Storage Program Overview
Advanced Research Projects Agency (ARPA-E)

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What Makes ARPA-E’s Mission Unique: Focus on High-Risk, Transformational Technologies
ARPA-E’s Project Portfolio
Three-year Programs with Focused Performance Targets
ARPA-E’s Storage Portfolio
Projects are Across 5 Programs, Plus 2 Open Solicitations

Transportation Energy Technologies

Stationary Energy Technologies

- PETRO
- Electrofuels
- MOVE
- RANGE
- BEEEST
- Solar ADEPT
- BEETIT
- GRIDS
- IMPACCT
- ADEPT
- GENI
- FOCUS

HEATS  AMPED  REACT  SBIR/STTR  METALS  SWITCHES
ARPA-E’s Storage Portfolio Has Grown Rapidly
>$200M of Funding for Storage Technology Since 2009

<table>
<thead>
<tr>
<th>PROGRAM</th>
<th>TECHNOLOGY AREA</th>
<th>FUNDING ($M)</th>
<th># PROJECTS</th>
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<td>OPEN 2009</td>
<td>Transportation &amp; Stationary: Metal Air; Flow cells, capacitors, solid state</td>
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<td>BEEST</td>
<td>Transportation: High Energy Density</td>
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<td>Stationary: Flow cells, conventional cells, SMES, reversible fuel cell, flywheels</td>
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<td>OPEN 2012</td>
<td>Transportation &amp; Stationary: New flow Cell Chemistries; solid state</td>
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<td>AMPED</td>
<td>Transportation &amp; Stationary: Improved BMS algorithms and sensors</td>
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<td>SBIR 2012</td>
<td>Transportation &amp; Stationary: Flow cells, advanced membranes, high-temp cells</td>
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<td>RANGE</td>
<td>Transportation: Robust Lower Energy Density Incorporated into Vehicle Design</td>
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Sample ARPA-E Project: CUNY
From High-Risk R&D to Storage Start-up in 48 Months

2010

- $3M ARPA-E award with aggressive life target (2000 cycles) for non-rechargable Zn-MnO₂ alkaline cell
- Technical focus was developing new cathode materials (MnO₂), electrode design, and cycling protocol
- Distinguished academic team with industry partners and T2M experience

2014

- >2000 cycles on Zn-MnO₂, now optimizing electrode composition and electrolyte to attain >3000
- UEP founded in 2012; secured additional R&D funding from NYSERDA, BPA, and ConEd
- Closed seed round in 2012; nearing close of Series A funding
Sample ARPA-E Project: Harvard University
Novel, Low-Cost Flow Battery is Maturing Rapidly

Quinone-Bromide Chemistry
- Low Cost Electrolyte: <$27/kWh at scale
- Fast Kinetics: 1000x faster than \( \text{VO}_2^+ / \text{VO}^{2+} \)
- Modest Stack Costs: carbon paper electrodes, no catalyst
- High Power: > 600 mW/cm\(^2\) (peak)
- Durable: > 99.8% capacity retention (700 cycles)
- Non-Hazardous: Aqueous, non-toxic electrolyte

Quinone-Quinone Chemistry
- Currently under development

Harvard Department of Chemistry & Chemical Biology

Nature 505, 195-198 (2014) doi:10.1038/nature 12909
How do we create a path to scale innovation?

- Need to demonstrate performance, cycle life, cost and manufacturability of new technology at a reasonable scale
- How can we screen and optimize promising technologies before we fund costly scale up?
CHARGES: Cycling Hardware to Analyze and Ready Gridscale Electricity Storage (CHARGES)

- Existing ARPA-E performers provide single cell and multi-cell systems for testing
- CHARGES awardees will provide analysis and testing expertise and the facility where new storage technologies can be tested under controlled conditions as well as under “real world” microgrid operating conditions
- CHARGES awardees also will facilitate information exchange with potential buyers of stationary storage systems, including utilities and IPPs
- The objective is to resolve fundamental challenges in physics and chemistry for emerging stationary storage technologies before substantial scaling is required
- Will also generate credible performance data in the process
www.arpa-e.energy.gov