U.S. DEPARTMENT OF ENERGY

Advanced Research Projects Agency - Energy (ARPA-E) Annual Report for FY2011

Report to Congress
June 2012

United States Department of Energy
Washington, DC 20585

Message from the Director

The U.S. Department of Energy's Advanced Research Projects Agency – Energy's (ARPA-E's) goal is to ensure U.S. technological leadership by investing in research of energy technologies that are too risky for private sector investment, but if successful, will enhance the national, economic, and environmental security of the United States. This report presents a summary of ARPA-E's activities during Fiscal Year 2011.

Pursuant to statutory requirements, this report is being provided to the following Members of Congress, the Chairman and Ranking Member of each relevant authorizing and appropriations committees:

The Honorable Fred Upton
Chairman, House Committee on Energy and Commerce

The Honorable Henry Waxman
Ranking Member, House Committee on Energy and Commerce

The Honorable Ralph Hall
Chairman, House Committee on Science, Space & Technology

The Honorable Eddie Bernice Johnson
Ranking Member, House Committee on Science, Space & Technology

The Honorable Andy Harris
Chairman, Subcommittee on Energy and Environment,
House Committee on Science, Space & Technology

The Honorable Brad Miller
Ranking Member, Subcommittee on Energy and Environment,
House Committee on Science, Space & Technology

The Honorable Hal Rogers
Chairman, House Committee on Appropriations

The Honorable Norman Dicks
Ranking Member, House Committee on Appropriations

The Honorable Rodney Frelinghuysen
Chairman, Energy and Water Development Subcommittee,
House Committee on Appropriations

The Honorable Pete Visclosky
Ranking Member, Energy and Water Development Subcommittee,
House Committee on Appropriations

The Honorable Jeff Bingaman
Chairman, Senate Committee on Energy & Natural Resources

The Honorable Lisa Murkowski
Ranking Member, Senate Committee on Energy & Natural Resources

The Honorable Maria Cantwell
Chairman, Subcommittee on Energy,
Senate Committee on Energy and Natural Resources

The Honorable James Risch
Ranking Member, Subcommittee on Energy,
Senate Committee on Energy and Natural Resources

The Honorable Daniel Inouye
Chairman, Senate Committee on Appropriations

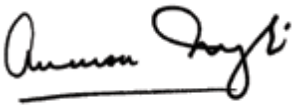
The Honorable Thad Cochran
Ranking Member, Senate Committee on Appropriations

The Honorable Dianne Feinstein
Chairman, Subcommittee on Energy and Water Development,
Senate Committee on Appropriations

The Honorable Lamar Alexander
Ranking Member, Subcommittee on Energy and Water
Development, Senate Committee on Appropriations

If you have any questions or need additional information, please contact me or Ms. Patricia Temple, Legislative Affairs Specialist, Office of Congressional and Intergovernmental Affairs, at (202) 586-4220.

Sincerely,



Arun Majumdar

Executive Summary

This report presents a summary of ARPA-E's activities during Fiscal Year 2011.

ARPA-E issued new funding solicitations in April 2011 across five technology areas: alternatives to rare earth materials, and breakthroughs in biofuels, thermal storage, grid controls, and solar power electronics. By September 2011, ARPA-E had announced the launch of 60 new projects totaling $156 million within these areas of focus.

From February 28 – March 2, 2011, ARPA-E held its second annual Energy Innovation Summit to engage a wide range of stakeholders in sharing ideas for the next generation of revolutionary energy technologies. From venture capitalists and business owners to policymakers and government officials, the event drew over 2,100 attendees and showcased over 200 transformational technologies. Speakers in attendance included former California Governor Arnold Schwarzenegger, Secretary of Energy Steven Chu, and Secretary of the Navy Ray Mabus.

In addition, ARPA-E signed non-binding non-exclusive Memoranda of Understanding (MOUs) to partner with the Electric Power Research Institute (EPRI) and Duke Energy in identifying opportunities to test and accelerate the commercialization of ARPA-E technologies that could bolster the electric grid. These partnerships will facilitate the exchange of information and offer test beds for further study of game-changing technologies.

