Energy Transformation Acceleration Fund
Advanced Research Projects Agency – Energy

Proposed Appropriation Language

For necessary expenses in carrying out the activities authorized by section 5012 of the America COMPETES Act (Pub. L. No. 110-69), as amended, $550,011,000, to remain available until expended.

Energy Transformation Acceleration Fund
Advanced Research Projects Agency – Energy

Overview

Appropriation Summary by Program

	FY 2010 Current Appropriation	FY 2011 CR	FY 2012 Request
Advanced Research Projects Agency – Energy (ARPA-E)			
Energy Transformation Acceleration Fund			
ARPA-E Projects	—	—	521,943
Program Direction	—	—	28,068
Subtotal, Energy Transformation Acceleration Fund	—	—	550,011
Wireless Innovation Fund[a]	—	—	100,000
Total , Advanced Research Projects Agency – Energy (ARPA-E)	—	—	650,011

Preface

The Advanced Research Projects Agency – Energy (ARPA-E) is devoted exclusively to funding specific high-risk, high payoff, game-changing research and development projects to meet the nation's long-term energy challenges.

In 2005, a bipartisan group of Members of Congress requested that the National Academies "identify the most urgent challenges the United States faces in maintaining leadership in key areas of science and technology."[b] In response, the National Academies authored a report entitled *Rising Above the Gathering Storm* in which was expressed grave concerns about the state of U.S. economic and technological competitiveness. Among the many recommendations in the *Gathering Storm* report enacted into law was the creation of ARPA-E.

Initially funded in FY 2009, ARPA-E is at the forefront of the Department of Energy's efforts to accelerate the pace of innovation. ARPA-E fulfills a critical need for transformational energy technologies. Given the recent surge in energy investments overseas, and unparalleled growth in the global demand for energy resources, the next few decades must be the most innovative period of U.S. history in order to remain competitive in the energy economy of the future. ARPA-E will play a key role in fostering that innovation. The magnitude of this challenge is enormous, as is the opportunity.

[a] The Wireless Innovation Fund is a separate legislative proposal for mandatory spending.

[b] National Research Council, Committee on Prospering in the Global Economy of the 21st Century, *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future* (2007), page 244.

Encouraging American innovation and maintaining our leadership in research and technology is a high priority for the Administration. In his State of the Union Address President Obama called this, "Our generation's Sputnik moment," adding, "We've begun to reinvent our energy policy. We're not just handing out money. We're issuing a challenge. We're telling America's scientists and engineers that if they assemble teams of the best minds in their fields, and focus on the hardest problems in clean energy."[a] To meet this challenge, the Director of ARPA-E will administer funds to projects that promise a high impact on the ARPA-E mission, and will create new and game-changing global business opportunities.

Within the Energy Transformation Acceleration Fund, the ARPA-E program currently has two programs, ARPA-E Projects (funding for research and development), and Program Direction (providing support and scrutiny to projects).

Mission

The mission of ARPA-E is to overcome the long-term and high-risk technological barriers in the development of energy technologies. To achieve this mission, ARPA-E will pursue the following goals: First, ARPA-E aims to enhance the economic security of the United States through the development of energy technologies. Second, ARPA-E aims to ensure that the United States maintains a technological lead in developing and deploying advanced energy technologies.

Benefits

ARPA-E is responsible for funding high-risk and high-payoff game-changing research and development projects to meet the nation's long-term energy challenges. ARPA-E identifies and promotes early-stage transformational research and development projects in areas that industry by itself cannot and will not support because of technical and financial uncertainty. ARPA-E pursues opportunities that have the promise to make revolutionary advances in breakthrough sciences, translate scientific discoveries and cutting-edge inventions into technological innovations, accelerate transformational technological advances, and ensure U.S. competitiveness and technical lead in developing and deploying advanced energy technologies.

Coordination between the Department's basic research and applied technology programs is a high priority for the Secretary of Energy. ARPA-E takes great care to ensure that its projects do not overlap with other DOE programs, but instead complement them in multiple ways. ARPA-E focuses on creating breakthrough energy technologies that do not exist in today's energy market, but if they did, these breakthrough technologies would make today's approaches obsolete and have huge commercial market impact. ARPA-E works in close coordination with DOE's basic science and applied research programs to avoid duplicative research and ensure a balanced research portfolio across the DOE. ARPA-E also seeks to bridge traditionally stove-piped DOE programs and proactively reaches out to form partnerships to transition successful projects to deployment. This coordination occurs at the senior DOE leadership level and the Program Director and staff level with regular and ad hoc planning meetings. 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.

ARPA-E is set up to be a lean and agile organization. ARPA-E has special hiring authority to bring on Program Directors and other program leadership, enabling it to recruit and rotate the best and brightest

[a] http://www.whitehouse.gov/the-press-office/2011/01/25/remarks-president-state-union-address

minds in the energy research fields. ARPA-E brings in top scientists and engineers to serve as Program Directors for limited terms and empowers them to make technical and programmatic decisions for the projects they oversee. The quality of the performers is important as well and ARPA-E strives to bring in world-class scientists and engineers in high-potential teams with the technical knowledge and motivation to succeed. ARPA-E also seeks to attract new researchers to focus on critical energy-related issues, and to push researchers currently in the field to produce transformational results.

ARPA-E has adopted several processes to expedite the program development and project selection process without compromising quality or integrity, while ensuring operational and mission success within rigid time constraints. For example, ARPA-E utilizes a program development process that includes extensive up-front technical research and technical workshops co-hosted with other DOE program offices, both with a great deal of technical community engagement. ARPA-E also employs a thorough peer review process. Further, ARPA-E has embedded dedicated procurement and legal teams, allowing ARPA-E to achieve exceptional speed and efficiency (usually two to three months) for processing awards from announcement to signing contracts.

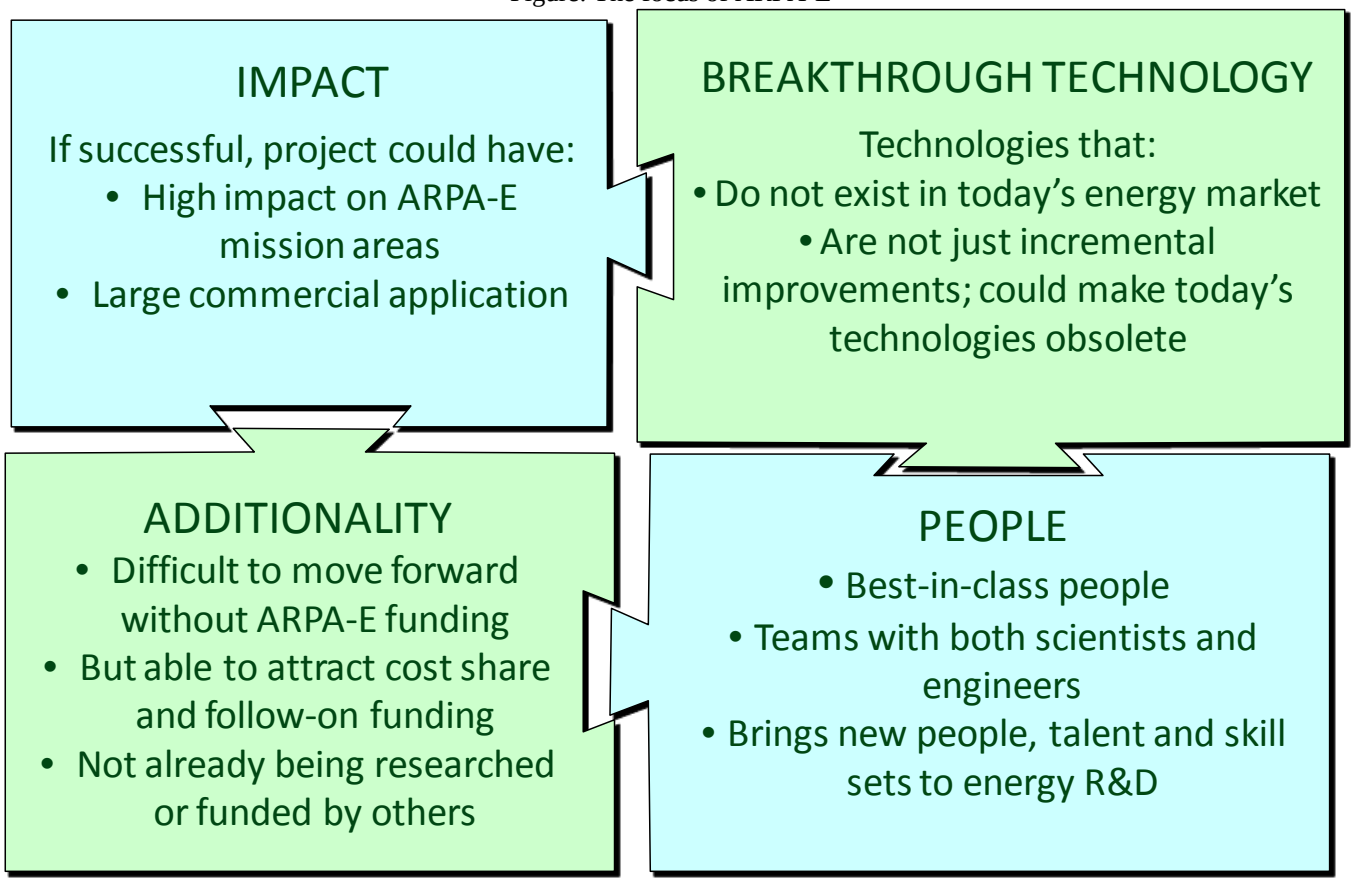
The inherent risk associated with the types of projects ARPA-E will fund means the agency fully expects a large number of projects to not fully achieve their prescribed technical milestones and deliverables. Indeed, ARPA-E embraces the possibility of failure with an entrepreneurial spirit and the strong belief that, "…fear of technology failure should not paralyze strategic investments in innovation, since some amount of failure is inevitable and essential to such a disruptive and non-linear process."[a] Given the transformational nature of the technologies, even a small percentage of successful projects would yield a payoff that will result in the flow of new ideas that will fuel the economy, create new jobs, provide security, and enhance the quality of life.

