Overview of U.S. DOE Office of Electricity Energy Storage Program and PNNL Efforts

Vincent Sprenkle, Cary Bloyd
Pacific Northwest National Laboratory

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

Pacific Northwest
NATIONAL LABORATORY

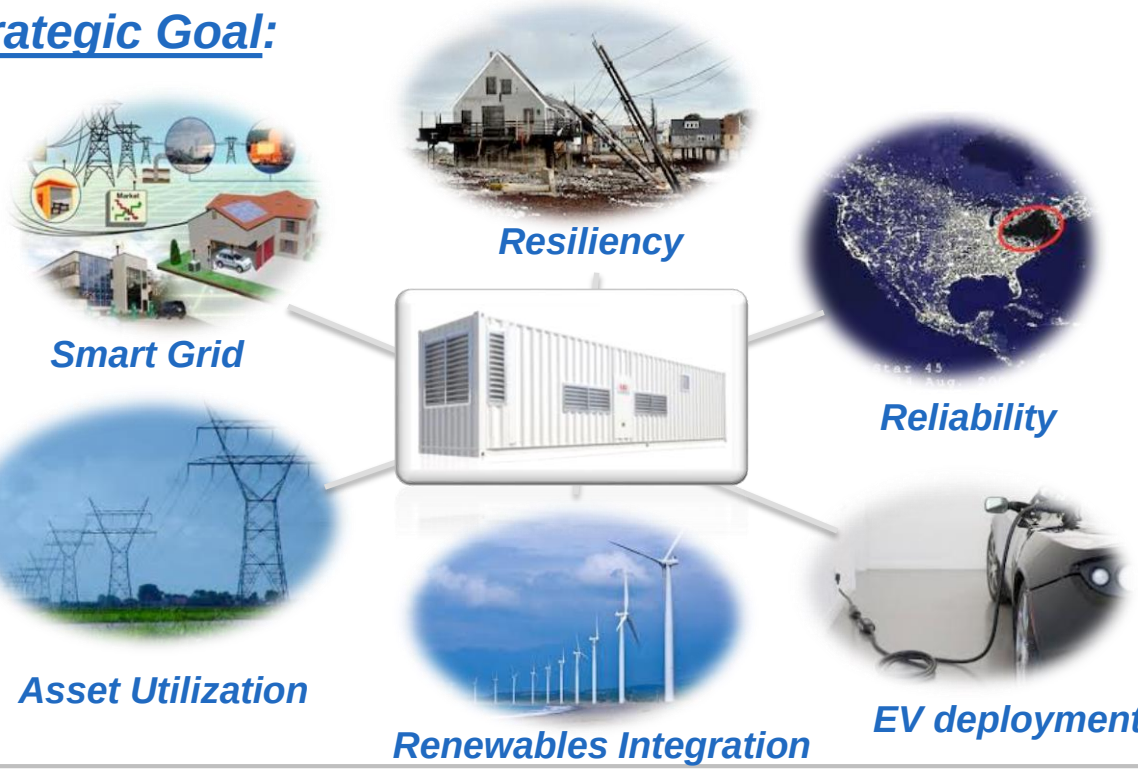
DOE OE Energy Storage Program

Challenges:

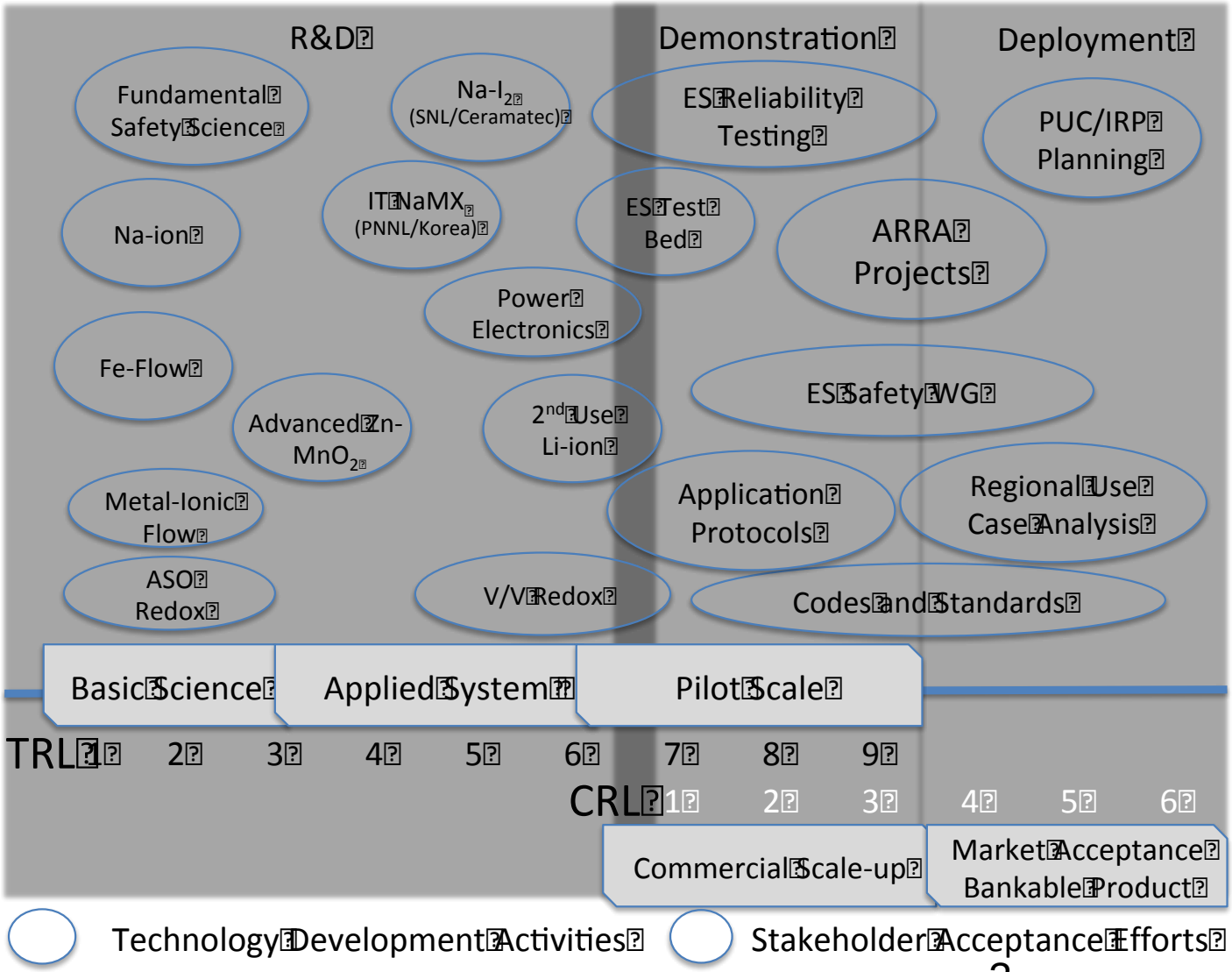
- **Cost competitive energy storage technologies**
  - Targeted scientific investigations of key materials and systems
- **Validated reliability & safety**
  - Independent testing of prototypic devices and understanding of degradation.
- **Equitable regulatory environment**
  - Enable Industry, Utility, Developer collaborations to quantify benefits provide input to regulators.
- **Industry acceptance**
  - Highly leverage field demonstrations and development of storage system design tools

