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ENERGY AND ENVIRONMENT OVERVIEW

Welcome
Clean & Prosperous Washington

September 19, 2024

Jud Virden

Associate Laboratory Director
Energy and Environment

U.S. DEPARTMENT OF ENERGY BATTELLE

PNNL is operated by Battelle for the U.S. Department of Energy

PNNL-EX-10345

PNNL exists to serve DOE's missions in science, energy, environment, and national security

The mission of the Energy Department is to ensure America's security and prosperity by addressing its energy, environmental and nuclear challenges through transformative science and technology solutions

Energy
Catalyze the timely, material, and efficient transformation of the nation's energy system and secure U.S. leadership in energy technologies

Science and Innovation
Maintain a vibrant U.S. effort in science and engineering as a cornerstone of our economic prosperity with clear leadership in strategic areas.

Nuclear Safety and Security
Enhance nuclear security through defense, nonproliferation, and environmental efforts

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DOE's 17 **national laboratories** tackle critical scientific challenges

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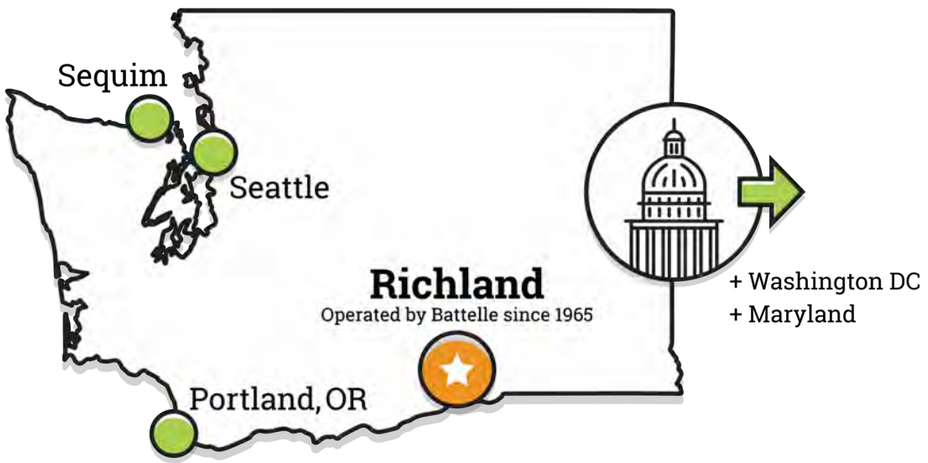
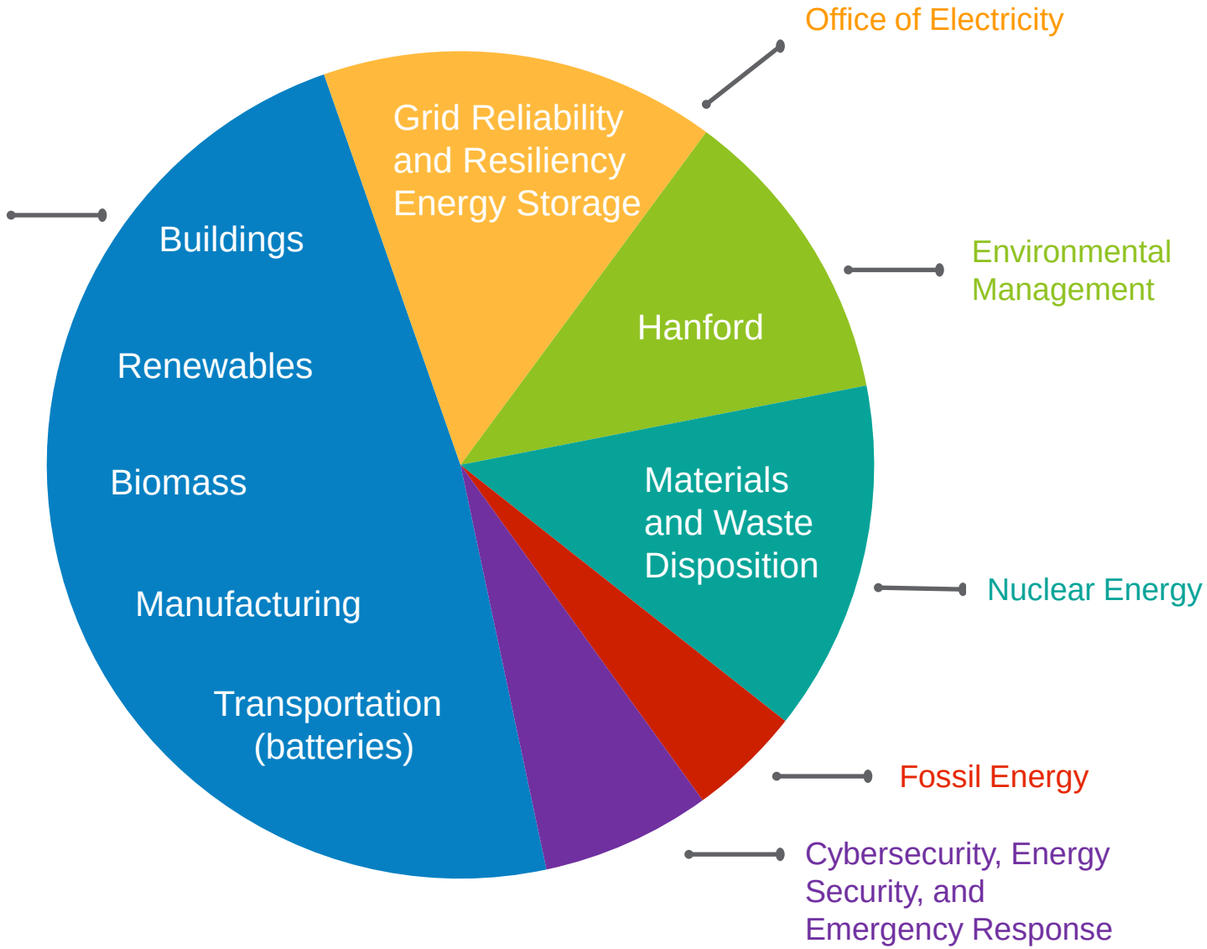
PNNL's **Energy and Environment** portfolio