As shown in the figure below, ARPA-E's focus is on:

- High-risk, high-impact projects;
- Disruptive applied technologies that don't now exist but have a large potential application;
- Breakthrough science that can transform a field with revolutionary technical advances;
- Projects in need of rapid and flexible experimentation and/or engineering;
- Attracting the next generation of energy researchers and entrepreneurs; and
- Merging technological opportunities with mission gaps that are not being addressed.

[a] American Enterprise Institute (AEI), Brookings Institution, and the Breakthrough Institute, *Post-Partisan Power: How a Limited and Direct Approach to Energy Innovation Can Deliver Clean, Cheap Energy, Economic Productivity and National Prosperity* (2010), page 7.

Figure: The focus of ARPA-E



Strategic Plan Implementation
The Department is in the process of updating its strategic plan, and has been actively engaging stakeholders including Congress. The draft strategic plan is being released for public comment concurrent with this budget submission, with the expectation of official publication this spring. The draft plan and FY12 budget are consistent and aligned.

To support the Department of Energy's strategic goal and objective, ARPA-E will pursue a strategy to develop technologies and assess capabilities that could potentially enable transformational changes in areas that address the biggest challenges of our lifetimes such as energy security and maintaining U.S. technological leadership.

ARPA-E will achieve this by identifying and promoting revolutionary advances in breakthrough sciences, translating scientific discoveries and cutting-edge inventions into technological innovations, and accelerating transformational technological advances in areas that industry by itself is not likely to undertake because of technical and financial uncertainty.

To this end, ARPA-E will help fill the gaps in the energy innovation pipeline through the targeted acceleration of:

- Development of novel, early-stage energy technologies that are potential game-changers for the energy industry and market;
- Development of techniques, processes, and technologies, and related testing and evaluation;

- Research and development of manufacturing processes for novel energy technologies; and
- Coordination with other government and non-government entities to facilitate technology transfer of ARPA-E projects.

Strategic Goal: Catalyze the timely, material, and economic transformation of the nation's energy system and secure U.S. leadership in clean energy technologies.

Objective: Discovering the new solutions we need.

Strategy: ARPA-E supports the strategic goal and objective by supporting early-stage research and development projects in a variety of energy technologies in areas that industry by itself cannot and will not support because of technical and financial uncertainty.

Energy Transformation Acceleration Fund
Advanced Research Projects Agency - Energy

Funding by Site by Program

(dollars in thousands)

	FY 2010 Current Approp	FY 2012 Request
Washington Headquarters		
ARPA-E Projects	—	521,943
Program Direction	—	28,068
Total, Washington Headquarters	—	550,011
Total, Energy Transformation Acceleration Fund	—	550,011

Major Changes or Shifts by Site

Washington Headquarters
ARPA-E Projects

- ARPA-E requests $521.9 million in FY 2012 to fund new projects. There are no major changes, simply an increase in the number of projects ARPA-E plans to fund.

Program Direction

- In FY 2012 the Program Direction element ARPA-E's request at $28.1 million will accommodate the hiring of federal employees and support service contractors, and commensurate increases in information technology purchases and costs for leased space, to allow ARPA-E to fulfill the mission of the program.

Site Description

Washington Headquarters

In support of the Energy Transformation Acceleration Fund and the Advanced Research Projects Agency – Energy (ARPA-E) subprograms, the Washington Headquarters site provides management and leadership of ARPA-E, oversight of the Fund, and also administers funding agreements with the award recipients, support services contracts, and all other financial/funding agreements associated directly with ARPA-E.

Advanced Research Projects Agency – Energy (ARPA-E)

Funding Profile by Subprogram

(dollars in thousands)

	FY 2010 Current Appropriation	FY 2012 Request
ARPA-E Projects		
Stationary Power	—	130,000
Electrical Infrastructure	—	80,000
End Use Efficiency	—	105,000
Embedded Efficiency	—	60,000
Transportation Systems	—	115,000
Seedlings/Broad Funding Announcement	—	17,329
SBIR/STTR	—	14,614
Total, ARPA-E Projects	—	521,943

Public Law Authorizations:

P.L. 95-91, "Department of Energy Organization Act" (1977)
P.L. 109-58, "Energy Policy Act of 2005"
P.L. 110-69, "America COMPETES Act" (2007)
P.L. 111-358, "America COMPETES Reauthorization Act of 2010" (2010)

Mission
ARPA-E Projects will identify and promote early-stage research and development projects with the promise to make revolutionary advances in breakthrough sciences, translate scientific discoveries and cutting-edge inventions into technological innovations, and accelerate transformational technological advances in areas that industry by itself cannot and will not support because of technical and financial risk and uncertainty.

Benefits
To accomplish its mission, ARPA-E will draw upon the nation's strengths of having the best R&D infrastructure in the world, an unparalleled innovation ecosystem in business and entrepreneurship, and the American enthusiasm for pioneering and taking risks. ARPA-E itself performs no research, but rather funds early-stage transformational energy research and development projects that are conducted by teams from universities, small businesses, large businesses, non-profits, national laboratories, and other federally funded research and development centers.

ARPA-E finds energy technologies at an early stage in their development and funds the most promising projects at a point when they are considered too high-risk to receive investment from private investors or other public sources.

Beyond providing funds to projects, ARPA-E's scientists, engineers, and entrepreneurs actively work with the project performers to help solve problems and keep projects on track. By supporting integrated teams of scientists and engineers, ARPA-E maintains continuous feedback loops to increase the speed of innovation. ARPA-E provides crucial financial, technical, and commercialization assistance to a selected portfolio of projects for a limited period, promoting their rapid development toward a point where interested private or public investors are willing to commit funds and bring them to market scale.

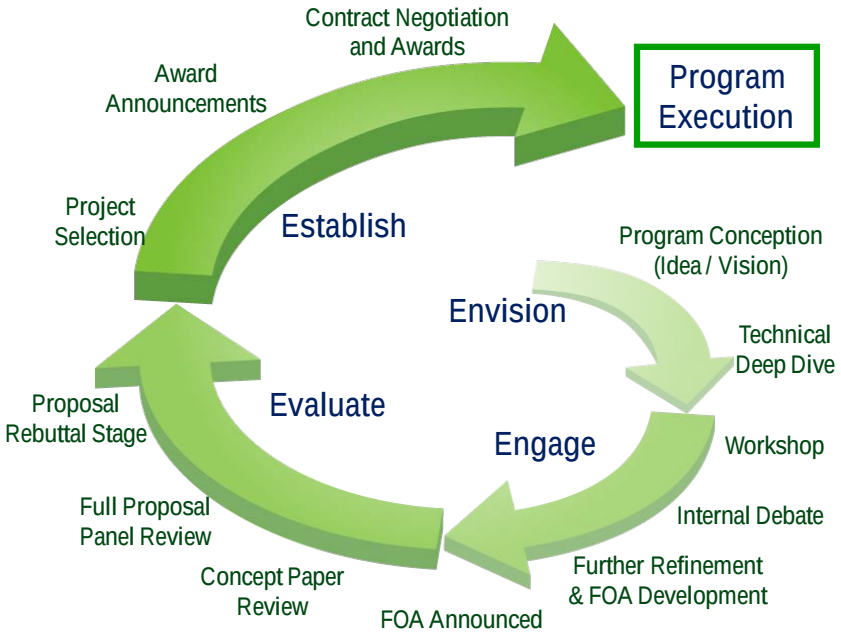
ARPA-E is organized and administered in ways that enable the program to be lean, effective, and agile and strives to be a model of excellence for a small agency. In its short existence of less than two years, ARPA-E has implemented several key business process innovations that have earned it recognition as an organization to emulate.

As noted in a 2010 report from the President's Council of Advisers in Science and Technology (PCAST), "Although the ultimate success of the research funded by ARPA-E is unknown, as evidenced by the solicitations managed by ARPA-E, that they have been successful in their peer review of proposals, quick negotiation of contracts, and rapid hiring of high-caliber personnel."[a] Some of the core ARPA-E innovations are described in more detail below.

<u>ARPA-E's program development process includes distinctive and desirable features</u>
ARPA-E implemented a novel process for the development and creation of programs that features extensive technical community engagement, topical workshops, a three-stage peer review process that allows for rebuttals to reviewer comments, and rapid contract negotiation, as shown in the figure below. Despite its depth of engagement and multi-stage evaluation, this model affords a timeline from conception to execution that is greatly accelerated—ARPA-E's timeline is typically only six to eight months. This in turn allows ARPA-E to respond rapidly to newly emerging technological discoveries and geo-political events in its creation of new programs.

