



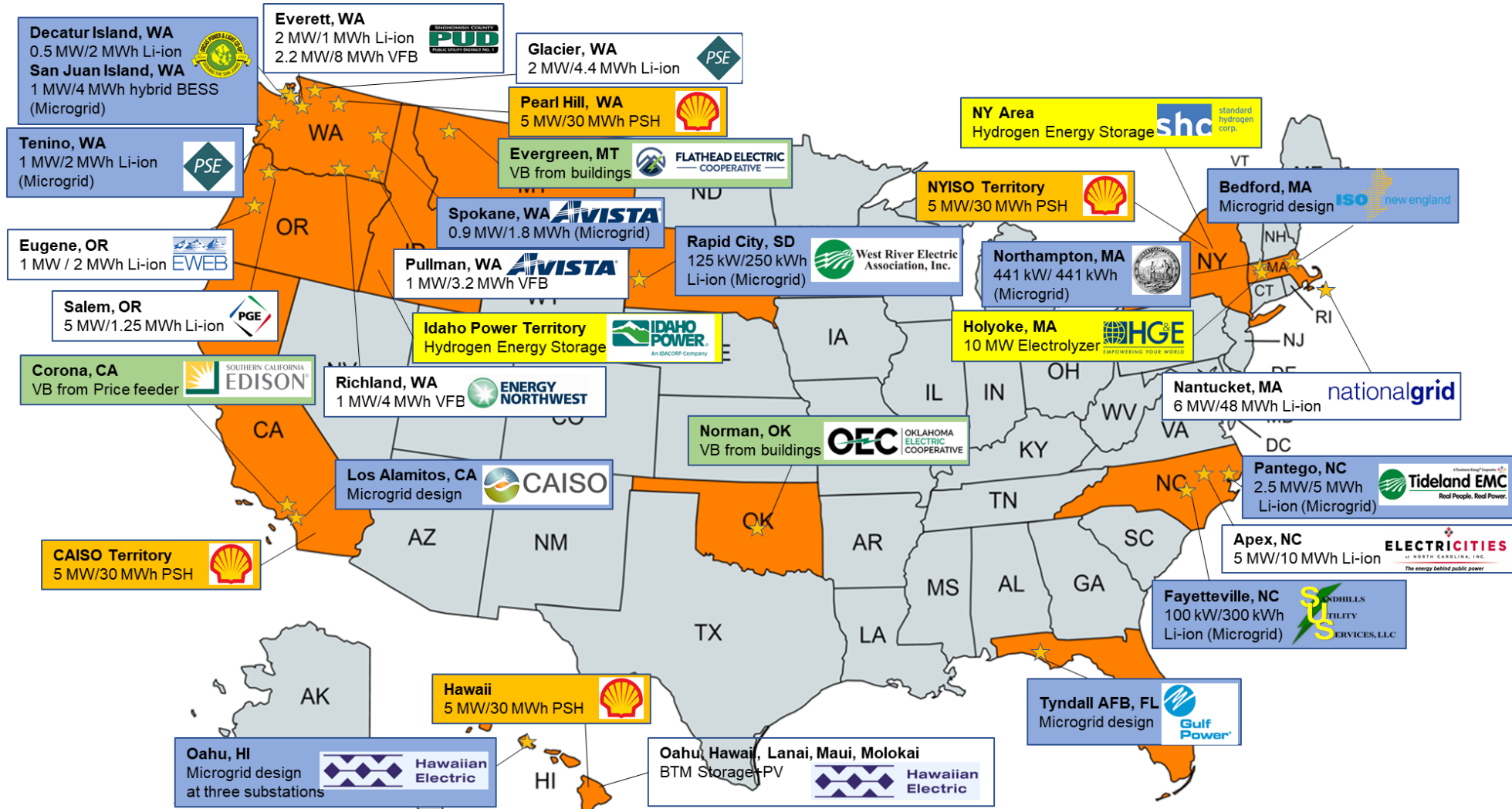
Energy Storage Modeling and Valuation Tools