1,700 Staff





FY23 funding - $473M

PNNL energy and Environment background and strategy

- 20 years ago, we were unknown with very little energy funding
  - Small amount of grid, buildings and materials work
- Our strategy:
  - Build partnership throughout the region, focus on the most important challenges.
  - Invest in key areas to build nationally recognized people, capabilities and partnerships
- Washington State DOC, other regional partners have been key to our success
- Grew from $190M to $500M/yr in funding in last 10 years
- Committed to helping Northwest compete for government funding
- Our strategy: Prioritize key technology or energy system problems that are 5-10 years out

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Examples of regional partnerships

AVISTA

ENERGY NORTHWEST

Bonneville POWER ADMINISTRATION

US Army Corps of Engineers®

McKinstry

Itron

Port of Seattle

WASHINGTON STATE UNIVERSITY

BENTON P.U.D

BOEING

Seattle City Light

PGE

Grant PUD

PSE PUGET SOUND ENERGY

UNIVERSITY of WASHINGTON

SNOHOMISH COUNTY PUD PUBLIC UTILITY DISTRICT NO. 1

Oregon State University

SEL SCHWEITZER ENGINEERING LABORATORIES

THE NORTHWEST SEAPORT ALLIANCE SEATTLE + TACOMA

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The Energy and Environment Directorate (EED) stewards a wide range of scientific capabilities

1,700 Staff

$450M in research and development

Five Divisions

Electricity Infrastructure & Buildings

- Energy System Control
- Infrastructure & Site Resilience
- Buildings

Energy Processes & Materials

- Solid Phase Processing
- Battery Materials & Systems
- Sustainable Carbon Utilization