[a] Executive Office of the President, President's Council of Advisers on Science and Technology, *Report to the President on Accelerating the Pace of Change in Energy Technologies Through and Integrated Energy Policy* (2010), page viii.

Figure: ARPA-E's Program Development Process



Timeline: 6-8 Months from Program Conception to Execution

The first two phases of the program development process serve to refine a good idea into an actual Funding Opportunity Announcement (FOA) in an area where ARPA-E's limited funding will have substantial impact in the long term. The third phase utilizes a novel peer review process to choose the projects that have the most potential to produce transformational and disruptive technologies. The fourth phase features the negotiation of contracts in only two to three months—a pace that is uncommon in the public sector.

The process begins with the idea or vision for a potential program. ARPA-E staff engages the technical community and performs extensive background research and a technical "deep dive" that seeks to state the problem, define the current state of the art, identify revolutionary advances in breakthrough sciences, and propose preliminary focus areas. ARPA-E staff concurrently engages DOE colleagues and others to identify the gaps in the current research portfolios for ARPA-E to fill. This also serves to leverage DOE knowledge to accelerate the development of a potential program and to eliminate redundancy.

In the second phase, Program Directors are required to hold a workshop in order to engage the scientific community, both within DOE and at large, to help ARPA-E determine the state of the art in a given field, to discuss solutions to the critical challenges identified, and determine performance targets the technical community thinks are aggressive yet reachable. If after a workshop ARPA-E determines to issue a FOA, the technical community is involved extensively again in the peer review process.

The third phase, ARPA-E's peer review process, is a key component of the program's success. Engaging the leading experts in the technical community at every turn is very important to ARPA-E. Program Directors and staff solicit input both formally and informally during the conceptualization phase and the workshops, but is perhaps most significant during the peer review process. The involvement of world-class scientists and engineers and leaders from the technical community brings to the process unparalleled expertise and knowledge. ARPA-E taps dozens of the leading experts in the world in a particular field. ARPA-E has them review concept papers and full applications over several weeks, and then brings them together for a Merit Panel Review. ARPA-E's evaluation process includes

another facet that is common for things such as journal articles, but rather distinctive among federal research and development programs – the opportunity for the applicant to read reviewers comments and to provide a rebuttal. This aspect of the ARPA-E process has been extremely well received in the technical community. In additional to the recognition from the PCAST report, the DOE Office of the General Counsel has circulated a summary of the ARPA-E review process to the rest of DOE as a template for all the applied research programs.

The final phase, the quick negotiation of cooperative agreements, is another key business innovation and is a hallmark of the ARPA-E process. A defining feature of this innovation is that ARPA-E has embedded dedicated procurement and contracting teams. Another example of ARPA-E striving to eliminate traditional bureaucratic stovepipes that hinder innovation and efficiency, this arrangement allows ARPA-E to achieve an unprecedented pace of transferring awards from announcement to signing cooperative agreements—usually about two to three months. This speed and efficiency of process is instrumental to ARPA-E's success and reputation.

During this final phase, the general cost and performance metrics developed for the FOA are negotiated with specificity for each selected performer. ARPA-E's cost and performance metrics are particularly aggressive, another characteristic of the program, and seek not to advance prevailing technology along existing learning curves, but rather to establish entirely new learning curves. These cost and performance metrics become technical deliverables and milestones for the selected projects and are codified in the final funding agreement.

ARPA-E Program Directors are world-class scientists and engineers, and are term-limited

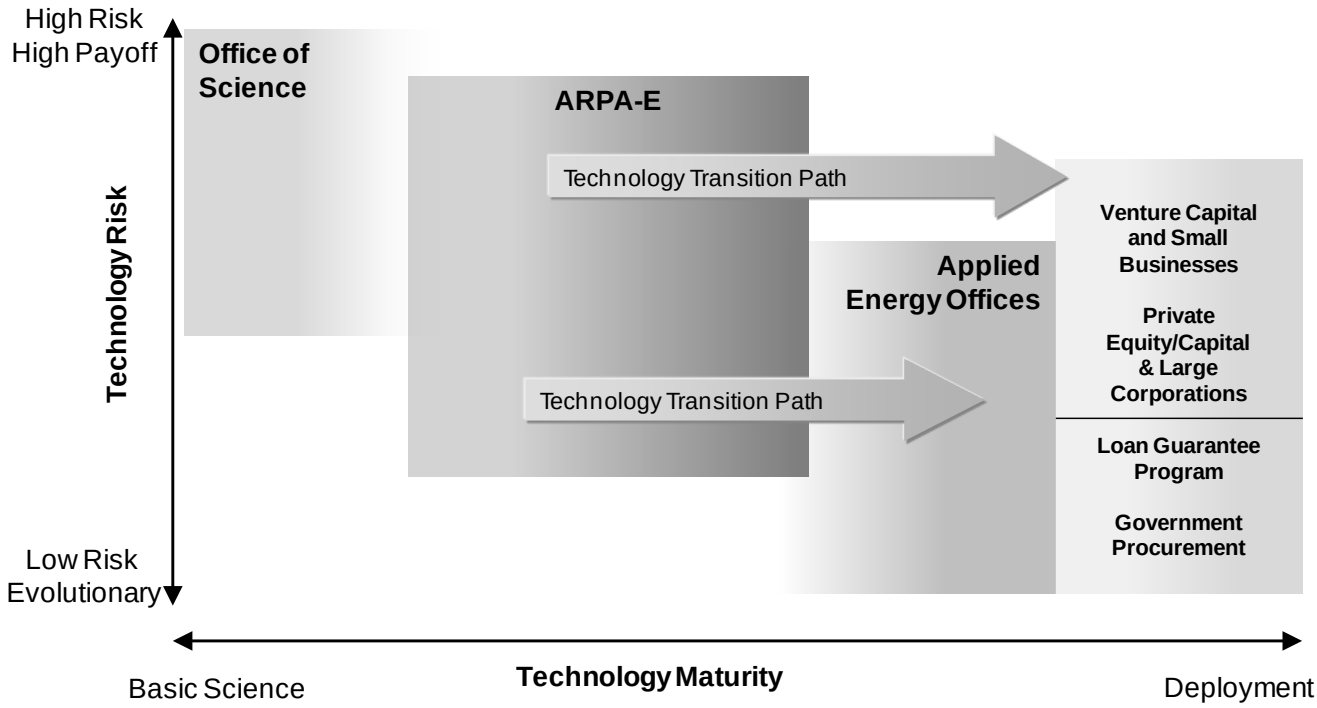
The rapid hiring of high-caliber personnel is one more notable feature of ARPA-E. ARPA-E has special hiring authority to bring on Program Directors and other program leadership for terms limited to three years. In turn, some of the best and brightest minds in the energy field have been attracted to come to ARPA-E to serve their nation for a few years and then return to the technical community. ARPA-E's Program Directors are the top scientists and engineers in the world and have significant experience in bridging science, technology and business with multidisciplinary teams. ARPA-E Program Directors lead topic programs and work directly with the award recipient project teams. They are expected to know all of the scientific details of the projects they manage. This enables technical brainstorming and sharing of knowledge that significantly shortens the technology development pipeline. ARPA-E Program Directors practice active hands-on risk management for each project, including at least two site visits per year, two program reviews, and go/no go technical milestones. Program Directors limited appointments last only the duration of the projects they support. Rotating program leadership in this way provides fresh perspective and enthusiasm to each round of funding for projects, and also leads to speed and a sense of urgency since Program Directors have only three years to deliver a technology and make an impact with the projects they fund.

ARPA-E is a catalyst for coordination within DOE

An additional benefit enjoyed by ARPA-E that is not related to an internal business process innovation has been ARPA-E's role in bringing together the traditionally stove piped DOE program offices. As noted in the overview, ARPA-E works in close coordination with DOE's basic science and applied research programs to avoid duplicative research and ensure a balanced research portfolio across the DOE. ARPA-E proactively reaches out to form partnerships to transition successful projects to deployment. Along with technical coordination within DOE, it is important for ARPA-E to coordinate with other stakeholders. The figure below charts the relationship between ARPA-E and DOE's Office of Science and Applied Offices as it relates to technology maturity and risk. The figure also illustrates the technology transition path for ARPA-E projects as they increase in technological maturity—either a

direct path to the investment community, DOE's Loan Guarantee Program, or other Government Procurement, or in some cases a hand-off to a DOE Applied Office for further development before going on to deployment.

Figure: ARPA-E Coordination within DOE and with Other Stakeholders



To facilitate senior management level coordination within DOE, the ARPA-E Director created the Panel of Senior Technical Advisors (PASTA), a group of technical leaders within DOE spanning the Office of Science, the Office of Fossil Energy, the Office of Nuclear Energy, the Office of Energy Efficiency and Renewable Energy, the Office of Electricity Delivery and Energy Reliability, and 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.

Below the senior management level, ARPA-E Program Directors frequently coordinate with their counterparts in other DOE program offices. In addition to maintaining regular contact, other DOE officials serve as ARPA-E concept paper and full application reviewers. ARPA-E works closely in collaboration with other DOE basic and applied research offices to identify gaps in their research portfolios ("white space") as well as through co-hosting topical workshops in the development of programs.

