Pacific Northwest
NATIONAL LABORATORY

Energy Storage Evaluation Tool (ESET™)

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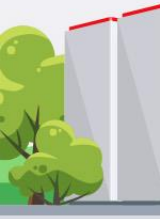
ENERGY STORAGE PROGRAM

U.S. DEPARTMENT OF ENERGY BATTELLE

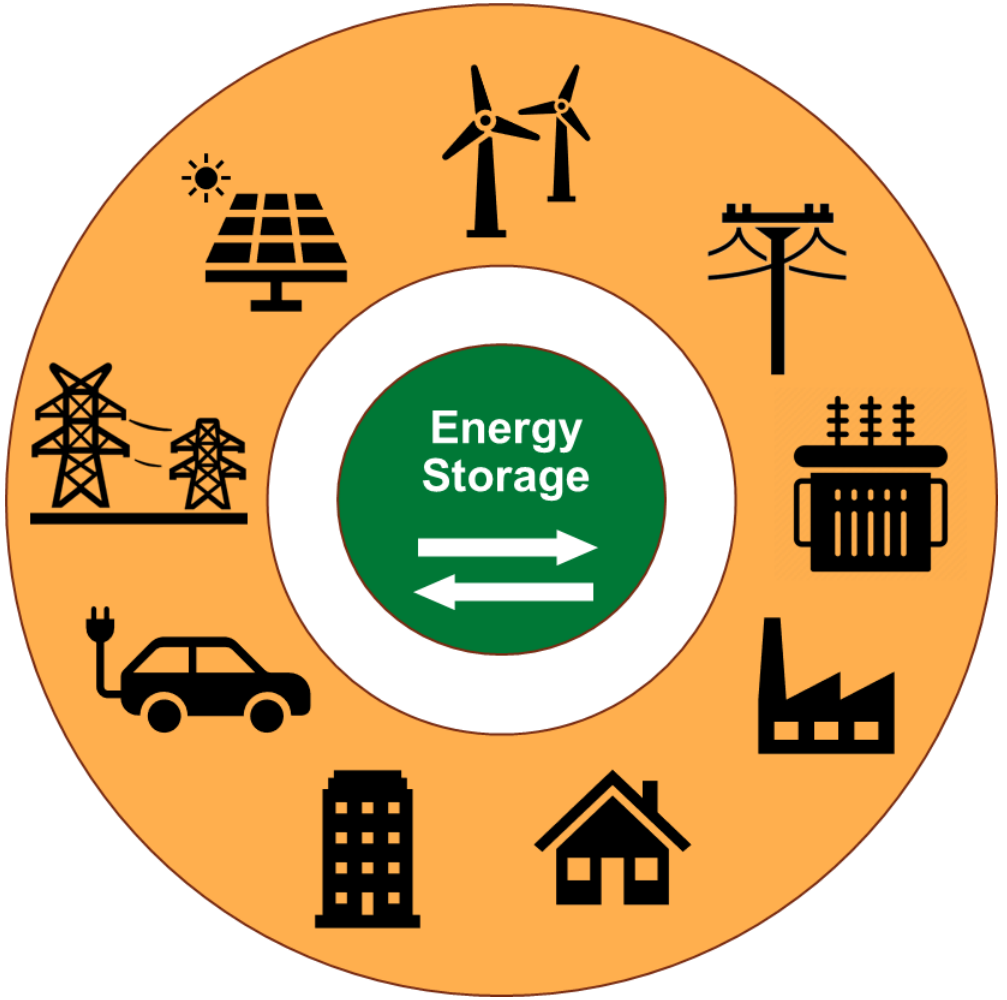
Outline

- Background and Motivation
- Overview of ESET™ and FY21 Research Activities
- Modeling and Valuation Methods
- Next Steps



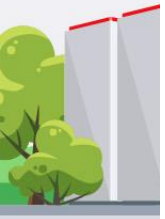
Storage Can Help Solve Problems in All Parts of The Grid

- Resource adequacy
  - System capacity
  - Flexible capacity
  - Local capacity
- Transmission adequacy
  - Support balancing load and generation
  - Support competitive markets
- Couplings between the two
  - Additional transmission capacity enhances the capacity value of variable generation
  - Energy storage and other resources are non-wire alternatives



