



# **Advanced Research Projects Agency- Energy**

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The Department of Energy's Congressional Budget justification is available on the Office of Chief Financial Officer, Office of Budget homepage at <http://www.cfo.doe.gov/crorg/cf30.htm>.



## Advanced Research Projects Agency - Energy (ARPA-E)

### Proposed Appropriation Language

For necessary expenses in carrying out the activities authorized by section 5012 of the America COMPETES Act (Public Law 110-69), as amended, \$350,000,000, to remain available until expended: Provided, That \$25,000,000 shall be available until September 30, 2014 for program direction.

#### **Explanation of Change**

The Department request of \$350,000,000 FY 2013 for ARPA-E projects, a 27 percent increase over the enacted FY 2012 level, underscores the Administration's commitment to invest in innovation. The increase in funding will enable ARPA-E to fund more projects that could lead to transformational energy technologies.



## Advanced Research Projects Agency - Energy (ARPA-E)

### Overview

#### Appropriation Summary by Program

(Dollars in Thousands)

	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
Advanced Research Projects Agency – Energy (ARPA-E) Projects	165,640	255,000	325,000
Program Direction	14,000	20,000	25,000
<b>Total, Advanced Research Projects Agency – Energy (ARPA-E)</b>	<b>179,640</b>	<b>275,000</b>	<b>350,000</b>

### Office Overview and Accomplishments

ARPA-E’s mission is to support energy technology innovations that will enhance the economic and energy security of the United States through the development of transformational technologies that reduce America’s dependence on energy imports; reduce U.S. energy related emissions; improve energy efficiency across all sectors of the U.S. economy; and ensure the U.S. maintains a technological lead in the development and deployment of advanced energy technologies. ARPA-E focuses exclusively on high-impact innovations, translating science into breakthrough technologies that promise genuine transformation in the ways we generate, store, and utilize energy.

ARPA-E employs a thorough merit review process to select projects based on their potential impact on ARPA-E’s mission and their innovative technical approaches and project teams. ARPA-E funds technologies that are not being supported by other parts of DOE or the private sector because of technical and financial uncertainty. ARPA-E coordinates closely with other DOE programs, the rest of the federal government, academia, and the private sector to identify “white space” where others are not making investments in innovation but that would be appropriate for ARPA-E’s support.

If just a fraction of the breakthrough technologies funded by ARPA-E are successful in reaching the marketplace they could render the prevailing technologies obsolete. Such innovations can benefit the United States through the creation of new industries and jobs, reductions in energy costs and increases in energy efficiency, and accelerating progress towards achieving the Administration’s energy and climate goals. Through its work, ARPA-E contributes to the achievement of the Department’s strategic goal, “**Transform our Energy Systems**: Catalyze the timely, material, and efficient transformation of the nation’s energy system and secure U.S. leadership in clean energy technologies.”

Advanced Research Projects Agency – Energy  
Overview

The role of ARPA-E is to translate science into innovative breakthrough technologies that no one else is pursuing, i.e. technologies that are defined by new learning curves. (see Figure). By definition, these involve new, innovative, but potentially riskier approaches than traditional or current learning curves. But they also offer the prospects of transformational and disruptive technologies by dramatically reducing their costs-to-performance ratio. ARPA-E’s goal is to support these approaches and to showcase them to enable further development through either the private sector or the federal government. Some of these approaches will potentially fail, but the ones that succeed could transform the energy sector and make today’s approaches obsolete. It is difficult to know which ones will fail or succeed, but all failures will provide opportunities to learn and could become the basis for further innovation. Such a process would help the U.S. embark on a path of continuous innovation and scaling and enhance US technological leadership in a globally competitive world.

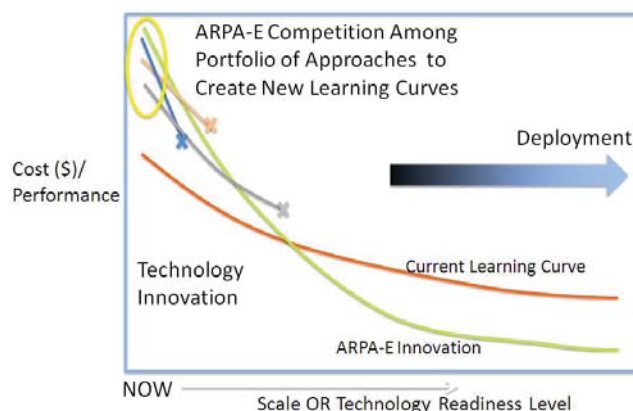


Figure 1: ARPA-E Innovations Create New Learning Curves

### **R&D Coordination across DOE**

ARPA-E actively coordinates with other DOE programs and Federal agencies and others in the technical community in order to ensure that its projects do not overlap with other programs at DOE or elsewhere, but instead complement them in multiple ways. ARPA-E engages these stakeholders when it conducts workshops, establishes technical metrics for potential funding solicitations and reviews applications.

