

Statement of the Director of ARPA-E, Arun Majumdar
Department of Energy
Subcommittee on Energy and Water Development, & Related Agencies
U.S. House Appropriations Committee
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ARPA-E
Catalyzing Energy Breakthroughs to Secure America's Future

Chairman Frelinghuysen, Ranking Member Visclosky, distinguished members of the Subcommittee, thank you for the opportunity to testify today on behalf of the Advanced Research Projects Agency-Energy (ARPA-E) for its Fiscal Year (FY) 2013 budget request of \$350 million. I want to first thank the committee for all of your support for ARPA-E. I also want to report to you the state of ARPA-E and its plans for the future.

Mission:

ARPA-E is focused on innovations in energy technologies. Let me explain what I mean by using an example from information technology. Until the 1970s, we used to use punch cards to enter data into computers. In only 30 years, we went from punch cards to smart phones. Today, punch cards have become not just obsolete, but forgotten. Most of the innovations that allowed the information revolution - transistors, integrated circuits, wireless communication, and the internet - were created first in the U.S., and then used globally. We didn't make better and better punch cards. We invented our way into the future using technology innovations based on our strong foundations in science and engineering. The U.S. has been doing this all throughout the last century - from the Wright brothers and the airplane, Jonas Salk and the polio vaccine, to Nikola Tesla and Westinghouse creating the first AC electric grid. These and many other innovations created the foundations for new industries that led to U.S. economic growth and also enabled the rest of the world. ARPA-E's goal is to catalyze similar innovations in the energy sector.

ARPA-E's statutory goal is to invest in research to rapidly translate science into breakthrough energy technologies that would enhance U.S. global competitiveness as well as our national, economic, and environmental security. ARPA-E projects create quantum leaps in energy technologies, are ones that are too risky for the private sector, but those that have the potential to be transformative and make large societal impact in the next 10-20 years. ARPA-E does not fund incremental improvements in existing technologies, but rather funds research that would create new technologies, which do not exist today, but if they did, they would make today's technologies obsolete.

Early Signs of Success

ARPA-E's goal is to identify and invest in very innovative research projects that last 2-3 years, but can have transformative impact measured by our technological leadership, economic prosperity, and national energy and environmental security 10-15 years from now. Awardees have cited ARPA-E's initial funding and active program management as critical factors in their

overcoming key technical barriers ahead of schedule which helped spur follow-on funding. To date, the Agency has awarded over \$520 million to 180 projects, which range from new approaches to making biofuels to new technologies that enable a smarter grid. While the Agency is still in its infant stage, the total amount of follow-on private sector investments will soon exceed the total ARPA-E investment. Furthermore, eleven of the first set of projects two and a half years ago that received \$40 million from ARPA-E produced breakthroughs that generated more than \$200 million in private sector investment.

Here is a small sample of some of our awardees:

- **Batteries for EVs/PHEVs:** ARPA-E's advanced battery program is working to develop a variety of rechargeable battery technologies that would reduce the cost of ownership of an EV or PHEV to that of a conventional automobile without subsidy. One ARPA-E awardee, Envia, announced at the 2012 ARPA-E Summit that they have doubled the energy density for a rechargeable lithium-ion battery to 400 Whr/kg, an innovation that will cut the cost of the battery pack in half. Other companies are targeting 600 Whr/kg. Our goal is to reduce the cost of rechargeable batteries to 20-25% of today's cost.¹ Achievements such as this drive key aspects of the EV Grand Challenge.
- **Transportation Fuels:** ARPA-E's Electrofuels program is focused on genetically engineering non-photosynthetic microbes to transform carbon dioxide and water into oil. This approach, powered by hydrogen or domestically produced electricity may be able to achieve 10 times more efficient biofuel production than plant-based photosynthesis. One of our awardees, OPX Biotechnologies of Boulder, Colorado has engineered microbes to use hydrogen and carbon dioxide to make liquid transportation fuel. If they can successfully scale their experiments in cost and volume, they could create the foundation for an entirely new industry to convert our domestic resources of natural gas into liquid transportation fuels through a process that results in less net emissions, including reduced greenhouse gas emissions, than from the oil-based fuel it displaces.
- **Electrical Power Technologies:** Cree, an ARPA-E awardee based in North Carolina, is creating a quantum leap in electrical power technology by developing a 1 MW transistor made of silicon carbide the size of your fingernail. Cree's goal is to have this transistor switch electrical power of 20,000 Volts at 50,000 Hz, as opposed to 60 Hz in today's transformers. With this transistor, a 1 MW transformer could shrink to 100 lbs from the current 8000 lbs with greatly reduced cost and increased reliability. Because the U.S. is the world's leading manufacturer of silicon carbide, the Cree project could transform future electrical power technologies and create a large export market.
- **Grid-Scale Electrical Storage:** The cost of renewable electricity from solar and wind continues to decline and could be competitive with that from natural gas (about 5-6 cents per

