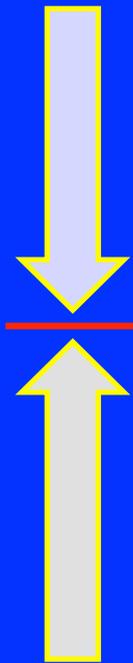


Developing Cost-effective Technology, Involving the States, and Assuring Safety

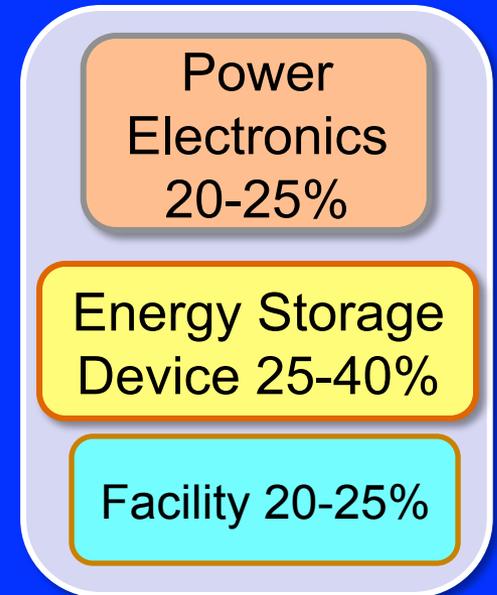
**IMRE GYUK, PROGRAM MANAGER
ENERGY STORAGE RESEARCH, DOE**

Storage Economics:



The **Cost** of a Storage System depends on the Storage Device, the Power Electronics, and the Balance of Plant

The **Value** of a Storage System depends on Multiple Benefit Streams, both monetized and unmonetized



LCOE depends on Application! Policy is important!

Energy Storage: Risk Reduction through Research and Development

- **Cost competitive energy storage technologies**
 - Targeted scientific investigations of key materials, devices, and systems
- **Validated reliability & safety**
 - Independent testing of prototypic devices and understanding of degradation. Safety Initiative.
- **Equitable regulatory environment**
 - Enable industry, utility, developer collaborations to quantify benefits, provide input to regulators.
- **Industry acceptance**
 - Highly leverage field demonstrations and development of storage system design tools

Teaming with PNNL, SNL, ORNL:

Materials – Devices – Systems – Analysis

Focused on Commercialization !