ARPA-E works in close coordination with program offices on its “borders” – DOE’s basic science and applied research programs – to avoid duplicative research and ensure a balanced research portfolio across the DOE. ARPA-E utilizes the close coordination and collaboration to identify gaps in research portfolios (“white space”). This coordination serves to inform all parties of each other’s ongoing research activities and to facilitate the transition of successful ARPA-E projects to other DOE programs or elsewhere.

An important part of ARPA-E’s coordination within DOE is the program’s Panel of Senior Technical Advisors (PASTA). PASTA consists of Assistant Secretaries (or their designee) of relevant applied energy offices as well as the heads of all the relevant offices in the Office of Science. The purpose of PASTA is to coordinate and leverage each of its programs and also to ensure that ARPA-E provides unique value within the DOE. In addition, the Director of ARPA-E actively coordinates with the Director of the Office of Science as well as the Under Secretaries for Energy and Science.

### **Program Accomplishments and Milestones**

In FY 2011, ARPA-E achieved significant accomplishments or milestones in program management and program development. Such accomplishments include:

1) *Follow-on funding*: Less than two years after ARPA-E’s initial investment in 121 projects of \$365 million, eleven of those projects have garnered over \$200 million in follow-on funding (not including required cost share) to support the further development and deployment of the ARPA-E-funded technologies. Awardees have cited ARPA-E’s initial funding and active program management as critical factors in their overcoming key technical barriers ahead of schedule which helped spur follow-on funding. While ARPA-E projects have yet to show ultimate success as deployed technologies, a possibility that may be 10-15 years away, ARPA-E considers follow-on funding to be an early indicator of success and highlights how small but strategic investments by the federal government could pay big dividends in the not-too-distant future.

2) *Demonstrated success of active program management approach*: All of ARPA-E’s awards are cooperative agreements, enabling the program to practice active program management on all of its projects. Since ARPA-E has been funding projects for just over two years, only one project has completed its funding to date. That project successfully met its technical milestones and the cognizant Program Director held a project wrap up meeting to capture what was learned and to begin to establish best practices. ARPA-E also has not hesitated to cancel projects that are not meeting their goals. ARPA-E has ended six projects funded through the Recovery Act to date and, per the statutory requirement, has returned the remaining funding from those projects to the Treasury. It is important to understand that we will learn not only from projects that succeed but also from projects that “fail.” ARPA-E will continue to actively manage and monitor projects, and will continue to cancel projects that are not meeting their technical milestones and metrics.

3) *New projects*: ARPA-E issued its fourth round of Funding Opportunity Announcements (FOAs) and announced 60 cutting-edge research projects aimed at dramatically improving how the U.S. produces and uses energy. Funded at over \$150 million in total, the new ARPA-E projects focus on accelerating innovations in clean energy technology. This is accomplished by increasing America's competitiveness in rare earth alternatives and by supporting breakthroughs in biofuels, thermal storage, grid controls, and solar power electronics. The projects selected are located in 25 states, with 50% of projects led by universities, 23% by small businesses, 12% by large businesses, 13% by national labs, and 2% by non-profits.

In FY 2012 ARPA-E held, or plans to hold, up to seven workshops and events on technical topics that may lead to future FOAs. Also, in FY 2012 ARPA-E plans to issue FOAs in the following areas:

1. Hybrid Energy Storage Modules (HESM)
2. Natural gas conversion and/or compression/storage for transportation systems
3. SBIR/STTR
4. Open FOA

These FY 2012 activities are detailed in the ARPA-E Projects section that follows.

### **Alignment to Strategic Plan**

The Department’s May 2011 Strategic Plan outlines the primary objective to which ARPA-E aligns its activities: Discover the New Solutions We Need. The Strategic Plan identifies four targeted outcomes to achieving these objectives, and ARPA-E is responsible for supporting Strategic Plan outcomes through its budget request. The targeted outcomes are:

- Catalyze by FY 2012 the development of transformative and potentially disruptive energy technologies;
- Drive the transition of high-impact energy innovations toward market adoption;
- Contribute to the advancement of U.S. leadership and global competitiveness in energy innovation; and
- Build itself as an innovative, highly effective, and sustainable organization.

