ADVANCED RESEARCH PROJECTS AGENCY (ARPA-E)

ARUN MAJUMDAR
DIRECTOR, ARPA-E
U.S. DEPARTMENT OF ENERGY

ARPA-E Energy Innovation Summit
Monday, March 1 2010
THREE SPUTNIKS OF OUR GENERATION

- Energy Security
- U.S. Technological Lead
- Greenhouse Gas Emissions & Climate Change
Purpose of Summit

- Define the ARPA-E DNA
  - Vision and mission
  - How do we operate (scientifically, administratively)?
  - What are we looking for (technical, people, ...)?
  - What are our metrics of success?

- Engage with the community

- Showcase ARPA-E funded projects

- Showcase projects that ARPA-E could not fund and expose them to other funding sources

- Engage all stakeholders to discuss how to foster and scale innovations in energy technologies
  - Technical community, small/large business, investment community, policy community, federal agencies, Congress, White House
RECRUITING

- **Program Directors (Max. 4 yrs):** Active researchers who have one foot in science & engineering and the other in technology development and business
  - Active academics or national lab researchers who have started businesses or who actively work with industry
  - Researchers from the industry who are active in research & technology development (publishing, patents, etc) and who have participated in business

- **ARPA-E Fellows (Max. 2 yrs):** Best and the brightest scientists, engineers and technical entrepreneurs to form a think tank - identify challenges, opportunities, and new approaches to address energy technologies.
  - Fellows < 3 years after PhD
  - Senior Fellows > 3 years after PhD
PLAN FOR THE DAY

- **ARPA-E Past and Present**
- **Morning Panels on Commercialization**
  - Energy Technology Commercialization
  - How to Take Advantage of SBIR
- **Report of Recent ARPA-E Workshops**
  - Grid-Scale Electrical Energy Storage
  - Building Energy Efficiency
  - Power Electronics
  - Energy from Wastewater
- **Afternoon Panels**
  - Best Practices in Technology Transfer
  - Next Generation Energy Entrepreneurs
- **Technology showcase**
ARPA-E Past and Present

ARPA-E Energy Innovation Summit
Monday, March 1 2010
The Brief History of ARPA-E

What is an ARPA-E Project

Representative ARPA-E FOA 1 Projects

ARPA-E: Moving Forward
ARPA-E’S ORIGIN

American Recovery and Reinvestment Act of 2009 (Recovery Act)

2007 America COMPETES Act

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

$400M appropriated for ARPA-E
President Obama launches ARPA-E in a speech at NAS on April 27, 2009
“Identify and promote revolutionary advances in fundamental sciences”

“Translate scientific discoveries and cutting edge inventions into technological innovations”

“To enhance the economic and energy security of the U.S.”

“To ensure U.S. technological lead in developing and deploying advanced energy technologies”
ARPA-E’S CULTURE

- **Excellence**: Recruit all-star team to ARPA-E; thought leadership; focus on potentially game-changing ideas; enable creation and support of the best teams

- **Openness**: Open to best ideas regardless of origin; sharing and partnership with Congress and other stakeholders; public understanding of value of technology for society

- **Integrity**: New program creation and proposal review process

- **Speed**: Streamline transactions; accelerate science to market; respond to community input

- **Metrics Driven**: Operations and program management driven measurable targets

- **Flat and Nimble**
ARPA-E as an organization is intended to be nimble and flat.
ARPA-E was created with a vision to bridge gaps in the energy innovation pipeline.

Existing Programs

Office of SC (5B)

- Basic Science

Applied Programs (4B)

- Applied Science

Loan Guarantees ($128B)

- Prototype/Demos

- Asset Investors

ARPA-E

what ARPA-E will do

- Seek high impact science and engineering projects
- Invest in the best ideas and teams
- Will tolerate and manage high technical risk
- Accelerate translation from science to markets
- Proof of concept and prototyping

what ARPA-E NOT will do

- Incremental improvements
- Basic research
- Long term projects or block grants
- Large-scale demonstration projects
FOA 1 – Open to all energy technologies; yet required to be game changing/high impact (Announced April `09, selections Oct `09)