Nuclear Sciences

- Radiolysis & Irradiation Effects
- Molten Salt Chemistry & Separations

Earth Systems Science

- Remote Interrogation of Environmental Systems
- Waterpower Engineering

Coastal Sciences

- Terrestrial-Aquatic Ecosystems
- Powering the Blue Economy

PNNL investments in capabilities for the energy transition (~$200M)

Internally Funded Research & Development

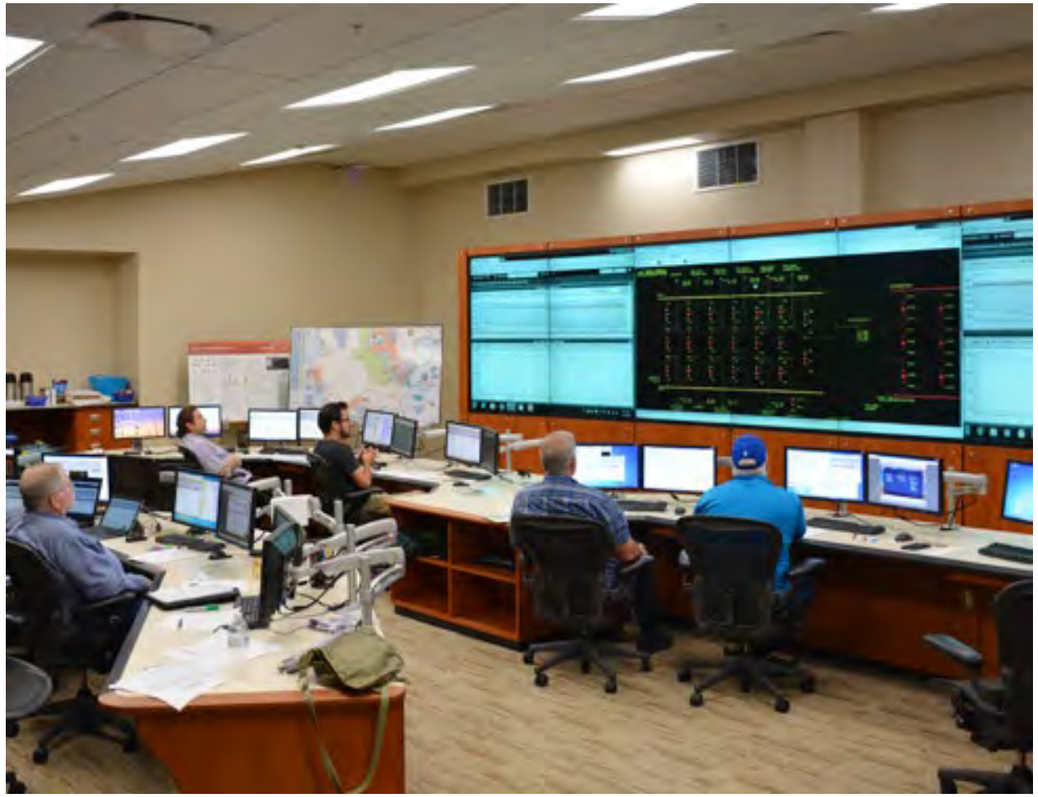
- Future Power Grid Initiative ($14M)
- Control of Complex Systems Initiative ($15M)
- Cyber Security Initiative ($14M)
- Data Intensive Computing Initiative ($15M)
- Cyber Secure Design ($3M)
- Institutional Computing ($15M)
- Transformational Materials Science Initiative ($13M)
- Chemical Transformations Initiative ($9.8M) Data Model Convergence Initiative ($12.75M)
- Solid Phase Processing Science Initiative ($12.75M)
- Energy Storage Materials Initiative ($15M)
- Resilience Through Data-driven, intelligently Designed Control Initiative ($12.75M)
- Grid Operations, Decarbonization, Environmental and Energy Equity Platform ($4M)
- Radiological Capabilities ($26M)

