Non-aqueous Flow Batteries for Grid Scale Energy Storage
DOE Office of Electricity, Priorities:

• Puerto Rico and U.S. Virgin Islands Restoration and Resiliency Efforts
• North American Energy Systems Resiliency Model
• Mega-Watt Scale Grid Storage
• Revolutionize Sensing Technology Utilization
• Operational Strategy for Cyber and Physical Threats
Energy Storage Program

Storage System

Materials

Researchers

Power Electronics
V/V Redox
Zn-MnO₂
Na-based
ASO Flow

Prototype

State Regulatory Support
Use Case Evaluation
Performance Protocols
Reliability Test Center

Industry

Stakeholder Engagement

Safety Codes and Standards

Developers

Safety
R&D

Deployment

Performance Protocols

Protocol Center

ASO Flow

Redox

V/V

State

Regulatory
Support

Power Electronics

Safety

R&D

Reliability

Test Center

Energy Storage Program

Advanced Grid Research

OFFICE OF ELECTRICITY
US DEPARTMENT OF ENERGY
Li-ion Batteries?
Low cost, market ready

Cycle life <<20 years
Safety Issues
Social & Ecological Issues
No Recycling!
No U.S. Manufacture
Mixed Acid V/V Redox Flow Battery
Enhanced Temperature Range, Good Energy Density, Cost Estimate $300/kWh, 20 year Cycle Life
Recycleable, Commercially Available
We want low Cost!
**Cost Goals for Focus Technologies**

*Manufactured at scale*

<table>
<thead>
<tr>
<th>Technology</th>
<th>Cost (kWh)</th>
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<tbody>
<tr>
<td>Aqueous Soluble Organic (ASO)</td>
<td>$125</td>
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<tr>
<td>Redox Flow Batteries (Stack+PE)</td>
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<tr>
<td>Zinc Manganese Oxide (Zn-MnO$_2$)</td>
<td>$50</td>
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<td>2 Electron System</td>
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<tr>
<td>Low Temperature Na-NaI based Batteries</td>
<td>$60</td>
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<tr>
<td>Advanced Lead Acid</td>
<td>$35</td>
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Standard potential (V) of redox couples

$E^\circ = 1.85$V

$E^\circ = 1.26$V

$E^\circ = 1.2$V

We want high Potential !
Non-aqueous Redox Flow Batteries

Flow Batteries decouple Energy and Power
Suitable for Long Duration Batteries.

High Cell Voltage, and high energy density (~4.5V)
Larger Temperature Window
→Increased Viscosities and Decreased Conductivities

Metal based: Ru, Fe, Mn, Cr, Ni, Co, V
All-organic Technologies
Hybrid Aqueous / Non-aqueous Systems
Non-aqueous Redox Flow Batteries show Considerable Promise and are well worth Research Investment!