- Rigorous review process with assistance from academia, industry and government
- Secretary Chu called for Nation’s experts assist with reviews
- The Nation responded - Over 500 reviewers participated
  - All reviewers vetted by senior DOE leadership
  - 8,694 review hours; 4.18 person years

---

Concept Papers
~3700 Received

Full Applications
~338 Received

Senior Panel

37 Projects
~$151 Million

FUNDING OPPORTUNITY
ANNOUNCEMENT - ROUND 1
DIVERSE PROJECT LEADS FOR FOA 1

Selected Projects Lead Organization Type

- Small Businesses 43%
- Educational Institutions 35%
- Large Businesses 19%
- Other Non-Profit 3%
37 PROJECTS WERE SELECTED FROM ACROSS THE COUNTRY

Legend
- Small Business (16)
- University (13)
- Large Business (7)
- Non-profit Organization (1)
- Team Members (54)

Source: Merit Review Board results; ARPA-E Full Application cover sheet submissions.
The Brief History of ARPA-E

What is an ARPA-E Project

Representative ARPA-E FOA 1 Projects

ARPA-E: Moving Forward
WHAT ARPA-E IS LOOKING FOR

High Impact on ARPA-E Mission Areas –
- Reduction in energy imports
- Improvement in energy efficiency
- Reduction in energy-related emissions, including greenhouse gases
- To “ensure” U.S. “technological lead in developing and deploying advanced energy technologies

Disruptive, Innovative Technical Approach –
- ARPA-E is focused on high risk/high reward R&D
- Interested in –
  - New technical approaches that move to entirely new learning curves
  - Fundamentally new areas of research with uncharted white space

Best-in-class People & Teams
- Complementary, cross-discipline skill sets
- Strong interest to bring in new, talented scientists and engineers to energy technology research
- Break down barriers between science and engineering

Strong Impact of ARPA-E Funding Relative to Private Sector –
- Invest in areas too risky for the private sector
- ARPA-E investments derisk technologies and catalyzes follow on private sector investments
FOA 1 projects can be categorized into one of ten energy technology areas.

- Energy Storage: 6 projects
- Biomass Energy: 5 projects
- Carbon Capture: 5 projects

VBR Power Systems
FOA 1 PROJECTS CAN BE CATEGORIZED INTO ONE OF TEN ENERGY TECHNOLOGY AREAS

- **Renewable Power**: 4 projects
- **Solar Fuels**: 5 projects
- **Vehicle Technologies**: 5 projects

**Components of Vehicle Technologies**:
- Fresh Air-Fuel Mixture
- Burnt Exhaust Gas
- Rotational Direction
- Loading
- Shock Wave
- Compression
- Constant Volume
- Combustion
- Expansion wave
- Turbomachinery
- Power Extraction
- Scavenging
FOA 1 PROJECTS CAN BE CATEGORIZED INTO ONE OF TEN ENERGY TECHNOLOGY AREAS

- Waste Heat Capture: 2 projects
- Building Efficiency: 3 projects
- Conventional Energy: 1 project
- Water: 1 project
The Brief History of ARPA-E

What is an ARPA-E Project

Representative ARPA-E FOA 1 Projects

ARPA-E: Moving Forward
RTI WILL DEVELOP A NOVEL CATALYTIC BIOMASS PYROLYSIS PROCESS TO PRODUCE STABLE BIO-CRUDE

Goal: A novel process that uses multi-functional catalysts for controlling and optimizing biomass pyrolysis chemistry to produce an intermediate that can be integrated with the existing transportation fuel production and distribution infrastructure.

Project Objectives:

- Develop multi-functional catalysts with selective oxygen removal and cracking functionalities for producing a pyrolysis product similar to crude oil.
- Develop a biomass pyrolysis process that optimizes carbon conversion, catalyst performance, and cost.
- Establish solid foundation for process scale-up, catalyst scale-up, bio-crude upgrading to fuels to accelerate technology transition and commercialization activities.

Team Members: ADM, Conoco Phillips, Albemarle Corp.
BIO-CRude will be fabricated as an intermediate for fuel production with tailored physical and chemical properties.