Facilities

- Systems Engineering Building ($9.9M)
- Electricity Infrastructure Operations Center ($5M)
- Advanced Battery Facility ($1.8M)
- Prismatic Cell Line ($4M)
- Transactive Campus ($4M from WA State)
- Aquatics Research Laboratory ($4M)

New prism line equipment at the Grid Storage Launchpad

Electricity Infrastructure Operations Center



- Fundamental and applied research spanning generation to end use, including renewable energy, electric vehicles, and building-grid integration
- Two functional control rooms use actual grid data for testing and training
- Connects PNNL buildings, creating a “living laboratory” for testing building controls
- Evaluating the effectiveness of energy storage on building and grid operations
- Testing power electronics and transactive controls for a flexible, resilient power grid

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Cybersecurity capabilities and focus areas

- Infrastructure/ testbeds
- Risk evaluation and management
- Resilient defenses
- Analytics and analysis
- Intel analysis

The PNNL-WSU Advanced Grid Institute

AGI Mission: Specialize in system-centric approach to assist with the rapid decarbonization and electrification of power grid.

We will achieve this by:

- advancing energy analytics upon integrating cross-infrastructural, cross-sectoral, and multi-domain information/influences
- developing targeted products/services for grid planners/operators for future grid readiness

Key technical areas:

- Energy Analytics and Decision Support
- Power Electronics-dominated Power Grid
- Resilience to Cyber and Natural Threats

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Equipment for sustainable advanced manufacturing

- ShAPE 2 machine accelerates research ranging from automotive components to ultra-conductors
- Equipment and programs supported by DOE and Washington State Department of Commerce

Next-generation Shear Assisted Processing and Extrusion (ShAPE™) machine

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Deploying and testing **novel building technologies** and energy-management approaches at the Eco-District in Spokane

The Catalyst Building at the Spokane South Landing Eco-District

AVISTA · McKinstry · KATERRA · EMERALD INITIATIVE · EASTERN WASHINGTON UNIVERSITY · WASHINGTON STATE UNIVERSITY

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Identifying electric grid and port operation interactions

Assessing fueling, siting, sizing, and design to enhance resilience during extreme events and defer electrical distribution systems upgrades

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PNNL-Sequim: DOE's only marine sciences laboratory

- Integrated Renewable Energy System (WA State $4.656M)
- R/V Resilience (DOE $4.6M)
- Shoreline Renovation (DOE $4.992M)
- Shoreline facilities and infrastructure to refresh and expand research (DOE $21.3M)

RV Resilience: our first hybrid electric marine research vessel

PNNL-WSU Bioproducts Institute

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WASHINGTON STATE UNIVERSITY

A Reliable and Safe Transportation Sector for the Future

Vertically Integrated Sustainable Aviation Ecosystem

Innovative Domestically-manufactured Carbon Products and Materials for Society

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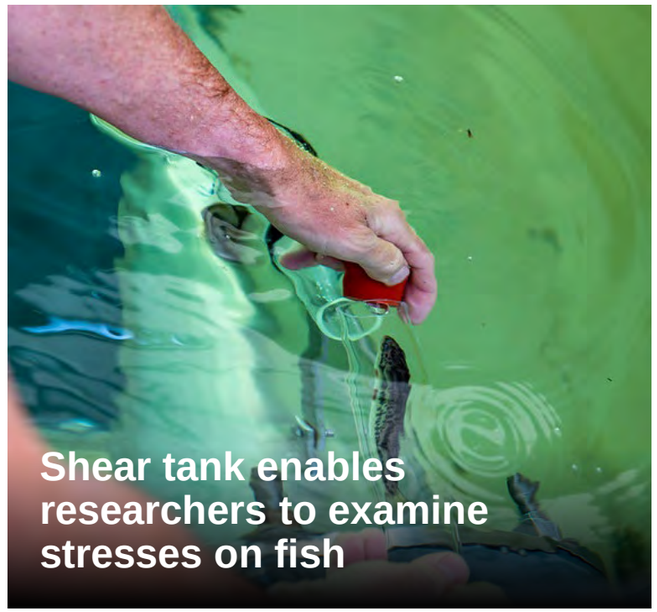
Aquatic Research Laboratory (ARL)