Further, at the 2011 ARPA-E Energy Innovation Summit, Navy Secretary Ray Mabus announced new steps to strengthen our national security through the continued research development of advanced energy technologies under a non-binding MOU signed by the Departments of Energy and Defense.[1]

[1] Unless otherwise stated, all information in this report is as of September 30, 2011, the last day of Fiscal Year 2011.

ARPA-E ANNUAL REPORT FOR FISCAL YEAR 2011

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I. Legislative Language

Pursuant to statutory requirements prescribed in P.L. 110-69 and P.L. 111-358, the Director of the Advanced Research Projects Agency – Energy (ARPA-E) is providing a report describing projects supported by the Agency during Fiscal Year (FY) 2011 to the Chairman and Ranking Member of each relevant authorizing and appropriations committee.

II. Fiscal Year 2011 Appropriation

FY2011 marked ARPA-E's first appropriation since being launched by the American Recovery and Reinvestment Act of 2009 (Recovery Act). ARPA-E was appropriated about $180 million for FY2011, as a part of the Department of Defense and Full-Year Continuing Appropriations Act, 2011, P.L. 112-10, which was signed into law on April 15, 2011.

III. Funding Opportunity Announcements (FOAs)

On April 20, 2011, ARPA-E issued solicitations to develop five new program areas that could spark critical breakthrough technologies and secure America's energy future. On September 29, 2011, ARPA-E announced 60 cutting-edge research projects.[2] Totaling $156 million, ARPA-E's new selections focus on accelerating innovations in energy technology while increasing America's competitiveness in rare earth alternatives and breakthroughs in biofuels, thermal storage, grid controls, and solar power electronics.

The projects selected are located in 25 states, with 50% of projects led by universities, 23% by small businesses, 12% by large businesses, 13% by national labs, and 2% by non-profits. Prior to this FOA ARPA-E awarded $365.7 million in funds to approximately 120 groundbreaking energy projects within seven program areas. The selections under the most recent FOAs brings ARPA-E's total to approximately 180 projects across 12 program areas, worth about $521.7 million.

The programs created by the FY2011 FOAs are:

- **PETRO: Plants Engineered To Replace Oil ($36 million)**
    - ARPA-E funds breakthrough technologies that optimize the biochemical processes of energy capture and conversion to develop robust, farm-ready crops that deliver more energy per acre with less processing prior to the pump. If successful, PETRO will create biofuels from domestic sources such as tobacco

[2] Unless otherwise stated, all information in this report is as of September 30, 2011, the last day of FY2011.

and pine trees for half their current cost, making them cost-competitive with fuels from oil.

- **Example PETRO Project: University of Florida – Gainesville, Florida ($6.3 million).** The University of Florida project will increase the production of turpentine, a natural liquid biofuel isolated from pine trees. The pine tree developed for this project is designed both to increase the turpentine storage capacity of the wood and to increase turpentine production from 3% to 20%. The fuel produced from these trees would become a sustainable domestic biofuel source able to produce 100 million gallons of fuel per year from less than 25,000 acres of forestland.

- **REACT: Rare Earth Alternatives in Critical Technologies ($31.6 million)**
  - Rare earths are naturally-occurring minerals with unique magnetic properties that are used in many existing and emerging energy technologies. Rising rare earth prices have already escalated costs for some energy technologies and may jeopardize the availability and widespread adoption of many critical energy solutions by U.S. manufacturers. ARPA-E funds early-stage technology alternatives that reduce or eliminate the dependence on rare earth materials by developing substitutes in two key areas: electric vehicle motors and wind generators.
  - **Example REACT Project: Pacific Northwest National Lab "Manganese-Based Permanent Magnet" – Richland, Washington ($2.3 million).** PNNL's team will reduce the cost of wind turbines and electric vehicles by developing a replacement for rare earth magnets based on an innovative composite using manganese material. Manganese composites could potentially achieve twice the strength of the magnets used today, while using inexpensive and abundant raw materials. The team will develop stronger magnets by leveraging high-performance supercomputer modeling and high-speed experiments of various metal composite formulations that do not contain rare earths. If developed successfully, these composite magnets will reduce the U.S. dependence on expensive rare-earth material imports, and reduce the cost and improve efficiency of green technologies.

