OVERVIEW OF ENERGY STORAGE PROGRAM AT THE PACIFIC NORTHWEST NATIONAL LABORATORIES

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Funded by the Energy Storage Systems Program of the U.S. Department Of Energy through Pacific Northwest National Laboratories
Launched the $15M Transformational Materials Science Initiative at PNNL to address the materials science challenges for energy storage in 2007.

**Core capabilities:**

- Controlled synthesis/assembly of complex materials
- In-situ measurement and characterization and modeling

**Focus areas:**

- Energy storage
- Energy conversion

Conducted a PNNL workshop on the research needs for stationary energy storage;

Initiated nanostructured electrode materials research for Li-ion batteries;

Initiated proof-of-concept work for planar Na-beta batteries;

Started to explore the fundamental chemistry in redox flow batteries;

Supported the initial development of the method for grid analysis.
Current Research focus areas

Economic and performance requirement for different applications

Materials and technology challenges

Current and emerging technologies for storage
Different technologies will have different applications. There will not be a single answer for the storage problem.

PPNL is working on three key technologies:

- **Li-ion battery**: inexpensive materials and safe chemistry;
- **Redox flow battery**: increase energy density and electrolyte stability;
- **Na-beta battery**: improve safety reduce operating temperature.
Addressing Fundamental Challenges for Large Scale Energy Storage

Tools and methodologies to predict and analyze the economics of specific technologies for different scales/different applications and guide smart grid integration;

Fundamental understand of the materials properties and chemical processes in complex, reactive environments and systems;

New materials, chemistry and components to significantly improve the efficiency, reliability, safety and life span of current and future storage systems;

Revolutionary designs, concepts and architectures that can significantly reduce the system and maintenance cost of large energy storage systems;

Novel energy storage mechanisms, energy storage technologies that are environmentally friendly and that are not dependent on materials and chemicals of limited supply.
In-situ TEM and advanced high field NMR techniques for characterization

C. Wang et al, Nano Lett, in revision
Separators and membranes are widely used, but suffer cross-contamination and fouling.

Schematic of Nafion membrane

![Schematic of Nafion membrane](image)

**Schematic of Nafion membrane**

(b)

![Graph of V4+ concentration vs. diffusion time](image)

(b) 2M V4+ Nafion  
1.8M V4+ Nafion  
1.8M V4+ Membrane A  
1.8M V4+ Nafion  
1.8M V4+ 2h polymerized  
1.8M V4+ 2h polymerized

**Graph of V4+ concentration vs. diffusion time**

(c)

![Graph of Ln(T2) sec vs. 1000/T (K)](image)

(c) Pure Nafion  
$E_a = 3.8 \text{ kJ/mol}$  
Nafion used in Flow Cell  
$E_a = 6.8 \text{ kJ/mol}$

**Graph of Ln(T2) sec vs. 1000/T (K)**

(d)

![Diagram of Nafion molecules](image)

(d) Nafion used in Flow Cell  
$E_a = 6.8 \text{ kJ/mol}$

**Diagram of Nafion molecules**

(e)

![Diagram of Nafion molecules](image)

(e) Nafion used in Flow Cell  
$E_a = 6.8 \text{ kJ/mol}$
New understanding of Nafion membranes: wide pore channels (2.4 nm), suggesting the importance of water diffusion for H conducting. Such water diffusion mechanism will also favor the diffusion of hydrated cations.

Integrated Energy Storage Team at PNNL

Transformational Materials Science Initiative

Transportation Storage: Li-ion, Li-S, Li-Air

Cross-cutting capabilities

Modeling Simulation

In-situ TEM and NMR

Grid analysis

Electrical infrastructure operation center

Stationary Technology Development

Redox flow batteries

Planar Na-beta batteries

Stationary Li-ion batteries

Low T Na batteries