¹ If we achieve this goal, the cost of an EV with a range 50% greater than today's EVs could be priced at \$20,000-25,000 without subsidy. A PHEV would be comparably priced. An American family that drives 12,000 miles per year will be spared a gasoline bill of \$1,440/year, assuming today's gasoline prices and a car that averages 30 MPG. The cost of electricity: about \$300/year, thus saving about \$100/month for American families.

kilowatt hour) within a decade. In order to better integrate these intermittent renewable sources on the grid, we will need a combination of improved transmission and distribution system and increased energy storage. Today, the lowest cost energy storage in the GigaWatt-hour scale is pumped-hydro or compressed air. While these forms of energy storage cost less than \$100/kWh, they are geographically limited. ARPA-E challenged the scientific community to invent new technologies that could achieve Gigawatts-hour scale storage. One awardee – a partnership between MIT and 24M – is using the chemistry of lithium-ion batteries in a new flow battery architecture that creates a hybrid between a battery and a fuel cell, with the goal to reduce battery grid storage to \$60/kWh.

- **Carbon Capture:** Today, the cost of capturing carbon dioxide from a coal-fired power plant is estimated to be about \$80/tCO₂, whereas the delivery price for CO₂ paid by oil companies for Enhanced Oil Recovery (EOR) is in the range of \$20 - \$35/tCO₂. ARPA-E funds 15 projects all aimed at lowering the capture cost to \$25/tCO₂, which will greatly increase the business opportunity for CO₂ in EOR and will greatly reduce the cost of Carbon Capture, *Utilization* and Storage (CCUS). Codexis, one of the program's awardees, is using directed genetic evolution to create a more robust and efficient biological enzyme, carbonic anhydrase. If this enzyme can be made to function in the exhaust stack of a coal plant, it will greatly increase the CO₂ capture rate, decrease the energy penalty, and dramatically lower the cost of carbon capture.

These projects are a small slice of the exciting technologies funded by ARPA-E. The complete list of the projects funded by ARPA-E, and links to fact sheets for each project, is available at: <http://arpa-e.energy.gov/ProgramsProjects/ViewAllProjects.aspx>.

Programs from Fiscal Year 2011 Budget

This past year, on April 20, 2011, ARPA-E put out a solicitation to develop five new programs that could spark critical breakthrough technologies and secure America's energy future, and on September 29, 2011, ARPA-E announced 60 cutting-edge research projects. Totalling \$156 million, the new ARPA-E selections focused 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.

The new programs announced and selected in FY2011 are:

- **PETRO: Plants Engineered To Replace Oil**

ARPA-E is funding 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 and pine trees for half their current cost, making them cost-competitive with fuels derived from oil.

- **REACT: Rare Earth Alternatives in Critical Technologies**
Rare earths are naturally-occurring minerals with unique 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 is funding 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.
- **HEATS: High Energy Advanced Thermal Storage**
More than 90% of the energy used in the U.S. involves 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 is helping develop revolutionary cost-effective, thermal energy storage technologies.
- **GENI: Green Electricity Network Integration**
ARPA-E is funding 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.
- **Solar ADEPT: Solar Agile Delivery of Electrical Power Technology**
The SunShot Initiative leverages the unique strengths across DOE to reduce the total cost of utility-scale solar power 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 electronics costs by up to 50 percent for utilities and 80 percent for homeowners.

Programs from Fiscal Year 2012 Budget

The last time I was before you, we spoke of ARPA-E's plans for 2012. Specifically, we spoke of natural gas for transportation, the option for an open funding opportunity, as we did in 2009, and our partnership with the Department of Defense. I am happy to report progress to you on all three of these areas.

Methane Opportunities for Vehicular Energy (MOVE)

This program was launched on February 23, 2012 and seeks to fund the development of transformational technologies that reduce the system-level cost of natural gas use in vehicles. Of particular interest are technologies that enable at-home refueling and low-cost on-board storage

for natural gas vehicles. This \$30 million funding announcement aims to engage our country's brightest scientists, engineers and entrepreneurs to find ways to harness our abundant supplies of domestic natural gas for vehicles and builds on an Administration-wide commitment to reducing our dependence on oil by encouraging greater use of natural gas in transportation,

Open Funding Opportunity Announcement

Just as ARPA-E did in its very first Funding Opportunity Announcement back in 2009, this open program, announced March 2, 2012, seeks to address the challenges imposed by the rapidly evolving global energy market. The \$150 million program will look at many areas including, but not limited to, electricity generation by both renewable and non-renewable means, electricity transmission, storage, and distribution; energy efficiency for buildings, manufacturing and commerce, and personal use; and all aspects of transportation, including the production and distribution of both renewable and non-renewable fuels, and electrification.