- **HEATS: High Energy Advanced Thermal Storage ($37.3 million)**
  - More than 90% of the energy consumed in the U.S. requires the transport and conversion of thermal energy. Therefore, advancements in thermal energy storage – both hot and cold – would dramatically improve performance for a variety of critical energy applications. ARPA-E will develop revolutionary cost-effective thermal energy storage technologies.
  - **Example HEATS Project: Massachusetts Institute of Technology "HybriSol" – Cambridge, Massachusetts ($2.9 million).** Using innovative nanomaterials, MIT will develop a thermal energy storage device, or a heat battery, that captures and stores energy from the sun to be released onto the grid at a later time. This energy storage device called "HybriSol" is transportable like fuels, 100% renewable, rechargeable like a battery and emissions-free. In addition,

"Hybrisol" can be used without a grid infrastructure for applications such as heating and water purification. If successful, this heat battery could have an unprecedented impact on efforts to decrease fossil fuel consumption and emissions, enabling solar energy to be accessible 24 hours a day.

- **GENI: Green Electricity Network Integration ($36.4 million)**
  - ARPA-E funds innovative control software and high-voltage hardware to reliably control the grid network, specifically: 1) cost-optimizing controls able to manage sporadically available sources, such as wind and solar, alongside coal and nuclear, and 2) resilient power flow control hardware – or the energy equivalent of an internet router – to enable automated, real-time control of grid components. If successful, these technologies will enable utilities and operators to optimally control the flow of power; making the grid more secure, resilient, reliable, and could potentially save billions of dollars every year.
  - **Example GENI Project: Texas Engineering Experiment Station – College Station, Texas ($4.9 million).** Historically the electric grid was designed to be passive causing electric power to flow along the path of least resistance. The Texas Engineering Experiment Station team will develop a new system that allows real-time, automated control over the transmission lines that make up the electric power grid. This new system would create a more robust, reliable electric grid, and reduce the risk of future blackouts, potentially saving billions of dollars a year.

- **Solar ADEPT: Solar Agile Delivery of Electrical Power Technology ($14.7 million)**
  - The SunShot Initiative leverages the unique strengths across DOE to reduce the total cost of utility-scale solar systems by 75 percent by the end of the decade. If successful, this would enable solar electricity to scale without subsidies and make the U.S. globally competitive in solar technology. ARPA-E's portion of the collaboration is the Solar ADEPT program, which focuses on integrating advanced power electronics into solar panels and solar farms to extract and deliver energy more efficiently. This program could reduce power conversion costs by up to 50 percent for utilities and 80 percent for homeowners.
  - **Example Solar ADEPT Project: Ideal Power Converters – Austin, Texas ($2.5 million).** Ideal Power Converters is developing light-weight electronics to connect photovoltaic solar panels to the grid. Their technology explores innovative circuits using revolutionary transistor designs to develop solar panel electronics for commercial-scale buildings that are compact enough to be installed on walls or roof-tops. The project goal is to reduce the weight of these electronics by 98%, reducing the cost of materials, manufacturing, shipping and installation, supporting the aggressive cost-reduction goals of the Department of Energy's SunShot Initiative.

Please find a full list of the projects announced under ARPA-E's FY2011 FOAs on September 29, 2011 in Appendix I.

IV. ARPA-E Energy Innovation Summit

The second annual ARPA-E Energy Innovation Summit was held from February 28 - March 2, 2011. It brought together key players from across the energy ecosystem to share ideas for researching and developing the next generation of energy technologies. The Summit's unique combination of leaders made it the perfect forum for developing energy solutions that will enable us to out-innovate our global competitors. Participants included the nation's leading individuals and organizations in energy innovation, including: technology entrepreneurs, large and small corporations with an interest in innovative energy technologies, venture capital investors, policymakers from the Administration and Congress and government officials.

