

2025 DOE OE ENERGY STORAGE PROGRAM ANNUAL MEETING AND PEER REVIEW
AUGUST 6, 2025



A BRIEF OVERVIEW OF ONGOING ENERGY STORAGE ANALYTICS RESEARCH AT ARGONNE NATIONAL LABORATORY



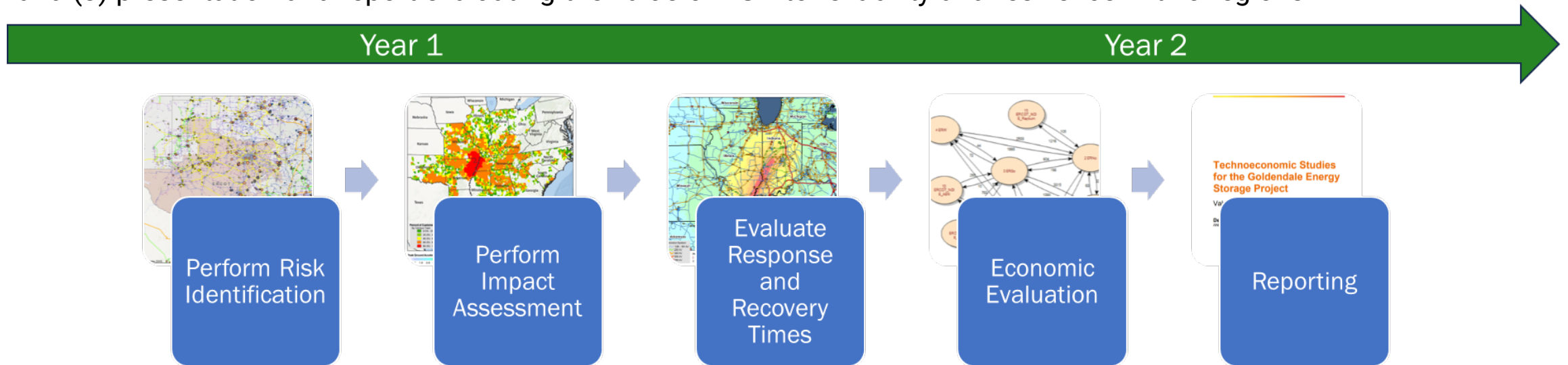
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Argonne National Laboratory

PRESENTATION ID#500

Value of Reliability and Resilience

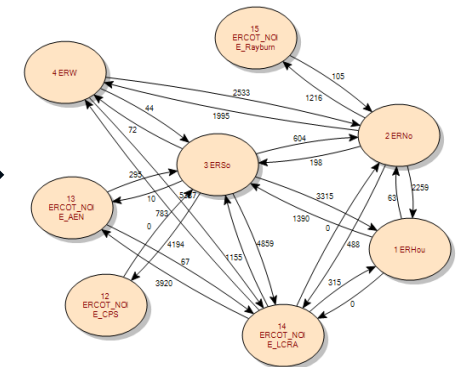
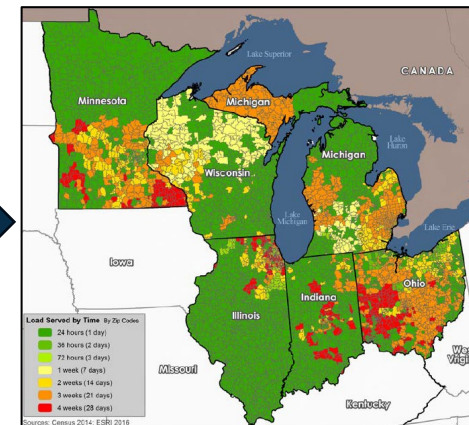
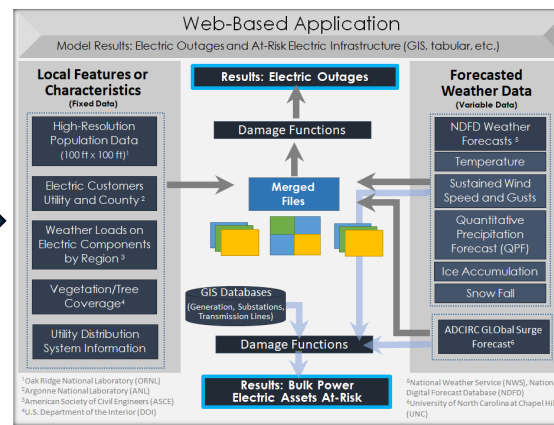
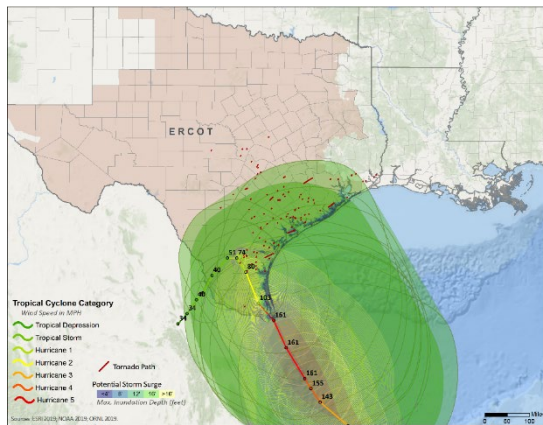
- **CHALLENGE:** The absence of consensus around approaches and models for estimating, and market mechanisms for monetizing, the value of reliability and resilience benefits provided through long-duration energy storage (LDES) investment severely restricts its ability to achieve its full value over its economic life
- **KEY OBJECTIVE:** Greatly improve the value proposition for LDES by developing a methodology and modeling framework for assigning value to reliability and resilience, and then testing that approach through evaluation of PSH in at least two US regions (ERCOT and CAISO)
- **KEY OUTCOMES:** (1) Basis for defining the value of reliability/resilience on an annualized basis for inclusion in valuation assessments and market products, (2) comprehensive modeling framework for defining value of reliability and resilience, and (3) presentation and report evaluating the value of PSH to reliability and resilience in two regions



