AI for Energy Storage Challenges and Opportunities

Workshop on AI for Energy Storage
April 16, 2024

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BERKELEY LAB

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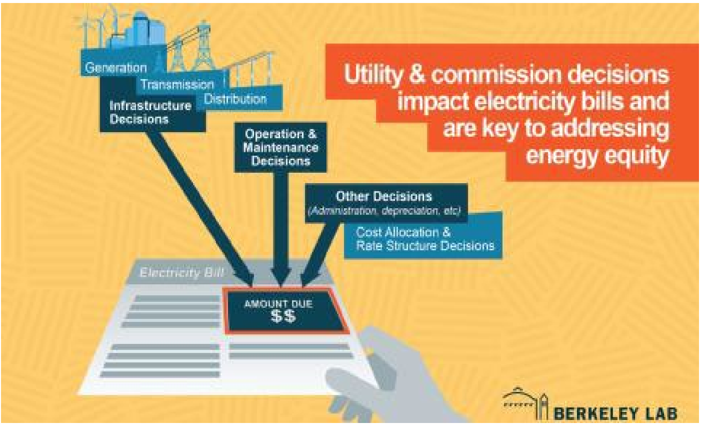
Grand Challenges

- **RAPID DEVELOPMENT OF ENERGY STORAGE TECHNOLOGY**

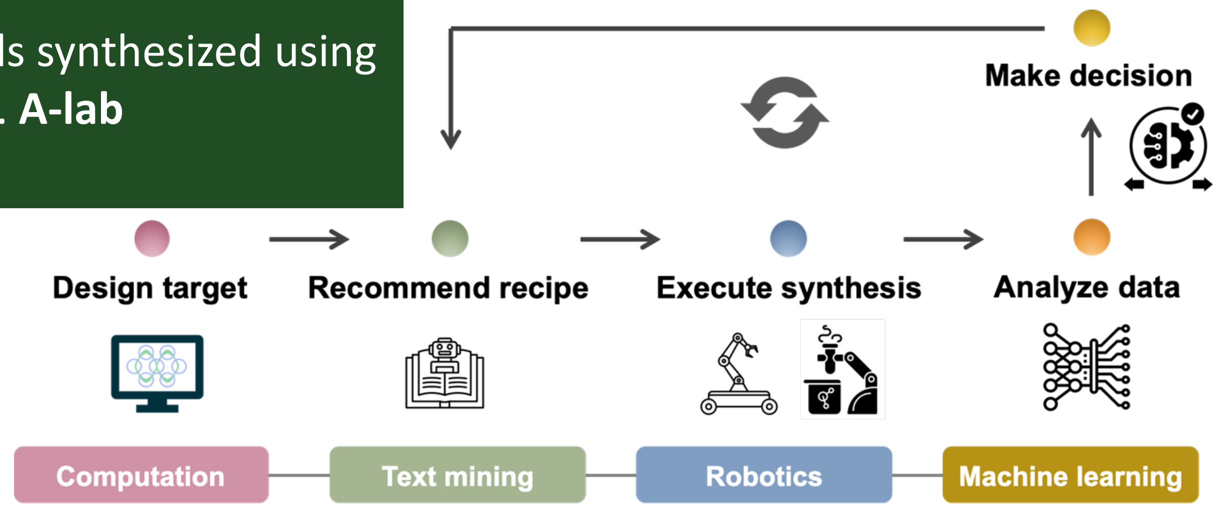
- **EFFICIENT ENERGY STORAGE DEPLOYMENT, OPERATIONS, AND CONTROL**

- **EQUITABLE AND ACCESSIBLE DEPLOYMENT**

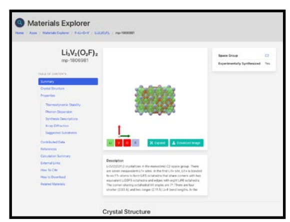


Rapid Development: Accelerate materials development with automation, robotics, theory, and AI

- New materials virtually pre-screened with supercomputers and AI, e.g., **Materials Project**
- Targets from computer models synthesized using robotic equipment and AI e.g. **A-lab**