Program Highlights

- 3-day event attracted 2,100 energy leaders from 49 states, Puerto Rico and 20 countries.
- Partnership announced between ARPA-E/Department of Energy and Department of Defense.
- More than 200 transformational technologies and exhibits took part in the Technology Showcase.
- 90 expert speakers and keynote addresses including:
    - Former Governor of California Arnold Schwarzenegger
    - Secretary of Energy Steven Chu
    - Secretary of the Navy Ray Mabus
    - ARPA-E Director Arun Majumdar
    - Senator Lamar Alexander (TN)
    - Senator Lisa Murkowski (AK)
    - Senator Mark Udall (CO)
    - Representative Steve Israel (NY)

V. Technical Partnerships: EPRI, Duke Energy, and the Department of Defense

In FY2011, ARPA-E signed partnership agreements with Duke Energy, one of the largest electric power companies in the United States, and with the Electric Power Research Institute (EPRI), a non-profit research organization that focuses on the electric power utility industry in the U.S. and abroad, to identify opportunities for testing and deploying ARPA-E funded projects that will bolster the electric grid.

Through the non-binding and non-exclusive Memorandums of Understanding (MOUs), ARPA-E, Duke Energy, and EPRI will identify opportunities to expand cutting edge smart

grid developments, grid-scale energy storage, power electronics, and energy efficient cooling technologies, among others.

Under the terms of the agreements, ARPA-E will facilitate the exchange of information between ARPA-E-supported projects, EPRI and Duke Energy, which delivers energy to approximately 4 million U.S. customers in five states. Duke Energy could deploy and test ARPA-E technologies at various power plants or wind farms. The technologies may also be studied at the company's McAlpine substation, a test bed for renewable, grid storage and smart grid technologies, or at the company's Envision Center, a smart grid demonstration and testing facility in Erlanger, KY.

EPRI, whose members represent more than 90 percent of the electricity generated in the U.S., will offer test-bed facilities at two of its research laboratories: a transmission and distribution research facility in Charlotte, North Carolina and at its Knoxville, Tennessee laboratory, where testing is conducted on consumer electronics, lightings, smart grid components, heating and cooling systems and electric vehicle infrastructure requirements.

At the 2011 ARPA-E Energy Innovation Summit, Navy Secretary Ray Mabus announced new steps to strengthen our national security through the continued research development of advanced energy technologies under a non-binding MOU signed by the Departments of Energy and Defense. The Department of Defense's (DOD) Office of the Assistant Secretary of Defense for Research & Engineering (ASD(R&E)) aims to take advantage of early technology breakthroughs funded by ARPA-E. Using ARPA-E's technical expertise in grid scale energy storage, batteries for electric vehicles, and power electronic, ASD(R&E) plans to develop an energy storage device that will provide future defense systems with long duration storage suitable for a variety of applications, including military bases and vehicles and eventually commercial grids.

Cost effective energy storage is also of interest to DOD's Installations and Environment office, which will work with ARPA-E to assess the technology requirements for storage across military installations. Vulnerability to energy supply disruption is a significant challenge for facilities dependent on the commercial power grid, and backup power is both limited and expensive. Onsite renewable electricity generation combined with grid scale storage would allow installations to maintain critical functions in the event of grid disruption and enhance installations' efforts to develop micro-grids for energy security.

VI. Conclusion

In FY2011, ARPA-E invested $156 million over five new technology areas, brought together the best minds throughout these emerging industries at its second annual Energy Innovation Summit, and secured partnerships with EPRI and Duke Energy that should help the innovative teams that ARPA-E supports to accelerate their technologies into the marketplace.

ARPA-E's goal is to help catalyze energy breakthroughs with speed and efficiency to secure America's future. By attracting the best minds and focusing on major technical challenges across multiple fields, ARPA-E's work is stimulating the technical and entrepreneurial communities to innovate and grow.

Over the past year, ARPA-E has fully dedicated itself to this fundamental goal, supporting game-changing, revolutionary projects that are already showing signs of technical and commercial success. These breakthrough energy technologies promise genuine transformation in the ways we generate, store, distribute, and utilize energy.

