

**Statement of
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ARPA-E: Catalyzing Energy Breakthroughs to Secure America's Future

Chairman Harris, Representative Miller, distinguished members of the subcommittee, thank you for the opportunity to testify today on behalf of the Advanced Research Projects Agency-Energy (ARPA-E) about our clean energy RD&D activities and our Fiscal Year 2012 Budget request.

I want to start on a historical note. On February 12, 1958, President Eisenhower signed Public Law 85-325, authorizing the creation of the Defense Advanced Research Projects Agency (DARPA). This was in response to the launch of Sputnik and to a realization that the U.S. had lost its technological lead and its future security was at stake. DARPA has since been responsible for the development of many transformational technologies, such as the precursors to the internet, stealth and GPS. As the President has said, today the U.S. faces a new Sputnik-like moment. Our future depends on three securities: national security, economic security and environmental security. At the foundation of all these securities are innovations in energy technologies that would reduce our dependence on foreign oil, provide clean and inexpensive electricity, and create a secure, efficient and sustainable infrastructure. As the first Director of ARPA-E, I am grateful for the opportunity to play some role in the creation of a secure American future.

ARPA-E can play a significant role in protecting America's energy security. As a country, we import more than 50 percent of the oil we use and export about \$400 billion per year (about \$1 billion per day).¹ The recent oil price spikes highlight just how vulnerable we are. This is not sustainable in the long-term. To decrease our reliance on oil, we must create a diverse portfolio of sustainable options for transportation and mobility based on domestic resources to decrease. In order to do so, we need innovations in energy technologies to drive down the cost of electricity from clean and sustainable sources (clean coal, nuclear, natural gas, solar, wind, geothermal etc.) so that energy is affordable to American families and our businesses are enabled to power the economy.

¹ U.S. Energy Information Administration 2011

ARPA-E can also help ensure America's economic security. Income levels are rising in the world, and the world needs more energy. More and more people around the world want to use sustainable and clean energy. Unfortunately, many of the technologies that will be needed do not exist today. If we are to win the future, we need to use our American ingenuity and technological leadership to invent affordable clean energy technologies, make them locally, and sell them globally, just as we did with information technology and biotechnology. This offers an important global business opportunity for the USA. We have a window of opportunity and we need to grab it; speed is of the essence.

ARPA-E focuses exclusively on breakthrough technologies promising genuine transformation in the ways we generate, store, distribute and utilize energy. If just a fraction of the projects funded by ARPA-E are successful, the U.S. could benefit greatly by creating new industries and jobs, making energy technologies substantially more cost-saving, profitable, and cleaner in a sustainable way.

Early Successes in Technology Innovations

How does ARPA-E measure success? ARPA-E enables the Nation's pioneers and entrepreneurs to innovate breakthrough technologies that do not exist today – but if they did, they would make today's technologies obsolete and create large commercial markets. For example, ARPA-E has invested in a portfolio of ideas on rechargeable batteries that would make electric cars have longer range and lower lifecycle cost than gasoline-based cars. This would enable electric vehicles manufacturing to scale without subsidies and significantly reduce our dependence on oil. We need to advance beyond today's lithium ion battery, and no one in the world has this future battery—the global race is on. ARPA-E is focused on identifying the opportunity and creating a competition among innovators.

The portfolio of ideas that ARPA-E funds are high risk projects in which the private sector is unlikely to invest. However, if one of the ARPA-E ideas is shown to be practical, it could indeed change the world. But transformations do not happen overnight – it will take at least 10-15 years to scale these technologies in cost and volume to achieve that global change. In the process, many of these ideas will fail, and ARPA-E will let the market pick the winners.

In the next 3-5 years, we can look for indicators of success: (1) Are we attracting world-class minds to energy R&D? Are we getting world-class ideas? (2) How many small businesses have been created? (3) Do we have the world's best performance? (4) How many patents have been filed and licensed? (5) If ARPA-E's funding has created value, how much follow-on funding has the private sector made?