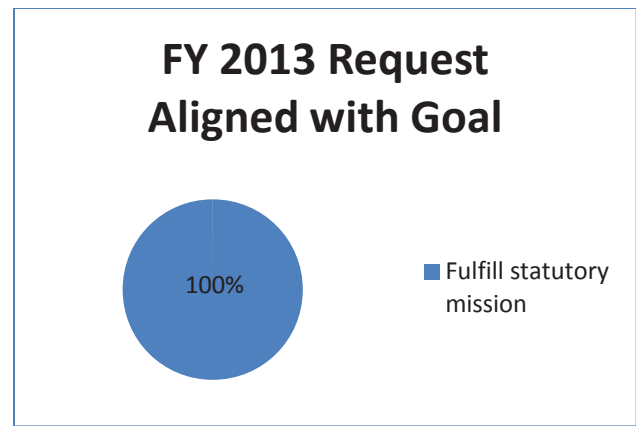
**Explanation of Changes**

The Department requests \$350,000,000 in FY 2013 for ARPA-E, which is a 27% increase over the current FY 2012 level. This increase underscores the Administration’s commitment to invest in innovation. The increase in funding will enable ARPA-E to fund more projects that could lead to game-changing, transformative technologies.

In FY 2013, ARPA-E is placing a particular priority on Transportation Systems, including advanced manufacturing for this sector and vehicles research and development. ARPA-E aims to create a diverse portfolio of technological options that would promote the efficient use of energy for transportation.

**Goal/Program Alignment Summary**

	GOAL 1: Fulfill statutory mission
ARPA-E Projects	100%
Program Direction	100%
Total, ARPA-E	100%





**Strategic Plan and Performance Measures**

<b>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.</b>		
<b>OBJECTIVE: DISCOVERING THE NEW SOLUTIONS WE NEED</b>		
<b>TARGETED OUTCOME: CONTRIBUTE TO THE ADVANCEMENT OF U.S. LEADERSHIP AND GLOBAL COMPETITIVENESS IN ENERGY INNOVATION</b>		
<b>FY11 ANNUAL MEASURE #1: CUMULATIVE PERCENTAGE OF FOLLOW ON FUNDING FROM OTHER FEDERAL (NOT ARPA-E) AND PRIVATE ORGANIZATIONS AFTER HAVING RECEIVED ARPA-E DIRECT FUNDING</b>		
	Target	Actual/ Met or Not Met
Budget Year	2013: 20%	N/A
Current Year	2012: 15%	N/A
Prior Year	2011: 10%	Actual: 54% / Met
Analysis	Provides an early indicator of success that ARPA-E has selected projects that show the potential to make progress towards achieving the agency's mission.	
<b>ANNUAL MEASURE #2: CUMULATIVE PERCENTAGE OF AWARD FUNDING COMMITTED 45 DAYS AFTER FUNDING OPPORTUNITY ANNOUNCEMENT (FOA) AWARD ANNOUNCEMENTS.</b>		
	Target	Actual/ Met or Not Met
Budget Year	2013: 70%	N/A
Current Year	2012: 70%	N/A
Prior Year	2011: 70%	Actual: 75% / Met
Analysis	Provides a measureable metric for the speed and efficiency of ARPA-E's procurement process.	

**Small Business Innovation Research/ Small Business Technology Transfer (SBIR/STTR)**

(Dollars in Thousands)

	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
ARPA-E SBIR/STTR	5,030	8,113	10,675
Total, ARPA-E SBIR/STTR	5,030	8,113	10,675

ARPA-E will establish an innovative SBIR/STTR program that is separate from the DOE-wide SBIR/STTR program. The ARPA-E SBIR/STTR program will employ the review, contracting, funding, and organizational reforms implemented successfully by ARPA-E. For example, ARPA-E will use its user-friendly online application portal, ARPA-E eXCHANGE, to receive and evaluate proposals. ARPA-E will reduce the average contracting period (from selection to award) to two months. Additionally, ARPA-E has undertaken a comprehensive survey of other Federal agencies' SBIR/STTR programs and has identified a number of best practices and innovations that may be used for its SBIR/STTR program.

