Overview of Gridscale Rampable Intermittent Dispatchable Storage (GRIDS) Program

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Energy Innovation Pipeline

Office of Science

ARPA-E

Transition Path

Transition Path

Applied Energy Offices

Venture Capital and Small Businesses
Private Equity/Capital & Large Corporations
Government Procurement

Basic Science
Technology Maturity
Deployment
Disruptive Technologies Not Only Result in Quantitative Advances – They are Fundamentally New Technology Learning Curves
FOA-1 Projects Span 10 Areas

- Energy Storage: 6 projects
- Biomass Energy: 5 projects
- Carbon Capture: 5 projects
- Solar Fuels: 5 projects
- Vehicle Technologies: 5 projects
- Renewable Power: 4 projects
- Building Efficiency: 3 projects
- Waste Heat Capture: 2 projects
- Conventional Energy: 1 project
- Water: 1 project
What makes an ARPA-E project?

1. Impact
   - High impact on ARPA-E mission areas
   - Credible path to market
   - Large commercial application

2. Transform
   - Challenges what is possible
   - Disrupts existing learning curves
   - Leaps beyond today's technologies

3. Bridge
   - Between basic science and applied technology
   - Not researched or funded elsewhere
   - Catalyzes new interest and investment

4. Team
   - Best-in-class people
   - Cross-disciplinary skill sets
   - Translation oriented
What is the Problem to be Solved?

Flow Technologies
US Power Grid: World Largest Supply Chain With No Warehouse

Electric Grid: Premier Achievement of 20th Century [NAE]

Harness Renewable Power: #1 Grid Challenge for 21st Century

Storage Separates Electric Generation and Load in Space and Time
Electric Energy Storage Applications

**Generation Related Attributes**
- Ancillary Services
- Renewable Integration
- Generator Cycling Cost
- Asset Capacity
- Price Arbitrage
- Peak Shaving
- Rate Optimization

**T&D Related Attributes**
- Reliability
- Power Quality
- Congestion Relief
- Asset Utilization
- T&D Upgrade Deferral
- T&D Life Extension

**Storage Duration**
Balancing Reserves Firm Wind Generation for High Renewable Penetration on Power Grid

System Challenge: Efficient Energy Storage at Minutes to Hours Duration to Firm Ramping Balance
Storage For Firming Renewables

**Problem:** Minutes-to-Hours Changes in Power

**Need:** Grid Storage that is Dispatchable and Rampable

**ARPA-E:** Energy Storage to Enable High Penetration of Renewables
Focus: Transformational approaches to energy storage to enable low cost

New Technology Need: Cost-Effective Energy Storage Solutions

Greater than 5000 cycles and 80% RTE

Economics of Hydro / Deploy Anywhere

Technology Agnostic: Chemical, Mechanical, Electromagnetic

Connect Across Industry for Handoffs

Grid-scale Rampable Intermittent Dispatchable Storage (GRIDS) Metrics

Costs comparison:
- Energy Storage Costs ($/kWh)
- Power Costs ($/kW)

New Storage Technologies:
- Pumped Hydro
- Underground Compressed Air
- 2-5X Lower

Limited Sites

Minimum Response Time:
- Seconds
- Minutes

Economics of Hydro / Deploy Anywhere

Technology Agnostic: Chemical, Mechanical, Electromagnetic

Connect Across Industry for Handoffs
Portfolio of Projects

UNIVERSITY/LAB

- USC University of Southern California
  - Rechargeable Fe-Air Battery
- Berkeley Lab
  - Advanced Flow Battery
- CUNY The City University of New York
  - Rechargeable Zn-MnO₂ Battery

SMALL BUSINESS

- Primus Power
  - New Flow Battery Electrode
- Fluidic Energy
  - High Power Metal-air Storage
- Proton Energy Systems
  - Neutral Water Fuel Cell

CORPORATION

- United Technologies Research Center
  - Advanced Flow Battery
- General Atomics and Affiliated Companies
  - Soluble Lead Flow Battery
- General Compression
  - Fuel-Free Isothermal Compression
- ABB
  - 2G-HTS SMES
- Boeing
  - High-Energy Flywheel
What is the Problem to be Solved?

Flow Technologies
Flow Assisted Rechargeable Zn-MnO$_2$ Battery

Several formulations of MnO$_2$ material cycled in 1.5 Ah Zn-MnO$_2$ batteries have reached >500 cycles demonstrating the cycleability of MnO$_2$ under the correct conditions.

- non-toxic
- extremely inexpensive
- water compatible
- $1200/MT
A unique flow battery cell that provides 10X increase in power density

Novel cell will reduce system cost by 2-4X

Initially Vanadium redox chemistry

Jump-starts domestic effort in redox flow batteries, which had migrated out of North America
Rechargeable Iron-Air Battery

**Cell Reaction:**
\[ Fe + H_2O + \frac{1}{2} O_2 \leftrightarrow Fe(OH)_2 \]

*Anode:* (discharge)
\[ Fe + 2OH^- \rightarrow Fe(OH)_2 + 2e^- \]

*Cathode:* (discharge)
\[ \frac{1}{2} O_2 + H_2O + 2e^- \rightarrow 2OH^- \]

< $100/kWh & >5000 cycles
high power, low cost, electrochemical storage

“Iron is Cheap, Air is Free”
400kW PowerPod™ System Concept

Unlike Today's Technology
~2 Years

ARPA-E Project Electrode for
>20 Year Lifetime
Grid Scalable Lead Acid Battery

Innovations
- MSA-based electrolyte
- Carbon-based electrodes
- Flow-battery design

Impact
- Cost Reduction
- Grid Scalable
- Cycle-life Improvement
Fuel Cells to Flow Systems

- Membrane Properties
- Catalysts
- Electrolyte Densities
- Electrode Materials

- By Another Name: Redox Flow Cell
  Metal-Air
  Alkaline Exchange
  Semi-Solid Flow
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Questions?