Dexin Wang, Senior Research Engineer
Pacific Northwest National Laboratory

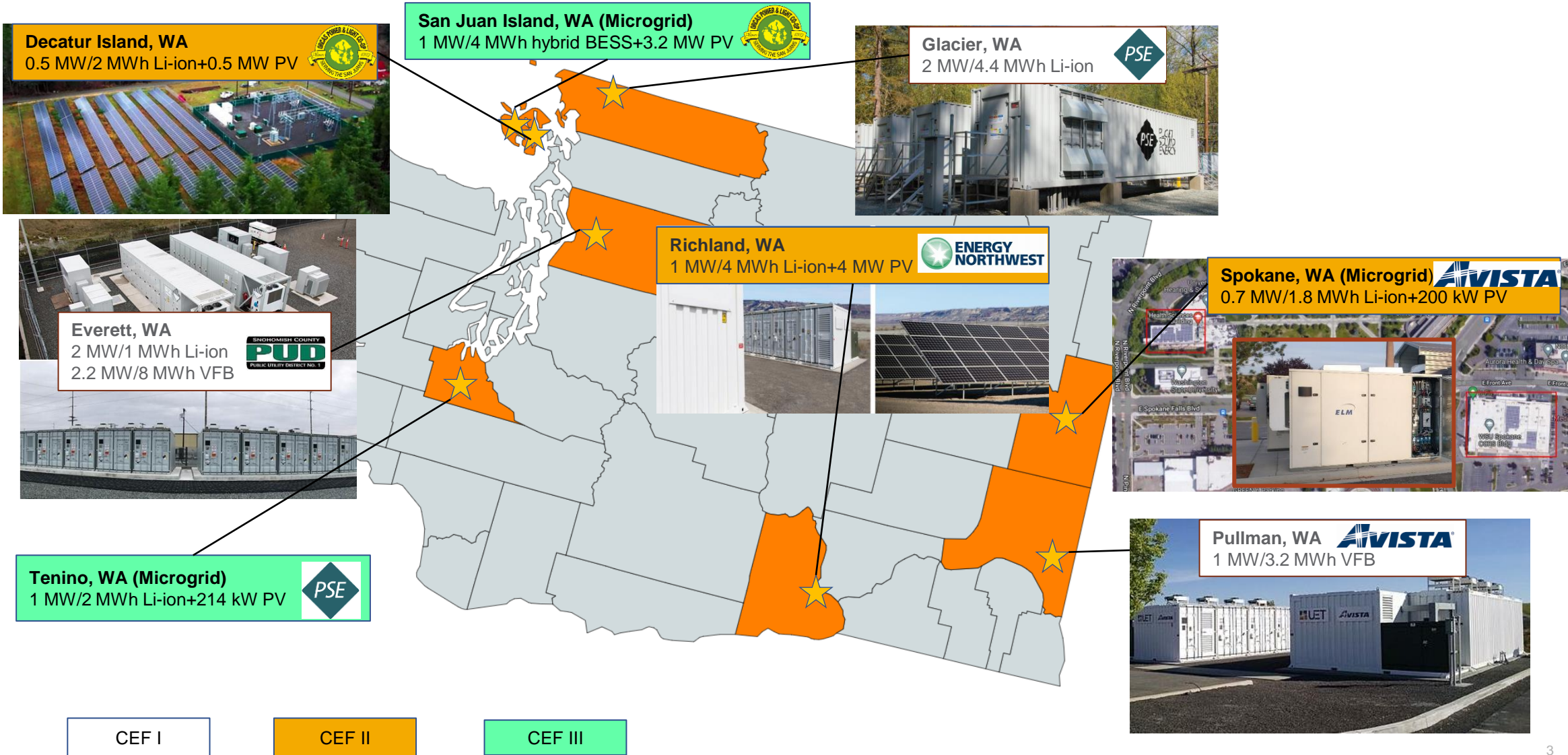
DOE Energy Storage Financing Summit
January 26th, 2023