100+ peer reviewed publications

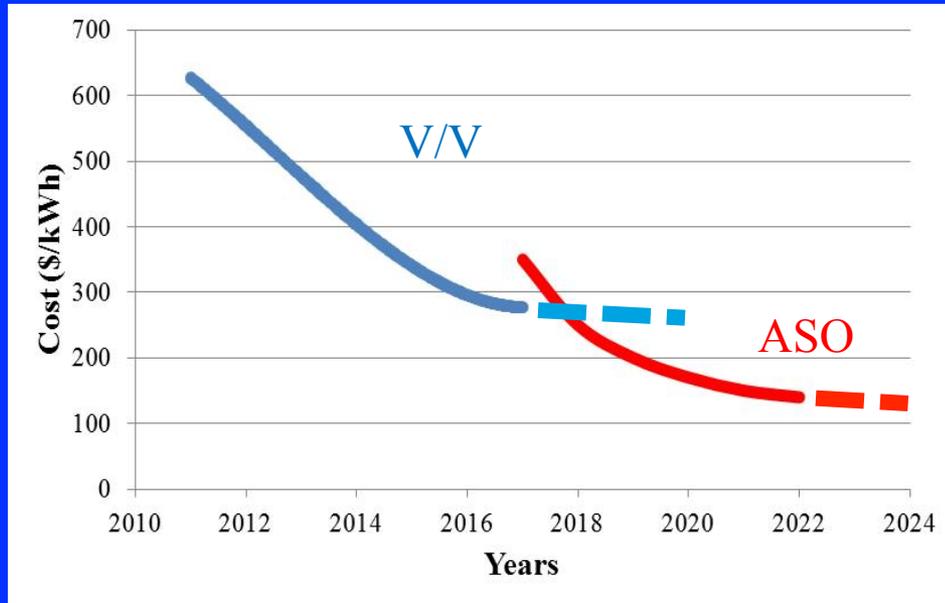
50+ Patents, 4 R&D 100 Awards

Fed. Lab Consortium Award for Tech Transfer

Projects at major Universities

Work with Korea, Japan, Singapore

Materials Research
For Cost Competitive
Energy Storage



V / V Redox System with Mixed Acid Electrolyte

- Temperature stability + 80%
- Energy density + 70%
- Projected system **cost** of \$300kWh for 4 hour system
- 5 Licenses

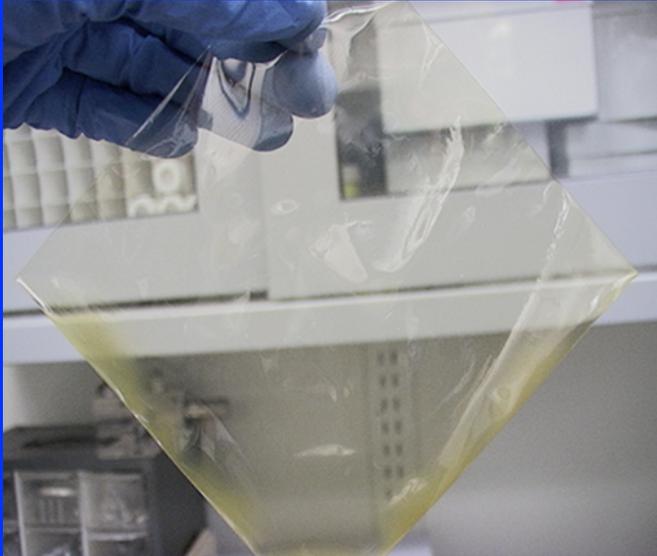
Following consistent Performance Enhancement, and Reduction in System Costs, Redox Material and Membrane Costs now predominate.

New Technology:
Aqueous Soluble Organics

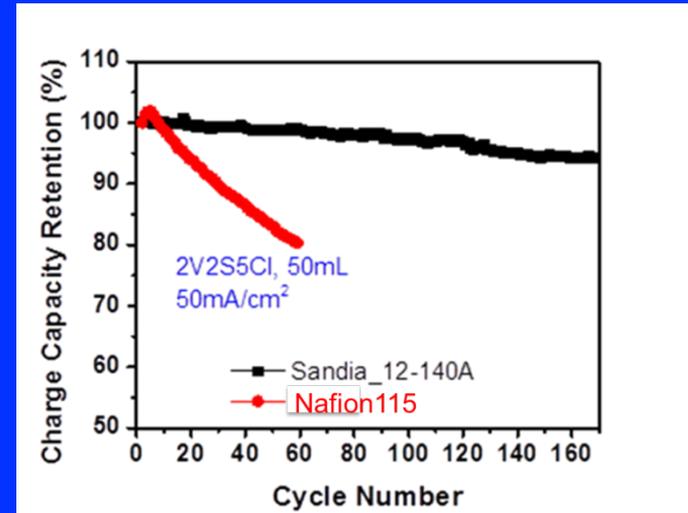


UniEnergy 600 kW/2.2MWh battery system

Membrane Development at SNL:



Development of high performance durable polymers at SNL leads to superior separators