Mission: To enable energy storage to provide multiple benefits for critical grid applications, DOE is accelerating adoption of energy storage through: improving the technology, field demonstrations, and innovative market design.

Strategic Goal:

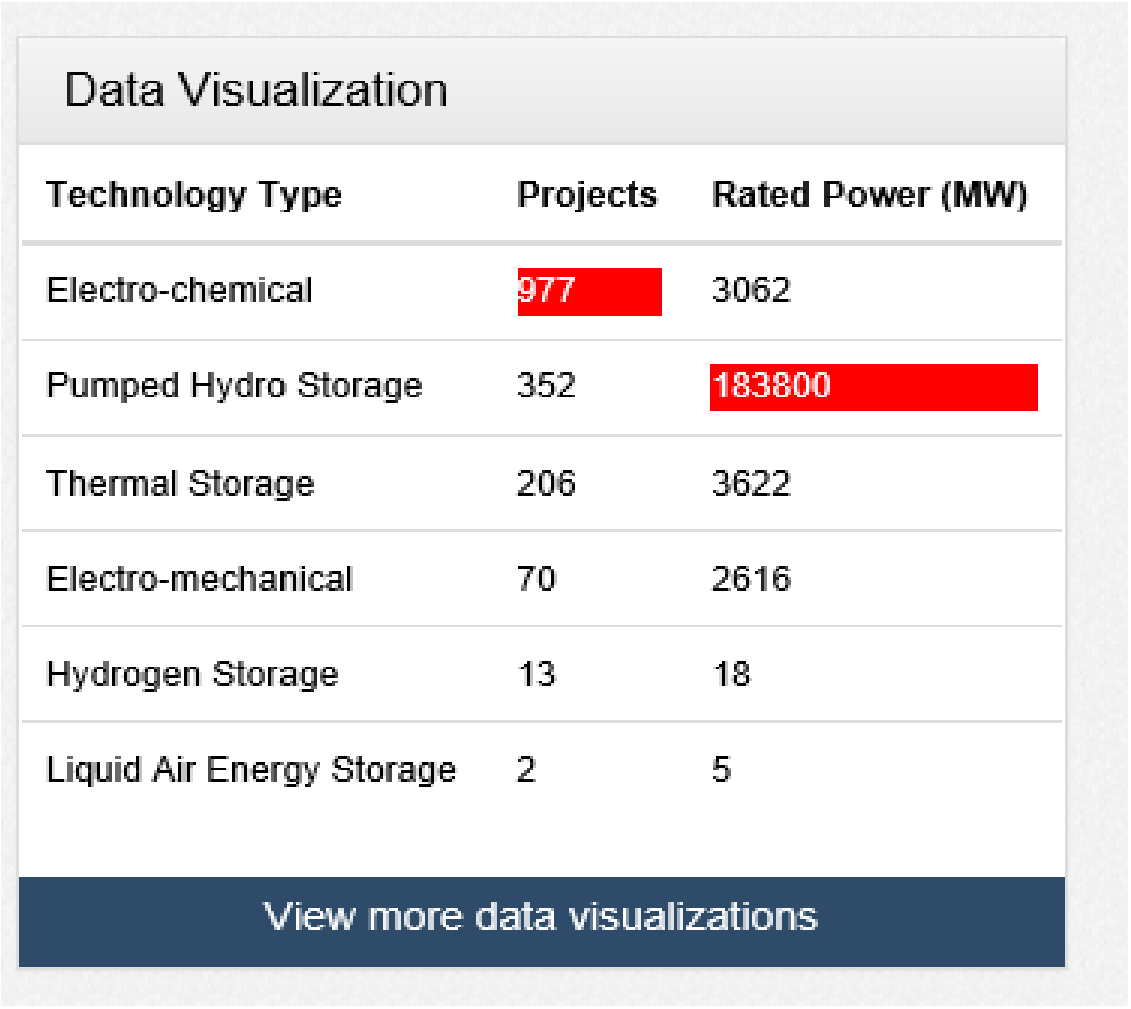


OE Energy Storage Program Activities



Coordinated effort between Sandia National Laboratories, PNNL, and ORNL

The U.S. DOE Global Energy Storage Database Provides Information on 1620 Projects Worldwide*