PNNL Has Assessed Energy Storage and Microgrid Systems at More Than 30 Sites



Clean Energy Fund Grid Demonstration Projects



CEF I

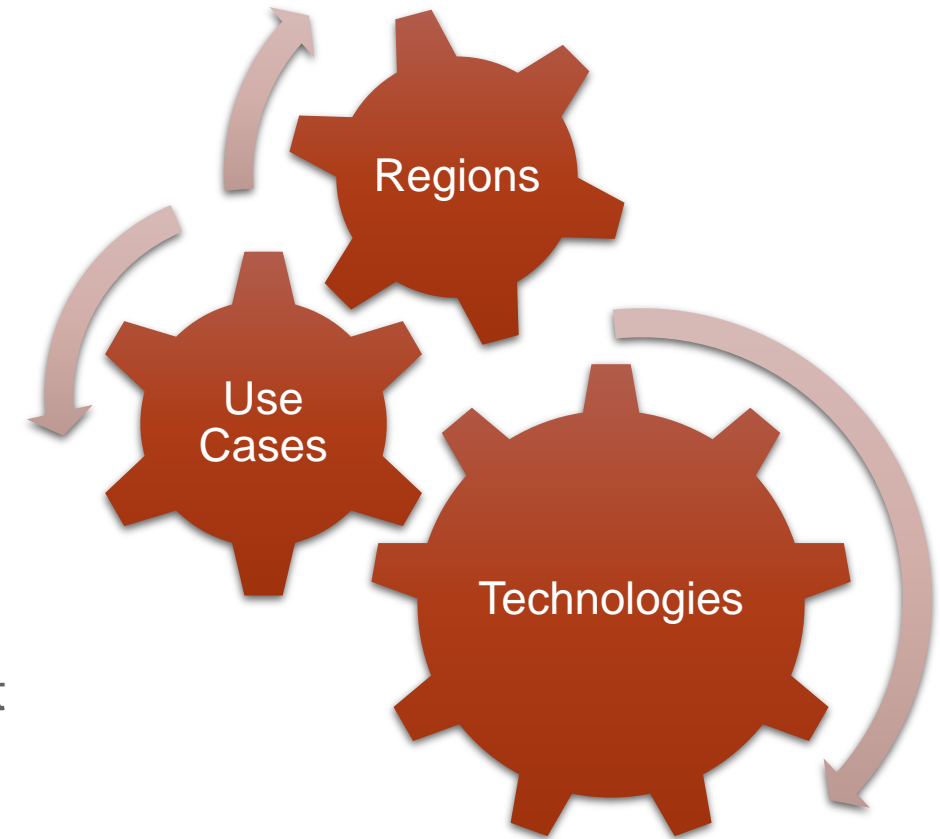
CEF II

CEF III

Needs of Energy Storage Analytics

Numerous Factors Affect Storage Valuation

- ESS physical capability
 - Energy storage technology, design, and characteristics
- Use cases
 - Vertically integrated utilities, electricity markets, distribution utilities, and large C&I customers
 - Bulk energy, ancillary service, transmission-level, distribution-level, and end-user services
- Regions and systems
 - Different generation mix, grid infrastructure, market structures/rules, distribution system capacity, and load growth rate



ESET™ Overview



A suite of applications that enable utilities, regulators, vendors, and researchers to model, optimize, and evaluate various energy storage systems for stacked value streams

- Battery Storage Evaluation Tool (BSET)
- Microgrid Asset Sizing considering Cost and Resilience (MASCORE)
- Virtual Battery Assessment Tool (VBAT)
- Pumped-Storage Hydropower Evaluation Tool (PSHET)
- Hydrogen Energy Storage Evaluation Tool (HESET)