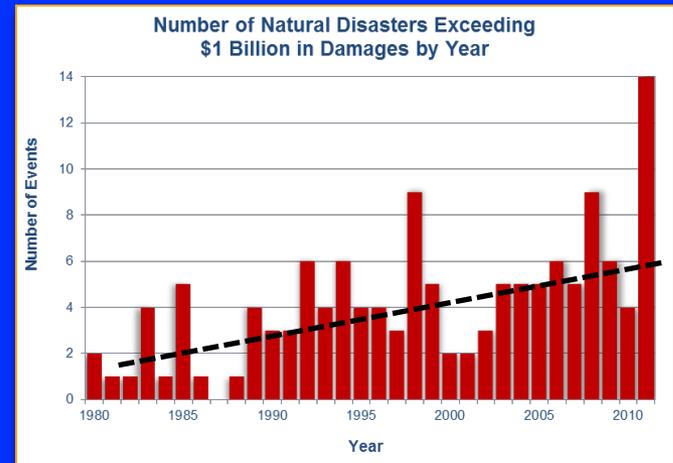
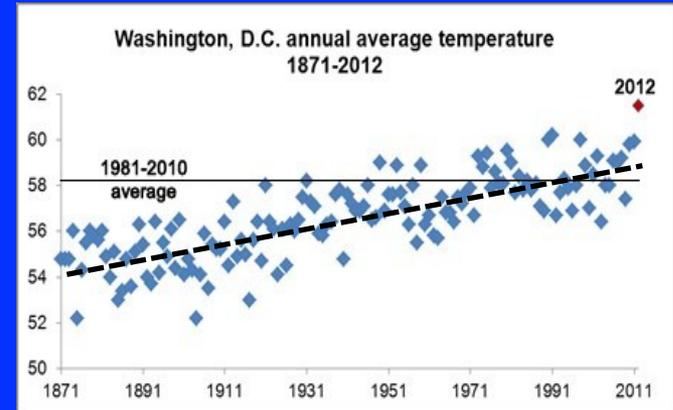
Performance of SNL Membrane vs. Nafion

Preliminary estimates show that the new membrane is two orders of magnitude less expensive than Nafion.

DOE / State Initiatives:
Grid Support,
Resilience, and
Emergency Preparedness

Energy Storage for Emergency Preparedness

Every \$1 on protection measurements
Can prevent \$4 in repairs after a storm!



Trends indicate the situation
will get worse not better!!

Vermont Public Service Dept. – DOE Green Mountain Power

Solicitation issued by VPS. Joint funding by VPS, DOE-OE, GMP

Rutland, VT
4MW / 3.4MWh of storage
Integrated with 2MW PV
Integrator: Dynapower

Groundbreaking: Aug. 12, 2014
Commissioning: Sep. 15, 2015



Situated on Brown Field area

Storage: Ancillary grid services, peak shaving during high load periods
PV: Green power for the grid

System can be islanded to provide emergency power for a resilient microgrid serving a highschool / emergency center.

➡ Referenced in Governor's Energy Plan!

➡ Hawaii

Washington State Clean Energy Fund:

Solicitation for \$15M for Utility Energy Storage Projects

Selected projects with UET vanadium flow battery:

- Avista (1MW / 4MWh) -- PNNL -- WA State U
- Snohomish (2MW / 8MWh) – PNNL -- 1Energy -- U of WA

Under a DOE / WA MOU, PNNL will participate in both projects, providing use case assessment and performance analysis.

Vanadium technology with
1.7x Energy density
developed at PNNL for DOE



Ribbon Cutting
Avista, April 2015

Oregon State, Joint Solicitation with OR-DoE

- March 2014 – Portland Storage Workshop
with OR-DOE and OR-PUC
- April 2015 – Joint Solicitation finalized. Notice issued
- May 2015 – Storage Bill passed; 5MW or 1%
of peak for major utilities by 2020
- July 2015 – Northwest PUC storage workshop
organized by OE / PNNL
- Sep. 2015 – Joint Solicitation issued
- Sep. 2015 – EESAT Meeting in Portland