**Mission impact:** This program aims to reduce the dependence on foreign oil and lower GHG emissions through the displacement of fossil fuels with biofuels.
ITN ENERGY SYSTEMS WILL DEVELOP ELECTROCHROMIC WINDOWS FOR ACTIVE CONTROL OF SOLAR HEAT AND LIGHT TRANSMISSION

**Goal:** Overcome manufacturing cost challenges that have prevented widespread adoption by fabricating electrochromic films on plastic substrates in a roll-to-roll process.

- Buildings account for 40% of U.S. energy use.
- Windows alone account for 4 quadrillion BTUs (quads).
- Modeling shows that electrochromic windows can reduce electricity use by 20-40%*

*“Early Market Study of Electrochromic Windows” Lawrence Berkeley Laboratories for California Energy Commission*

**Team Members:** EPRI, MAG Industrial
SOLID-STATE ELECTROCHROMIC FILMS REDUCE HEATING AND COOLING LOADS AND MINIMIZE OVERHEAD LIGHTING USE

- Tunable transmission to match variable building loads
- Achievable range: visible transmission from 2 to 70%
- Voltage required for switching only: maintains color state without power

Mission impact: adapt advanced roll-to-roll manufacturing used in thin film solar markets to enable widespread adoption of highly efficient windows
NANOASIS WILL UTILIZE CARBON NANOTUBES (CNTS) TO MAKE INDUSTRIALLY-SCALABLE REVERSE OSMOSIS (RO) MEMBRANES

**Goal:** Transform desalination and wastewater reuse and produce dramatic energy savings with advanced membranes and reduced capital costs

---

**SuperFlux™**

Carbon Nanotube Membrane

Sea / Brackish Water

Clean Water
No Salt, Contaminants, Bacteria / Viruses

Water Passes More Freely Through the Membrane
Requiring 30-50% Less Energy
CARBON NANOTUBES WILL BE USED TO IMPROVE MEMBRANE PERMEABILITY AND REDUCE THE COST OF WATER GENERATED

- Frictionless, Atomically Precise Pore
- **Enhanced Flux** 1,000-10,000X vs. Conventional Pores

**Mission impact**: increased membrane permeability, resulting in 30-50% energy savings and 10-23% lower capital costs for reverse osmosis plants

**LOW COST MEMBRANE ARCHITECTURE**
- SuperFlux™
- 10X Higher Membrane Permeability vs. Today’s State of the Art

**ULTRA-HIGHLY PERMEABLE SMALL DIAMETER CARBON NANOTUBE**
The Brief History of ARPA-E
What is an ARPA-E Project
Representative ARPA-E FOA 1 Projects

ARPA-E: Moving Forward
ACTIVE PROJECT MANAGEMENT

- **Project Team:**
  - Program Directors Deeply Technically Engaged with Projects
  - Technical, Administrative, Contracting, Legal, Commercialization Support

- **Invested in Your Success:**
  - Milestones & Deliverables Negotiated with Program Director
  - Quarterly Site Visits/Meetings
  - Aggressive, but Realistic, Annual “Go/No-Go” Decision Points
    - Re-scope or terminate non-performing projects
  - Program Flexibility
    - Can accommodate changes in approach if warranted and agreed to by all parties
  - Support in Finding Next Stage Support for Successful Projects
WIDE OPEN FOA 1 ➔ FOCUSED PROGRAMS IN ROUNDS 2 & 3

Inputs to Focused FOA Development

- FOA 1: Snapshot of Current U.S. Energy Technology Landscape
- 550 Responses to “Request for Information” Suggesting High Impact Program Areas
- 7 Focused Workshops

FOCUSED FUNDING OPPORTUNITIES ($30-$35M programs)

Round 1

- Wide open “Early Harvest” solicitation
- Seeking to support best U.S. energy technology concepts across the board

Round 2 & Round 3 FOAs

- Focused funding opportunities around a grand market or technical challenges
- Metrics driven programs with clear “over the horizon” cost and/or performance metrics
PROCESS FOR DEVELOPING FOCUSED PROGRAMS