- 7,400 sq. ft. laboratory w/ flowing Columbia River water
- Advanced aquaculture and water reuse system
- Equipment simulates conditions at water development projects (hyperbaric and hypobaric chambers, shear and turbulence tanks, etc.)
- Space dedicated to surgery, necropsy, and analytics

Fish tanks and hatchery for raising fish

Barotrauma chambers expose fish to rapid decompression

Surgical space for tagging fish or for necropsy to determine injuries



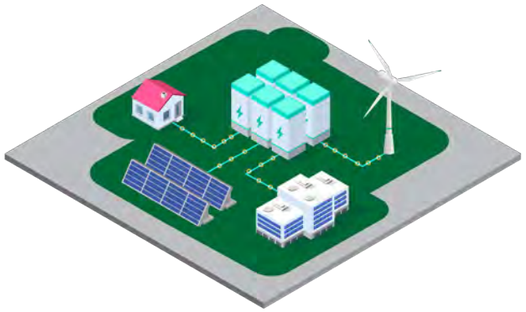
Shear tank enables researchers to examine stresses on fish

PNNL's approach to accelerate battery development

Scientific Capabilities

Rigorous Testing

Manufacturing and Industry Partnerships



Stationary

Transportation

Grid Storage Launchpad: A new DOE national capability at PNNL

- 93,000 sq ft facility
- Provide systematic and independent validation of new grid storage technologies from basic materials and components, through prototyping under grid operating conditions (<100kW)

$75M TOTAL ESTIMATED FACILITYCOST

100 WORKSTATIONS

30+ LAB MODULES

$35M NON-FEDERAL INVESTMENTS

$15M LD RD

$7M

$8M

$5M BATTELLE

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PNNL Battery Materials and System Group