Data Visualization

Technology Type	Projects	Rated Power (MW)
Electro-chemical	977	3062
Pumped Hydro Storage	352	183800
Thermal Storage	206	3622
Electro-mechanical	70	2616
Hydrogen Storage	13	18
Liquid Air Energy Storage	2	5

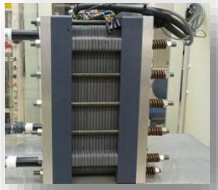
View more data visualizations

*http://www.energystorageexchange.org/

PNNL Role - OE Energy Storage Program

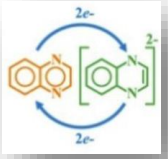
Cost Competitive Technologies

Vanadium Redox Flow Battery



- *Mixed acid increases T_{op} by 80%, energy density 70%.*
- *Additives for sulfate V/V shows similar T_{op}*
- *5X stack power without decreasing efficiency*

Aqueous Soluble Organic RFBs



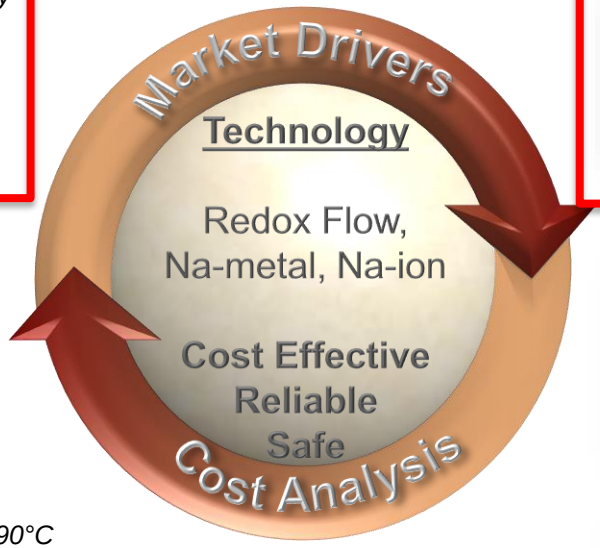
- *At higher performance levels, Vanadium 55% of cost.*
- *Developing engineered molecules that can be drop in replacement for V/V systems*

IT Sodium Metal Halide Batteries

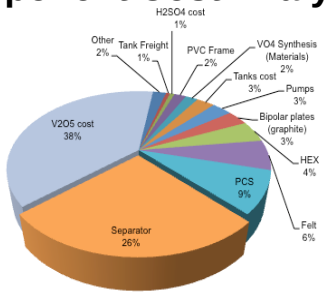
- *Decreased T_{op} from 350°C to 190°C improving lifetime.*
- *DOE-KETEP MOU to leverage PNNL IT chemistry with RIST/POSCO scale-up efforts.*

Sodium-ion Batteries

- *Analog to Li-ion utilizing existing production capabilities.*
- *Offers potential for longer cycle-life and lower cost.*



Component Cost Analysis



Market Acceptance

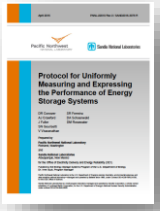
Storage use-case analysis

- *7MW/15MWh - WA CEF I*
- *EWEB – Eugene, OR (w/ Sandia)*
- *MA DOER - Northampton, MA*
- *WA CEF II (AVISTA, OPALCO) GMLC – PGE (Salem, OR), GMP (Rutland, VT), EPB (Chattanooga, TN), LMC (Los Alamos, NM)*

Safety Standards

- *Leading OE Safety Codes and Standards Working Group*
  - *CSR 101*
  - *CSR Inventory*
  - *ESS Compliance Guide*