Coordinating with other DOE offices on workshops is an essential way to avoid duplicative research and ensure a balanced research portfolio across the DOE. This also serves to inform all parties of each other's ongoing research activities to facilitate the transition of successful ARPA-E projects to other DOE programs. A few examples of workshops follow:

- Grid Scale Energy Storage Workshop: ARPA-E and the Office of Electricity Delivery and Energy Reliability co-hosted a workshop as a complement to the Department of Energy-sponsored Electrical Energy Storage Applications and Technology Conference 2009 (EESAT 2009). ARPA-E used information from this workshop to shape the scope and focus of its funding opportunity announcement of the GRIDS program.

- Advanced Building Energy Technologies Workshop: ARPA-E and the Office of Energy Efficiency and Renewable Energy (EERE) held a workshop on the topic of advanced building energy technologies. The objective of this workshop was to gain a deeper understanding of those areas and technologies that have the highest potential to meet DOE's goal of developing the technical foundations necessary to enable massive reductions in energy consumption in buildings. ARPA-E used the information from this workshop to shape the scope and focus of its funding opportunity announcement of the BEETIT program.

It is important to note that not all workshops necessarily lead to programs.

Currently Funded Programs

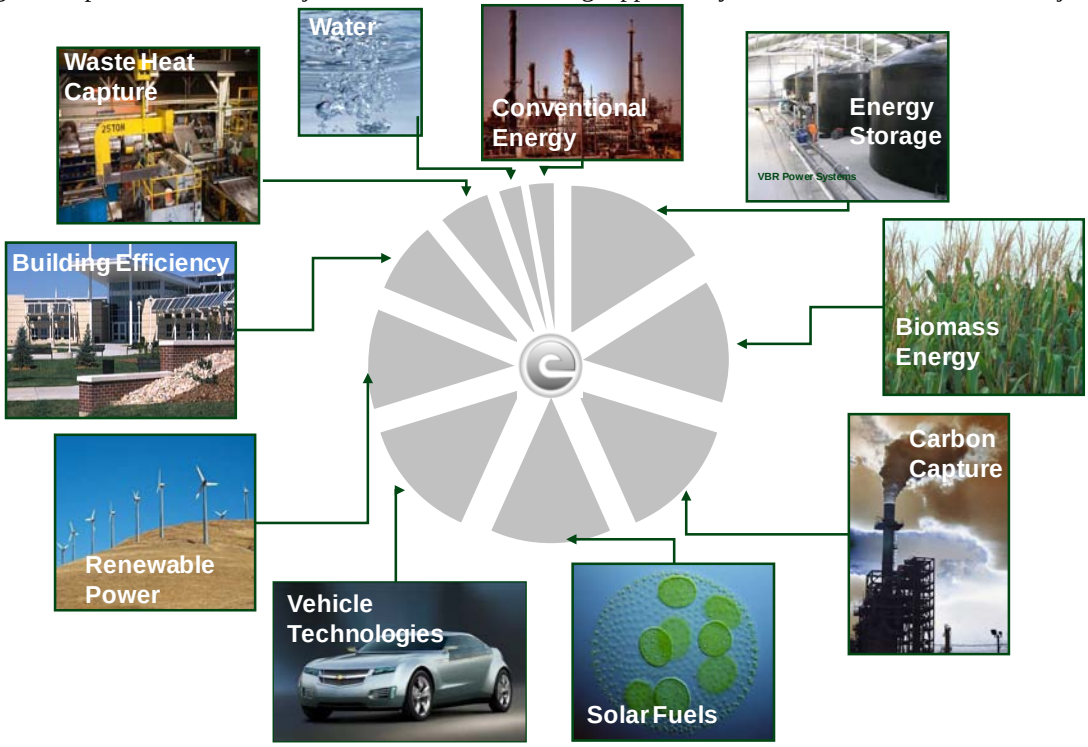
Since April 2009, ARPA-E has issued seven Funding Opportunity Announcements (FOAs) and received an overwhelming response from the technical community. ARPA-E has reviewed 4,786 concept papers and 688 full proposals, from which 121 projects were selected for funding.

ARPA-E was substantially oversubscribed, and many projects which showed potential to be truly transformational could not be funded. ARPA-E elected to give these non-selected but high-potential projects exposure by including them on the ARPA-E website. These projects teams are also invited to the ARPA-E summit and afforded the opportunity to showcase their technologies. This provides them exposure to other ARPA-E teams for potential partnerships and to potential investors.

ARPA-E selected projects with extraordinary potential, but because of their high-risk nature of the research involved not all of them will be successful. If just a fraction of the projects funded by ARPA-E are successful in reaching the marketplace, the U.S. will benefit greatly by creating new industries and jobs, making energy technologies substantially more efficient and profitable, and accelerating the timeframe for achieving energy and security goals.

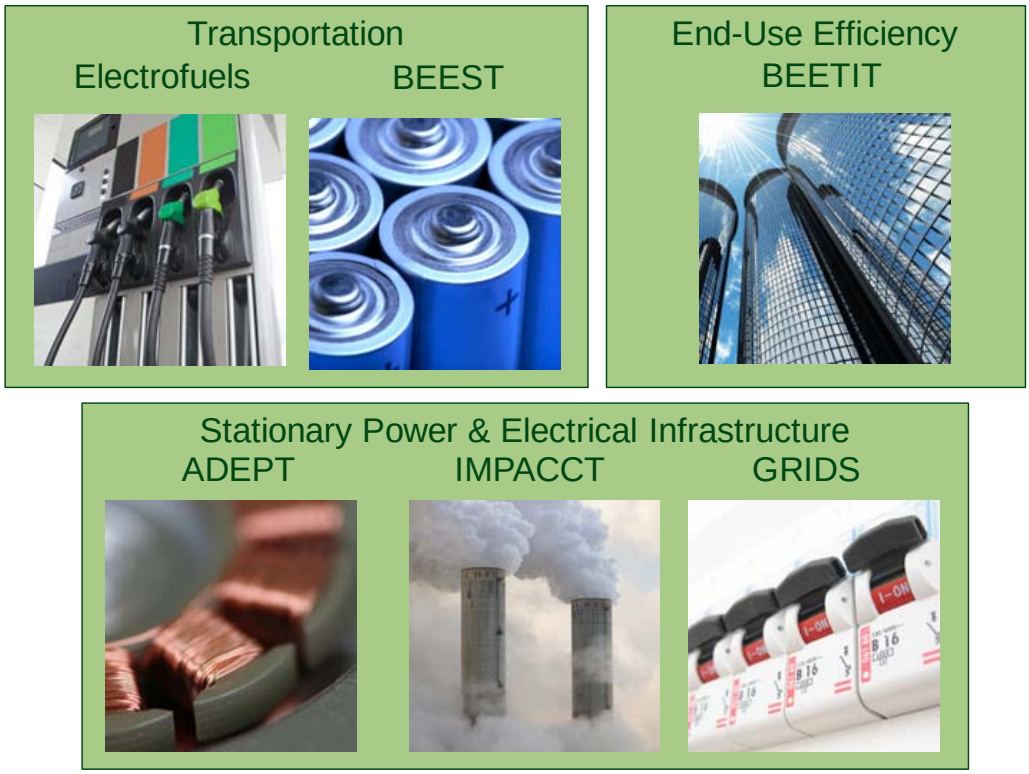
ARPA-E's inaugural FOA did not seek a specific technological goal. Rather, this FOA was open to all energy ideas and technologies, but focused on applicants who already had well-formed research and development plans for potentially high-impact concepts or new technologies. Projects spanning ten topic areas were selected based on impact on ARPA-E's mission, innovative technical approaches, high-performance teams, and opportunities for the U.S. to gain leadership, as well as to pursue technologies that are underserved by other parts of DOE and the private sector (see figure below for details). If successful, these technologies could be game-changing and launch new opportunities for American businesses and jobs.

Figure: Topics of ARPA-E Projects from the first Funding Opportunity Announcement and Other Projects



ARPA-E's subsequent FOAs targeted specific topics, in contrast to the open approach of the initial funding opportunity. These programs fund competitive approaches, setting market-relevant and aggressive cost and performance metrics as ends for performers to achieve while allowing performers to determine the specific technological means to do so. These six FOAs are described in detail below.

Figure: ARPA-E Topical Funding Opportunity Announcements (FOAs) by Primary Focus and Programs



Electrofuels

New and advanced liquid fuel technologies are needed to address the challenges associated with reliance on oil. While domestically-produced biofuels increase the nation's energy security, there remains a considerable need for next-generation renewable fuels that are compatible with today's fuel refining and distribution infrastructure. To address this need, the Electrofuels program is exploring ways that have never been tried before to produce renewable liquid transportation fuels—without using petroleum or biomass—by using microorganisms to harness chemical or electrical energy to convert carbon dioxide into liquid fuels. Theoretically such an approach could be 10 times more efficient than current photosynthetic-biomass approaches to liquid fuel production.

Batteries for Electrical Energy Storage in Transportation (BEEST)

The BEEST program aims toward making a new generation of ultra-high energy density, low-cost battery technologies for long-range (300 to 500 miles) plug in hybrid electric vehicles (PHEVs) and electric vehicles (EVs). Successful development of these types of batteries will make PHEVs and EVs more useful to more people and will put more cars on the road that run on U.S.-generated electricity rather than imported oil. ARPA-E investments in this area run from moderately risky projects to take lithium ion batteries (the current industry standard) to the next level, to pushing the boundaries of batteries by using lithium air systems that can hold as much energy as a tank of gasoline in the same volume. Other projects in the BEEST program are looking at new ways to safely store energy that will provide cars with energy for up to a 500 mile range and be able to fully charge in minutes. ARPA-E is funding research efforts that will promote U.S. leadership in the emerging EV battery market.