VII. Appendix I, Fiscal Year 2011 Project Selectees

Program	Awardee	Project Title	ARPA-E Funds (Million $)[3]
PETRO	Donald Danforth Plant Science Center	Center for Enhanced Camelina Oil (CECO)	$5.5
PETRO	North Carolina State University	Jet Fuel from Camelina Sativa: A Systems Approach	$3.7
PETRO	University of Florida	Commercial Production of Terpene Biofuels in Pine	$6.4
PETRO	University of Massachusetts Amherst	Development of a Dedicated, High-Value Biofuels Crop	$1.5
PETRO	Arcadia Biosciences Inc.	Vegetative Production of Oil in a C4 Crop	$0.9
PETRO	Chromatin, Inc	Plant-Based Sesquiterpene Biofuels	$5.8
PETRO	Lawrence Berkeley National Laboratory	FOLIUM - Installation of Hydrocarbon Accumulating Pathways in Tobacco Leaves	$4.8
PETRO	Texas Agrilife Research	Synthetic Crop for Direct Drop-in Biofuel Production through Re-routing the Photorespiration Intermediates and Engineering Terpenoid Pathways	$1.9
PETRO	University of California, Los Angeles	Energy Plant Design	$2.2
PETRO	University of Illinois	Engineering Hydrocarbon Biosynthesis and Storage together with Increased Photosynthetic Efficiency into the Saccharine	$3.3
REACT	Ames Laboratory	Novel High Energy Permanent Magnet without Critical Elements	$2.2
REACT	Argonne National Laboratory	Soft Core/Hard Shell Nanocomposite Exchange-Spring Magnets for Motor and Generator Applications	$3.0
REACT	Baldor Electric Company	Rare-Earth-Free Traction Motor for Electric Vehicle Applications	$2.9

[3] Data is as of September 29, 2011, the day these project selections were publicly announced. More detailed information on each of these projects is available on ARPA-E website at: http://arpa-e.energy.gov/ProgramsProjects/Programs.aspx, as well as an interactive map of all ARPA-E projects here: http://arpa-e.energy.gov/ProgramsProjects/InteractiveProjectMap.aspx.

REACT	Brookhaven National Laboratory	Superconducting Wires for Direct-Drive Wind Generators	$1.4
REACT	Case Western Reserve University	Transformation Enabled Nitride Magnets Absent Rare Earths (TEN Mare)	$1.0
REACT	General Atomics	Double-Stator Switched Reluctance Motor Development Program	$2.8
REACT	Northeastern University	Multiscale Development of L10 Materials for Rare-Earth-Free Permanent Magnets	$3.4
REACT	Pacific Northwest National Laboratory	Manganese Based Permanent Magnet With 40 MGOe at 200°C	$2.3
REACT	QM Power, Inc.	Advanced Electric Vehicle Motors with Low or No Rare Earth Content	$2.3
REACT	Regents of the University of Minnesota	Synthesis and Phase Stabilization of Body Center Tetragonal (BCT) Metastable FeN Anisotropic Nanocomposite Magnet - A Path to Fabricate Rare Earth Free Magnet	$2.5
REACT	The University of Alabama	Rare Earth Free Permanent Magnets for Electrical Vehicle Motors and Wind Turbine Generators: Hexagonal Symmetry Based Materials Systems Mn-Bi and M-type Hexaferrite	$1.3
REACT	Trustees of Dartmouth College	Nanocrystalline τ-MnAl Permanent Magnets	$0.4
REACT	University of Houston	High Performance, Low Cost Superconducting Wires and Coils for High Power Wind Generators	$3.1
REACT	Virginia Commonwealth University	Discovery and Design of Novel Permanent Magnets using Non-strategic Elements having Secure Supply Chains	$2.9
HEATS	Abengoa Solar Inc.	High Solar-Electric Conversion Power Tower	$3.6
HEATS	Halotechnics, Inc.	Advanced Molten Glass for Heat Transfer and Thermal Energy Storage	$3.3
HEATS	MIT	Hybrid Nanostructures for High-Energy-Density Solar Thermal Fuels	$3.0
HEATS	MIT	Metallic Composites Phase-Change Materials for High-Temperature Thermal Energy Storage	$0.9
HEATS	MIT	Advanced Thermo-Adsorptive Battery Climate Control System (ATB)	$2.7