Multi-Hazard Risk Analysis

LDES has demonstrated the capacity to enhance grid resilience, but resilience benefits are poorly defined and generally ignored in energy storage valuation studies and market structures. Reliability benefits are often evaluated using system models with inconsistent assumptions governing individual service values while resilience benefits are typically evaluated using customer damage functions and interruption cost studies or sometimes evaluated using willingness to pay studies and input-output analysis.

Multi-hazard risk analysis that relies on expected value calculations and an annual risk premium approach like the type used by insurers, while addressing a broad range of hazards and values tied to the value of lost load, surging locational marginal prices and potentially reduced economic productivity, would represent a significant advancement in the state of the art. Argonne has a suite of tools that can be used to evaluate the annualized risk premium associated with LDES' impact on resilience & reliability.



Threat Identification Impact Assessment Response & Recovery Economic Valuation

Models: HEADOUT & EPfast

Model: EGRIP

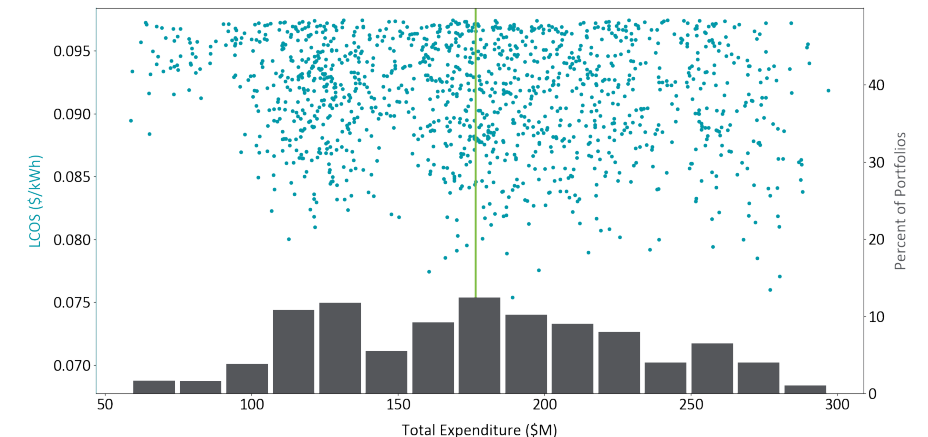
Models: A-LEAF & ICE Calculator

Storage Innovations 2030

- SI 2030 Framework Study to be updated and published bi-annually
- Website under development – to include links to current reports, interaction with key 2030 graphics, advanced visualization techniques to present cross-technology results
- Technology taxonomy framework established to systematically review and update the list of technologies. Technologies defined for 2025:
 - Li-ion NMC
 - Li-ion LFP
 - Pumped Storage Hydro
 - Compressed Air Energy Storage
 - Hydrogen Storage
 - Thermal Storage
 - Zinc Batteries
 - Lead-acid Batteries
 - Redox Flow Batteries
- New nascent technology papers
- New limits placed on cycle life and round-trip efficiency
- Recently published paper defining levelized cost of storage
 - W. Hill Balliet, Patrick Balducci, Venkat Durvasulu, Thomas Mosier, Determining the profitability of energy storage over its life cycle using levelized cost of storage, Energy Economics, Volume 142, 2025, 108174, ISSN 0140-9883, <https://doi.org/10.1016/j.eneco.2024.108174>.

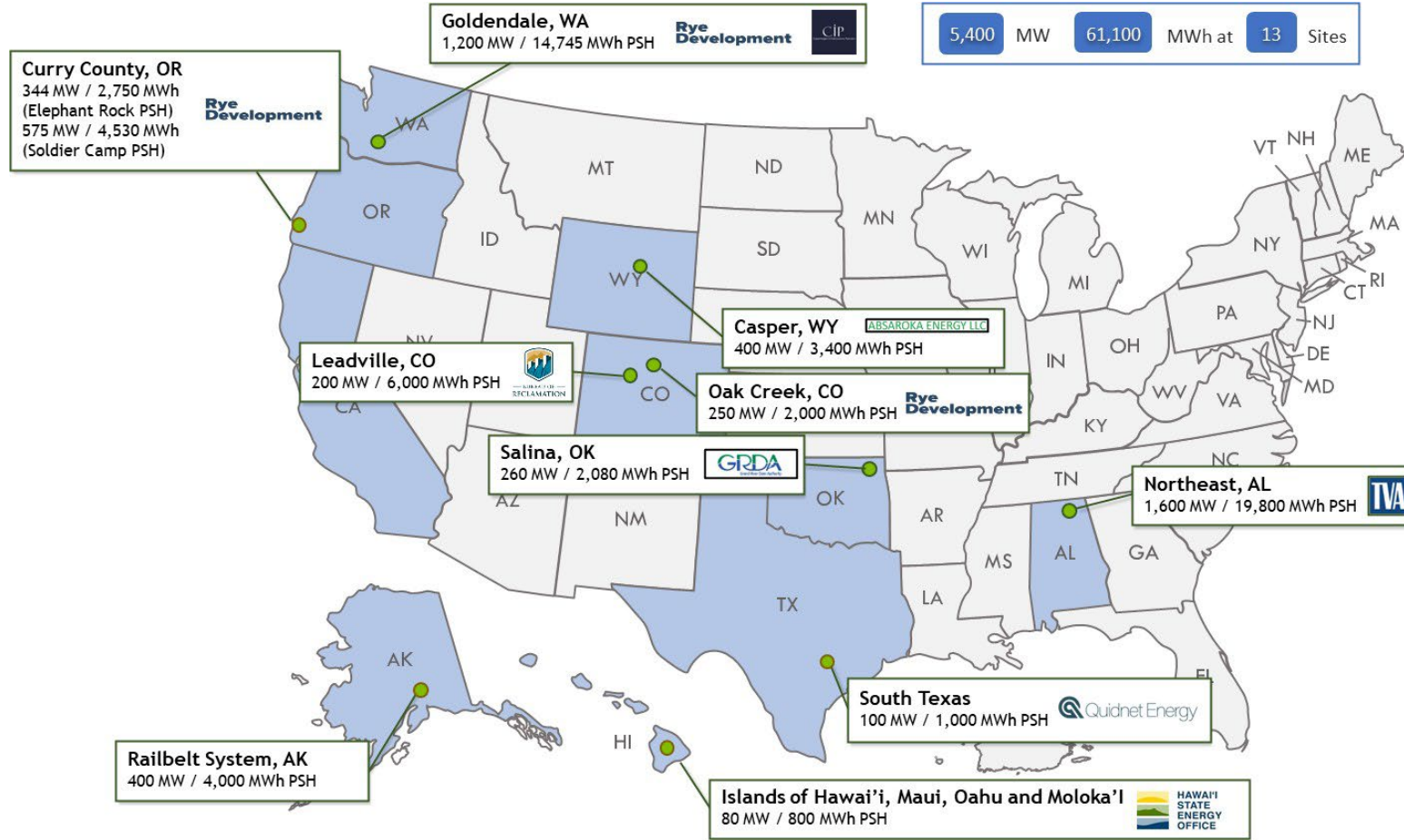
We need your input!

