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Advanced Research Projects Agency - Energy
ICEF Roadmap Workshop

April 22, 2016
Energy and Emissions - World

CO₂ emissions

18.3 Gtonne/yr 32.3 Gtonne/yr 45.5 Gtonne/yr

Energy Consumption, QBtu


OECD

Non-OECD

Historical

Projection


* Includes both traditional and modern uses of biomass
The ARPA-E Mission

**Mission:** To overcome long-term and high-risk technological barriers in the development of energy technologies

**Goals:** Ensure America’s

- Economic Security
- Energy Security
- Technological Lead in Advanced Energy Technologies

**Means:**

- Identify and promote revolutionary advances in fundamental and applied sciences
- Translate scientific discoveries and cutting-edge inventions into technological innovations
- Accelerate transformational technological advances in areas that industry by itself is not likely to undertake because of technical and financial uncertainty
If it works…

will it matter?
Energy and Emissions – Changing what’s possible

U.S. CO₂ emissions (Gtonne/yr)


U.S. Energy Consumption, QBTu

- Petroleum (liquids)
- Coal
- Natural gas
- Nuclear
- All renewables*

* Includes both traditional and modern uses of biomass

5.5 (2025 target: 4.3)

U.S. CO₂ emissions, Gtonne/yr


EIA Reference Case, 2040

IEA 450 Scenario, 2040

Other Renewables
Bioenergy
Hydro
Nuclear
Natural gas
Coal
Oil

5.6

1.9

U.S. CO₂ emissions (Gtonne/yr)

2010

2020

2030

2040

5.6

1.9

U.S. 2050 target ~1.2

Note: EIA biofuels projection moved to “Bioenergy” to match IEA categorization

Left: EIA AEO Figure MT-9 (Reference Case), 2013 updated for Actual Right: EIA 2014 AEO Tables A2 and 17, and IEA World Energy Outlook 2014, Table 2.1

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ARPA-E goal: Disruptive technologies

- Disruptive technology
- Transformational potential
- Existing learning curve
- New learning curve – disruptive technology

- Steam-powered Cugnot (1769)
- Benz Motorwagen (1885)
- Ford Model T (1914)
Program Directors and T2M Advisors

Program Directors and T2M advisors serve 3-year terms

ROLES & RESPONSIBILITIES - PD

‣ Perform technical deep dive soliciting input from multiple stakeholders
‣ Present & defend program concept in climate of constructive criticism
‣ Actively manage portfolio projects from merit reviews through project completion
‣ Develop milestones and work “hands-on” with awardees in value delivery
‣ Represent ARPA-E as a thought leader in the program area

ROLES & RESPONSIBILITIES – T2M

‣ **Manage** the Commercialization progress of project technologies
  – Manage project teams’ T2M efforts through T2M Plans and jointly developed milestones
‣ **Advise:** support project teams with skills and knowledge to align technology with market needs
  – IP and competitor management
  – Value Chain and Market analysis
  – Product hypothesis
  – Economic analysis
  – Partner discovery and engagement
Metrics of Transition Toward Market

Since 2009 ARPA-E has supported more than 475 projects with approximately $1.3 billion of R&D funding. Of those, 206 are alumni projects.*

45 ARPA-E projects have attracted more than $1.25 billion in private-sector follow-on funding*

Cumulative number of projects that have:
- Received Follow on Funding from the Private Sector
- Formed New Companies
- Continued development with Funding from Government Programs

* As of the end of Feb 2016
GRIDS
GRID-SCALE ENERGY STORAGE

Program Director: Eric Rohlfing; Dr. Patrick McGrath  Tech-to-Market Advisor: Sue Babinec  Year: 2010

Goals

- System Capital cost < $100/kWh
- Round trip storage efficiency > 80%
- Lifetime > 5000 cycles and 10 years

Grid batteries Investments

- OPEN 2009: 3 projects
- GRIDS: 7 projects
- SBIR: 4 projects
- OPEN 2012: 8 projects
- OPEN 2015: 1 project