200+ staff work in energy storage, $62 million/year

54 U.S. patents granted

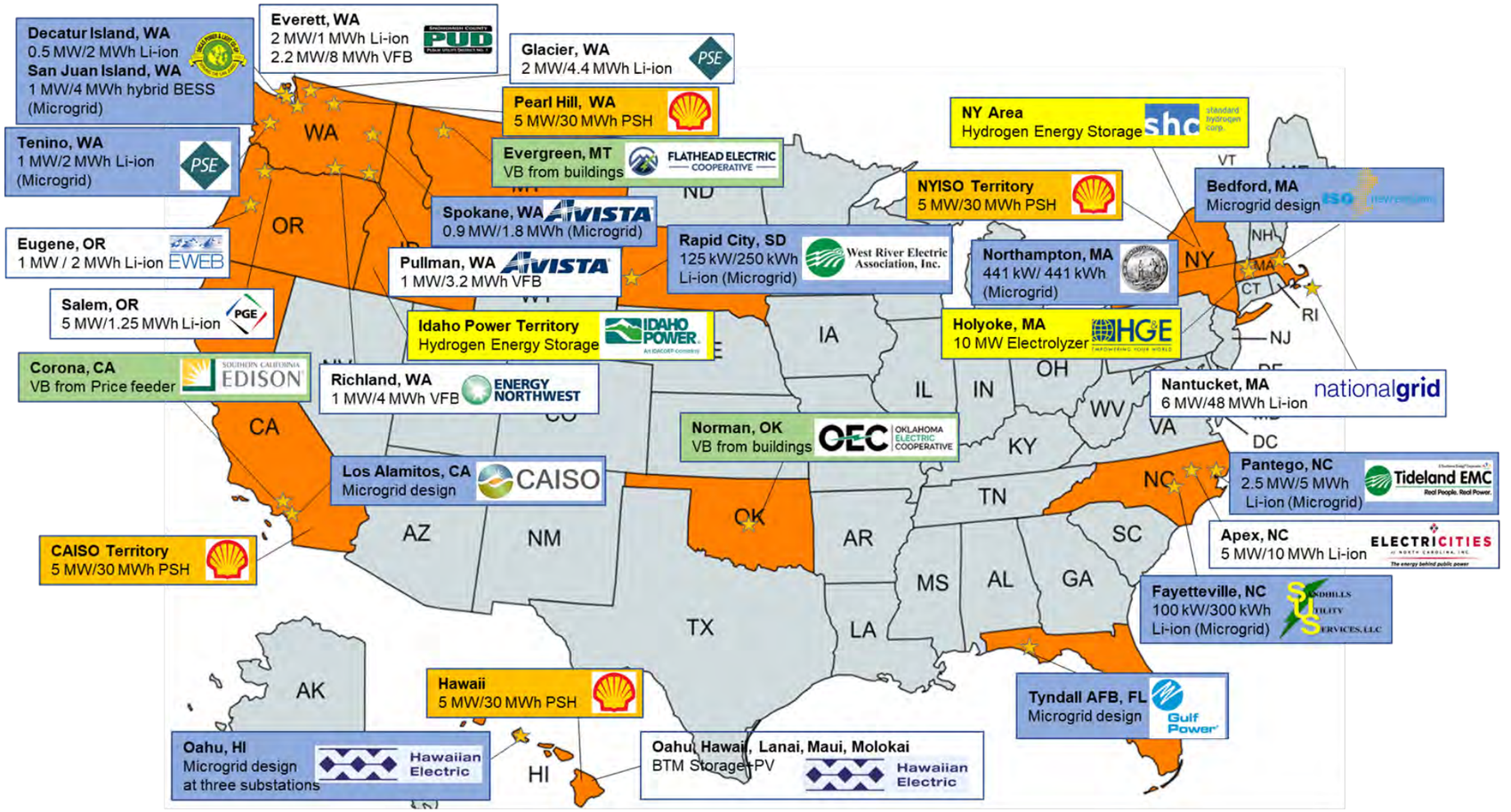
188 U.S. patent applications

24 licenses for energy storage technologies

26 active Battery Energy Storage Evaluation Tool licenses

13 current battery projects with industry

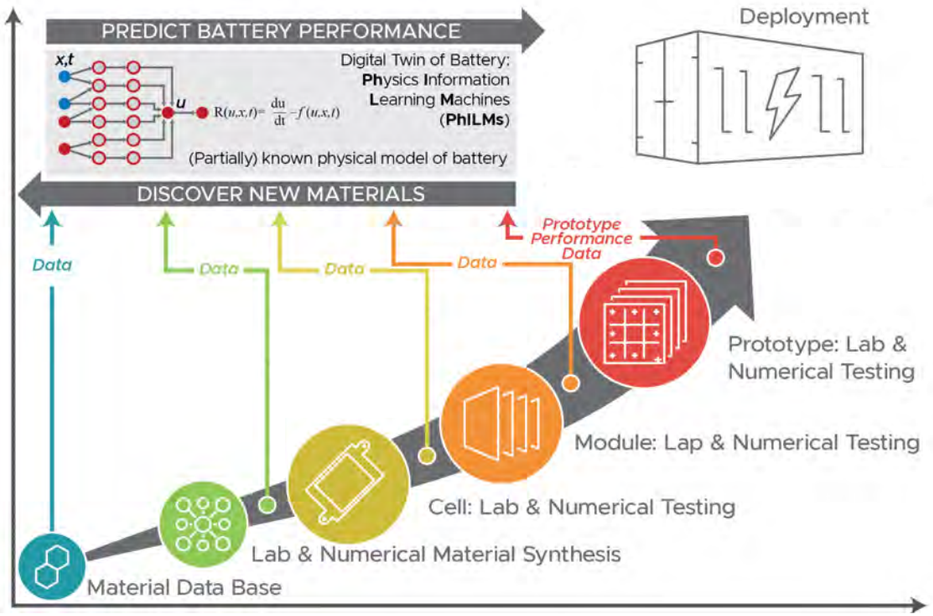
National partnerships validating deployed storage systems