Recruit Program Director → Program Director Deep Dive/Outreach → Public Workshop/Publish Results

Internal Program Presentation/Debate → Program Improvement → Program Pitch to Director

Yes ▶ No
New ARPA-E REVIEW PROCESS

- **FOA Announced**
- **Concept Papers Received**
- **Full Applications Received**
- **External Review of Concept Papers; Encourage Full Applications from High Promise Concept Papers**
- **External Full Application Review/Panel Meeting in Washington, DC**
- **Reviewer Comments Sent to PIs, 4 days to respond to reviewer comments w/ data, explanations, etc...**
- **Program Director Integrates All Information To Make Selections for Award**
- **PD Presentation to Director to Approve Selections and Final Program Budget**
<table>
<thead>
<tr>
<th>Event</th>
<th>Date</th>
<th>Presenter(s)</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grid Scale Electrical Energy Storage</td>
<td>Oct 4</td>
<td>Mark Johnson, David Danielson, &amp; Imre Gyuk</td>
<td>(Mark Johnson, David Danielson, &amp; Imre Gyuk)</td>
</tr>
<tr>
<td>Building Energy Efficiency</td>
<td>Dec 15</td>
<td>Colin McCormick &amp; Ravi Prasher</td>
<td>(Colin McCormick &amp; Ravi Prasher)</td>
</tr>
<tr>
<td>Direct Solar Fuels</td>
<td>Oct 21</td>
<td>Eric Toone</td>
<td>(Eric Toone)</td>
</tr>
<tr>
<td>Energy from Wastewater</td>
<td>Jan 27</td>
<td>Mark Shannon</td>
<td>(Mark Shannon)</td>
</tr>
<tr>
<td>Carbon Capture &amp; Conversion</td>
<td>Oct 29</td>
<td>Mark Hartney</td>
<td>(Mark Hartney)</td>
</tr>
<tr>
<td>Power Technologies</td>
<td>Feb 9</td>
<td>Rajeev Ram</td>
<td>(Rajeev Ram)</td>
</tr>
<tr>
<td>Electrical Energy Storage for Vehicles</td>
<td>Nov 3</td>
<td>David Danielson</td>
<td>(David Danielson)</td>
</tr>
</tbody>
</table>
### ARPA-E ROUND 2 – FIRST FOCUSED FUNDING OPPORTUNITIES

- **3 Focused Programs Totaling ~$100M; 2-3 Year Projects**
- **10 – 15 Projects per Program**

<table>
<thead>
<tr>
<th>2nd Round FOAs</th>
<th>Focus</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Batteries for Electrical Energy Storage in Transportation (BEEST)</strong></td>
<td>Electrical Energy Storage for PHEV-100+ and EV’s &lt;br&gt; &gt; 400 Wh/kg, &gt; 600 Wh/liter (cell) &lt;br&gt; &lt; $250/kWh (system) &lt;br&gt; Moving beyond traditional lithium ion batteries</td>
</tr>
<tr>
<td><strong>Innovative Materials and Processes for Carbon Capture Technologies (IMPACCT)</strong></td>
<td>Materials and processes for drastic reductions in energy penalty and cost of post combustion CO2 capture</td>
</tr>
<tr>
<td><strong>Electrofuels</strong></td>
<td>Develop modular non-photosynthetic, autotrophic biosynthetic systems that can assimilate energy from abundant sources for the production of energy dense liquid transportation fuels.</td>
</tr>
</tbody>
</table>
HOW TO PLUG INTO ARPA-E

- Join ARPA-E mailing list – http://arpa-e.energy.gov
- Engage ARPA-E with your ideas
- Participate in upcoming ARPA-E Workshops
- Apply to become an ARPA-E Program Director
- Apply to the ARPA-E Fellows Program
  - ARPA-E-jobs@hq.doe.gov
- Submit Concept Papers to Open ARPA-E Funding Opportunities
- Participate in ARPA-E Review Process
THANK YOU FOR YOUR ATTENTION
- Q & A -

Arun Majumdar
Shane Kosinski
Dave Danielson
Mark Hartney
Eric Toone