In FY2010, ARPA-E invested \$24 million in six projects. I am happy to report that the initial investments allowed these innovators to do the research and overcome technical barriers ahead of schedule. Only after these successes happened did the private sector invest more than \$100M in just one year. In total, ARPA-E projects have received over \$285 million in follow-on funding, and we have already seen 17 patents filed.

In April, ARPA-E signed a memorandum of understanding 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 Memoranda 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.

ARPA-E Operational Success – Institutionalizing a Sense of Fierce Urgency

In order to win the future in a globally competitive world, speed is of the utmost importance. Since ARPA-E demands speed from the innovator community, others should demand speed and urgency from ARPA-E. Congress established ARPA-E to have an unusual degree of flexibility. ARPA-E is administered in ways that enable the agency to be lean, effective, and agile. ARPA-E strives to be a model of excellence for a small agency. In its short existence of less than two years, ARPA-E has implemented several key business practices that have earned it recognition as an organization to emulate.

We have streamlined operations to improve speed and efficiency. ARPA-E has created a 5-Es process for program creation and management:

- (1) *Envision* a new opportunity for a program and do background in-house research;
- (2) *Engage* the experts from the technical community for stakeholder input, an internal debate about reasons for creating a new program, and the announce a new program and receive proposals;
- (3) *Evaluate* the proposals based on merit-based technical peer review;
- (4) *Establish* the program by selecting awardees and contracting multiple awards;
- (5) *Execute* the program with active hands-on project management by ARPA-E program directors for proper stewardship of taxpayer dollars (see later).

This process has not only increased the speed and efficiency but has also improved the quality of its reviews and project management. The total process from conception of a new program to contracting awards (first 4 Es) takes 6-8 months, with contracting in 2-3 months. ARPA-E achieves this by utilizing a program development process that includes extensive up-front technical research and technical workshops co-hosted with other DOE program offices and technical community members. ARPA-E also employs a thorough merit-based peer review process. Further, ARPA-E has embedded dedicated procurement and legal teams, allowing ARPA-E to achieve exceptional speed and efficiency for processing awards from announcement to signing contracts. This speed, efficiency and transparency are critical for meeting ARPA-E's goals. You could call ARPA-E the "urgency agency."

As noted in a report from the President's Council of Advisors in Science and Technology (2010)², "Although the ultimate success of the research funded by ARPA-E is unknown... they have been successful in their peer review of proposals, quick negotiation of contracts, and rapid hiring of high-caliber personnel."

The success of these technologies depends not only on the scientists, engineers and entrepreneurs that we fund, but also on the program directors we have hired. By statute, ARPA-E program directors will stay at ARPA-E and serve a maximum term of 3-4 years. But while they are here, our program directors are involved in active project management, engaging directly with the teams they are funding to help them speed up the process of innovation. They have a fierce sense of urgency, and they are demanding speed from our teams.

Technical flexibility, speed, agility and empowerment of Program Directors are key aspects of ARPA-E's programs. For example, the emerging importance of rare earth metals in the energy sector has been highlighted by the mismatch between the rapidly growing demand relative to the limited global supply. ARPA-E was able to respond to this pressing problem and arranged a workshop in December 2010 to bring together thought-leaders from across scientific and engineering disciplines to identify transformational, early-stage applied research and development approaches to address the technical challenges related to the potentially limited availability of rare earth metals and critical materials in the energy sector. This led to a Funding Opportunity focused on rare earth metals in 2011, and we will continue our collaborative efforts on this critical issue both within DOE and with other partner agencies.

ARPA-E and National Security – Partnership with Department of Defense

Rare earth metals are just one of many areas in which ARPA-E is collaborating with key agency partners. The Department of Defense is a prime energy consumer, in the Federal government accounting for 80 percent of the U.S. government's energy consumption. The Department of Defense has a global presence as it operates more than 500 major military installations worldwide. Building on an already strong cooperation between the Department of Energy and the Department of Defense on national security issues ARPA-E and the Department of Defense signed a Memorandum of Understanding in July of 2010 to jointly develop energy technologies.