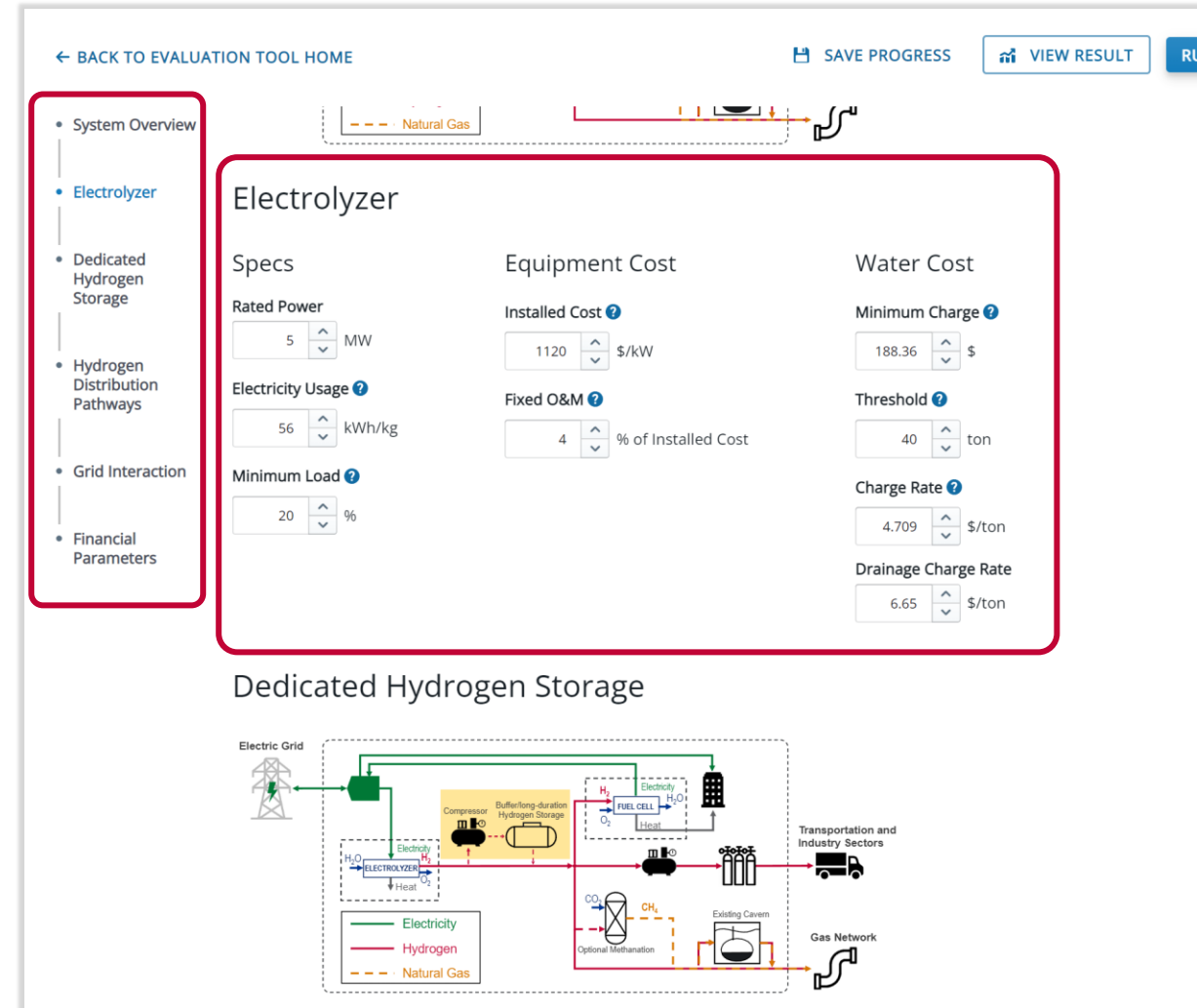


ESET Features

- **Various ESS models**
 - Different energy storage, hybrid, or microgrid systems
 - Appropriate levels of complexity and fidelity
 - Technical characteristics and physical capabilities
- **Advanced optimization and control methods**
 - Technically achievable benefits considering multi-dimensional couplings
 - Economic, environmental, and resilience
- **Built-in databases**
 - Electricity market prices
 - Utility rates
 - Renewables and building loads, and
 - Energy storage cost
- **Improved user experience design**

User Experience Enhancements

- Heuristic evaluation against web application usability principles
 - Home page
 - Navigation
 - Account management
 - Modules
- Improvements
 - Better visibility of system status
 - Better organization of information with visual hierarchy
 - More informative and useful feedback
 - More consistent visual cues across ESET
 - Improved aesthetics and minimalistic design
 - New features that support more flexible inputs and better presentation of results



The screenshot displays the 'Electrolyzer' configuration interface within the ESET tool. The interface includes a navigation sidebar on the left with options like 'System Overview', 'Electrolyzer', 'Dedicated Hydrogen Storage', 'Hydrogen Distribution Pathways', 'Grid Interaction', and 'Financial Parameters'. The main content area is titled 'Electrolyzer' and is divided into three columns: 'Specs', 'Equipment Cost', and 'Water Cost'. Each column contains several adjustable parameters with up/down arrows and question marks for help.

Specs	Equipment Cost	Water Cost
Rated Power: 5 MW	Installed Cost: 1120 \$/kW	Minimum Charge: 188.36 \$
Electricity Usage: 56 kWh/kg	Fixed O&M: 4 % of Installed Cost	Threshold: 40 ton
Minimum Load: 20 %		Charge Rate: 4.709 \$/ton
		Drainage Charge Rate: 6.65 \$/ton