HEATS	NAVITASMAX	Novel Tuning of Critical Fluctuations for Advanced Thermal Energy Storage	$0.8
HEATS	Pacific Northwest National Laboratory	Electric-Powered Adsorption Heat Pump for Electric Vehicles	$0.8
HEATS	Pacific Northwest National Laboratory	Thermal Storage Concept for Next-Generation High-Efficiency, High-Temperature CSP and Nuclear Power Generation	$0.7
HEATS	Regents of the University of Minnesota	Solar Fuels via Partial Redox Cycles with Heat Recovery	$3.6
HEATS	Sheetak Inc.	Thermoelectric Reactors for Efficient Automotive Thermal Storage (TREATS)	$4.7
HEATS	The University of Texas at Austin	Thermal Batteries for Electric Vehicles	$2.5
HEATS	United Technologies Research Center	Thermal Storage Using Hybrid Vapor Compression Adsorption System	$2.7
HEATS	University of Florida	Solar Thermochemical Fuel Production Via a Novel Low Pressure, Magnetically Stabilized, Non-Volatile Iron Oxide Looping Process	$3.0
HEATS	University of South Florida	Development of a Low Cost Thermal Energy Storage System Using Phase Change Materials with Enhanced Radiation Heat Transfer	$2.4
HEATS	University of Utah	A New Generation of High Density Thermal Battery Based On Advanced Metal Hydrides	$2.7
GENI	AutoGrid, Inc.	Highly Dispatchable and Distributed Demand Response for the Integration of Distributed Generation	$3.5
GENI	California Institute of Technology	Scalable Real-Time Decentralized Volt/VAR Control	$1.4
GENI	Charles River Associates	Transmission Topology Control for Integration of Renewable Generation	$1.3
GENI	Cornell University	GridControl: A Software Platform to Support the Smart Grid	$1.3
GENI	General Atomics	Magnetically Pulsed Hybrid Breaker for HVDC Power Distribution Protection	$2.5
GENI	GE Global Research	Nanoclay Reinforced Ethylene-Propylene-Rubber for Low Cost HVDC Cabling	$0.8

GENI	GE Global Research	Resilient Multi-Terminal HVDC Networks with High-Voltage High-Frequency Electronics	$4.5
GENI	Georgia Tech Research Corporation	Prosumer-Based Distributed Autonomous Cyber-Physical Architecture for Ultra-reliable Green Electricity Internetworks	$2.0
GENI	Michigan State University	Transformer-less Unified Power Flow Controller for Wind and Solar Power Transmission	$2.4
GENI	Oak Ridge National Laboratory	Magnetic Amplifier for Power Flow Control	$2.0
GENI	Smart Wire Grid, Inc	Distributed Power Flow Control using Smart Wires for Energy Routing	$4.4
GENI	Texas Engineering Experiment Station	Robust Adaptive Topology Control (RATC)	$4.9
GENI	University of Washington	Energy Positioning: Control and Economics	$1.4
GENI	Varentec, inc.	Compact Dynamic Phase Angle Regulators for Transmission Power Routing	$4.0
Solar ADEPT	Carnegie Mellon University (CMU)	Nanocomposite Magnet Technology for High Frequency MW Scale Power Converters	$1.7
Solar ADEPT	Ideal Power Converters	Dual Bi-directional Silicon IGBTs Modules Enables Breakthrough PV Inverter using Current-Modulation Topology	$2.5
Solar ADEPT	Regents of the University of Colorado Boulder	Wafer-Level Sub-Module Integrated DC/DC Converter	$1.2
Solar ADEPT	Satcon Technology Corporation	Agile Direct Grid Connect Medium Voltage 4.7-13.8 kV Power Converter for PV Applications Utilizing Advanced Wide Band Gap Devices	$3.0
Solar ADEPT	SiCLAB, Rutgers University, NJ	First in Class Demonstration of a Completely New Type of SiC Bipolar Switch (15kV-20kV) for Utility Scale Inverters	$0.9
Solar ADEPT	SolarBridge Technologies, Inc.	Scalable Submodule Power Conversion Methods for Power Density, Efficiency, Performance, and Protection Leaps in Utility-scale Photovoltaics	$1.8
Solar ADEPT	Transphorm Inc.	Four Quadrant GaN Switch Enabled Three Phase Grid-Tied Microinverters	$3.6