NERSC



Materials Project

AI recipes based on scan of literature

A-lab

Iterative AI refines recipe to synthesize target phase

Rapid Development: AI for Validation of Energy Storage Durability and Health

R&D Problems:

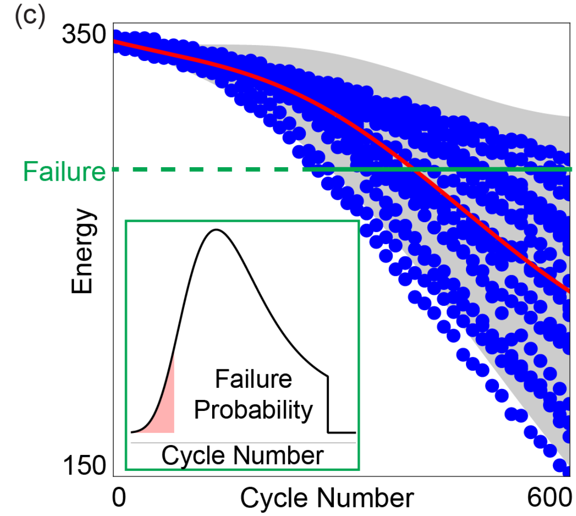
- Need 15-yr warranties
- Understand battery state of health

Role of AI:

- Physics informed Gaussian Process can evaluate failure distribution

Why it Matters:

- Achieved accurate early estimation of failure with minimum testing
- Predicted failure distributions in 4D parameter space

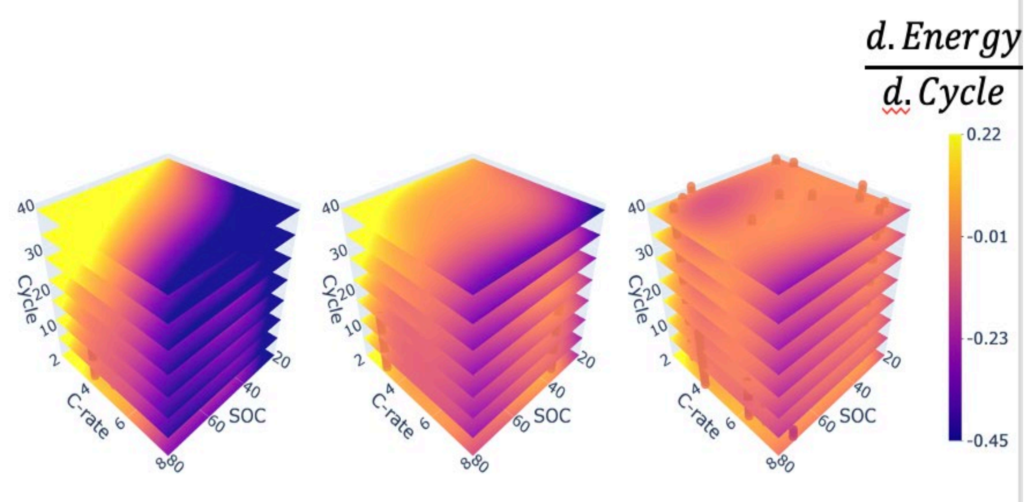


CelPress

Perspective

Statistical and machine learning-based durability-testing strategies for energy storage

Stephen J. Harris[1,*] and Marcus M. Noack[2]



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Grid Operations: Urban Digital Twins Combine AI and Physics-based Models to Inform City Planners and Grid Operators