Battery Energy Storage | Hydrogen | Microgrids | Building as storage | Pumped Storage Hydro

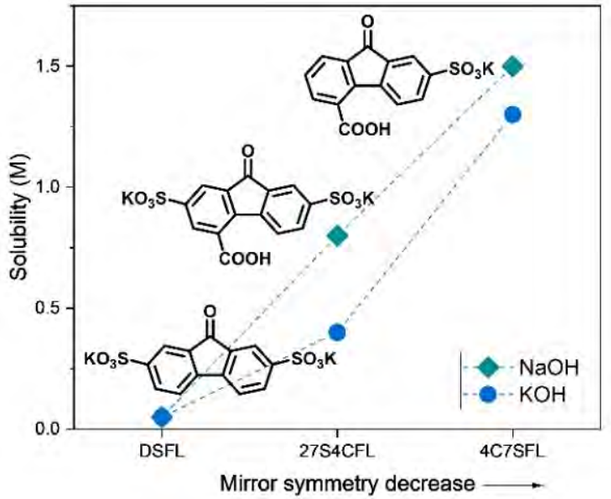
Accelerate battery materials development through digital twin approach

Digital twin-based battery materials discovery and development

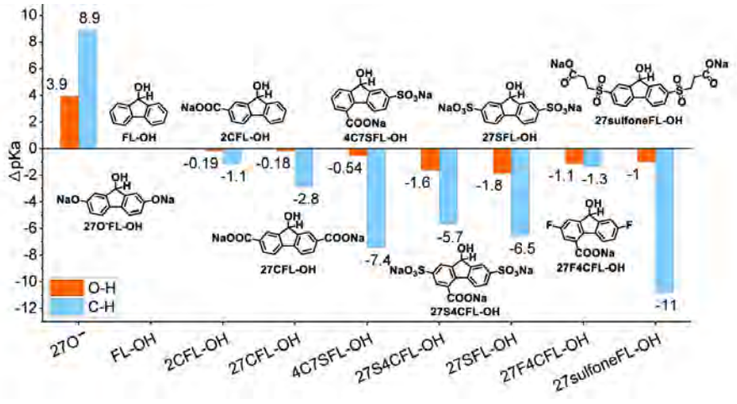


Using ML-guided molecular design, property prediction, and automated experimentation to reduce Fluorenone molecule development time by ~50%.

Automated screening for molecules with high solubility



ML-based molecular structure design with predicted pKa value



Feng et al., *Science* **372**, 836–840 (2021)

Battery500 Consortium aligns multi-disciplinary teams to address key challenges

- 4 national labs + 9 universities + GM, Industry Advisory Board
- Design, fabricate and validate high energy pouch cells up to 500 Wh kg^{-1}
- Demonstrate long cycle life up to 1,000 deep charge-discharge cycles

Tien Duong
DOE program manager
EERE Vehicle Technology Office

Jun Liu
PNNL

Jie Xiao
PNNL

Jihui Yang
University of Washington

Stan Whittingham
Binghamton

Yi Cui
Stanford/SLAC

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Flow battery demonstration project at PNNL

- Evaluate technical performance of first battery with 24-hour capacity to be deployed and tested in the field
- Investment of $10M from Office of Clean Energy Demonstrations

500kW flow battery can sustain facilities with critical functions during prolonged power outages

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Thank You