This partnership has been initiated and co-funding will commence in the 2012 fiscal year. The Department of Defense's Office of the Assistant Secretary of Defense for Research & Engineering (ASDR&E) aims to take advantage of early technology breakthroughs funded through ARPA-E. In particular, using ARPA-E's technical expertise in grid scale energy storage, batteries for electric vehicles, and power electronics, ASDR&E plans to develop hybrid energy storage systems that would provide future electric energy systems with long endurance, rapid charge/discharge platform electrical grids while maintaining a restrictive size and weight form factor, along with assured life and safety under a wide range of application and installation environments. Integrated into advanced military systems, hybrid energy storage modules

² President's Council of Advisors on Science and Technology, "Report to the President on Accelerating the Pace of Change in Energy Technologies Through an Integrated Federal Energy Policy" November 2010 <http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-energy-tech-report.pdf>

(HESMs) would be key components for extending fuel duration up to 30 percent in forward bases and military platforms while providing robustness and easy maintenance. If successfully developed, HESM technologies will also enable reduced vehicle signatures and ensure continuous operation in casualty situations. For example, in maritime operations, ships will maintain combat and self-protection capabilities longer while absorbing battle-damage. In commercial energy applications, HESM technology would enable an electric grid to effectively match the power and energy requirements of industrial and residential consumers to the intermittent and non-dispatchable generation of renewable resources while maintaining customer power reliability and assurance. ARPA-E recently held a workshop with key participants from the military, academic, and private sectors to explore advanced scientific and technical challenges to the development of HESMs.

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 currently 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.

ARPA-E is continuing its discussions and holding workshops with the DOD to build upon these partnerships and create other ones where innovations in clean energy technologies would make our nation more secure.

ARPA-E Energy Innovation Summit

At the end of February, ARPA-E hosted its second annual Energy Innovation Summit. We attracted world class innovators from industry, academia, and government. The Summit had over 2,000 registered participants spanning all stakeholder communities, including scientists and engineers, entrepreneurs, small and large business CEOs and CTOs, technology investors from the venture community and investment banks, policy researchers and NGOs. A key feature of the Summit is the technology showcase, where ARPA-E showcases not only the technologies that we have funded but also other promising technologies. The goal is to ensure that America wins the future, not just that we promote ARPA-E technologies.

The Summit also brought together as speakers and panelists an incredible lineup of energy thought leaders from around the country. We intend to host another Summit in 2012, and we hope you will join us next year.

Uniqueness of ARPA-E Programs and Projects and Coordination with the rest of DOE

ARPA-E enables the Nation's pioneers and entrepreneurs to innovate technologies that do not exist today – but if they did, would make today's technologies obsolete and create large commercial markets. ARPA-E does not focus on exploratory science, but instead on translating basic science into breakthrough technologies that are too risky and early-stage for private sector investment. The goal is to identify opportunities and develop those energy technologies that

establish entirely new learning curves to make our nation secure and clean energy affordable and sustainable.

ARPA-E programs generally fall into two categories:

- *Translating New Areas of Science into Technology*—for example, ARPA-E’s current Electrofuels program. In contrast to today’s biofuels (based on algae, sugarcane, corn or cellulose) that use photosynthesis, the goal of the Electrofuels program is to create a biological, non-photosynthetic process to produce liquid fuels. This is an innovative way of creating biofuels that is potentially more than ten times more efficient than today’s biofuels, which could potentially mitigate the problems of land and water use. This approach is not being pursued anywhere else.
- *Creating a Quantum Leap in Technology* —for example, ARPA-E’s current program called Batteries for Electrical Energy Storage in Transportation, or BEEST. While DOE applied programs and most outside R&D are focused on lithium-ion batteries, ARPA-E is looking for other battery chemistries, such as Zinc and Magnesium, that, if successful, would yield batteries that are less expensive and could enable longer range vehicles than those using today’s lithium-ion batteries.

Please note that ARPA-E identifies opportunities and creates a competition. In its solicitations, ARPA-E provides cost and performance metrics for projects to meet or beat, and does not prescribe the method up front, i.e. it is technology agnostic. ARPA-E funds a portfolio of competitive approaches and then seeks to let the scientific competition play out and leave it to the private sector to pick which technologies will be commercialized.