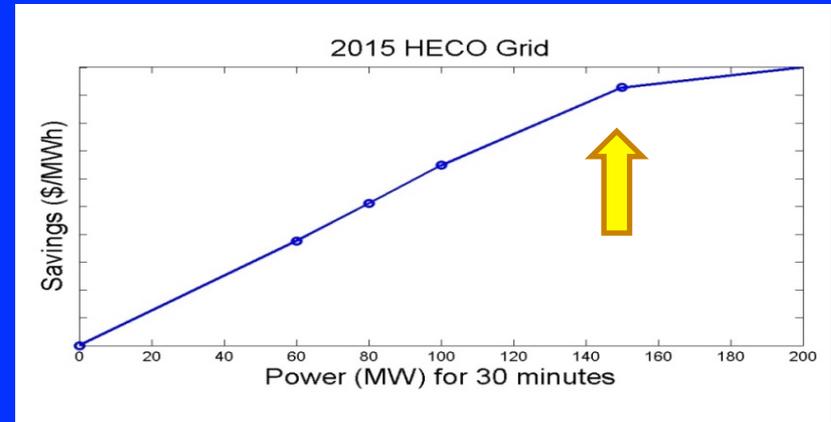
Hawaii Electric Company (HECO)

Motivation:

- Oahu relies on Diesel and Coal: Expensive! Large carbon footprint
- HI plans to increase renewables; Large scale wind, rooftop solar
- Variability of wind/solar presents grid integration challenges

Solution:

- HECO issues RFP 072114-01
- 60-200MW of energy storage
- 30 minute duration
- DOE MOU with HI in preparation



Analysis: Storage, how much?

- Production cost modeling to
 - Optimize generation mix to minimize system costs
 - Using different storage scenarios
- Results for 2015 scenario
 - Storage lowers costs
 - Analysis of increased renewable penetrations in progress

INDUSTRY TOOLS

SNL Energy Storage System Analysis Laboratory

Reliable, independent, third party testing and verification of advanced energy technologies from cell to MW scale systems



GS Battery at DETL



Energy Storage Test Pad (ESTP)



Milspray Deka Battery under testing

System Testing

- Scalable from 5 KW to 1 MW, 480 VAC, 3 phase, Both power and energy use tests.
- 1 MW/1 MVAR load bank for either parallel microgrid, or series UPS operations
- Subcycle metering in feeder breakers for system identification and transient analysis
- Safety Analysis

➔ Singapore

DOE International Energy Storage Data Base

energystorageexchange.org supported by Strategen

Over 1400 energy storage projects from 60 countries.

50 energy storage technologies are represented

The screenshot shows the homepage of the DOE International Energy Storage Database (beta). The header features the Department of Energy logo on the left, the site title "DOE International Energy Storage Database (beta)" in the center, and the Sandia National Laboratories logo on the right. A left-hand navigation menu includes links for Home, PROJECTS (Basic Search, Advanced Search), US POLICIES (Basic Search, Advanced Search), UPLOAD INFORMATION (New Project, New Policy), and Contact Us. The main content area displays a world map with several location pins (orange and green) indicating project sites. Below the map are two large buttons labeled "Projects" and "Policies". To the right of the map, a text block describes the database's purpose: "The DOE International Energy Storage Database (beta) provides free, up-to-date information on grid-connected energy storage projects and relevant state and federal policies." A final paragraph states: "All information is vetted through a third-party verification process. All data can be exported to Excel or PDF. Our hope is that this site will contribute to the rapid development and deployment of energy storage technologies."

DOE International Energy Storage Database (beta)

Sandia National Laboratories

Home

PROJECTS

- Basic Search
- Advanced Search

US POLICIES

- Basic Search
- Advanced Search

UPLOAD INFORMATION

- New Project
- New Policy

Contact Us

The DOE International Energy Storage Database (beta) provides free, up-to-date information on grid-connected energy storage projects and relevant state and federal policies.

All information is vetted through a third-party verification process. All data can be exported to Excel or PDF. Our hope is that this site will contribute to the rapid development and deployment of energy storage technologies.