Needs for Storage Valuation Tools

- Energy storage technology has advanced
- Technical feasibility has been demonstrated
- Few existing projects were truly cost-effective
- Value streams need to be identified and appropriately monetized
- Capturing stacked value streams is important for a project to be financially viable



The lack of ability to model and value energy storage systems became a significant barrier to their penetration in the marketplace

ESET™ Overview

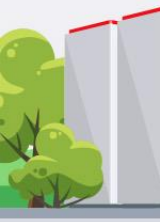
A suite of applications that enable utilities, regulators, vendors, and researchers to model, optimize, and evaluate various energy storage systems for stacked value streams

- 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)

Web-based ESET: https://eset.pnnl.gov

FY21 Research Activities

- Formally launched the web-based ESET
  - Enhanced BSET and MASCORE apps
  - Developed a new app for hydrogen valuation
  - Integrated the pumped storage evaluation tool
- Developed user's guide and online documentation
- Better incorporated operational uncertainties into storage valuation
- Developed multi-resolution stochastic scheduling for long-duration energy storage



Project Team

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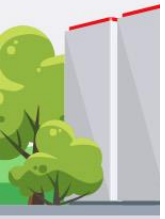
- Dr. Di Wu – Principal Investigator
- Dr. Sen Huang – Platform Development
- Dr. Xu Ma – Modeling & Optimization
- Dr. Dexin Wang – Modeling & Optimization
- Dr. Thia Ramachandran – Modeling & Optimization
- Alasdair Crawford – Battery Energy Storage Modeling
- Dr. Vish Viswanathan – Battery Energy Storage Modeling
- Tao Fu – Load Modeling and Forecasting
- Dr. Bowen Huang – Platform Development
- Trisha Henriksen – Web Design and Implementation
- Yanyan Zhu – Web Design and Implementation
- April Sun – Financial Analysis Engine
- Mark Weimar – Financial Analysis Engine



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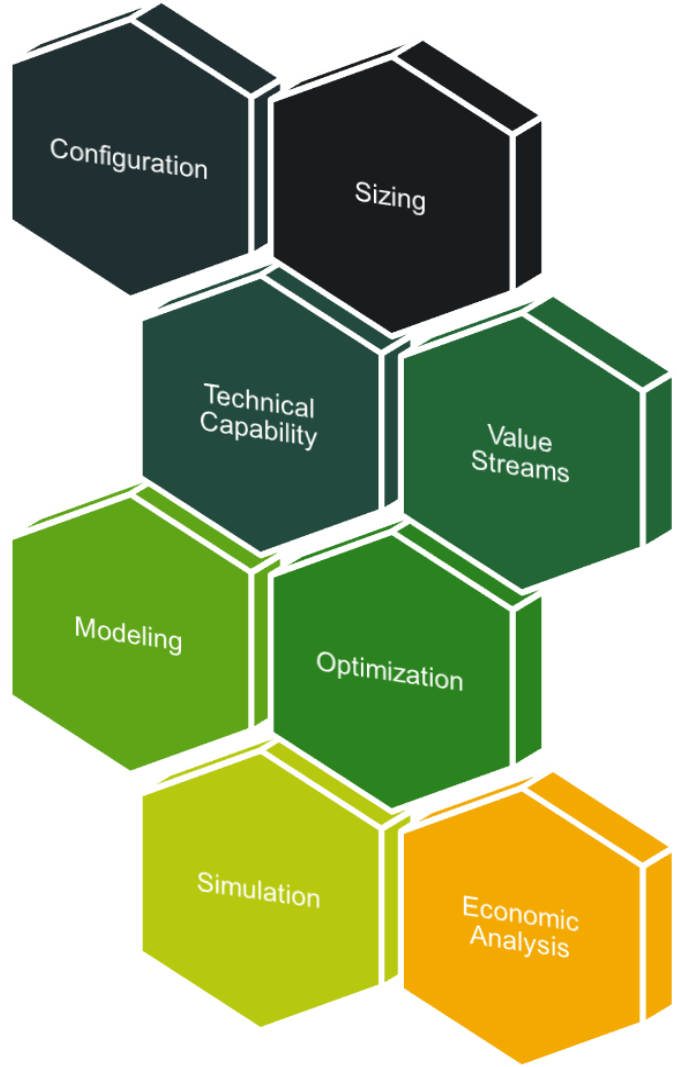
- PJ Rehm – Use Case and Evaluation
- Andy Fusco – Use Case and Evaluation
- Jason Thigpen – Utility Data