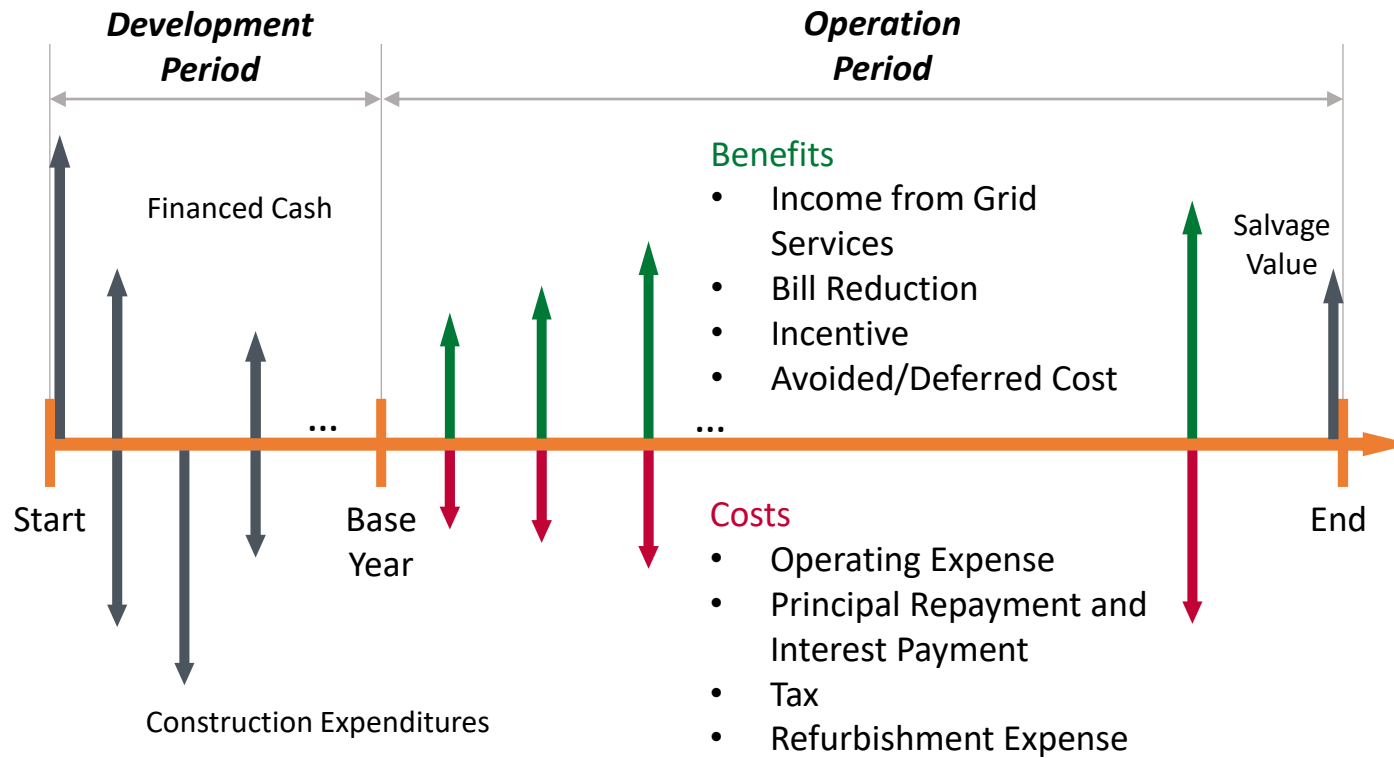
Below the configuration screen is a 'Dedicated Hydrogen Storage' flow diagram. It illustrates the integration of an electrolyzer, compressor, storage tank, and fuel cell, connected to an electric grid, a gas network, and transportation/industry sectors. The diagram uses color-coded lines: green for electricity, red for hydrogen, and orange for natural gas. Key components include an electrolyzer, compressor, buffer/long-duration hydrogen storage, fuel cell, and optional methanation process.

Integrated Databases

- ISO market prices, including NYISO, ERCOT, SPP, ISO-NE, and CAISO (in progress)
 - Energy – LMP
 - Ancillary services: regulation (up, down, and mileage), spin/non-spin reserve
- Utility rate structures
 - *The Utility Rate Database (URDB)* – 3,833 EIA-recognized utility companies
 - Energy and demand charges: flat, time-of-use, tiered
- Typical building load profiles
 - *Commercial and Residential Hourly Load Profiles for all TMY3 Locations in the United States* developed by NREL
- Detailed energy storage cost
 - *Energy Storage Cost and Performance Database* developed by PNNL