Building Energy Efficiency Through Innovative Thermodevices (BEETIT)

The BEETIT program seeks to develop energy-efficient building cooling technologies that will reduce energy consumption from: (a) overall cooling and (b) refrigerants used in vapor compression systems. Project teams are developing the most efficient cooling technologies that are also cost-competitive with current methods. These more advanced technologies will be suitable for both warm and humid climates (e.g. Florida) and hot and dry climates (e.g. Arizona). Further, it is planned that these technologies could be retrofitted into existing buildings. The U.S. demands technologies that will retrofit into current cooling systems, while developing economies, because of new construction, can readily incorporate new cooling technologies. Developing these technologies significantly increase the U.S. technological lead in rapidly-emerging clean energy industries.

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. These investments could potentially leapfrog existing power converter performance and reduce costs. The result of improved efficiency of electric power conversion will then be seen in applications such as the lamp drivers commonly used for LED lighting. These improved lamp drivers will be ten times smaller and will reduce the amount of heat loss. Additionally, improved electrical power efficiency could result in smaller personal computers and computer servers, and produce lightweight chargers for electric vehicles. In total, these advanced transistors will enable miniaturization, increased efficiency, and reduced costs. The ADEPT program also focuses on creating high-voltage transistors for utility power networks that can allow for the controlled movement of electricity by selective routing through transmission lines to avoid congestion and overloading. Innovations in power electronics could significantly reduce costs, which would promote U.S. businesses through technological leadership.

Innovative Materials and Processes for Carbon Capture Technologies (IMPACCT)
The IMPACCT program seeks to reduce the cost of carbon capture significantly by revolutionizing the technologies used to capture carbon dioxide—through a combination of new materials, improvements to existing processes, and demonstration of new capture processes. ARPA-E seeks to complement existing DOE efforts in the field of carbon capture, led by the Office of Fossil Energy and National Energy Technology Laboratory, by accelerating promising ideas from the basic research stage towards large-scale demonstrations and, ultimately, commercialization. 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 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. While valuable applications for grid-scale storage exist, this program focuses on technologies that balance the short-duration variability in renewable generation. Investing in these technologies will position the U.S. as the technology and manufacturing leader of the emerging, and potentially massive, global market for stationary electricity storage infrastructure. The GRIDS program seeks to develop revolutionary modular storage systems that provide the energy, cost, and lifecycle of pumped hydropower, and can be widely implemented across the power grid. Specifically, GRIDS considers two areas: 1) proof–of-concept storage-component projects focused on validating new, over-the-horizon, electrical energy storage concepts, and 2) advanced system prototypes that address critical shortcomings of existing grid-scale energy storage technologies. Ultimately, technologies developed through this program will be scalable to megawatt and megawatt-hour levels of power and energy capacity. GRIDS will complement other DOE grid-scale energy storage efforts by focusing on technology prototyping and proof-of-concept research and development.

Potential Future Programs
As noted in the section above describing ARPA-E's program development process, topical workshops engaging the leading experts in DOE and in the technical community at large are a key component of ARPA-E's success. The workshops serve as a forum for ARPA-E to determine the state of the art in a given field, to discuss solutions to the critical challenges identified, and determine performance targets the technical community thinks are aggressive yet reachable. While not all workshops necessarily lead to ARPA-E programs, they do inform the direction of the program in particular energy technology areas. A listing of recent ARPA-E workshops is below. Summary reports from all ARPA-E workshops are available on the ARPA-E website (http://arpa-e.energy.gov/EventsWorkshops/PastEvents.aspx).

- $1/W Workshop (August 2010) – To complement the Office of Energy Efficiency and Renewable Energy's (EERE) highly-productive photovoltaic (PV) program, ARPA-E co-hosted with EERE a workshop explored the possibility of developing products and processes that would enable PV facilities priced at $1 per watt, fully-installed.

- Applied Biotechnology for Transportation Fuels Workshop (December 2010) – This workshop brought together thought leaders from distinct science and engineering communities to develop new ideas and identify practical approaches toward increasing the efficiency of light collection by biological systems and the conversion of that energy into liquid forms of chemical energy that can be used for transportation. Focus was directed towards the production of high-energy content fuel molecules by photosynthetic systems rather than processes that convert lignocellulose or other sources of biomass to usable fuels.

- Critical Materials Technology Workshop (December 2010) – The importance of critical materials in the energy sector has been highlighted by the mismatch between the rapidly growing demand relative to the limited global supply of rare earth materials. The goal of the workshop was 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 critical materials in the energy sector. Technology solutions focused on both the supply side and demand side of critical materials challenges are of interest. Specifically, ARPA-E was interested in exploring potentially disruptive (not incremental) technology solutions.

- Green Electricity Network Integration Workshop (December 2010) – This workshop addressed the challenges and opportunities associated with incorporating renewable energy sources into the nation's power grid. The goal of the workshop was to develop new ideas and identify the most promising research and development pathways to better accommodate the alternatives to traditional electricity generation and the use of plug-in hybrid electric vehicles while improving the reliability, controllability, and performance of the power grid. Specifically, ARPA-E examined grid control in a highly variable environment for electricity generation, islanding and microgrids, flexible A/C transmission systems (FACTS) devices, and high-voltage direct current (HVDC) transmission.

- High Density Thermal Energy Storage Workshop (January 2011) – Thermal energy transport and conversion play a very significant role in more than 90% of energy technologies. Approximately two thirds of thermal energy is wasted. Thermal energy storage can significantly reduce this waste and enhance the efficiency of energy delivery and consumption. Applications range from low temperature cold storage to high temperature nuclear reactors. Efficient storage of thermal energy can lead to grid power profile balancing, an increase in building envelope thermal mass, efficient use of heat in combined heat and power systems, less intermittent and more cost-effective solar thermal power plants, and the use of nuclear energy for meeting seasonal as well as hourly variation in electricity demand. This workshop brought together a diverse community of scientists (e.g. chemists, materials scientists, and physicists) and engineers (e.g. mechanical, thermal, chemical) to develop new ideas and identify the most promising R&D pathways for thermal energy storage.

- Power Electronics in Photovoltaic Systems Workshop (February 2011) – ARPA-E co-hosted a follow-up to the $1/W workshop with EERE's Solar Energy Technologies Program focusing on power electronics in photovoltaic (PV) systems. One part of the workshop addressed the challenges and opportunities associated with incorporating advanced power electronics into photovoltaic sources of electricity generation, while the other part focused on system related issues such as grid-integration. The workshop brought together some of the world's foremost experts in PV technology as well as leaders from industry, academia, and government with diverse perspectives to discuss the challenges and opportunities related to the generation of solar power.

ARPA-E programs generally fall into two categories:

- New Areas of Science and Technology—for example, ARPA-E's current Electrofuels program the goal of which is to create a biological non-photosynthetic process to produce liquid fuels. This is not being done anywhere else and, if successful, could create an entirely new industry.

- New Generation Technology—for example, ARPA-E's current program called Batteries for Electrical Energy Storage in Transportation, or BEEST. While DOE and most outside R&D is focused on lithium batteries, ARPA-E is looking for other battery chemistries that, if successful, would yield batteries that are less expensive and provide longer range and storage capabilities than today's approaches.

ARPA-E continues to improve its internal strategic vision for the future direction of the agency. This internal strategic plan, formally titled Strategic Vision Roadmap, is still being developed; but the broad strokes of the plan are codified in an updated matrix organization structure, shown in the figure below, that hones in on the broad strategic areas in which ARPA-E will seek to fund projects.

Building on the matrix organization structure that ARPA-E has in place already, the "Applied Science and Technologies" columns remain the same but the "Integrated Energy Systems" rows have been regrouped to reflect the program's internal strategic thinking on the focus of future projects. Additionally, relative to the matrix in the FY 2011 budget request, ARPA-E has shifted the contents of some cells to indicate where the current projects and planned future FOAs should now be considered to fall; as well as to show other refinements to ARPA-E's strategic thinking. This updated matrix now reflects ARPA-E's best estimates as to the areas of focus for ARPA-E currently and in FY 2012.

The five broad thematic strategic direction areas, shown in the bulleted list below, are explored more deeply in the detailed justification section that follows. Described therein are areas of technical interest that ARPA-E will explore at the requested funding level. Technical flexibility and empowerment of Program Directors is a key aspect of ARPA-E. Before starting a program ARPA-E will do in-depth research, market studies, have discussions with experts from the technical community, and hold a technical workshop to determine if an area of interest is ready for an ARPA-E program.

- Stationary Power

- Electrical Infrastructure

- End Use Efficiency

- Embedded Efficiency

- Transportation Systems

ARPA-E is required by statute to provide 5% of appropriated funds for technology transfer and outreach. These activities will be funded within the programs below.