**Advanced Research Projects Agency - Energy (ARPA-E)  
Funding by Site by Program**

(Dollars in Thousands)

	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
Washington Headquarters			
Advanced Research Projects Agency – Energy (ARPA-E)	179,640	275,000	350,000
Total, Washington Headquarters	179,640	275,000	350,000
Total, Advanced Research Projects Agency – Energy (ARPA-E)	179,640	275,000	350,000



**ARPA-E Projects  
Funding Profile by Subprogram and Activities**

(Dollars in Thousands)

	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
ARPA-E Projects			
Projects	160,610	246,887	314,325
SBIR/STTR	5,030	8,113	10,675
Total, ARPA-E Projects	165,640	255,000	325,000

**Comparable Funding Profile by Subprogram and Activities**

(Dollars in Thousands)

	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
ARPA-E Projects			
Transportation Systems <sup>1</sup>	60,610	142,887	184,325
Stationary Power Systems <sup>1</sup>	100,000	104,000	130,000
SBIR/STTR	5,030	8,113	10,675
Total, ARPA-E Projects	165,640	255,000	325,000

<sup>1</sup> Because the Transportation Systems and Stationary Power Systems thrusts are new for the FY 2013 Congressional Budget, a comparable funding profile is provided to show estimates for how the FY 2011 and FY 2012 funds are split between the Transportation Systems or Stationary Power Systems thrusts. The FY 2012 Enacted figure includes estimate as to how funding from the planned Open FOA will be distributed across the thrusts.

**Public Law Authorizations**

Public Law 95-91, "Department of Energy Organization Act" (1977)

Public Law 109-58, "Energy Policy Act of 2005"

Public Law 110-69, "America COMPETES Act of 2007"

Public Law 111-358, "America COMPETES Reauthorization Act of 2010"

**Overview**

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

ARPA-E programs generally fall into two categories:

- New Areas of Science and Technology—for example, the goal of ARPA-E's current Electrofuels program is to produce biofuels in a

new way from non-photosynthetic autotrophic bacteria. This first-of-kind program is emblematic of ARPA-E 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's applied energy activities 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. Reflecting this internal strategic thinking on the focus of future projects, ARPA-E has moved to incorporate a project management model hierarchy of thrust-portfolio-program-project. ARPA-E will have two primary thrusts: Transportation Systems and Stationary Power Systems. The two broad

thematic strategic thrusts and their attendant portfolios and programs are explored more deeply in the Transportation Systems and Stationary Power Systems sections that follow.

### **Program Accomplishments and Milestones**

In FY 2011, ARPA-E issued Funding Opportunity Announcements (FOAs) totaling \$130 million to develop five new program areas that could spark critical breakthrough technologies and secure America's energy future.

- **Plants Engineered To Replace Oil (PETRO):** Technologies that optimize the biochemical processes of energy capture and conversion to develop robust, farm-ready crops that deliver more energy per acre with less processing prior to the pump. If successful, PETRO will create biofuels for half their current cost potentially making them cost-competitive with oil-based fuels.
- **High Energy Advanced Thermal Storage (HEATS):** 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 base load resources the flexibility to meet peak demand, 2) fuel produced from the sun's heat, and 3) HVAC systems that use thermal storage to improve the driving range of electric vehicles by up to 40 percent.
- **Rare Earth Alternatives in Critical Technologies (REACT):** 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):** Innovative grid control software and high-voltage hardware, specifically: 1) controls able to manage 10 times more sporadically available wind and solar electricity than currently on the grid, and 2) resilient power flow control hardware - or the energy equivalent of an internet router - to enable significantly more electricity through the existing network of transmission lines.
- **Solar Agile Delivery of Electrical Power Technology (Solar ADEPT):** The DOE SunShot Initiative leverages strengths across DOE to reduce the total cost of utility-scale solar systems by 75 percent by the end of the decade. If successful, this collaboration would deliver

solar electricity at roughly 6 cents a kilowatt hour. ARPA-E's portion of the collaboration is the Solar ADEPT program, which focuses on integrating advanced power electronics into solar panels and solar farms to extract and deliver energy more efficiently.

