ARPA-E Storage Overview

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September 26, 2012
DOE Energy Storage Review
A Brief History of ARPA-E

2006
*Rising Above the Gathering Storm* (National Academies)

2007
America COMPETES Act

2009
*ARPA-E Launched at National Academies: April 27, 2009*

First Funding Announcement: May 2, 2009

2009 ARRA
($400M appropriated)

FY11 Budget CR
($180M appropriated)

FY12 Budget
($275M appropriated)

Innovation based on science and engineering will be primary driver of our future prosperity & security
Energy Innovation Pipeline

Office of Science

ARPA-E

Technology Transition Path

Technology Transition Path

Applied Energy Offices

Basic Science

Technology Maturity

Deployment

Venture Capital and Small Businesses

Private Equity/Capital & Large Corporations

Government Procurement
Progress of Disruptive Technologies

Transformational & disruptive technologies that lead to new learning curves

Steam-powered Cugnot (1769)
Benz Motorwagen (1885)
Ford Model T (1914)

Transformational & disruptive
existing learning curve
new learning curve
tipping point

cost / performance

time
Societal Problem Driven Fundamental Research: Industrial Synthesis of Ammonia

Food Global Population, on Track to Exceed 2,000,000,000

Food Production (Wheat) in Concentrated Locations (US)

$N_2 + 3H_2 \rightarrow 2NH_3$

“...the fixation of Nitrogen is vital to the progress of civilized humanity”

William Crookes (1898)
Ammonia R&D Timeline

Royal Academy
“Wheat Problem”

Understanding Properties Of Ammonia

Academic Fight

Lab Demo

Pilot Scale

Production

“Grand Challenge”

Basic Research

Break-Through

“Catalyst Genomics”

1898  1900  1902  1904  1906  1908  1910  1912  1914

Crookes

Ostwald & Nernst

Haber

Bosch

Mittasch
Technology Innovators Might be Found in Unlikely Places

Samuel Langley
Ivy League Faculty
Smithsonian President
Well Funded

Wright Brothers
Little Education
Bicycle Mechanics
Boot-Strapped
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
Characteristics of Renewable Electricity Balancing Reserves
Firm Wind Generation for High Renewable Penetration.

**System Challenge:** Efficient Energy Storage at Minutes to Hours Duration to Firm Ramping Balance

Wind Capacity: 3372 MW

Hydropower Range: 1600-2000 MW
Balancing Wind and Load Has Gotten More Challenging

Wind Capacity 4711 MW

September 2012 Update Example

Hydropower Range 1600-2000 MW
Externality

$2.50 / MBTU for Natural Gas

and $25-50 / MWh for Electricity

Storage Need to Be **Systems** Solutions at **Low Cost**
Focus: Transformational approaches to energy storage to enable low cost

New Technology Need: Low-Cost Energy Storage Solutions

Grid-scale Rampable Intermittent Dispatchable Storage (GRIDS) Program Metrics

Balancing Reserves at <$100/kWh

Greater than 5000 cycles and 80% RTE

Economics of Hydro / Deploy Anywhere

Technology Agnostic: Chemical, Mechanical, Electromagnetic

Connect Across Industry for Handoffs
ARPA-E Stationary Energy Storage Portfolio

Capacity & Energy

Power Density (Capacity)

Flywheel

SMES

Flow Cells

E-C Cells

CAES

Stationary Storage

FOA1: 6
GRIDS: 12
SBIR: 4
GRIDS: Sample Efforts

**General Compression**
Isothermal Compression: Technology Bridge to Commercial Follow-on

**United Technologies**
High Current Density Flow Battery

**University of Southern California**
Iron-Air: Iron is Cheap & Air is Free

**City University of New York**
Cheap, Recyclable Alkaline Cell
ADEPT: Agile Delivery of Electrical Power Technologies

Integrated Circuits for Power Systems

- On-chip inductors and transformers
- High-voltage transistors (GaN and SiC)
- High-energy capacitors
Magnetics
- largest, most expensive part of a power converter

>92% Dimmable LED Driver (comm. 37-50% of luminaire cost)

1MW Photovoltaic Inverter
($0.2/W)

40% Magnetics

\[ Z = j\omega L \]

Discrete inductors
- Large inductance
- Large volume
- Poor AC performance

Planar spiral inductors
- Small area consumption
- Small inductance
- Limited performance in sub-GHz applications

Source: Shan Wang, Stanford
High Voltage Solid-State Devices
20kV & 1MW SiC Transistors

- Significantly improved SiC IGBTs
  - High voltage (20kV)
  - Extremely efficient (>98%)
  - Fast switching (50kHz)
  - Higher minority carrier lifetimes, and blocking layers – improved reliability and lifetime
  - High device yields

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<td>50 kHz</td>
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Electric Grid Energy Storage

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

**T&D Related Attributes**
- Reliability
  - New Potentially Disruptive Applications
    - Consumer-Side Storage
    - EV Charging Support
  - T&D Upgrade Deferral
  - T&D Life Extension

Storage Duration
Recent Opportunities

Energy Storage SBIR/STTR [7 new]

Advanced Management and Protection of Energy-Storage Devices (AMPED) [12 new]

Open FOA

https://arpa-e-foa.energy.gov/
Meet the ARPA-E Project Teams at Poster Session this Afternoon

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A123 SYSTEMS

EnerVault Safe, Reliable, Cost-Effective Energy Storage