Figure: ARPA-E's Updated Matrix Organization Structure

APPLIED SCIENCES AND TECHNOLOGIES							
Marketing & Decision Science	**Information Science & Device Engineering**	**Electronic & Structural Materials Science & Device Engineering**	**Thermal Science & Device & Process Engineering**	**Chemical & Biological Science & Process Engineering**		**FY 2012**	
		ADEPT, GRIDS, & BAA $1/W Solar	**IMPACCT** Thermal Battery	**IMPACCT**	**Carbon-Free Power (Nuclear, Solar, Wind, Hydroelectric, & Geothermal)** **Carbon Dioxide Capture & Utilization**	**Stationary Power** **FY 2012 $130M**	INTEGRATED ENERGY SYSTEMS
	Grid Security Optimization	**ADEPT & GRIDS**			**Transmission & Distribution**	**Electrical Infrastructure** **FY 2012 $80M**	
BAA Performance Measurement, Education	Systems Integration, Control, and Optimization for Energy Use		**BEETIT** Thermal Battery		**Buildings & Appliances (Homes, Buildings, Data Centers)**	**End Use Efficiency** **FY 2012 $105M**	
		BAA Biological Chemical Precursors	**BAA**	**BAA**	**Industrial Power Generation & Use (Cement, Metals, Glass, Paper)** **Water & Agriculture**	**Embedded Efficiency** **FY 2012 $60M**	
		BEEST, & BAA	**BAA**	**Electrofuels** Natural Gas Generation and Storage	**Transportation** **Fuels Synthesis**	**Transportation Systems** **FY 2012 $115M**	

Shaded cells show topic areas (Current Projects or potential future FOA) for ARPA-E funding

IN BOLD: FOA title, or Broad Agency Announcement (BAA), ongoing and fully funded
UNDERLINED: focus of potential upcoming FOAs

FY 2012 funding levels shown represent broad categories of ARPA-E's strategic focus and will guide hiring of future Program Directors, workshops, and FOAs

Annual Performance Targets and Results

Strategic Goal: Transforming our Energy Systems: Catalyze the timely, material, and economic transformation of the nation's energy system and secure U.S leadership in clean energy technologies
Strategic Objective: Discovering the new solutions we need
Strategy: Accelerate energy innovation through pre-competitive R&D
GPRA Unit Program Goal: Issue Funding Opportunity Announcements that will focus on enhancing the economic and energy security of the United States through the development of energy technologies and ensure that the United States maintains a technological lead in developing and deploying advanced energy technologies' that will focus on transformational energy technology projects

Performance Measure: Cumulative percentage of award funding committed 45 days after funding opportunity announcement (FOA) award announcements.

FY 2009	FY 2010	FY 2011	FY 2012 Request	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
T: n/a A: 75%	T: n/a A: n/a	T: 70% A: n/a	T: 70% A:	T: 75% A:	T: 75% A:	T: 75% A:	T: 85% A:	T: 85% A:	T: 85% A:

Performance Measure: Cumulative percentage of follow on funding from other Federal (not ARPA-E) and Private organizations as a result of ARPA-E direct funding.

T: n/a A: 35%	T: n/a A: n/a	T: 10% A: n/a	T:10% A:	T:10% A:	T:15% A:	T:15% A:	T: 15% A:	T: 20% A:	T: 20% A:

Means and Strategies

ARPA-E will pursue the following means and strategies to achieve its goals:

- Lead the rapid development of transformational energy technologies;
- Drive the swift transition of energy innovations toward market impact;
- Contribute to the advancement of U.S. leadership and global competitiveness in advanced energy technologies; and
- Build an innovative, highly effective, and sustainable organization.

Validation and Verification

The validation and verification of ARPA-E's activities are subject to continuing review by Congress, the Government Accountability Office (GAO), and the DOE Inspector General. ARPA-E will conduct an annual internal controls review under the Federal Managers' Financial Integrity Act. ARPA-E's performance measures and associated quarterly milestones will be reviewed and approved by the ARPA-E Director. Performance measures on quality improvements are being established and monitored.

Detailed Justification

(dollars in thousands)

FY 2010 Current Approp	FY 2012 Request
Stationary Power	**— 130,000**

ARPA-E is investing in transformational R&D in a number of power generation technologies, and coordinating that investment with basic energy sciences and the applied programs to identify programs with potential for game changing developments to meet the ARPA-E mission. To date, ARPA-E activities relating to stationary power have focused on improving the economics and performance of conventional wind turbine through new designs based on jet engine technology, novel ways to tune and optimize blades that are much simpler to manufacture, and airborne wind turbines at modest altitudes; novel fabrication processes for solar technology that reduces the cost of manufacturing silicon substrates; new drilling technology, allowing vastly more economical access to deep under- ground thermal reservoirs; and innovative materials and processes to reduce the cost of carbon capture.

Given the increasing reliance on an overwhelming percentage of the nation's electricity that comes from stationary power sources, ARPA-E will continue to make strategic investments in this sector. 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.

ARPA-E's goal is to create a diverse portfolio of technological options for low-cost power generation from traditional and renewable sources. This will make US the world leader in these technologies and thereby lead to economic prosperity and American jobs. These 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 is 5-6 cents/kWh.
- Integrated energy supply systems for distributed supply of heating, cooling, and power in optimal ways.

Potential areas of investment are identified below.

As renewable and distributed generation technologies are added to the electric generation mix, energy flow changes from a unidirectional flow – from supply to demand – to a complex bidirectional supply/demand optimization problem. The U.S. is committed to installing low-cost, clean, renewable energy resources and, as a result, needs to develop an intelligent system capable of balancing the needs and demands of each building. ARPA-E, in coordination with other DOE offices engaged in complimentary activities, will investigate novel operating system/sensor pairings that effectively balance the use of renewable energy sources to maximize both utilization and efficiency and minimize the use of non-renewable energy sources.

The salt concentration gradient where freshwater rivers reach saltwater oceans can be harnessed to create electricity. While this technology has the potential to generate gigawatts of clean, renewable energy, the concept is still largely theoretical, and membrane performance is far from what is needed. ARPA-E will consider programs in advanced membranes and osmotic power generation strategies to simultaneously produce electricity and improve desalination efficiency.

(dollars in thousands)

FY 2010 Current Approp	FY 2012 Request

Natural gas (methane) currently provides 25% of U.S. energy, and is a clean, low carbon, energy source. The use of natural gas could be expanded for both stationary power and as a transportation fuel. Additionally, methane generated in a renewable fashion could serve as a zero-carbon fuel. ARPA-E will investigate methods to produce methane via approaches that would transform natural gas from a non-renewable to a renewable clean fuel.

Solar technologies such as photovoltaics have received extensive federal and private support. Still, high efficiency, low-cost solar solutions do not exist. ARPA-E is considering a radically different approach to solar power generation, specifically the storage of incident sunlight as chemical energy that could be released on exposure to a catalyst. This novel concept would facilitate solar storage in such a fashion that renewable energy could be harvested when available and harnessed as needed.

Conventional power generation facilities – both nuclear and fossil-fuel fired – present extraordinarily harsh conditions under which construction materials must survive and perform. As a result, high temperature, radiation-hard, and corrosion-resistant materials have been the focus of intense study. While numerous advances have been made in areas such as nickel-based superalloys, improved efficiency remains out-of-reach due to materials limitations. ARPA-E will consider high-risk programs in advanced coolants, computationally-guided discovery of high temperature metal alloys, and advanced manufacturing processes. ARPA-E will focus on the manufacture and integration of high-temperature materials (e.g. those that can withstand 1300 degrees Celsius) for low-cost power generation (e.g. Brayton cycle) through high-efficiency engines. In addition, ARPA-E will coordinate with other DOE offices to investigate radically new molding and manufacturing techniques for jointless radiation-hard, high-temperature materials for advanced nuclear reactors.

Stationary Power is a new subprogram for FY 2012.

Electrical Infrastructure **— 80,000**

The U.S. electric grid is undergoing a technical renaissance through the deployment of initial smart-grid technologies, catalyzed significantly through U.S. federal support. This technical renaissance is motivated by the need to modernize the grid for the 21st century: supporting a diverse mix of renewable, efficient, and clean generation; providing greater flexibility and control of electricity for the consumer; greater reliability and security in the delivery of electricity; and a sustainable electric energy foundation for our information-intensive economy.

The US grid is many decades old and often running at maximum capacity, making it vulnerable to outages and security threats. Meanwhile, other nations such as China are investing heavily in those technologies that will leap frog and create the most advanced grid.

While the first generation of smart-grid technology is being deployed as a high-speed information network in parallel with the energy network, ARPA-E looks forward to developing technologies that can realize the full vision of a smart grid. Leveraging the smart grid information network provides a platform for new energy technologies: from widespread deployment of breakthrough approaches to

energy storage; to highly distributed, efficient, and modular approaches to energy generation; to more efficient and secure approaches to controlling the cyber-physical transmission grid system.

ARPA-E's goal is to develop those 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, thus leading to American jobs and economic prosperity. Some broad goals 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 US transmission-distribution system.

Potential areas of investment are identified below.

Renewable sources of electricity such as wind and solar offer clean power, but their intermittent nature complicates consistent deployment of base-load power. Grid-scale energy storage technologies buffer variation in renewable generation and ensure stability of the electric grid. The ARPA-E Grid-scale Renewable Intermittent Dispatchable Storage (GRIDS) program is currently developing low-cost grid-scale energy storage technologies. Future ARPA-E investment in this area will integrate novel technologies developed in the GRIDS program into full systems that can be scaled for use on the electric grid, as well as storage strategies effective over longer time-frames. Future programs may explore other approaches to grid-scale energy storage, such as reduced transmission line congestion.