Please reach out to Patrick Balducci at pbalducci@anl.gov or Hill Balliet at william.balliet@inl.gov to inquire into how you can participate in the study.



Top 10% of Portfolios for Lead-acid Batteries

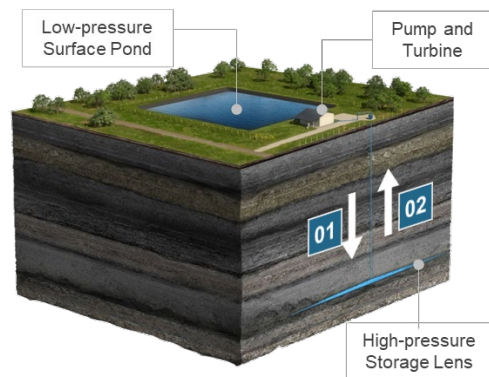
Pumped Storage Hydro Technical Assistance Work at Argonne National Laboratory



Quidnet Geomechanical Pumped Storage

Problem Statement

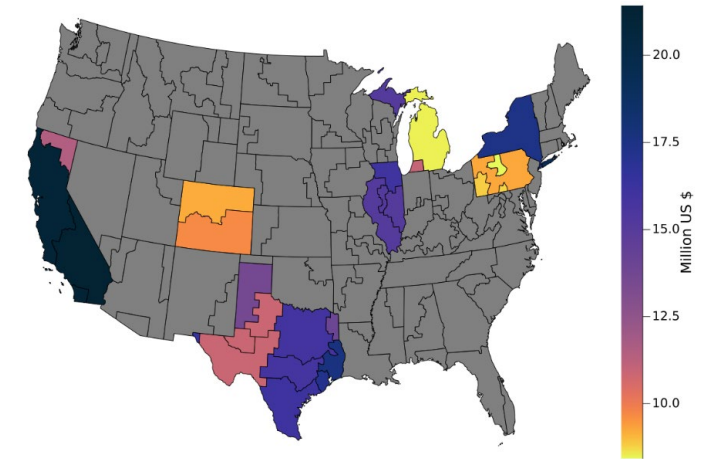
- Wide geographic distribution of flexible assets required to maintain grid stability under high variable energy scenarios
- Geomechanical Pumped Storage (GPS) is feasible across ~80% of US
- Comprehensive understanding of use cases and relative value is vital to identifying areas best suited to GPS



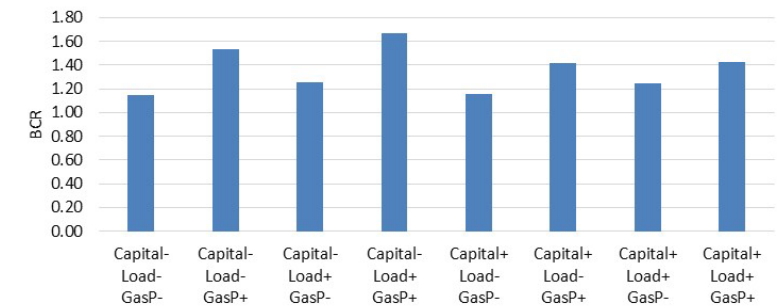
Quidnet GPS System

Successes and Findings

- We have added several new data sets / capabilities to the Pumped Storage Hydro Valuation Tool (PSHVT)
 - Default natural gas prices by region by year embedded in model
 - Ability to evaluate multiple cases simultaneously
 - Capacity to view breakdown of generation portfolios, tracking of state of charge, and weekly revenue
- PSHVT used to evaluate financial viability of GPS in 30 balancing areas (BAs) in 7 states (CA, CO, IL, MI, PA, NY, and TX), with strong revenue potential in CA, TX, IL, and NY
- Detailed analysis performed for BAs 63 and 65 (Texas) yields strong financial results under multiple scenarios



PSH Revenue in First Year of Operation



Revenue Under Multiple Cases for BA 63

Sunshine Hydro Super Hybrid Project

1. Project Objective

- Adapt and validate the AESOP optimization tool for U.S. electricity markets (starting with CAISO), using it to coordinate dispatch across a Superhybrid system combining PSH, H₂ production (electrolyzers, H₂ storage, fuel cells), and variable energy resources (VERs).