ARPA-E proactively seeks out unexplored “white spaces” where it can fill a vital gap in early stage research and development; coordination between the Department’s basic research and applied technology programs is a high priority for the Secretary of Energy. For example, ARPA-E has created a Panel of Senior Technical Advisors (PASTA), a group of technical leaders within DOE spanning the Offices of Science, of Fossil Energy, of Nuclear Energy, of Energy Efficiency and Renewable Energy, of Electricity Delivery and Energy Reliability, and as well as others from senior DOE leadership positions. The intent of the PASTA meetings is to share information, avoid duplication, and engender coordination, cooperation, and collaboration among all of the DOE research programs. In addition, other DOE programs are involved from beginning to end in ARPA-E’s program development process—providing technical consultation, co-hosting technical workshops, and serving as reviewers for ARPA-E concept papers and full applications.

The SunShot Initiative represents a significant change to the Department’s pursuit of photovoltaic (PV) and other advanced solar technologies and of cost reduction for electricity produced from these technologies. The SunShot Initiative brings a renewed focus on cutting edge R&D across multiple technologies and all parts of the research, development, and demonstration spectrum. Specifically, the goal of the SunShot program is to create a technical program that focuses the effort across the DOE towards a common goal of 5-6 cents/kWhr for solar electricity, broadly across the United States, making it cheaper than electricity from

traditional sources, and enabling it to scale-up without subsidies. If we can reach this goal, it could make the U.S. globally competitive in a very large export market.

The SunShot Initiative leverages strengths from all parts of DOE (EERE, ARPA-E and Science), linking relevant research activities in the Office of Science and ARPA-E with those within the Solar Energy Technology Program to ensure that all the Department's resources are efficiently focused on this common goal to make the U.S. globally competitive. For example, ARPA-E has developed a program in power electronics that will make U.S. globally competitive in this important field of smart grid technology. SunShot will leverage the power electronics effort in ARPA-E and use its technology for integrating solar electricity from photovoltaics to the grid via, for example, low-cost and reliable inverter technologies.

To enable this pan-DOE effort, we have created a joint management structure incorporating a team of members from EERE, ARPA-E and Office of Science that helps coordinate every activity (workshops, funding opportunity announcements, etc) related to SunShot.

Current ARPA-E Programs

ARPA-E's programs and projects to date have included:

- **Electrofuels:** ARPA-E seeks to use microorganisms to harness energy and convert carbon dioxide into liquid fuels. Theoretically, this could be ten times more efficient than current approaches.
- **Batteries for Electrical Energy Storage in Transportation (BEEST):** The goal of the BEEST program is simple: Create a new generation of rechargeable battery technologies that will allow a longer range and lower life-cycle cost than gasoline-based cars, so that electric vehicle production can scale without subsidies.
- **Building Energy Efficiency Through Innovative Thermodevices (BEETIT):** The BEETIT program seeks to develop cost-competitive energy-efficient building cooling technologies that will reduce energy consumption from overall cooling and refrigerants used in vapor compression systems.
- **Agile Delivery of Electrical Power Technology (ADEPT):** The ADEPT program seeks to create microelectronic circuits that incorporate transistors able to handle high voltages and advanced magnetic materials for much smaller power transformers and inductors. The improved electrical power efficiency from ADEPT could result in smaller personal computers and computer servers, produce lightweight chargers for electric vehicles and allow for the controlled movement of electricity by routing through transmission lines to avoid congestion and overloading.
- **Innovative Materials and Processes for Carbon Capture Technologies (IMPACCT):** IMPACCT is pushing the boundaries of carbon capture research through technologies such as new liquid chemistries that dissolve carbon dioxide and a capture system inspired by jet engines that transforms carbon dioxide from a gas into pellets of dry ice. If

successful, the IMPACCT program will allow the continued use of America's coal-based power infrastructure without further increases in carbon dioxide emissions.

