Advanced Research Projects Agency - Energy (ARPA-E)

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U.S. Department of Energy

http://arpa-e.energy.gov/
SPUTNIK MOMENT OF OUR GENERATION

Greenhouse Gas Emissions & Global Warming

Energy Security

U.S. Technological Lead
WHICH PATH SHOULD WE TAKE?

CO₂ Emissions of Selected Countries

Business-as-usual vs Opportunity

GDP per capita (PPP, $1995)

CO₂ emissions per capita (tCO₂)
Game Changers from 20th Century

Artificial Fertilizers
Green Revolution
Polio Vaccination
Antibiotics
Airplanes
Electrification
Nuclear Energy
Transistor
Integrated Circuits
Fiber Optic Communication
Wireless Communication
Internet

100 years

20 years

Imagine all of this happening in the next 20 years...

- Solar electricity generation at a cost lower than that from fossil fuels
- Carbon capture and utilization at net cost lower than its market price
- Car batteries with 3X energy density and 4X lower cost
- Transportation fuels from sunlight and/or agricultural waste at cost lower than petroleum
- 50-80% reduction in energy consumption in homes and buildings
- Optimized and secure grid with storage
- Cement, steel, glass … production at 5X lower carbon emissions
- .......
THE U.S. IS FALLING BEHIND IN THE CLEAN ENERGY RACE

Worldwide shipments of Solar Cells in 2008 (Megawatts)

Lithium-ion battery manufacturing volumes in 2009 (millions of cells/year)

John Goodenough, U. Texas at Austin
CREATION OF ARPA-E

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

2007
America COMPETES Act

American Recovery and Reinvestment Act of 2009  
(Recovery Act)

$400M appropriated for ARPA-E  
President Obama launches ARPA-E in a  
speech at NAS on April 27, 2009
FIRST ROUND OF FUNDING

Concept Paper Phase

- Review 312 Encouraged Full Applications
  - April - June 2009

Full Application Phase

- Panel Reviews
  - June - July 2009

Final Selection

- 37 Projects (avg. $4M) (2-3 years)
- September – Early October 2009
- Announced on October 26
EXAMPLES FROM FIRST ROUND OF FUNDING

Cellulosic Biofuels

- Artificial Cellulose Breakdown is Expensive ($$)
- Physical pre-treatment, chemicals and enzymes
- Fuel-producing microorganisms
- Solar energy

Cellulosic Biofuels

- Mimic jet engines, not propellers, for wind turbine
- 40% lower cost expected vs. horizontal axis wind turbines (HAWT)

Breakthrough High Efficiency Mixer/Ejector Wind Turbine (MEWT) – FloDesign Wind Turbine Corp.

GreenGenes™ Technology

- Putting the cow inside the plant!
- Plant produces all the enzymes & chews itself from the inside!!

Grid-Level Electricity Storage - MIT

- Megawatts of storage
- For several hours

Potential Cost: $50/kW-hr

Lithium Ion Laptop Battery: $2000/kW-hr
Lithium Ion Car Battery: $1000/kW-hr
Sampling of New Programs

Wayne Gretzky

“I skate where the puck is going to be, not where it has been”

“You miss 100% of the shots you don’t take”
BATTERIES FOR ELECTRICAL ENERGY STORAGE FOR TRANSPORTATION (BEEST)

Where We Are Now

- Expensive cars
- Powered by Li-ion batteries
- Battery Cost: approx. $15,000
- Limited range: 40 miles
- Cell-level energy density: 150 W-hr/kg
- Cost: approx. $1000/kW-hr

Majority of Current Investments:
Improvement in Today’s Lithium Ion Batteries

Where We Need to Go

- Broad range of vehicle types
- Battery Cost < $10,000
- Range of 300+ miles
- Targets:
  - Cell-level energy density: 400 W-hr/kg
  - Cost: $250/kW-hr
  - New architectures & manufacturing processes
    - Examples
      - Metal-air batteries
      - Li-S batteries

Japanese gov’t investing $60M/yr
ELECTROFUELS

1. Difficult to store
2. Difficult to store
3. Greenhouse gas emissions
4. 60% imported

CO₂

Electricity

H₂

Gasoline

Octane

1. Difficult to store
2. Difficult to store
3. Greenhouse gas emissions
4. 60% imported
ARPA-E Focus: Transformational approaches to energy storage that enable grid-scale deployment at very low cost (~$100/kWh)

<table>
<thead>
<tr>
<th>Energy Storage Costs ($/kWh)</th>
<th>Power Based Cost ($/kW)</th>
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<td>$10K</td>
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<td>$1K</td>
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Energy Storage Cost Target: 2-5X Lower

Minimum Response: 10min

Minimum Response: 1hr at 1 GW

Need: Innovative Technologies for Cost-Effective Energy Storage
FOA 3: Building Energy Efficiency Through Innovative Thermo-devices (BEETIT) – Building Cooling

Primary Energy Use for Cooling
(kJ of energy used to cool 1 kg of air.)

In this example, we assume:

- $T_{\text{amb}} = 90^\circ \text{F}$, Rel. Hum. = 0.9
- $T_{\text{supply}} = 55^\circ \text{F}$, Rel. Hum. = 0.5

Today:
\approx 100-120 \text{ kJ/kg}

ARPA-E Target

Theoretical Limit:
\approx 10-12 \text{ kJ/kg}

ARPA-E Focus: Cut cooling energy consumption and GHG emissions by 25 – 40%
Advanced circuit architectures... coupled with advanced circuit architectures and scalable manufacturing processes...