Techno-economics

\[
\text{Cost per Storage Cycle (} \$/\text{kWh}_e) = \frac{\text{Energy Storage Cost (} \$/\text{kWh)}}{\text{Cycles(#)} \times \text{Round Trip Efficiency}}
\]

Levels of integration of battery system components
Example: Primus Power
CEO: Tom Stepien

- Flow Cell Energy Storage
  - Zn-Br cell chemistry
  - Modular 25 kW, 125kWh units
  - Good cycle-life with potential for significant increase

- Demonstration underway at Miramar Marine Corps Air Station
  - 250-kilowatt, 1-megawatt-hour system
  - Purpose to reduce mid-afternoon utility premiums and supply full power to one building for 2-3 days

- Status
  - Over $60M in venture funding
  - Products on the market
  - Strategic agreement with Samruk Energy (Kazakhstan) to supply 1,250 batteries
MONITOR
Methane Observation Networks with Innovative Technology to Obtain Reductions

Mission
Develop innovative, cost-effective technologies that can accurately detect and measure methane emissions associated with natural gas production and distribution.

Goals
- Detect a methane leak of at least 6 SCFH, locate the leak within 1 meter, and quantify the flow rate
- Significantly decrease the cost of methane detection, yielding a system cost less than $3,000/year/wellhead
- Improve the sustainability of domestic natural gas production

<table>
<thead>
<tr>
<th>Program Director</th>
<th>Dr. Bryan Willson</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year</td>
<td>2014</td>
</tr>
<tr>
<td>Projects</td>
<td>11</td>
</tr>
<tr>
<td>Total Investment</td>
<td>$31 million</td>
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The Portfolio: 3 Technology Categories

- **LONG DISTANCE**
- **AERIAL**
- **POINT SENSORS**
- **IMAGER**

**Fixed Technology Categories**
- University of Colorado Boulder
- PARC
- IBM
- Duke University

**Mobile Technology Categories**
- Bridger Photonics
- Rebellon Photonics
- PSI Physical Sciences Inc.

**Enabling Technology Categories**
- THORLabs

Image courtesy of Cuadrilla Resources
Portable Imaging Spectrometer for Methane Leak Detection

**PROJECT HIGHLIGHTS**

- Miniaturization of Rebellion’s Gas Cloud Imager (GCI), a long-wave infrared imaging spectrometer
- Camera will be lightweight and portable – the size of a Red Bull can - and capable of being incorporated into personal protective equipment
- Data processing uses cloud-based computing architecture that streams results to mobile device

**AWARD AMOUNT:** $4.3 million
ARPA-E goal: Disruptive technologies

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

Transformational potential:
- Existing learning curve
- New learning curve – disruptive technology
DELTA
Delivering Efficient Local Thermal Amenities

Mission
Develop Localized Thermal Management Systems (LTMS) such as wearables or locally installed systems to heat or cool the physical space around the human body rather than the entire building.

Goals
• Improve overall building performance and reduce Heating Ventilation and Air Conditioning (HVAC) energy consumption by at least 15%
• Enable energy savings of upwards of 2% of the total domestic energy supply
• Enable radical and sustainable architecture in next generation energy-efficient building design

Program Director
Dr. Jennifer Gerbi

Year
2014

Projects
11

Total Investment
$29.8 million
Personal heating and cooling

Ventilation comes to you

Comfort control through clothing
ARPA-E supports multi-institutional teams with substantial involvement from the private sector:

- 74% of projects involve more than one institution
- 79% of projects include the private sector, as leads or partners
Transitions Toward Market Adoption

R&D → Prototype → Demonstration → Commercialization

Valley of Death #1: Public Funds
Valley of Death #2: Follow-on Development Funds
Valley of Death #3: Venture Capital/Private Equity

Time
Investment
DELTA
Delivering Efficient Local Thermal Amenities

- High-efficiency heat pump
- Temporal load shifting
- Radiative
- Conductive
- Convective
- Active heat removal

**DELTA Portfolio**

- Near range energy transfer
- Extended range energy transfer
- Wearable technologies
- Office suite retro-fit

Direct heating and cooling
Comfort driven office equipment