- **Grid-Scale Rampable Intermittent Dispatchable Storage (GRIDS):** The GRIDS program seeks to develop new technologies that enable widespread use of cost-effective grid-scale energy storage.

ARPA-E Program Directors have been actively managing projects within these programs and evaluating them against their challenging performance benchmarks. ARPA-E anticipates that some of these current projects will have to be terminated for not achieving the goals of the program and in those cases the money will be returned to the Treasury.

2011 Funding Opportunity Announcements

ARPA-E received \$180 million in the FY 2011 Continuing Resolution. On April 20th, we issued our 4th round of funding opportunities in five new programs areas that could lead to transformative energy technologies. We are currently reviewing Concept Paper Applications and anticipate making selections in late summer/early fall. Solicitations were issued in the following areas:

- **Plants Engineered To Replace Oil (PETRO):** PETRO aims to create plants that capture more energy from sunlight and convert that energy directly into fuels.
- **High Energy Advanced Thermal Storage (HEATS):** HEATS seeks to develop revolutionary cost-effective thermal energy storage technologies in three focus areas: 1) high temperature storage systems to deliver solar electricity more efficiently around the clock and allow nuclear and fossil baseload resources the flexibility to meet peak demand, 2) fuel produced from the sun's heat, and 3) HVAC systems that use thermal storage to dramatically improve the driving range of electric vehicles.
- **Rare Earth Alternatives in Critical Technologies (REACT):** REACT aims to fund 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.
- **Green Electricity Network Integration (GENI):** GENI aims to fund innovative control software and high-voltage hardware to reliably control the highly dynamic grid of the future.
- **Solar Agile Delivery of Electrical Power Technology (Solar ADEPT):** Solar ADEPT aims to invest in key advances in magnets, semiconductor switches, and charge storage, which could reduce power conversion costs and enable broader use of solar power.

2012 Programs –Potential Topics

The following five broad thematic strategic direction areas are areas of technical interest that ARPA-E plans to explore in FY 2012. ARPA-E will coordinate closely with the Department's basic research and applied technology programs, and others throughout the federal government and private sector, during the program development process in all of the following areas.

Transportation Systems: Broadly speaking, reduction in imported petroleum is critical for our national and economic security. ARPA-E will continue to invest in the transportation sector, in both alternative domestic sources of sustainable fuels and electrification of vehicles. Some broad areas of interest include:

- Development of those batteries and systems that would enable electric vehicles to have a range of 300-500 miles and be less expensive than cars having internal combustion engines. This would enable electric vehicles to be market competitive without government subsidies.
- Development of sustainable and market-competitive transportation fuels using domestic resources such as natural gas or a combination of carbon dioxide and hydrogen, that have 5-10 times less land and water use than that of biomass or algae based biofuels. This would be especially attractive for long-haul trucks and air transport where electrification is unlikely to make an impact.
- Development of techniques for using information technology to reduce fuel consumption, avoid traffic congestion, and optimize use of existing transportation resources.
- Development of cost-effective power generation or propulsion systems that have significantly higher efficiency than today's internal combustion engines, and thereby maximize the use of transportation fuels.

Stationary Power: ARPA-E's goal is to create a diverse portfolio of technological options for low-cost clean electricity from traditional and renewable sources. This will make the U.S. the world leader in these technologies and thereby lead to economic prosperity and American jobs. Areas of interest include:

- Electricity generation from solar, wind, natural gas, nuclear, clean coal and other sources to meet base load and peak power at levelized cost of electricity of 5-6 cents/kWh.
- Integrated energy supply systems for distributed supply of heating, cooling, and power in optimal ways.

Given the Nation's increasing reliance on electricity from stationary power sources, ARPA-E is developing specific future focus areas for programs that employ novel approaches, materials, devices, and processes to make revolutionary advances in the way we capture and utilize energy from a portfolio of diverse renewable and other power sources.

Electrical Infrastructure: The U.S. electric grid is undergoing a technical renaissance through the initial deployment of smart-grid technologies. This technical renaissance is motivated by the need to modernize the grid for the 21st century: the U.S. grid is many decades old and often running at maximum capacity, making it vulnerable to outages and security threats.