2. Key Elements

- AESOP enhances operational and financial performance by optimizing generation, storage, and fuel production.
- The Superhybrid system is designed to deliver continuous power and support fuel production. Long-term contracts and trading strategies support market participation and system flexibility.

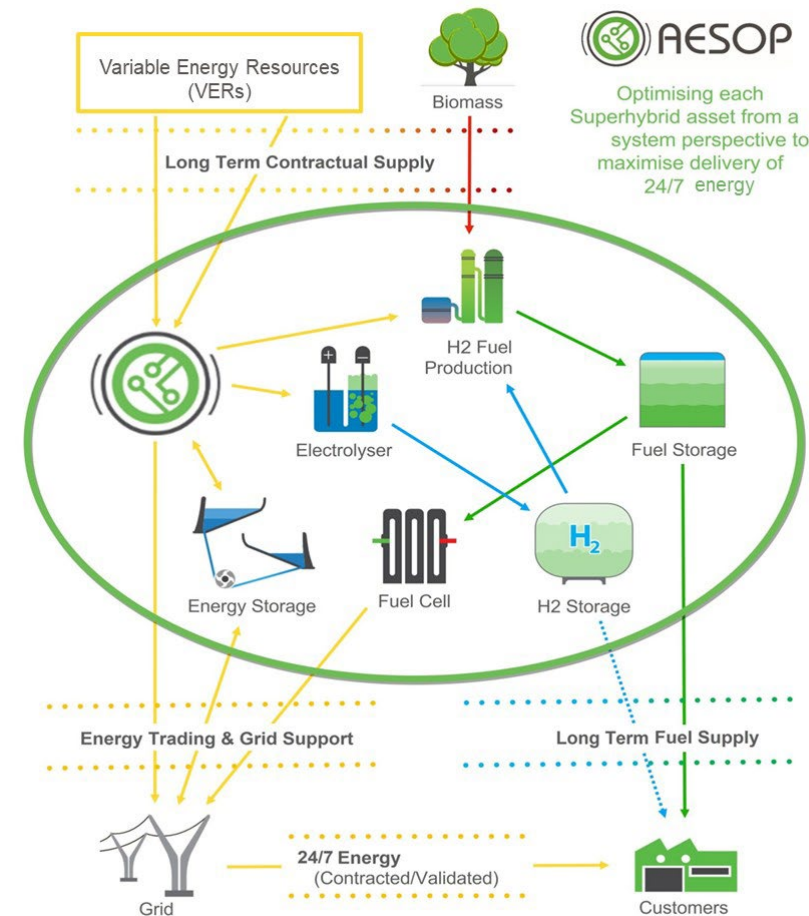
3. Expected Outcomes & Value

- Benchmark Superhybrid vs. alternative configurations.
- Assess economic viability and market compatibility in the U.S. framework.
- Identify policy, technical, and market barriers to deployment.

4. Superhybrid System Benefits

- Improved grid reliability and flexibility.
- Integrated balancing of VERs and demand.

Schematic of the AESOP architecture
Source: <https://sunshinehydro.com/technology/>



Kit Carson Microgrid Project

1. Project Objective

- a. Design and optimize three community-scale microgrids at critical locations in the Kit Carson Electric Cooperative (KCEC) service area (New Mexico), combining VERs and Battery Energy Storage Systems (BESSs).

