Evaluating Tradeoffs between Multiple Parties

- Solving a multi-objective optimization problem is not as straightforward
- Scalarizing method: convert the original problem with multiple objectives into a single-objective optimization problem
- Linear scalarization: $\max \sum \omega_1 f_{Army}(x) + \omega_2 f_{Utility}(x)$

$$\begin{aligned} \text{s.t. } & \text{Battery operating constraints} \\ & \text{Behind meter service constraints} \\ & \text{Uitility service constraints} \\ \text{where } & \omega_1, \omega_2 \geq 0, \ \omega_1 + \omega_2 = 1 \end{aligned}$$

Exploring Tradeoffs between Operating Strategies (1.5 MW PV + 500 kW / 500 kWh Energy Storage System)

Key Point: Our approach can be used to assess tradeoffs based on different microgrid design and operating schedules.



Conclusions

- We have developed procedures to site and size energy storage systems and have made our tool (BSET) available for free licensing
- Dispatch control systems that optimize performance are required to advance ESS
- We are also testing ESS to evaluate performance and will be developing dispatch control algorithms as part of our Washington Clean Energy Fund engagement
- We have successfully built several microgrid benefits to the customer (energy charge reduction, demand charge reduction, and outage mitigation) and utility (regulation up, regulation down, capacity reserve, non-spin reserve, and arbitrage) into BSET
- We have modified BSET in order to optimize system deployment and assess tradeoffs between the utility and customer both in terms of alternative investment and operating strategies
- BSET can be used to optimize the power and energy capacities of the ESS given system costs/constraints and price signals
- Generators would be useful in mitigating demand charges if there were no emissions constraints; under current regulations, their only practical use is outage mitigation
- By minimizing purchases in generators, the microgrid can be optimally scaled to minimize operational costs.

Acknowledgements

- Support from US DOE Office of Electricity Delivery & Energy Reliability
  - Dr. Imre Gyuk, Energy Storage Program Manager

- Support from US Army Office of Energy Initiatives
  - Kathy Ahsing, Director, Renewable Energy Programs and Business Operations

- PNNL Contributors
  - Patrick Balducci
  - Dr. Di Wu
  - Dr. Trevor Hardy
  - Dr. Michael Kintner-Meyer
  - Dr. James Follum
  - Dr. Tao Yang

Pacific Northwest
NATIONAL LABORATORY