...results in low-cost, higher performance power electronics across many applications.

- Fully integrated, chip scale power converters (10-50W, >100V)
- Kilowatt scale package integrated power converters (3–10 kW, >600V)
- Lightweight, solid state, medium voltage energy conversion (1MW, 13kV)

Advancements in power electronics materials...

- Soft magnetics
- High voltage switches
- High-density charge storage

Energy density [Wh/kg] Power density [W/kg]
DEPARTMENT OF ENERGY

Office of the Secretary
Dr. Steven Chu, Secretary
Daniel B. Poneman, Deputy Secretary*

Office of the Under Secretary
For Nuclear Security/Administrator for National Nuclear Security Administration
Thomas P. D'Agostino

Office of the Under Secretary
For Science
Dr. Steven E. Koonin, Under Secretary for Science

Office of the Secretary for Energy Efficiency and Renewable Energy
Assistant Secretary for Energy Efficiency and Renewable Energy

Office of the Secretary for Nuclear Energy
Assistant Secretary for Nuclear Energy

Office of the Secretary for Science
Assistant Secretary for Science

Office of the Secretary for Fossil Energy
Assistant Secretary for Fossil Energy

Office of the Secretary for Nuclear Management
Assistant Secretary for Nuclear Management

Office of the Secretary for Energy Security
Assistant Secretary for Energy Security

Office of Food Energy
Assistant Secretary for Food Energy

Office of the Secretary for Nuclear Management
Assistant Secretary for Nuclear Management

Office of the Secretary for Energy Security
Assistant Secretary for Energy Security

Office of Science
Advanced Scientific Computing Research
Basic Energy Sciences
Chemical, Environmental Sciences
Geosciences
Health Sciences
High Energy Physics
Nuclear Physics

Office of Legacy Management
Office of Management
Office of Public Affairs
Office of the General Counsel
Office of the Inspector General
Office of the Assistant Secretary for Field Operations
Office of the Assistant Secretary for Energy Efficiency and Renewable Energy
Office of the Assistant Secretary for Nuclear Energy
Office of the Assistant Secretary for Policy, Energy and International Affairs
Office of the Assistant Secretary for Technology
Office of the Assistant Secretary for Planning and Evaluation
Office of the Assistant Secretary for Nuclear Management
Office of the Assistant Secretary for Energy Security
Office of the Assistant Secretary for Science

Assistant Secretary for Energy Information Administration
Assistant Secretary for Nuclear Management
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Assistant Secretary for Energy Security
Assistant Secretary for Science

* The Deputy Secretary also serves as the Chief Operating Officer

26 May 09
ARPA-E ORGANIZATION
Lean, Nimble, Collaborative, Flat

Coordinates with Office of Science
Technology Push Office

All-Star Program Directors (4 yrs max)

- Break down stovepipes
- Encourage debate and partnership between technology pushers and pullers
- Provide thought leadership to create new programs

BEEST
BEETIT
IMPACCT
GRIDS
ADEPT
Electrofuels
BUILDING ON OUR STRENGTHS

- Best R&D infrastructure in the world

- Best innovation ecosystem in business and entrepreneurship

- Highly energized youth, ready to deeply engage
  - **ARPA-E Fellows Program** (Launched Dec 8th at MIT Energy Club): bring best and brightest scientist, engineers, and technical entrepreneurs in to ARPA-E and create a think tank
MANAGING EXPECTATIONS

NOW 3 - 5 YRS 10+ YRS

- Follow on investment post ARPA-E award ($)
- Increase in enterprise value of company ($)
- Companies created (#)
- Initiating new technology-business ecosystems
- Accelerated market entry - Products to market (#) / Product sales ($)
- Patents filed and licensed (#)
- Papers published in top journals (#)
- World Record-setting “best-in-class” performance (#)
- Help identify mechanisms for scaling innovations

Home Runs

- Domestic and global sales, US market share ($)
- Avoided greenhouse gas emissions (tCO₂ equivalent)
- Reduced oil imports (barrels of oil equiv.)
- Creation of new technology/business or new industry ecosystem (#)
- Jobs created (#)
- Beating current projections and trajectories (Moving McKinsey GHG abatement cost curves, EIA & IPCC projections, etc.)
Historically: 
(a) Change is slow; 
(b) Energy is a ubiquitous commodity; 
(c) Investments & systems can last a long time
Panel Topics

- How do we foster and identify game-changers? Is it random or is there a system?
- How do we go from lab to market with disruptive energy technologies that challenge business-as-usual?
- How do we scale innovations in the US? How do we accelerate the pace?
- How do we balance global competitiveness and partnerships?
- How do we ensure national security through energy technologies?
- How do we build and engage regional innovation clusters through private-public partnerships?
- How can DOE play a role in energy innovation?

Scientist/Engineer (Academia, National Labs, Industry); Investors; Small/Large Industry Senior Management; Policy Groups; Congress; White House

- 1700 people on 2 months notice
- Technology showcase
Martin Luther King (1967):

“....We are now faced with the fact, my friends, that tomorrow is today. We are confronted with the fierce urgency of now. In this unfolding conundrum of life and history, there is such a thing as being too late.”