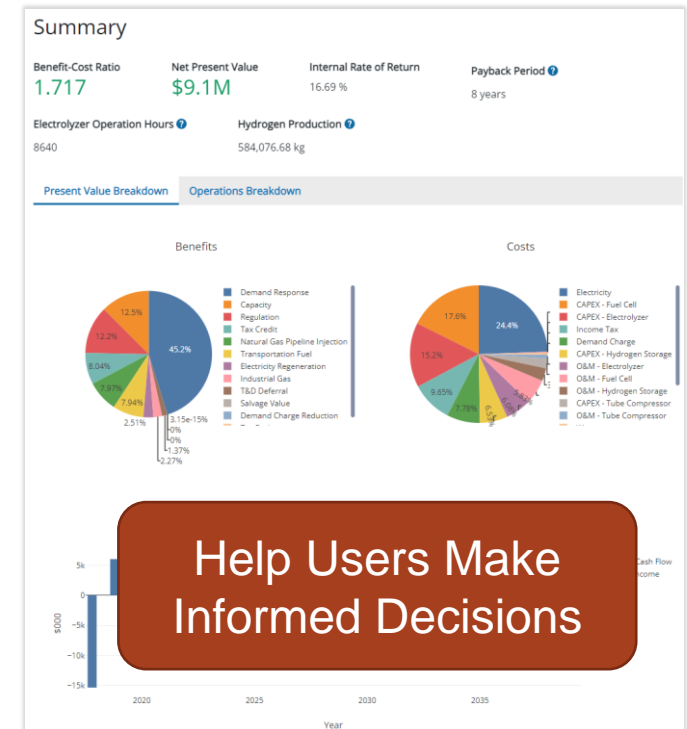
Comprehensive Cost-Benefit Analysis Engine

• Typical Cash Flow for ESS Projects



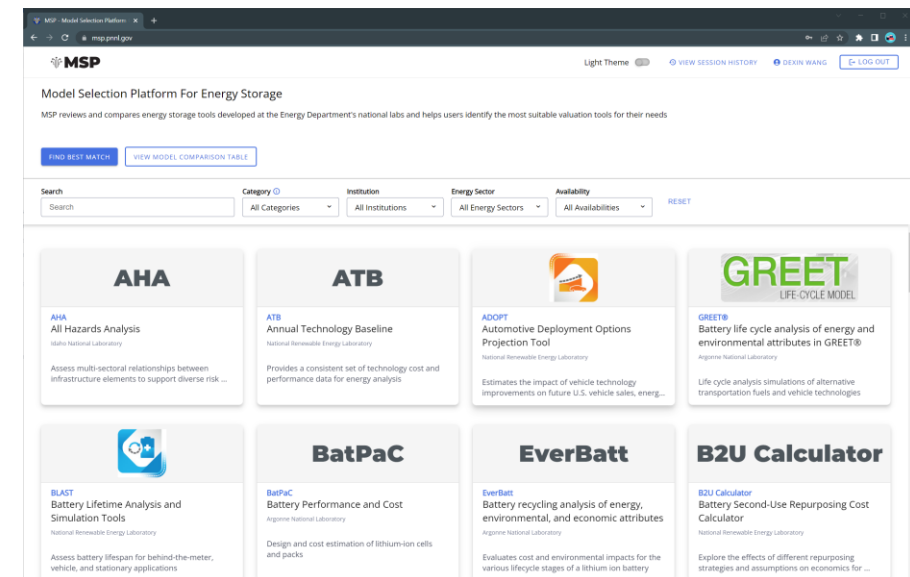
Results

- BCR, NPV, IRR
- Itemized PV Benefits and Costs
- Net income over time
- Free cash flow over time



Model Selection Platform for Energy Storage

- Not easy to tell
 - How are they different in terms of functionalities and capabilities?
 - Which one should I choose?
- MSP reviews and compares a list of tools and suggests the best-suited tools based on users' needs and requirements
- The core of MSP selection wizard is based on:
 - Specification discovery procedure
 - Scoring engine
- Progress in the last year
 - Includes 64 tools (up from 5 in previous release)
 - Production cost modeling (PCM) tools in selection wizard and comparison table