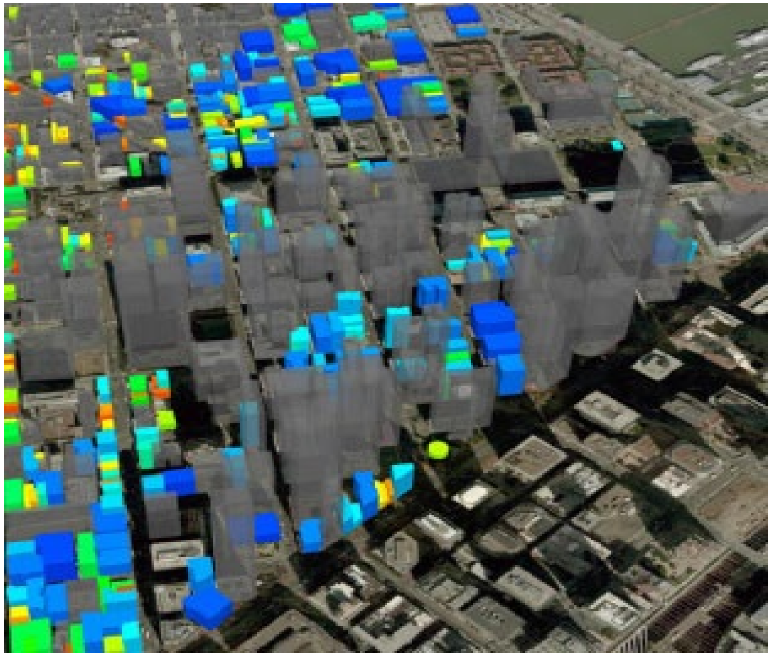
AI/ML Supports Models

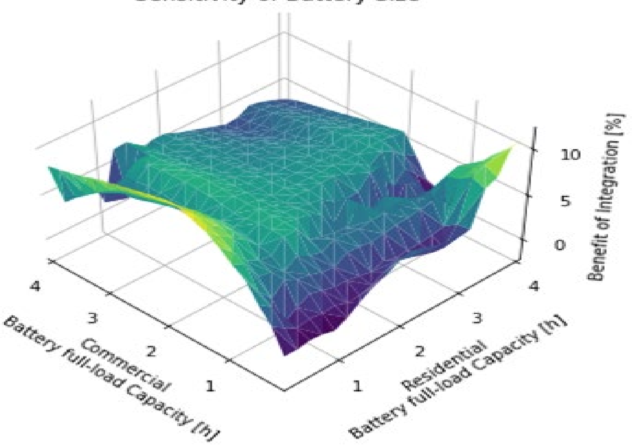
- Provide data and improve input
- Analyze output
- Calibrate models and create surrogates