Advanced Management and Protection of Energy-storage Devices (AMPED)

In 2011, U.S. Secretary of the Navy, Ray Mabus, announced at the 2nd annual ARPA-E Energy Innovation Summit a new partnership between ARPA-E and the Department of Defense to jointly develop energy technologies that will be used to make our nation and our armed forces secure. As a part of this partnership, I am happy to report that ARPA-E plans to issue a new Funding Opportunity Announcement (FOA) early next month entitled "Advanced Management and Protection of Energy-storage Devices" (AMPED).

The objective of the AMPED FOA will be to identify and support novel, high-impact sensing and control technologies that can significantly increase performance and accelerate adoption of energy storage systems. Cost effective, safe, and long-life energy storage is of interest to DOD, which will work with ARPA-E to assess the technology requirements for storage across military installations and transportation. Research of these technologies is also well-aligned with ARPA-E's mission to enhance the energy security of the U.S. through advanced energy technologies.

Speed, Efficiency and Talent

To remain at the global forefront of energy technology, speed is of the essence. ARPA-E has developed a streamlined process so that it can execute with a fierce sense of urgency and unprecedented speed and efficiency. For example, ARPA-E has reduced contracting time down to three months. ARPA-E has instituted a recruiting and hiring process that attracts some of the best and brightest talent from the technical community to be Program Directors (PDs). The PDs stay for three to four years and then they must leave – this is not a permanent job. The term limits have fostered a focus on outcomes.

Stewardship and Integrity

Being vigilant stewards of taxpayer dollars is built into ARPA-E's DNA. All ARPA-E projects are selected on merit, based on input from a panel of experts. Once selected, ARPA-E PDs work personally with every project they manage to help overcome technical barriers. But if a technology does not work and the project cannot reach its "go-no go" milestones, ARPA-E discontinues the project before the end date.

ARPA-E Energy Innovation Summit

ARPA-E recently hosted its third annual Energy Innovation Summit featuring a number of the nation's leaders across industry, Congress, and academia, and covered a wide range of critical energy topics. The summit included 107 speakers and attracted 2,440 attendees from 49 states and 26 countries. Attendees included members of research and development institutions, global corporations, technology entrepreneurs, investors, policymakers and government officials including two member of this Subcommittee, Representatives Chaka Fattah and Steve Womack.

A key feature of the Summit is the technology showcase, where ARPA-E showcased and displayed over 240 breakthrough energy developments from ARPA-E's awardees and other innovative companies in areas including grid-scale storage, power electronics, batteries for electric vehicles, building efficiency, advanced carbon capture, and electrofuels. The showcase featured not only the technologies that ARPA-E invested in, but also other promising technologies to ensure that America wins the future, regardless of if the technology was supported by ARPA-E or not.

We intend to host another Summit in 2013, and we hope you will join us next year.

2013 Programs – Potential Topics

The President's request of \$350 million in FY2013 for ARPA-E includes \$325 million that will be devoted to funding projects. The increase in budget compared to FY2012 underscores the Administration's commitment to invest in an "all of the above" approach to energy technology innovation. The increase in funding will enable ARPA-E to fund more projects that could lead to game-changing, transformative technologies for America's energy security.

ARPA-E continues to improve its internal strategic vision for the future direction of the agency. Reflecting this internal strategic thinking on the focus of future projects, ARPA-E has moved to incorporate a project management model hierarchy of thrust-portfolio-program-project. ARPA-E will have two primary thrusts: Transportation Systems and Stationary Power Systems.

Transportation Systems

The ARPA-E Transportation Systems thrust seeks to create a diverse portfolio of technological options that would reduce our dependence on oil, and instead rely on the efficient use of domestic sources of energy for transportation, while also focusing on reducing fuel consumption and energy-related emissions through advances in fuel/propulsion and vehicles.

Some broad goals and benefits of the Transportation Systems thrust in FY2013 may include game-changing research into: batteries and energy storage systems, competitively-priced alternative transportation fuels, novel uses of information technology to improve energy efficiency, unexplored ways to more efficiently utilize our natural gas resources, and advanced manufacturing and vehicles research.

Stationary Power

The ARPA-E Stationary Power Systems thrust supports high-impact technologies that are not related to transportation. Some of these fields include: power electronics, solar, wind, osmotic power, smart grid technologies, natural gas, geothermal, and waste heat capture.

ARPA-E will continue its mission in this sector to move beyond incremental changes to existing energy technology and to identify those transformational technologies will make current technologies obsolete. ARPA-E is investing in transformational research in a number of power generation technologies and coordinating that investment with the DOE's Office of Science and applied research programs, to identify programs with potential for game changing developments that meet ARPA-E's statutory mission.

Conclusion

ARPA-E's goal is to help catalyze energy breakthroughs with speed and efficiency to help ensure America's energy security by attracting the best minds to focus on the major technical challenges in this field and by stimulating technical and the entrepreneurial community to innovate on energy technologies.

Again, I thank you for the opportunity to testify before this Subcommittee, and I am happy to answer any questions you may have.