ESS Performance Protocols

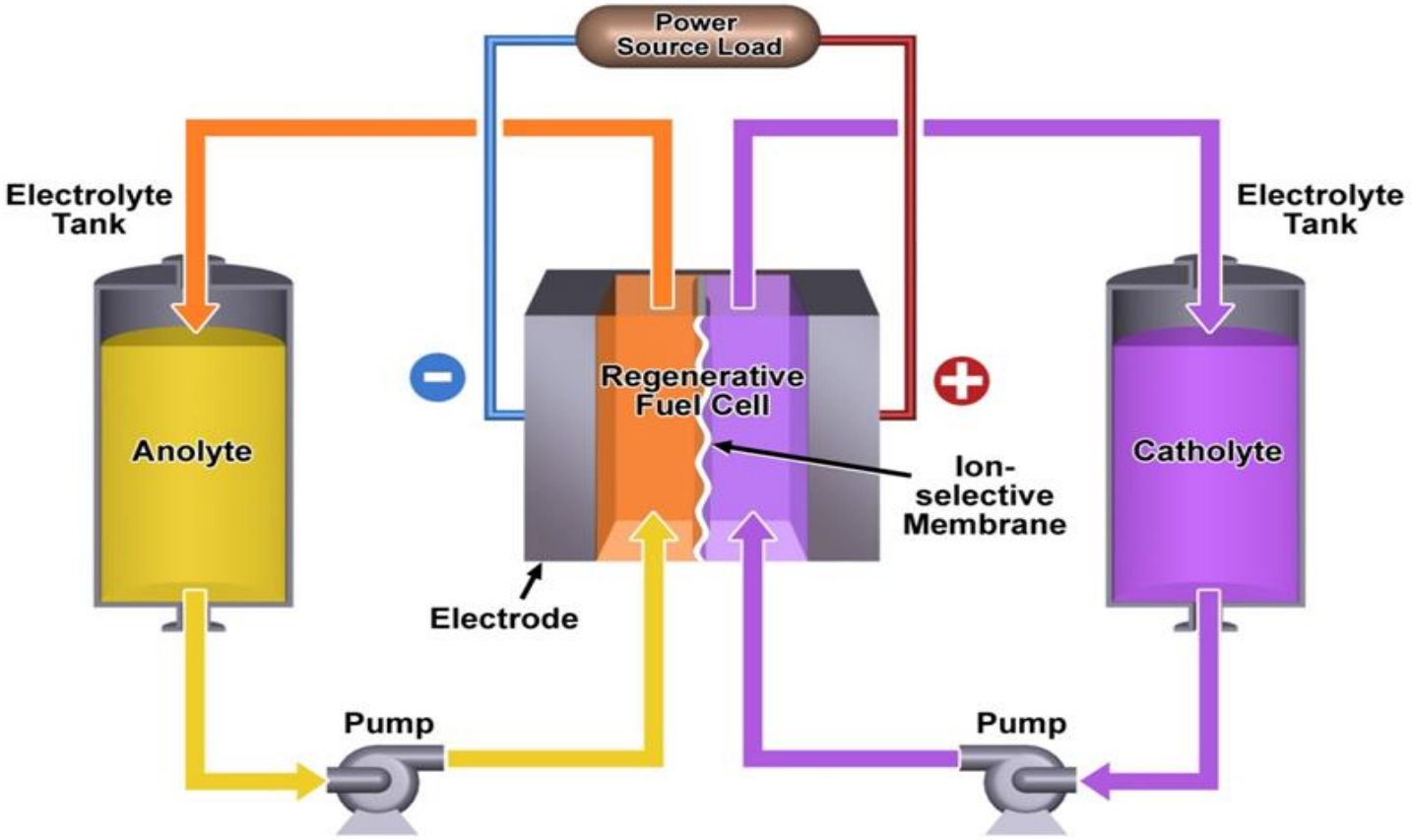


- *Rev 2 released April - 2016*
- *8 performance metrics developed for ESS Applications.*
- *International adoption TEC 120*
- *Basis for new standards from NEMA, IEE.*

Regulatory Support

- *PNW PUC Workshop July - 2015*
- *Supporting WA and OR dockets on ESS*
- *FERC engagement: barriers to bundled services, modeling cost-service tradeoffs.*

Why Redox Flow Battery?