Detect façade from street view

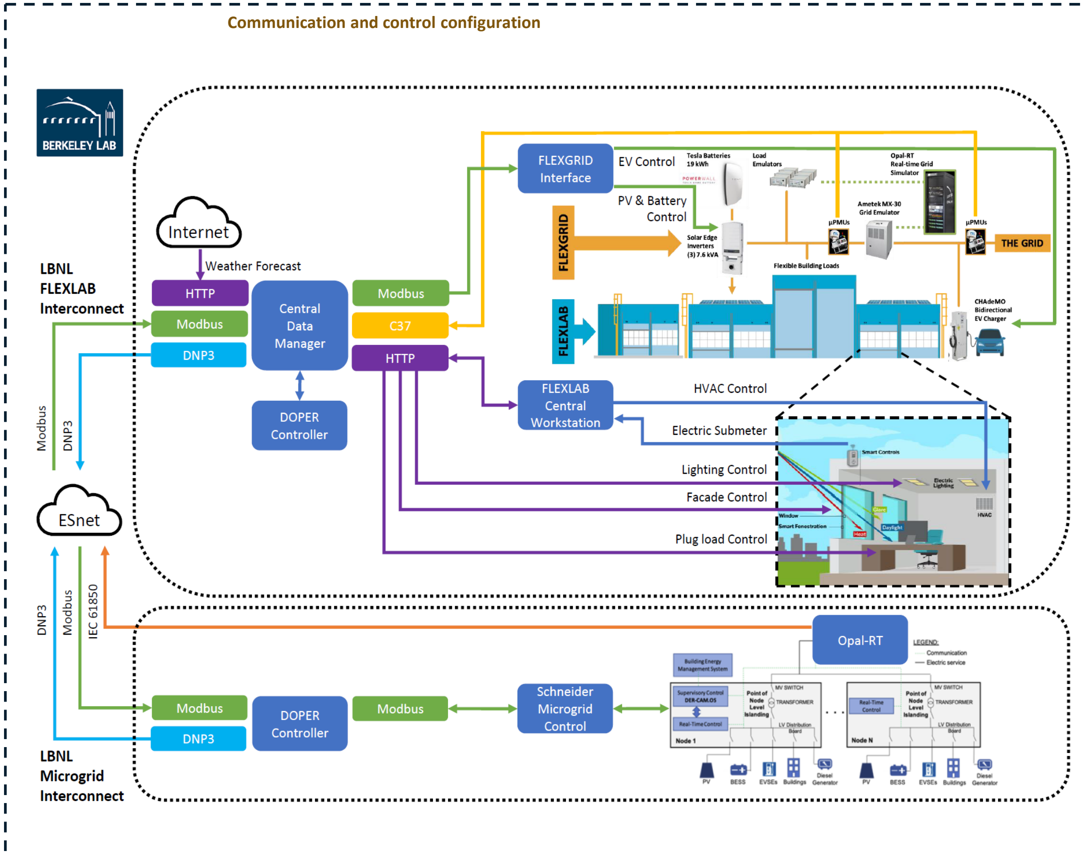
Models enable

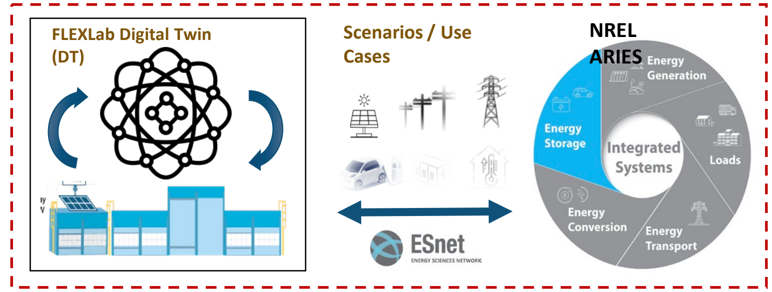
- User interactions and visualization to plan, design and use storage
- Input from building sensors, IoT devices, storage to optimize for reliable, resilient, affordable and clean grid

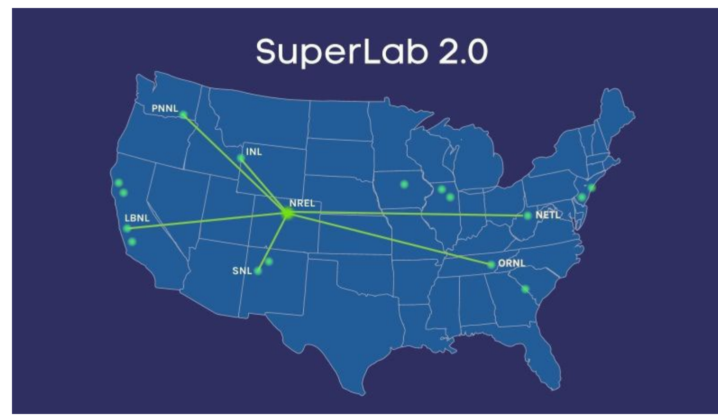




Grid Operations: Integrate Digital-Twins to Control Storage and Flex Loads with Grid via SuperLab







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NETL National Energy Technology Laboratory
Los Alamos National Laboratory
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Oak Ridge National Laboratory
Argonne National Laboratory
Pacific Northwest National Laboratory
Brookhaven National Laboratory

Grid Operations: Power System Optimal Decision Making under Wildfire Events

R&D Problem:

- Predict line failure, load shedding and generation operations with wildfire

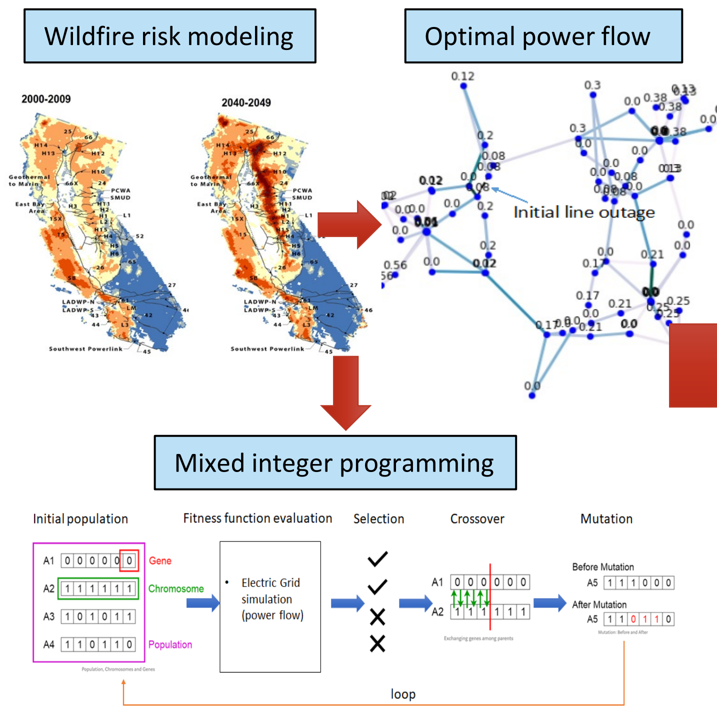
Role of AI:

- Use AI/ML for decision support

Why it Matters:

- Developed ML pipeline to surrogate computationally expensive contingency analysis

Optimization based solution

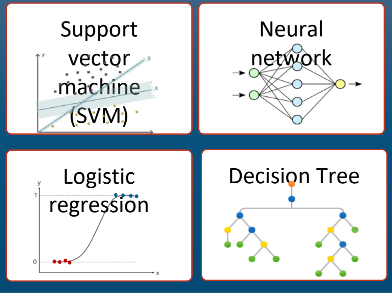


AI based solution

Inputs

- Generator status (P_g)
- Load profile (P_d, Q_d)
- Powerline ignition risk topology (N)

Classification Models



Outputs

- Generator dispatch
- Load shedding
- Cascade failure

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W. Hong, B. Wang, M. Yao, D. Callaway, L. Dale, and C. Huang, "Data-Driven Power System Optimal Decision Making Strategy under Wildfire Events," presented at the Hawaii International Conference on System Sciences, 2022. doi: 10.24251/HICSS.2022.436.

Grid Operations: Voltage-Dependent Demand Response and Optimal Battery Dispatch using Reinforcement Learning in Microgrids

Role of AI:

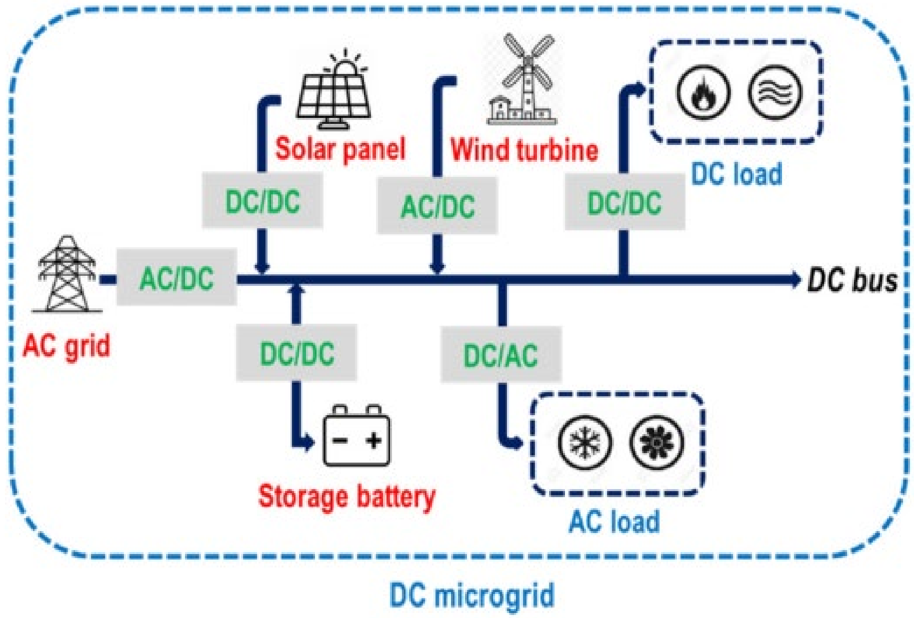
- Use AI (deep Q-network-based reinforcement learning) for optimal battery dispatch