NC STATE UNIVERSITY

- Dr. Ning Lu – Energy Management System
- Rongxing Hu – Load Modeling
- Han Pyo Lee – Load Modeling

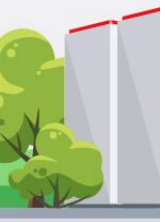
Numerous Factors Affect Storage Valuation

- ESS design and characteristics
  - Energy storage technology, physical capability, and characteristics
- Use cases
  - Vertically integrated utilities, electricity markets, distribution utilities, and large C&I customers
- Applications and services
  - 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



Modeling With a Good Balance Between Fidelity and Simplicity

- A set of equations and constraints, or tables representing operational flexibility and physical constraints
- Often black- or grey-box models at the system level
- Relaxed and approximated models



Batteries

- Operational flexibility
  - Constant vs varying efficiency
  - Static vs dynamic operating range
- Degradation effects
  - Loss of life
  - Degradation in performance

Pumped Hydro

- Fixed vs adjustable speed
- Various configurations: separate and reversible pump/turbine as well as ternary sets
- Unit- and plant-level HSC

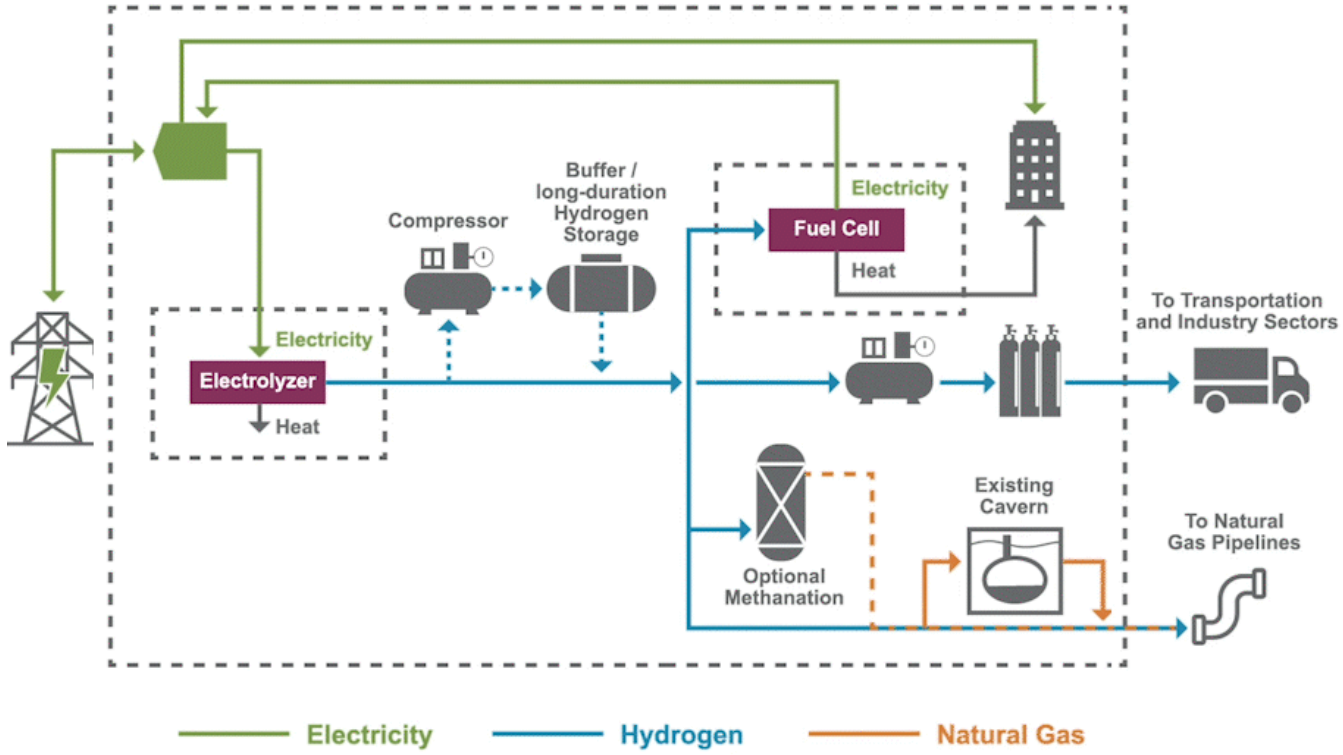
Hydrogen

- Multiple energy delivery pathway
- Component-level modeling
- Coupling among different pathways and grid services