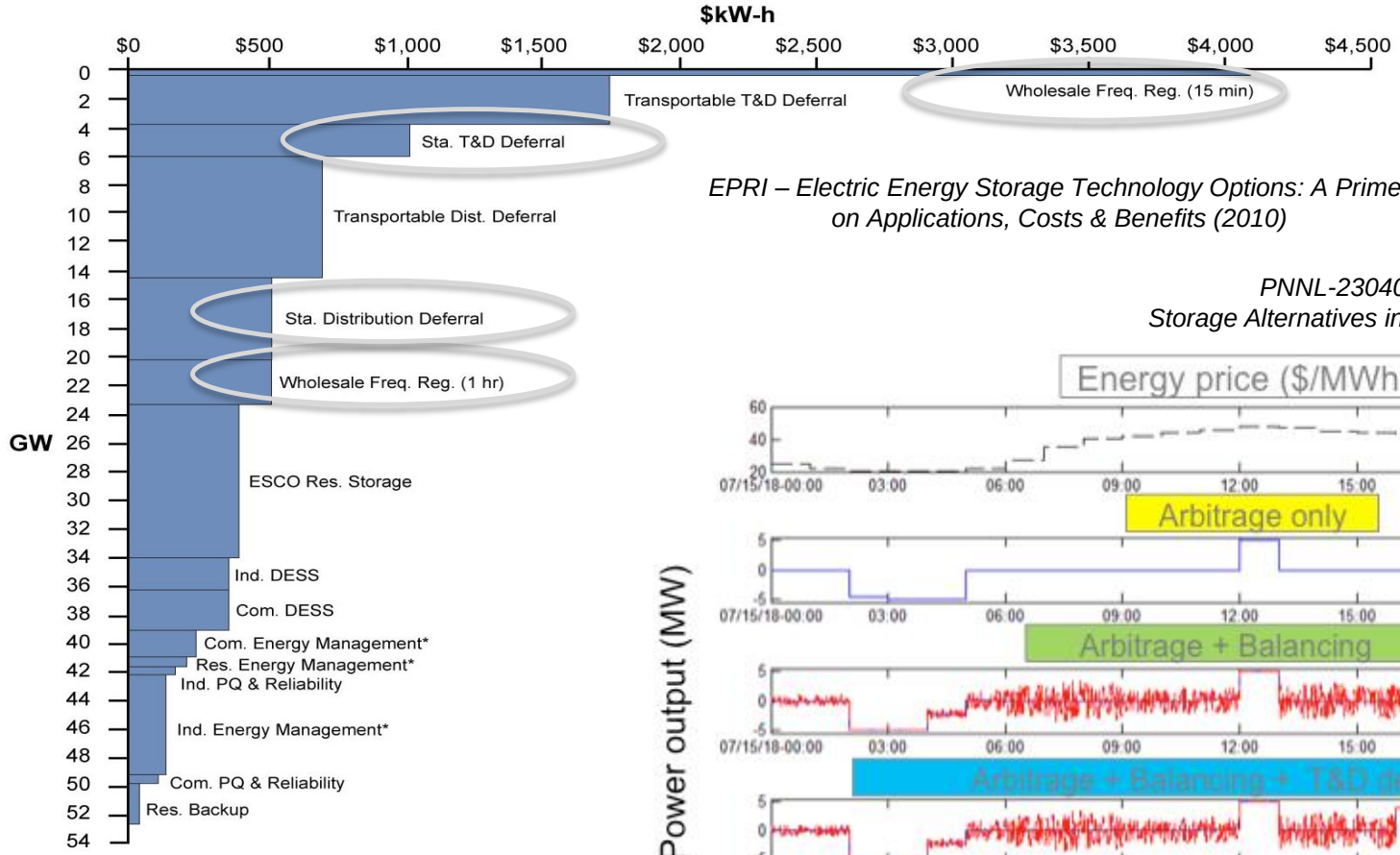


Key Aspects

- ***Power and Energy are separate enabling greater flexibility and safety.***
- Suitable for wide range of applications 10's MW to ~ 5 kw
- Wide range of chemistries available.
- Low energy density ~ 30 Whr/kg

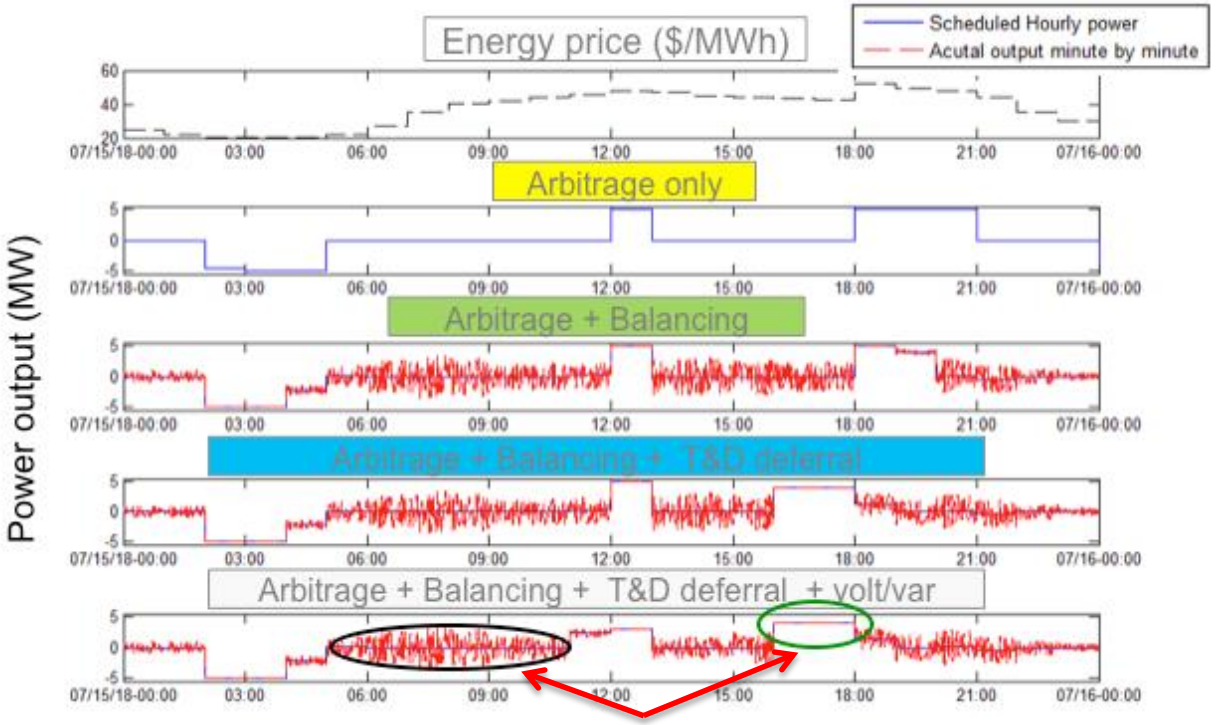
Pacific Northwest
NATIONAL LABORATORY

Grid Energy Storage Diverse Markets Encourage Bundling and Cost Reduction.