Projects Policies

Grid Energy Storage Safety Initiative

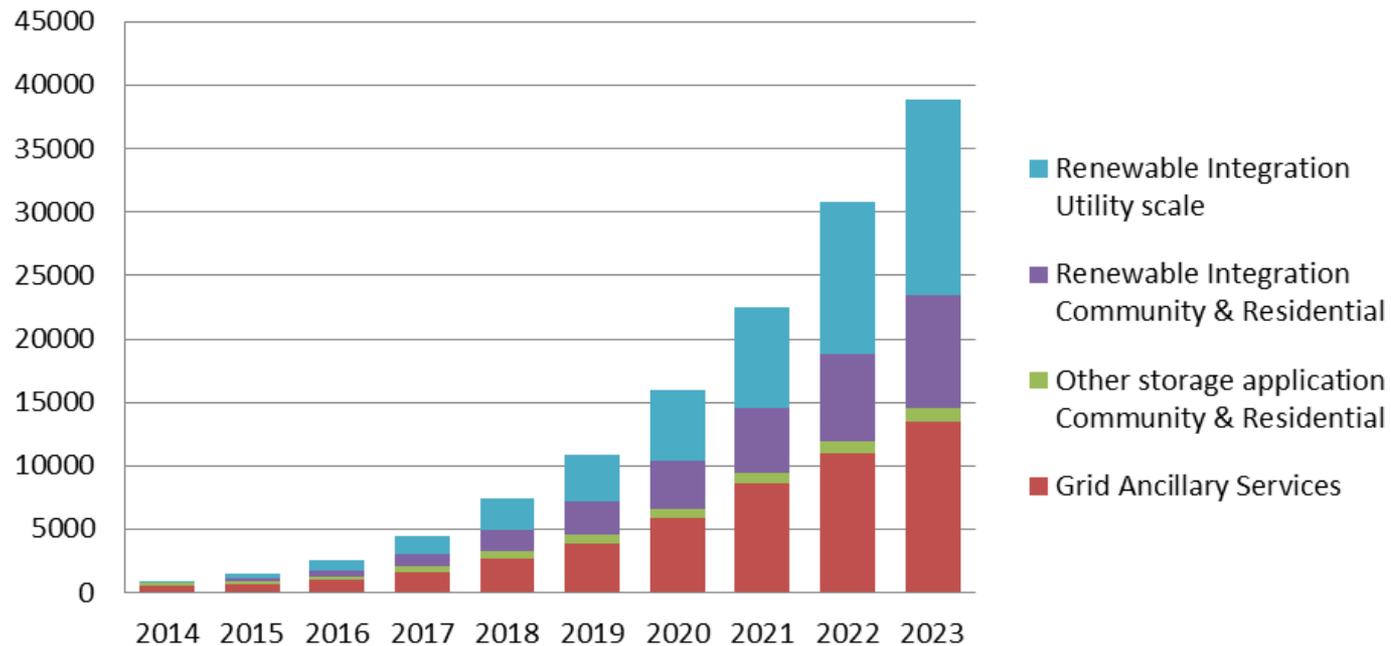
DOE identified *Validated Safety* as a critical need for the success of grid energy storage.

DOE is engaging key energy storage stakeholders:

- DOE OE Energy Storage Safety Workshop, Feb. 2014
- Published Inventory of Codes and Standards
- *Strategic Energy Storage Safety Plan – Dec. 2014*
- ES Working Group to consider storage safety
 - Safety Research Issues
 - Outreach to Responders
 - Codes and Standards



Total installed capacity (MW) of battery ESS by Application type



The Energy Storage Market is headed for major Expansion

New Cost Effective Technologies

New Benefit Streams opened

Major Solicitations / Mandates in:

California (1.3 GW)

Hawaii (200 MW)

Ontario (50 MW)

Involvement of States: VT, WA, OR, HI

Widespread Interest in China, Korea, Japan, EU

Energy Storage is Coming of Age!

PNNL 22010, June 2014; Protocol for Uniformly Measuring and Expressing the Performance of Energy Storage Systems; D. Conover et al.

PNNL 23390, June 2014; Determination of Duty Cycle for Energy Storage Systems Integrated with Microgrids

DOE-EPRI 2013 Energy Storage Handbook in Collaboration with NRECA

 <http://www.sandia.gov/ess/publication/>

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