Hydrogen Energy Storage for Multiple Energy Delivery Pathways and Grid Applications

A co-optimal dispatch is developed to evaluate the potential benefits and ensure no double-counting

- Economic and technical characteristics of individual components
- Modeling of each pathway and the coupling between different pathways
- Rules and requirements of different grid services, and competition among them for limited capacity
- Coupling between grid services and hydrogen energy delivery pathways
- Temporal interdependency



Needs for Incorporating Operational Uncertainties

- Capacity charge rate: > $20/kW-month
- ElectriCities does not know exactly when the peak hour will occur
  - Cannot tell exactly whether tomorrow is the peak day of the month
  - Cannot tell exactly whether the next hour is the peak of the day
- **Two-step dispatch under uncertainties considering degradation**
  - Seamlessly integrates load forecast and dispatch to model and address uncertainties
  - Effectively explores the trade-off between demand reduction effectiveness and battery life
  - Optimizes distribution of battery life to maximize the present value of benefits

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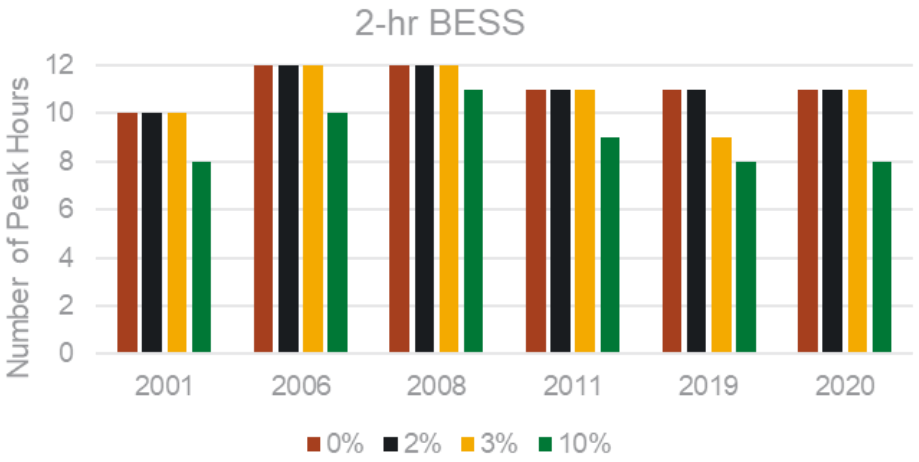
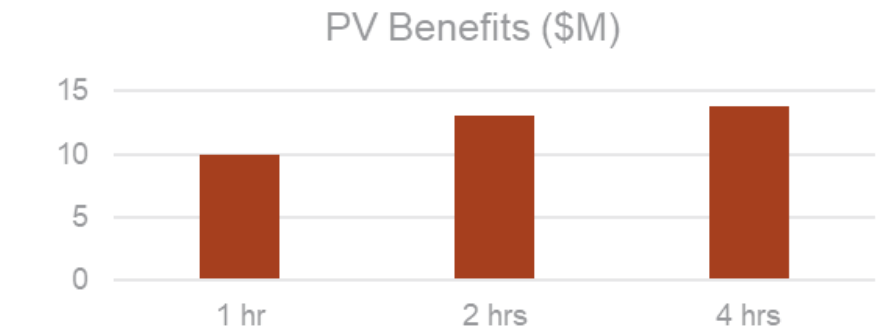
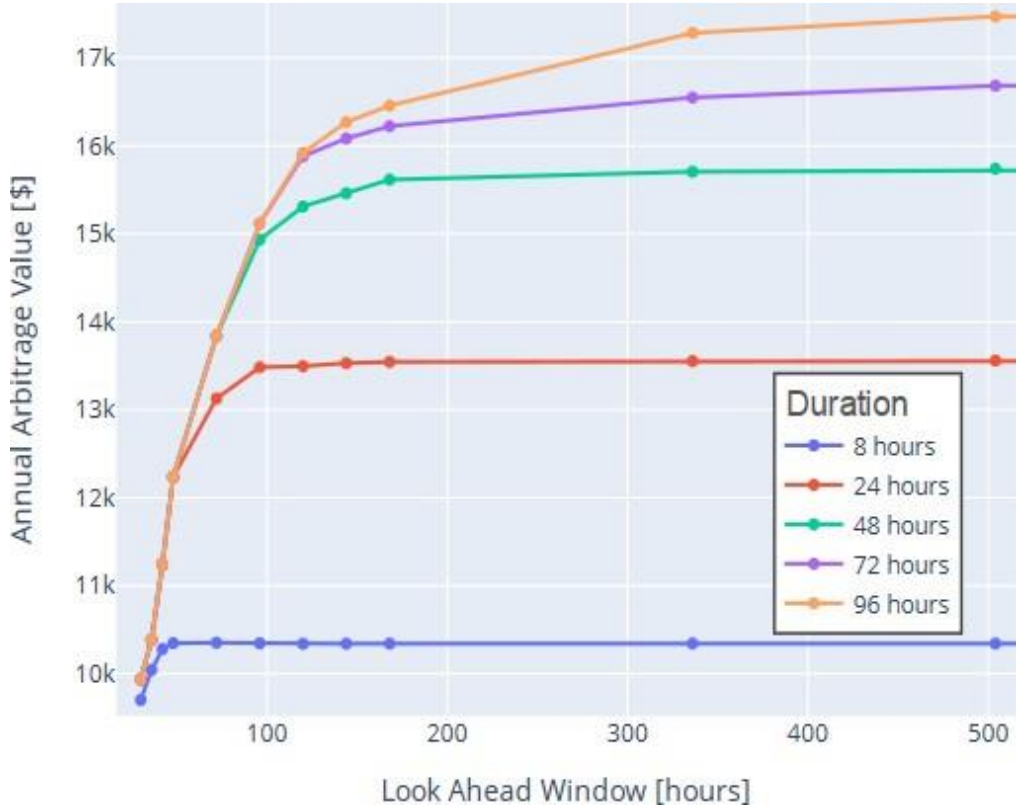
- **Capture peak hours in 10-12 months a year**
- **7-8 cycles per month**