EPRI – Electric Energy Storage Technology Options: A Primer on Applications, Costs & Benefits (2010)

PNNL-23040 Assessment of Energy Storage Alternatives in the Puget Sound Energy System

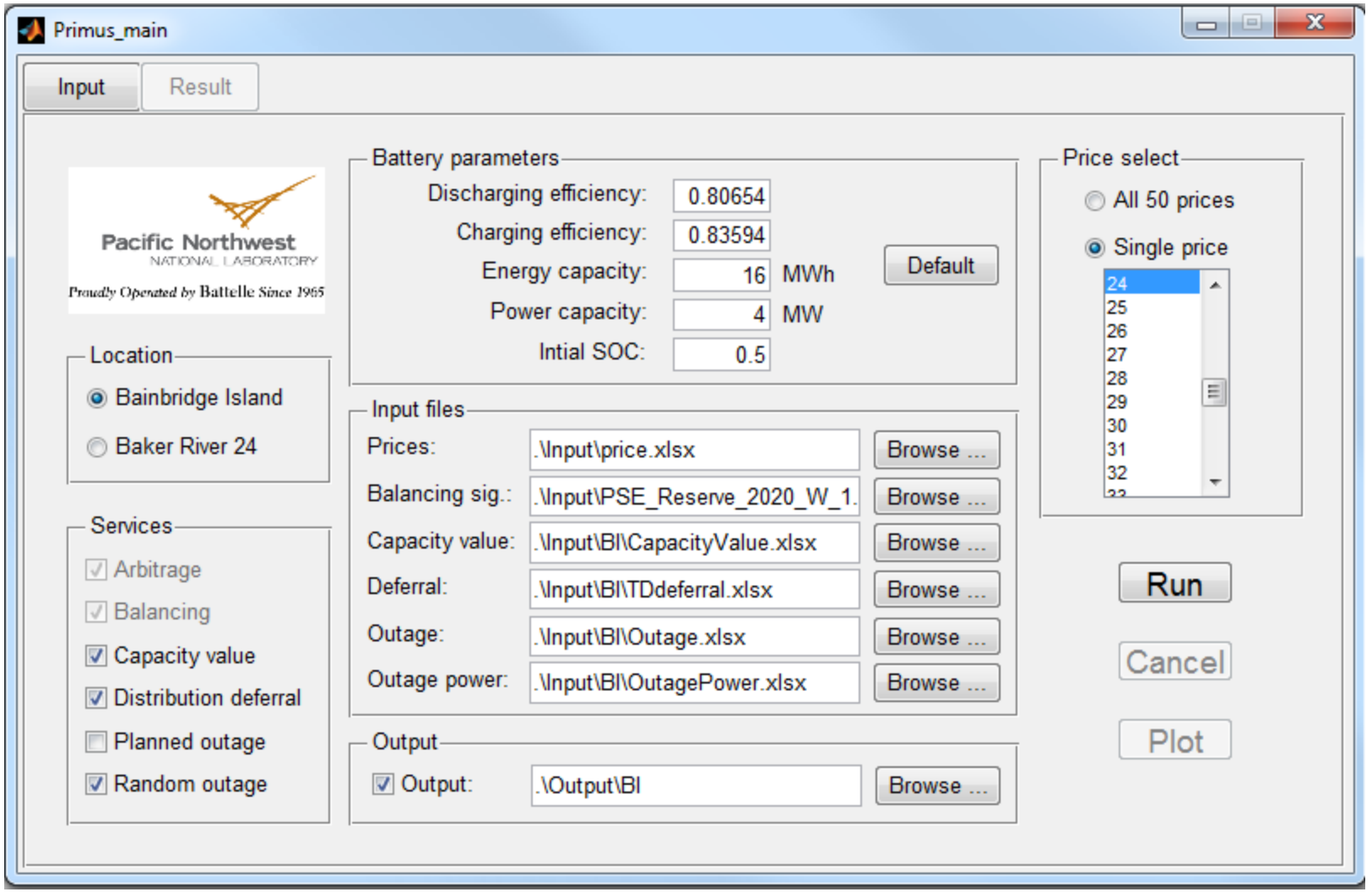


Want energy storage systems that can provide *for both*:

Faster response balancing services *and*

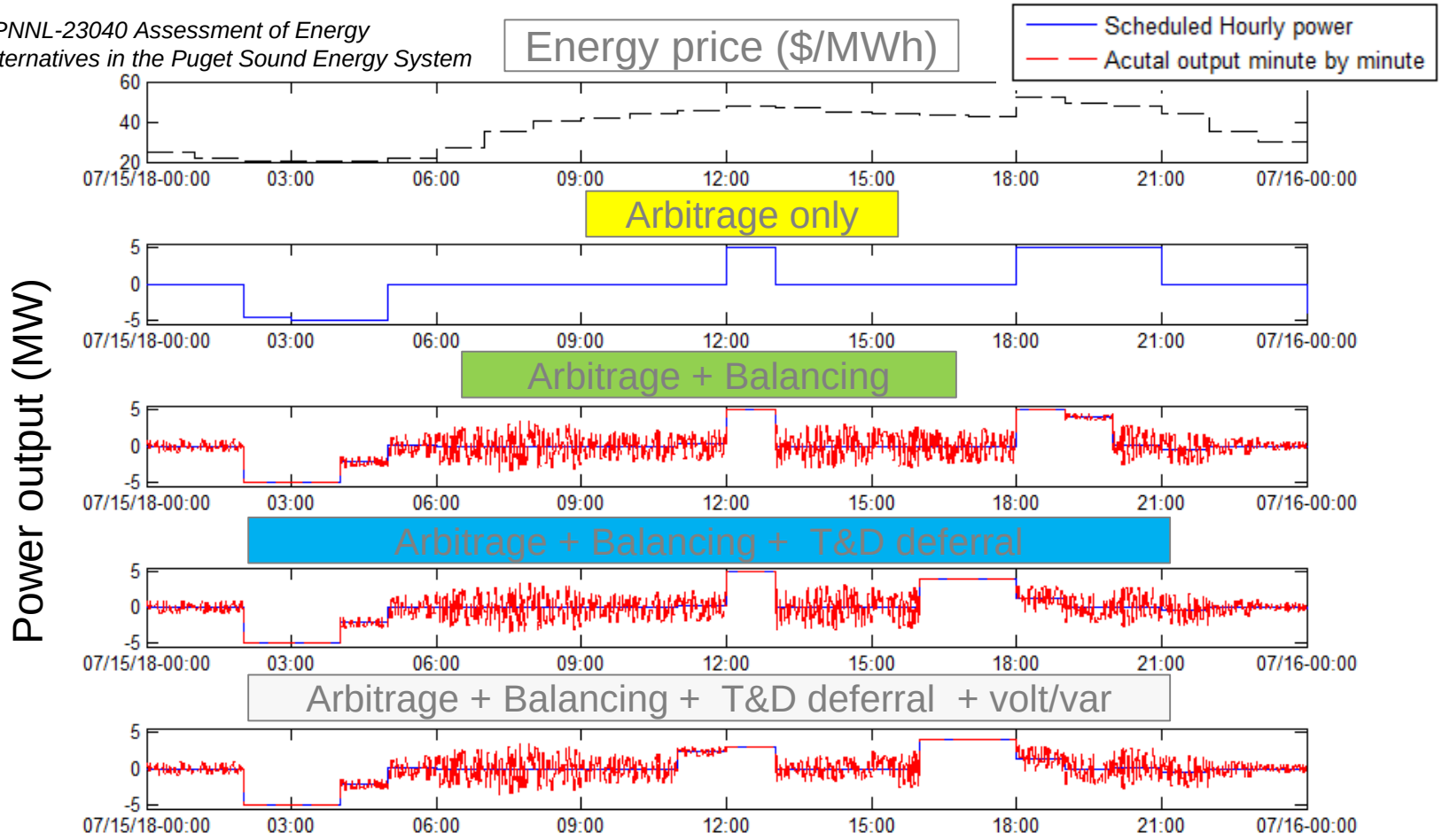
Longer duration (2^+ hr) deferral and outage mitigation.

Energy storage optimization tool



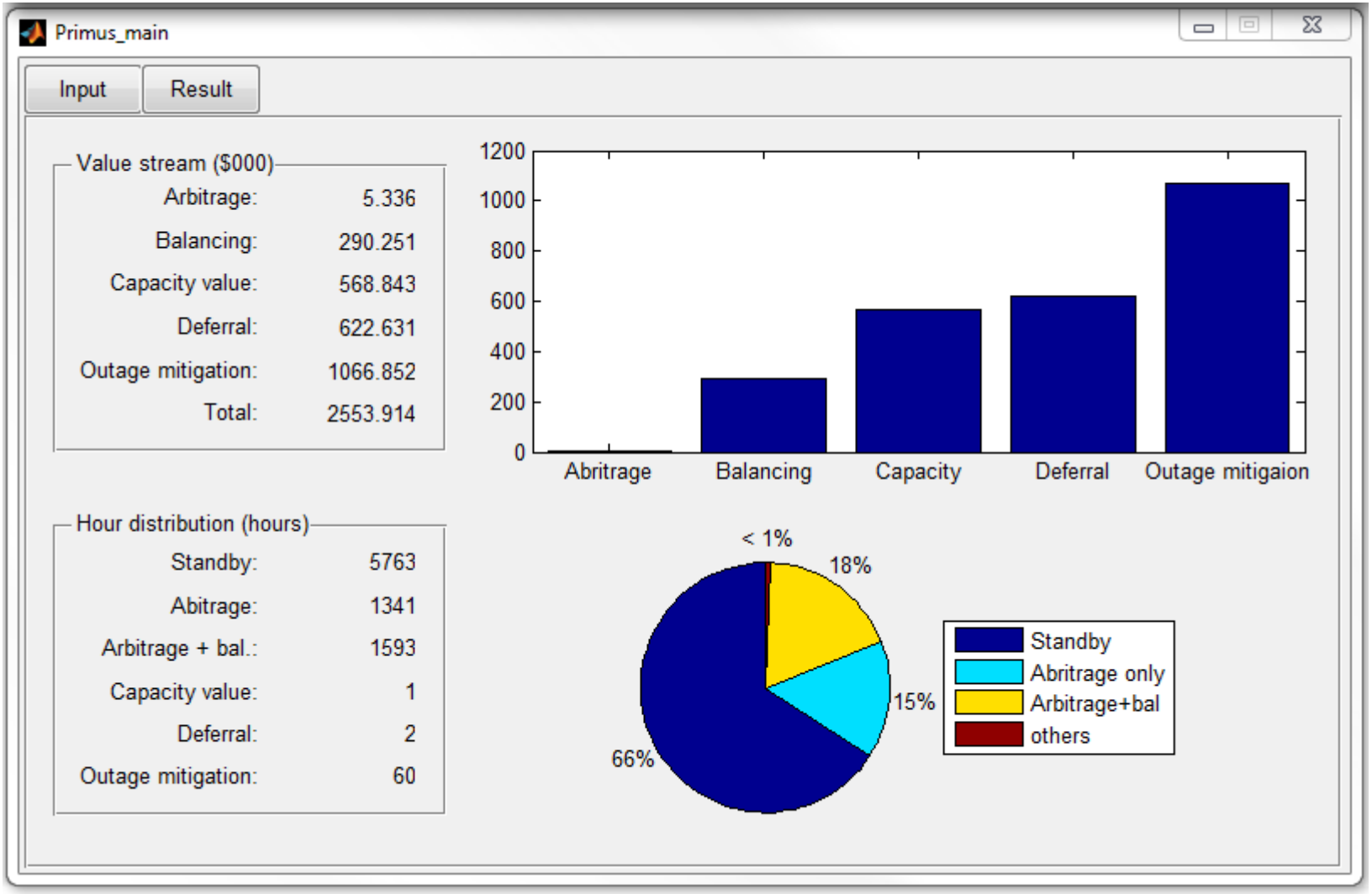
Energy Storage Bundled Services:

PNNL-23040 Assessment of Energy Storage Alternatives in the Puget Sound Energy System

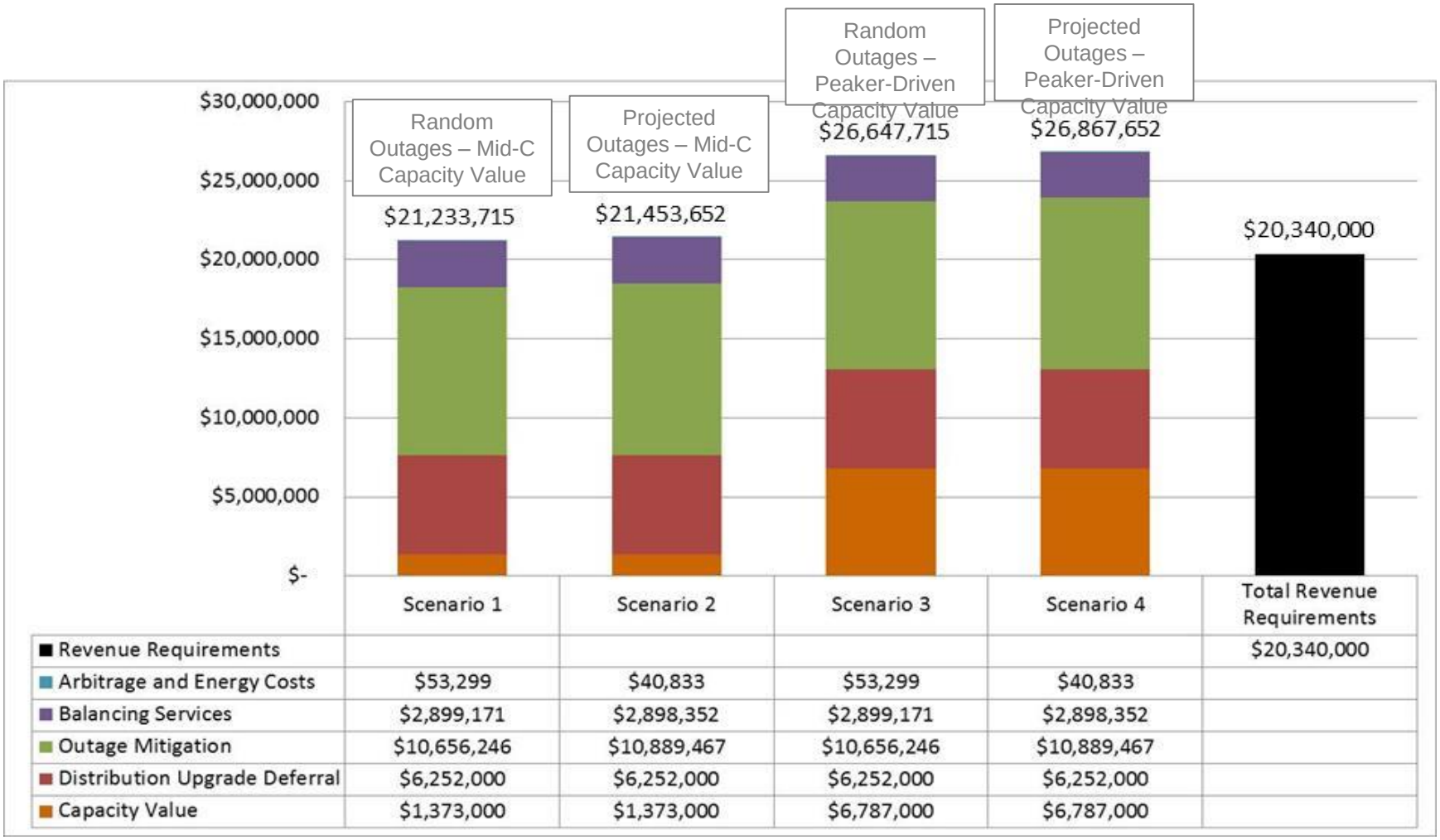


Pacific Northwest NATIONAL LABORATORY

Energy storage optimization tool output



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	

Energy storage provides multiple benefits

- Improved power quality and the reliable delivery of electricity to customers
- Improved stability and reliability of transmission and distribution systems
- Increased use of existing equipment, thereby deferring or eliminating costly upgrades
- Improved availability and increased market value of distributed generation sources
- Improved value of renewable energy generation
- Cost reductions through capacity and transmission payment deferral

Pacific Northwest
NATIONAL LABORATORY

Acknowledgements

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

Pacific Northwest
NATIONAL LABORATORY