To harness new renewable sources of electricity such as wind, solar, and geothermal, the nation's network of electricity transmission lines must be expanded. Such deployment can take years to secure new "rights of way" for electricity transmission projects, and routes through densely-populated areas are often closed indefinitely to development. Although the U.S electric grid includes hundreds of thousands of miles of transmission lines, less than 1000 miles of new interstate transmission were added during the last decade. To address this problem, ARPA-E will explore technologies that permit transmission of larger amounts of electricity through existing corridors, including devices that enable the operation of transmission systems at 1000 kV (one million volts) and above.

Today's electric grid includes a complex network of power lines, transformers, and substations that relay power from the high voltage transmission system to the homes and businesses in which it is used. Known as the "distribution grid," this network is largely "dumb:" it provides little information to either operators or users. ARPA-E will consider increasing the intelligence of the distribution network to increase the efficiency and reliability of this critical portion of the electric grid. ARPA-E will explore technologies that complement existing smart grid technologies (such as residential "smart meters") and enable more efficient routing of electricity, more efficient operation of transformers and substations, and more effective diagnosis of and rapid response to system faults, including the use of wireless

(dollars in thousands)

FY 2010 Current Approp	FY 2012 Request

technology.

Electrical Infrastructure is a new subprogram for FY 2012.

End Use Efficiency **— 105,000**

Energy efficient technologies for buildings, both commercial and residential, offer a tremendous opportunity to reduce energy demand and green house gas emissions. Buildings consume 40 percent of energy in the U.S., while the industrial sector consumes 30 percent. 72 percent of the nation's electricity and 55 percent of natural gas is used in buildings. The cooling and heating of buildings consumes 30 percent of the total energy used in buildings; which corresponds to 30 percent of CO2 emissions. This translates into 12 percent primary energy use and 12 percent CO2 emissions 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.

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 broad goals include:

- 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

Potential areas of investment are identified below.

Lighting is among the greatest consumers of electricity. To produce light when the sun is below the horizon, electricity is transformed into light. ARPA-E will investigate technologies that *directly* store photons during the day and emit light on demand, significantly reducing the electric demand for electricity for lighting.

Thermal imaging of buildings and real time monitoring of power use on an outlet by outlet basis can detect hidden energy losses. On the other hand, measurement systems necessary to facilitate such monitoring are both crude and expensive. Residential and commercial buildings consume approximately one third of all the energy in the U.S. and reduction in energy lost through inefficient power management would make a significant reduction in the nation's total energy consumption. ARPA-E will investigate ways to dramatically improve building efficiency through innovative technologies that identify energy losses without the need for expensive system retrofitting, including wireless technology.

(dollars in thousands)

FY 2010 Current Approp	FY 2012 Request

The integration of individual building systems such as lighting, air conditioning, etc. into a single, "smart" building-wide system has the potential to dramatically reduce energy consumption and improve both quality of life (residential) and worker productivity (commercial). However, such systems do not yet exist. ARPA-E will consider programs, building off the successes of the ADEPT program as well as in new areas, that reduce the energy consumption through the development of a building operating system, minimizing losses due to unnecessary power usages, the detection and correction of building "faults," a decrease in installation costs with integrated wireless modules, and reduction of electrical losses due to standby power consumption via power management, including the use of wireless technology.

Heating, ventilation, and air conditioning (HVAC) is the largest contributor to building energy use. ARPA-E has created a program, BEETIT, to improve air conditioning efficiency, which will lead to transformational improvements through reduction in air conditioner loads. ARPA-E is considering building on the success of the BEETIT program both through the expansion of promising technology areas, including thermoelastic cooling, membranes for dehumidification, and reverse osmosis refrigeration cycle, as well as consideration of approaches not currently represented.

ARPA-E will investigate integrated electrothermal energy systems integrated with electrothermal storage to match electrical and thermal energy supply and demand for building at the seasonal, weekly and daily basis. Through such a program ARPA-E expects to cut the primary energy consumption by more than 20% even if existing energy service technologies such as lighting, air-conditioning, etc. are used. Combined with the other programs on improvement of energy service technologies mentioned above, further significant reduction will be achieved in buildings.

End Use Efficiency is a new subprogram for FY 2012.

Embedded Efficiency **— 60,000**

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 about 28 percent, and industry about 32 percent. In the case of buildings and transportation, energy is used predominantly for the direct benefit of the people enjoying the services provided by that energy. Energy use in the industrial sector primarily goes into the creation of products and materials such as chemicals, cement, steel, aluminum, glass, etc, which are then used in consumer goods, buildings, and transportation. Energy consumption in the industrial sector, therefore, is embedded in the materials and goods that are produced and used in other parts of our economy. Reduction of energy consumption in the industrial sector is essential to ARPA-E's mission and will be achieved through "embedded efficiency" programs.

Another example of embedded efficiency is the use of water in agriculture, power generation, natural gas production, etc. Unchecked use of water in industrial processes can lead to shortages of potable water, which then necessitates consumption of significant energy to produce clean water. Hence, sustainable and low-energy pathways of reusing water and producing drinkable water are within the realm of ARPA-E's emphasis on embedded efficiency.

(dollars in thousands)

FY 2010 Current Approp	FY 2012 Request

In the first round of funding, ARPA-E funded one project on desalination of water through novel carbon nanotube based membranes that consume less energy than traditional reverse-osmosis membranes. As part of the FY 2012 budget, ARPA-E will consider developing programs in Embedded Efficiency that will fall within the industrial energy or water sectors.

ARPA-E's goal is to focus on the industrial sector with the aim to develop cost-competitive technologies and industrial processes to significantly reduce energy consumption and emissions. Some of the program's broad goals include:

- 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.

Potential areas of investment are identified below.

Over 97 percent of the earth's water is salty; for agriculture and other human needs, salt must be removed. In many areas of the United States fresh water is already a limiting resource, and this shortage will increase in coming years. Current desalination techniques are prohibitively energy intensive, which limits the deployment of large scale desalination plants. Revolutionary advances in desalination would expand those regions of the world amenable to human settlement, and vastly increase the fraction of the world's landmass capable of supporting agriculture. In coordination with ongoing DOE efforts, ARPA-E will investigate advanced technologies for both centralized and decentralized desalination applications.

The manufacturing of important building materials such as steel, cement, and glass is highly energy-intensive, in large part because the processes to manufacture these materials operate at high temperatures. Industry consumes one third of all energy used in the United States, and much of that energy is lost as waste heat in exhaust and waste streams. ARPA-E will develop programs designed to dramatically increase the fraction of waste heat captured from industrial manufacturing, massively increasing the energy efficiency of such plants, and look at alternative processes with a dramatically reduced need for thermal energy inputs.

Embedded Efficiency is a new subprogram for FY 2012.

Transportation Systems **— 115,000**

In 2008, the U.S. consumed 19.5 million barrels of petroleum per day, 57 percent of which was imported from foreign sources. The U.S. transportation sector represents nearly 70 percent of U.S. petroleum consumption and accounts for roughly 30 percent of U.S. CO2 emissions. Broadly speaking, reduction in fuel consumption and energy-related emissions can be achieved through advances in fuel/propulsion, vehicles, and driver behavior. To date, activities at ARPA-E in the transportation sector have focused largely on fuels. ARPA-E will continue to invest in the transportation sector, in both fuels

(dollars in thousands)

FY 2010 Current Approp	FY 2012 Request

and vehicles.

ARPA-E is focusing 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 addressing the other statutory goals mentioned above. Some broad goals follow:

- Development of those batteries and systems that would make electric vehicles have a range of 300-500 miles and be less expensive than cars based on 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.
- Novel uses of information technology to reduce fuel consumption, avoid traffic congestion, and optimize use of existing transportation resources.
- Novel 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.

Potential areas of investment are identified below.

Development of those batteries and systems that would allow electric vehicles to have a range of 300-500 miles, and be less expensive than cars based on internal combustion engines, would enable electric vehicles to be market-competitive. ARPA-E will expand its support of electric vehicle technologies, which will enable the United States to simultaneously reduce its dependence on petroleum. While remaining cognizant of other DOE activities in these areas in order to avoid duplication, future ARPA-E programs will support the design and development of advanced battery systems based on the high-capacity battery cells developed in the existing Batteries for Electrical Energy Storage in Transportation (BEEST) program. These battery systems may target high energy and power densities by combining batteries and ultracapacitors with lightweight structural packaging materials and appropriate thermal management. The goal is overcome "range anxiety" (>300 miles driving range) and simultaneously delivery sufficient power for acceleration. Low-cost, high-efficiency, user-friendly vehicle charging technology will also be developed, including "fast charging" systems that provide sufficient power for >80 miles of driving range in less than 15 minutes of charging time, without degrading battery life or adversely impacting the electric grid. While much current investment is focused on vehicle development, ARPA-E will also consider allied technologies required to ensure successful deployment of a mass-market product.

ARPA-E will continue and expand support for novel approaches to energy-dense, infrastructure-compatible fuels, which will simultaneously reduce the nation's dependence on foreign petroleum and reduce greenhouse gas emissions. Future programs will build on the ARPA-E Electrofuels Program, which considers non-photosynthetic approaches to convert renewable energy resources and carbon dioxide directly into fuel. Successful Electrofuels approaches will be improved to increase conversion

(dollars in thousands)

FY 2010 Current Approp	FY 2012 Request

efficiency and lower cost, subject to rigorous techno-economic analysis to ensure cost-effective deployment, and scale-up to de-risk commercial investment.