ARPA-E's goal is to develop next generation technologies that will make today's approaches obsolete, and would truly revolutionize the grid for secure, stable, and reliable transmission and distribution of electrical power and maximize the capacity of today's infrastructure. These technologies could be sold globally, potentially creating American jobs and enhancing economic prosperity. Some areas of interest are as follows:

- Low-cost electrical storage to increase utilization of renewable resources such as wind and solar.
- Advanced, low-cost and smart components for high-efficiency power transmission, conversion and management at ultrahigh voltages for transmission and medium-to-low voltages for distribution networks.
- Technologies for system-level stability, security, high capacity and reliability for the whole U.S. transmission-distribution system.

End Use Efficiency: Energy efficient technologies for buildings, both commercial and residential, offer a tremendous opportunity to reduce energy demand. Buildings consume about 40 percent of energy in the U.S., while the industrial sector consumes about 30 percent. About 72 percent of the Nation's electricity and 55 percent of natural gas is used in buildings. The cooling and heating of buildings consumes 40 percent of the total energy used in buildings. This translates into 12 percent primary energy use in the U.S. To date, activities in ARPA-E in energy efficiency have focused mainly on buildings.

ARPA-E will continue to invest in the buildings sector to develop high-efficiency energy technologies, including an expansion of the current BEETIT program and new technologies for energy measurement systems and integrated building operations, as well as a novel way to light a room. This will be coordinated closely with the new Buildings Energy Innovation Hub as well as all the activities in the Office of Energy Efficiency and Renewable Energy.

ARPA-E's goal is to develop those technologies that do not exist today, but if they did they would lead to substantial life-cycle monetary savings by increasing the efficiency of how energy is used in buildings and industry. Some of the program's areas of interest include those aimed at:

- Reduction of energy consumption by 50% with a pay-back period of less than 5 years by highly efficient and smart use of heating, cooling and electrical power in homes and commercial buildings.
- Advanced and alternative technologies to provide industrial goods and services with substantial reduction in energy consumption and a pay-back period of less than 5 years.

Embedded Efficiency: On the demand side of our energy economy, energy is consumed primarily in three sectors—buildings, transportation and industry. Buildings consume approximately 40 percent of our primary energy, transportation and industry about 30 percent each. Reduction of energy consumption in the industrial sector is essential to ARPA-E's mission and will be achieved through "embedded efficiency" programs.

ARPA-E's goal is to focus on the industrial sector with the aim of developing cost-competitive technologies and industrial processes to significantly reduce energy consumption and emissions. Some of the program's areas of interest include those aimed at:

- Advanced and alternative technologies to provide industrial goods and services with substantial reduction in energy consumption and a pay-back period of less than 5 years.
- Utilization of waste heat from industry and other uses in intelligent ways to reduce primary energy consumption.

Wireless Innovation Fund: The President's Wireless Innovation and Infrastructure Initiative proposes to reallocate a total of 500 megahertz of Federal agency and commercial spectrum bands over the next 10 years in order to increase Americans' access to wireless broadband. As part of this initiative, ARPA-E will participate in the WIN Fund by supporting clean energy activities.

An additional \$100 million in mandatory funding is proposed from the Wireless Innovation Fund for ARPA-E to develop cutting-edge wireless technologies. In FY 2012, ARPA-E plans to utilize funds available from the Wireless Innovation Fund on projects related to wireless information technology, particularly in Electrical Infrastructure, End Use Efficiency, and Transportation Systems.

Seedlings/Broad Funding Announcement: The focus of the Seedlings/Broad Funding Announcement is to provide funding for innovative projects that happen to fall outside the boundaries of a specific topic area FOAs. ARPA-E believes it is important to capture any truly innovative projects that may be out there and to foster an inclusive community that demonstrates ARPA-E is open to funding projects that are outside of the specific focus topic areas FOAs. In FY 2012, ARPA-E plans to have at least one Broad Funding Announcement.

Conclusion

ARPA-E's goal is to help catalyze energy breakthroughs with speed and efficiency to secure America's future 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 at this time.