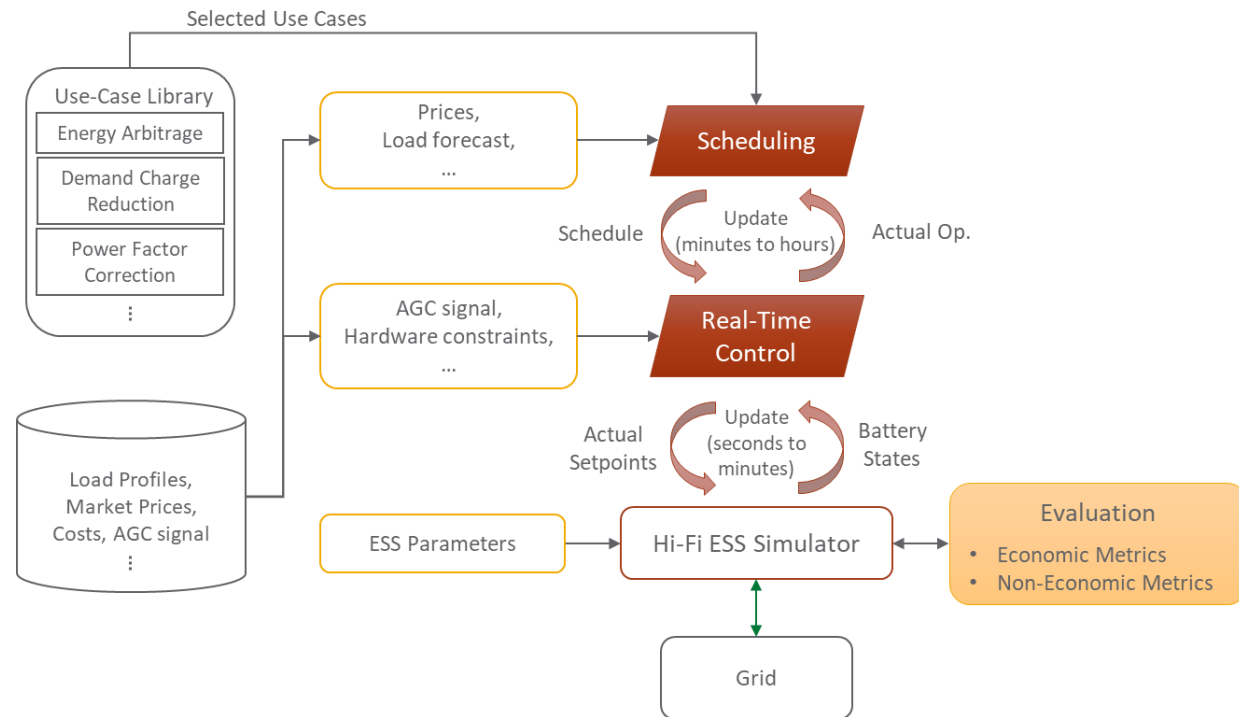


<https://msp.pnnl.gov>

ES-Control

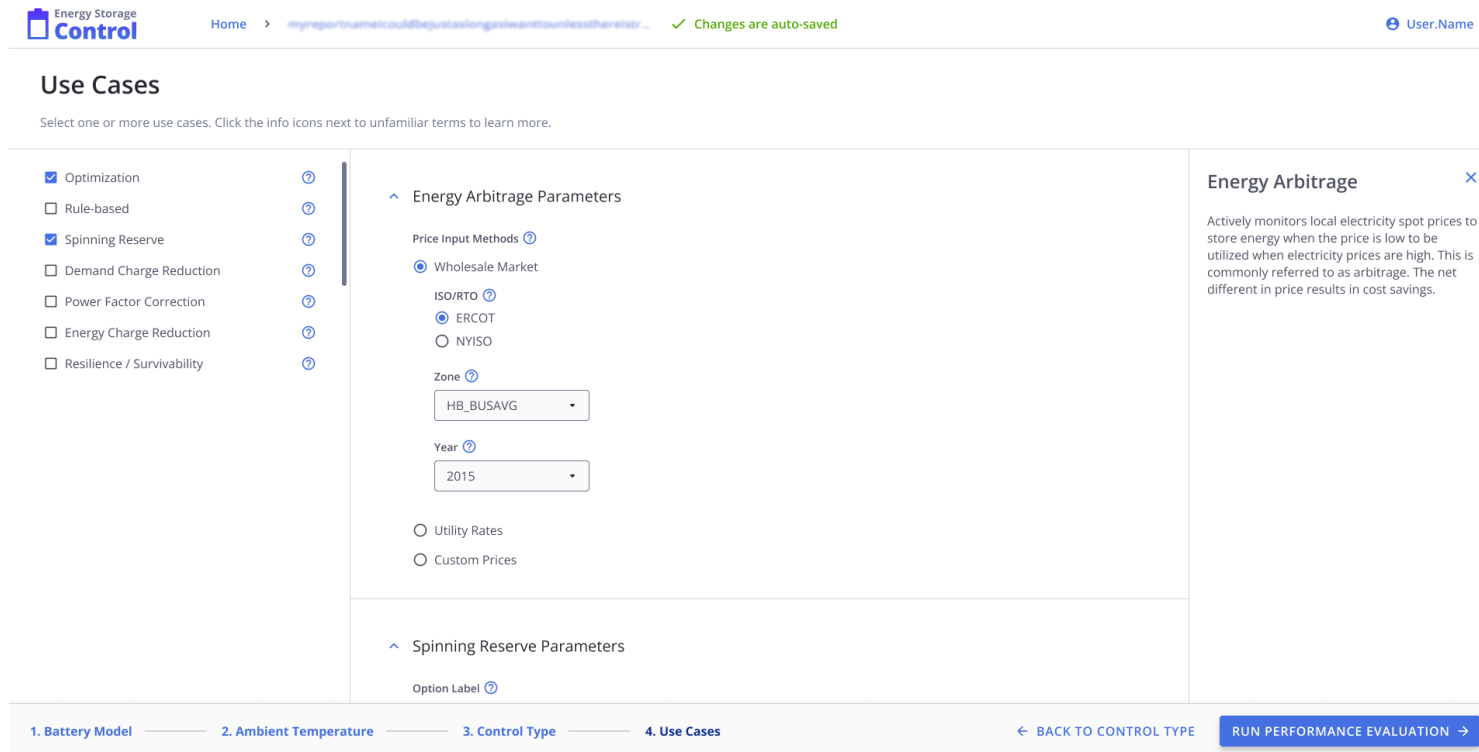
ES-Control is a platform for evaluation and testing of energy storage control strategies and algorithms with diversified time scales in a realistic setting, considering deployment options, use cases, and applications.