2. Modeling Approach

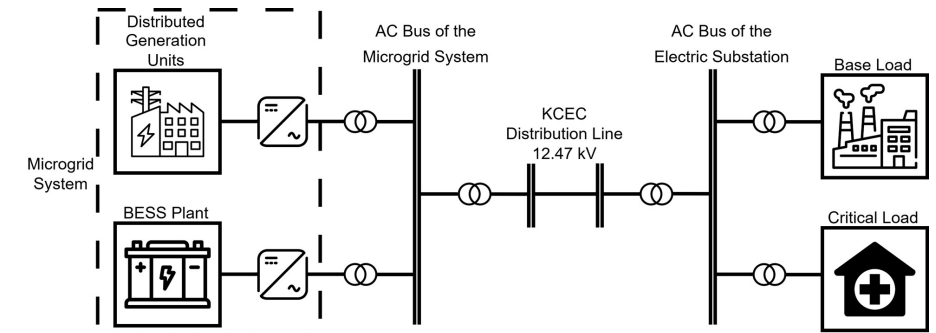
- a. Customize the Energy Storage Microgrid Optimization (ESMO) tool to determine optimal siting, sizing, and dispatch of VERs and BESSs.
- b. Evaluate wildfire resilience, electrification goals, and load growth (e.g., Taos Ski Valley fleet electrification).
- c. Explore participation in CAISO's imbalance market and ancillary services, including spinning reserve.

3. Expected Outcomes

- a. Define cost-effective and resilient microgrid configurations.
- b. Quantify economic value streams from market participation.
- c. Support KCEC's transition to reliable, distributed energy systems.

4. Microgrid Systems Impact

- a. Enhance energy security for critical infrastructure (e.g., hospitals, water systems)
- b. Improve service continuity during wildfires, snowstorms, and Public Safety Power Shutoff (PSPS) events.



Schematic of the KCEC microgrid architecture



Schematic of the Argonne National Laboratory ESMO Tool

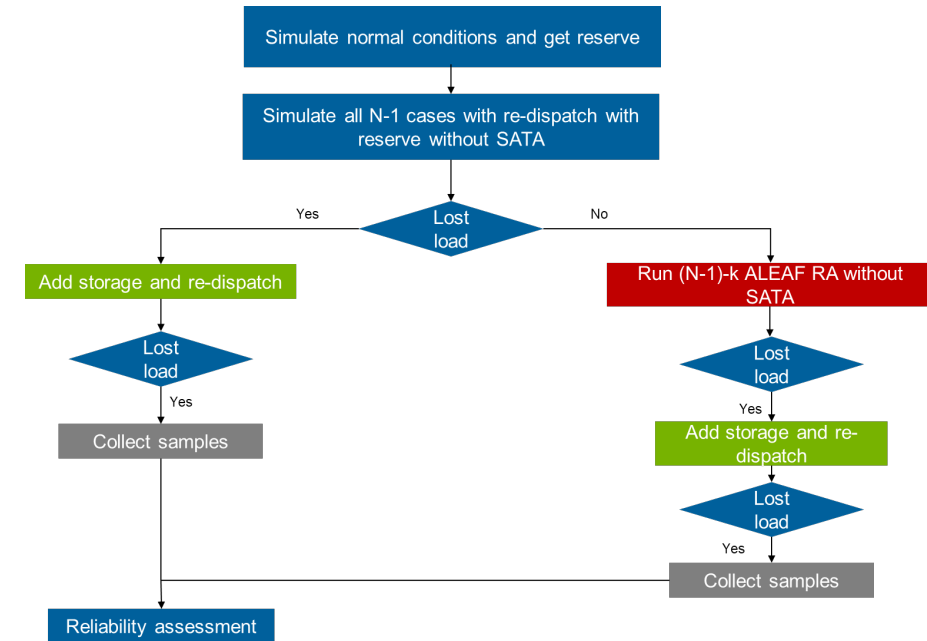
Energy Storage as a Transmission Asset

Objectives

- Build a computational tool that can accurately model and assess the reliability contribution of energy storage (ES) when deployed under two distinct operational scenarios.
 - Solely as a transmission asset with its operational framework fully compatible with existing transmission planning and operational processes.
 - Dual-use application of ES, where it acts as both a transmission & market asset.

Technical Questions

- What transmission services can ES provide as a transmission asset?
 - Real-power based: thermal overloading mitigation, etc.
 - Reactive-power based: voltage support, etc.
- When and how SATA can be called for transmission services?
 - Only when there is contingency, which can only be addressed by any market measures.
 - May depend on specific transmission services.
 - Requirement of operational status (e.g., SOC, state of health) when standby as transmission services.
- Based on the operational rules, how to quantify SATA's reliability contribution?
 - When storage as a transmission asset only.
 - When storage as a dual-use asset – allowing market participation when the transmission system is secure.



Modeling Flowchart – Reliability Assessment

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