Multi-resolution Stochastic Scheduling for LDES

- Challenges in LDES scheduling
  - Longer look-ahead windows required
  - Increased operational uncertainties
- Proposed multi-resolution stochastic scheduling
  - Varying time step sizes with coarser resolutions for periods farther into the future
  - Two-stage stochastic scheduling with uncertainties explicitly modeled
- Key takeaways
  - Longer look-ahead windows enable better opportunities for energy shifting
  - The look-ahead window needs to be at least twice of duration to realize 95% of the potential benefits



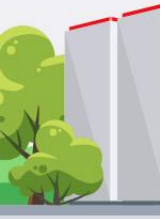
Benefits depend on not only the duration but also the look-ahead window length

Looking Forward

- Publications
  - D. Wu and X. Ma, “Modeling and optimization methods for controlling and sizing grid-connected energy storage: a review,” *Current Sustainable/Renewable Energy Reports*, vol. 8, no. 1, pp. 123–130, Mar. 2021.
  - D. Wu, X. Ma, P. Balducci, and D. Bhatnagar, “An economic assessment of behind-the-meter photovoltaics paired with batteries on the Hawaiian Islands,” *Applied Energy*, vol. 286, Mar. 2021, 116500.
  - Y. Du and D. Wu, “Deep reinforcement learning from demonstrations to assist service restoration in islanded microgrids,” under review.
  - D. Wu, D. Wang, and T. Ramachandran, “A techno-economic assessment of hydrogen energy storage toward multiple energy delivery pathways and grid services,” under review.
  - D. Wu, X. Ma, T. Fu, and Z. Hou, “A dispatch and valuation framework for battery storage under uncertainty considering degradation,” under review.
- Next steps
  - Maintain and enhance the web-based ESET based on users’ feedback
  - Continue to develop capabilities for modeling and valuation of long-duration energy storage
  - Develop modeling capabilities for assessing energy storage as an equity asset
  - Continue to use ESET to support energy storage assessment projects

Acknowledgment

Dr. Imre Gyuk, DOE – Office of Electricity



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

Thank You

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