- Sandbox environment for modeling, control, simulation, and evaluation
- Representative built-in control strategies with adjustable parameters
- Open API for customized control
- Diversified energy storage models with different levels of complexity and fidelity
- Built-in database of energy storage costs, market prices, utility tariffs, etc.



ES-Control (cont.)

- A web-based application
- Microservices architecture for rapid iteration and scalability
- Off-the-shelf AWS services for fast development and industry standard security



The screenshot shows the ES-Control web application interface. At the top, there is a navigation bar with the "Energy Storage Control" logo, a breadcrumb trail "Home > myreportnamecouldbejustaslongaswewanttoincludehere", a status indicator "Changes are auto-saved", and a user profile "User.Name". Below the navigation bar is a "Use Cases" section with the instruction "Select one or more use cases. Click the info icons next to unfamiliar terms to learn more." A list of use cases is shown on the left, with "Optimization" and "Spinning Reserve" selected. The main content area is divided into two sections: "Energy Arbitrage Parameters" and "Spinning Reserve Parameters". The "Energy Arbitrage Parameters" section includes "Price Input Methods" (Wholesale Market selected), "ISO/RTO" (ERCOT selected), "Zone" (HB_BUSAVG), and "Year" (2015). The "Spinning Reserve Parameters" section includes "Option Label". On the right side, there is a "Energy Arbitrage" panel with a close button and a description: "Actively monitors local electricity spot prices to store energy when the price is low to be utilized when electricity prices are high. This is commonly referred to as arbitrage. The net different in price results in cost savings." At the bottom, there is a progress bar with four steps: "1. Battery Model", "2. Ambient Temperature", "3. Control Type", and "4. Use Cases". Navigation buttons include "← BACK TO CONTROL TYPE" and "RUN PERFORMANCE EVALUATION →".

Conclusions and Future Work

- System design and project development require appropriate energy storage models with a good balance between fidelity and complexity
- Advanced modeling and analytical methods and tools are required to define technically achievable benefits
 - Integrated forecasting and stochastic dispatch for modeling and addressing uncertainties
 - Ensemble machine learning for enhanced long-duration energy storage scheduling
 - Risk-aware scheduling to better balance economic and resilience benefits
- Additional research is needed to properly select, size, and value storage with different durations for future decarbonized grid
 - Electrification of transportation, building, and industry
 - Extreme weather conditions
 - Policy design and incentive mechanisms

Acknowledgments

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Mission – to ensure a resilient, reliable, and flexible electricity system through research, partnerships, facilitation, modeling and analytics, and emergency preparedness.

<https://www.energy.gov/oe/activities/technology-development/energy-storage>

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Jeremy Berke



Thank You

Dexin Wang

dexin.wang@pnnl.gov

(509) 372-6231

<https://www.pnnl.gov/energy-storage>

<https://eset.pnnl.gov/>

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