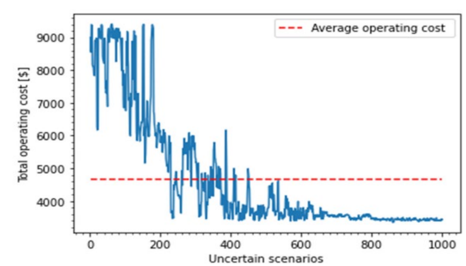
Role of AI

- AI addresses **uncertainty** to minimize operating cost while enhancing resilience

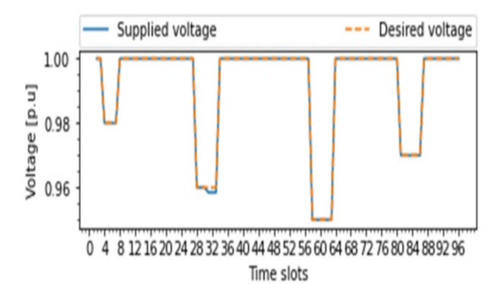
Why it Matters:

- Adding AI-based storage for Autonomous Load Management to support **EV charging depots**





Operating cost of Microgrid



Voltage deviation of Microgrid

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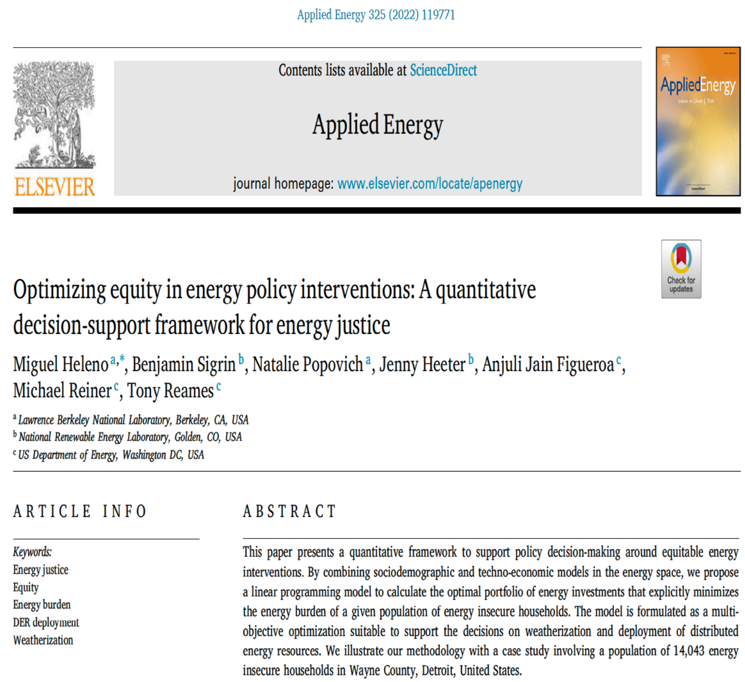
Thanh, V.-V.; Su, W.; Wang, B. Optimal DC Microgrid Operation with Model Predictive Control-Based Voltage-Dependent Demand Response and Optimal Battery Dispatch. *Energies* **2022**, *15*, 2140. https://doi.org/10.3390/en15062140

Where Are We Headed?

Role of AI:

- Accelerate and validate new energy storage technologies
- Integrate and control storage with grid
- Enable equity and train workforce of the future



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Optimizing equity in energy policy interventions: A quantitative decision-support framework for energy justice

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ABSTRACT

This paper presents a quantitative framework to support policy decision-making around equitable energy interventions. By combining sociodemographic and techno-economic models in the energy space, we propose a linear programming model to calculate the optimal portfolio of energy investments that explicitly minimizes the energy burden of a given population of energy insecure households. The model is formulated as a multi-objective optimization suitable to support the decisions on weatherization and deployment of distributed energy resources. We illustrate our methodology with a case study involving a population of 14,043 energy insecure households in Wayne County, Detroit, United States.

Contributions from Tianzhen Hong, Bin Wang, Anuhbav Jain, Stephen Harris, Miguel Heleno