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, would directly reduce foreign imports of oil, and will be especially attractive for long-haul trucks and air transport where electrification is unlikely to make an impact. ARPA-E will develop unique approaches for the conversion of natural gas into energy-dense, infrastructure-compatible liquid fuels for transportation. This effort will leverage the nation's remarkable reserves of natural gas to displace imported petroleum in the transport sector without modification to the millions of vehicles currently in service. Although natural gas can be converted to diesel through Fischer–Tropsch processes, CAPEX demands largely preclude widespread commercial deployment. ARPA-E will support exploration of methanotroph-based conversion protocols that convert natural gas to gasoline and diesel cleanly, efficiently, and at a cost equal to or less than petroleum fuels.

ARPA-E will support development of novel information technology systems for the transportation sector, including wireless technology. ARPA-E will coordinate with the U.S. Department of Transportation's Intelligent Transportation Systems (ITS) program, administered by the Research and Innovative Technology Administration (RITA), to develop technologies which aim to decrease congestion and increase the efficiency of existing transport networks, leading to lower petroleum usage and costs, as well as emissions in the transportation sector. Future programs may include development of advanced systems that allow vehicles to communicate with both roadways and other vehicles, and new network monitoring and optimization tools that dynamically reroute traffic and alter traffic signals. While some technology development is occurring in all of these areas, the ARPA-E effort will aim to optimize large portions of the existing transportation network in ways that are distinct from ongoing efforts.

ARPA-E will investigate novel 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. ARPA-E will support the development of high-efficiency vehicle propulsion systems so efficient and inexpensive that they could replace the conventional internal combustion engine. The engines in our cars and trucks waste over half of the available energy in each gallon of gasoline they consume; more efficient technologies would reduce our dependence on foreign petroleum and lower emissions. Future programs will support the development of radically new volumetric fuel cells that generate electricity more efficiently than combustion processes. While today's fuel cell systems are too expensive for deployment and have a limited lifespan, ARPA-E will explore novel designs that lower cost and increase available power by expanding the reaction site.

Transportation Systems is a new subprogram for FY 2012.

Seedlings/Broad Funding Announcement	**—**	**17,329**

The focus of the Seedlings/Broad Funding Announcement line 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.

Seedlings/Broad Funding Announcement is a new subprogram for FY 2012.

SBIR/STTR	**—**	**14,614**

The FY 2012 amount shown is the estimated requirements for the continuation of the mandated SBIR and STTR programs.

Total, ARPA-E Projects	**—**	**521,943**

Explanation of Funding Changes

	FY 2012 vs. FY 2010 Current Approp ($000)
Stationary Power The increase is due to this being a new subprogram for FY 2012.	+130,000
Electrical Infrastructure The increase is due to this being a new subprogram for FY 2012.	+80,000
End Use Efficiency The increase is due to this being a new subprogram for FY 2012.	+105,000
Embedded Efficiency The increase is due to this being a new subprogram for FY 2012.	+60,000
Transportation Systems The increase is due to this being a new subprogram for FY 2012.	+115,000
Seedlings/Broad Funding Announcement The increase is due to this being a new subprogram for FY 2012.	+17,329
SBIR/STTR	+14,614

	FY 2012 vs. FY 2010 Current Approp ($000)
The increase is due to the increased amount of the request for new funds for ARPA-E Projects in FY 2012.	
Total Funding Change, ARPA-E Projects	**+521,943**

Program Direction

Funding Profile by Category

(dollars in thousands)

	FY 2010 Current Approp	FY 2012 Request
Headquarters		
Salaries and Benefits	—	8,493
Travel	—	1,500
Support Services	—	15,575
Other Related Expenses	—	2,500
Total, Headquarters	—	28,068
Full Time Equivalents	—	38
Total Program Direction		
Salaries and Benefits	—	8,493
Travel	—	1,500
Support Services	—	15,575
Other Related Expenses	—	2,500
Total, Program Direction	—	28,068
Total, Full Time Equivalents	—	38

Detailed Justification

(dollars in thousands)

	FY 2010 Current Approp	FY 2012 Request
Salaries and Benefits	**—**	**8,493**

ARPA-E federal staff will provide leadership and management for ARPA-E in both the administrative and program management functions. Administrative functions include the Director's office, contract management, general counsel, financial management, and human capital management. Program Directors will establish research and development goals, solicit applications for specific technology areas of particular promise, build research collaborations, select projects to be supported under the program, monitor the progress of those projects, and recommend program restructure or termination of research partnerships or whole projects. The Director will ensure, to the maximum extent practicable, that the activities of ARPA-E are coordinated with, and do not duplicate the efforts of, programs and laboratories within the Department, or other relevant research agencies.

Travel	**—**	**1,500**

The request funds travel by ARPA-E staff to carry out the activities supported under the program. The amount requested includes all costs of transportation of persons, subsistence of travelers, and incidental travel expenses in accordance with federal travel regulations which are directly chargeable to ARPA-E. ARPA-E Program Directors and staff travel to award recipient locations to conduct first-hand monitoring and evaluation of progress towards technical deliverables and milestones. This travel is essential to assessing the performer's research efforts and informing any decision to stop targeted programs on the basis of performance.

Support Services	**—**	**15,575**

The ARPA-E Support Services subprogram provides funds for non-federal contractor support functions, defined as advisory and assistance services acquired by contract from non-governmental services, necessary to carry out the activities supported under the program. Included under this element for FY 2012 are technical support, program management support, information technology and computer system operations support, and administrative and clerical support.

Other Related Expenses	**—**	**2,500**

The Other Related Expenses subprogram includes costs for building leases, and other related expenses (communications, utilities, computer and video support, training, printing and graphics, photocopying, postage, supplies, and common administrative services) not covered by the Working Capital Fund. The request funds training for ARPA-E Program Directors and staff. ARPA-E will have a relatively limited number of federal employees who will require training on policies and procedures for both DOE and the federal government, since many hired staff will be new to the federal government. Other Related Expenses provides ARPA-E's contribution to the Department's Working Capital Fund (WCF) for common administrative services at HQ, such as rent and building operations, telecommunications, network connectivity, supplies/equipment, printing/graphics, copying, mail, contract closeout, purchase card surveillance, and salary and benefit expenses for federal employees who administer the Working Capital Fund business lines per the Department's new policy being implemented in FY 2012. In addition, WCF services assessed to and used by HQ, OSTI, and the Field include online training, the Corporate Human Resource Information System, payroll processing, and the Project Management Career Development Program.

	(dollars in thousands)	
Total, Program Direction	**—**	**28,068**

Explanation of Funding Changes

	FY 2012 vs. FY 2010 Current Approp ($000)
Salaries and Benefits The increase is due to the fact that ARPA-E received no funding in FY 2010, and will accommodate the employment of an estimated 38 federal employees in FY 2012.	+8,493
Travel The increase is due to the fact that ARPA-E received no funding in FY 2010. ARPA-E performs significant oversight and diligence on its performers with multiple site visits per year by the program director, as well as performer community meetings which bring together performers from similar or complimentary technology areas for collaboration.	+1,500
Support Services The increase is due to the fact that ARPA-E received no funding in FY 2010.	+15,575
Other Related Expenses The increase is due to the fact that ARPA-E received no funding in FY 2010.	+2,500
Total Funding Change, Program Direction	**+$28,068**

Support Services by Category

(dollars in thousands)

	FY 2010 Current Approp	FY 2012 Request
Technical Support		
Management and Technical Services	—	7,825
Total, Technical Support	—	7,825
Management Support		
Administrative Services	—	7,750
Total, Management Support	—	7,750
Total, Support Services	—	15,575

Other Related Expenses by Category

(dollars in thousands)

	FY 2010 Current Approp	FY 2012 Request
Other Related Expenses		
Rent to Others	—	900
Communications, Utilities, Misc.	—	250
Printing and Reproduction	—	100
Other Services	—	50
Purchases from Gov. Accounts	—	25
Supplies and Materials	—	50
Equipment	—	125
Training	—	250
Working Capital Fund	—	750
Total, Other Related Expenses	—	2,500

Wireless Innovation Fund
Advanced Research Projects Agency - Energy

(dollars in thousands)

	FY 2010 Current Approp	FY 2012 Request
Wireless Innovation Fund	—	100,000
Total, Wireless Innovation Fund	—	100,000

Detailed Justification

(dollars in thousands)

	FY 2010 Current Approp	FY 2012 Request
Wireless Innovation Fund	**—**	**100,000**

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. Repurposing spectrum will greatly facilitate access for smart phones, portable computers, and innovative technologies that are on the horizon. This effort will also enhance Americas public safety, infrastructure, and competitiveness by investing some of the expected auction receipts in the creation of a broadband network for public safety, expanding access to wireless broadband in rural America, and a Wireless Innovation (WIN) Fund to help develop cutting edge wireless technologies. 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, as outlined in the detailed justification of the projects section, particularly in Electrical Infrastructure, End Use Efficiency, and Transportation Systems.

Explanation of Funding Changes

	FY 2012 vs. FY 2010 Current Approp ($000)
Wireless Innovation Fund	+100,000

The increase is due to this being a new one-time source of funding for ARPA-E, available in FY 2012.