In FY 2012 ARPA-E held, or plans to hold, workshops and events on the following technical topics:

1. Tool Development for Transformational Biotechnology Advances Workshop (October 2011)
2. Soft Magnetic Materials Review (December 2011)
3. Natural Gas Conversion Technologies Workshop (January 2012)
4. Natural Gas Vehicle Technologies Workshop (January 2012)
5. Large-Scale Behavioral Analytics in Personal Transportation & Motor Fuel Purchases Workshop (February 2012)
6. Advanced Inductance Motors Seminar (March 2012)
7. Power Grid Gaming Workshop (not yet scheduled)

In FY 2012 ARPA-E plans to issue the following FOAs:

1. Hybrid Energy Storage Modules (HESM) that couple and optimize attributes of different energy storage technologies with real-time sensory, analysis, and control techniques to increase efficiency, capacity utilization, reliability, and lifetime across transportation and stationary applications. This FOA was developed jointly with the Department of Defense.
2. Natural gas to explore unique approaches for the conversion of natural gas into energy-dense, infrastructure-compatible liquid fuels for transportation, and/or novel and low-cost natural gas compression and storage technologies enabling widespread adoption of natural gas fueled vehicles.
3. SBIR/STTR
4. Open FOA in March 2012. This will be ARPA-E's second Open FOA and, similar to ARPA-E's initial FOA from April 2009, the FY 2012 Open FOA will be open to any transformational energy technology.

### **Milestone**

Make decisions on program goals,

### **Date**

December

activities and funding based on annual review, contingent upon appropriations.	2011
Hire new Program Directors who will be able to lead FOAs focused on transportation.	January 2012
Continue active program management of existing transportation projects.	Ongoing

**Explanation of Changes**

The Department requests \$325 million in FY 2013 for ARPA-E projects, which is a 27 percent increase over the enacted FY 2012 level. This increase underscores the Administration’s commitment to invest in innovation. The increase in funding will enable ARPA-E to fund more projects that could lead to game-changing, transformative technologies.

In FY 2013, ARPA-E is placing a particular priority on Transportation Systems, including advanced manufacturing and vehicles research and development. ARPA-E aims to create a diverse portfolio of technological options that would reduce our dependence on foreign energy imports, and instead promote the efficient use of domestic sources of energy for transportation. This focus may include another round of funding in the Electrofuels program, taking a new look at transformational biofuels approaches, and investing in innovative approaches to natural gas conversion and/or compression/storage for transportation systems. ARPA-E plans to also further explore game-changing battery technologies for plug-in hybrid electric vehicles (PHEVs) and electric vehicles (EVs).

**Program Planning and Management**

ARPA-E exists to aid the development and accelerate the deployment of transformational and disruptive energy technologies—technologies that hold the potential to radically shift the nation’s energy sector. ARPA-E selects potential investment areas by considering the science and technology landscape, the market landscape, and the regulatory landscape. ARPA-E will invest in technology development only in instances where circumstances in each of these areas are aligned to enable transformative, breakthrough discoveries that have the potential to then be brought to market scale. ARPA-E programs are created through a detailed process that begins with a thorough vetting of a particular technology concept. Figure 2 shows the full life cycle of an ARPA-E program (Envision, Engage, Evaluate, Establish, and Execute) from program conception through transition toward market adoption (See Figure).

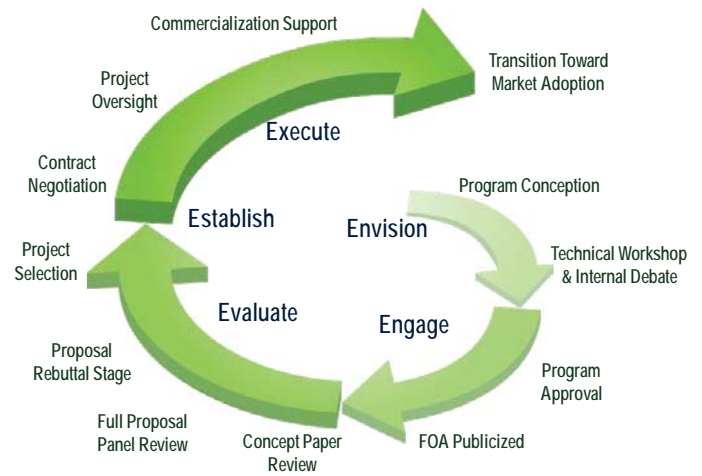


Figure 2: ARPA-E Technology Acceleration Approach

Technical flexibility and empowerment of Program Directors are key aspects 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 ARPA-E should start a program in an area of interest.

By bringing together experts from across disciplines in science, technology, and business, ARPA-E breaks down silos between disciplines. This cross-disciplinary inquiry bridges the gap between basic and applied research and development. ARPA-E workshops bring together the leading experts to identify technical challenges and opportunities that connect science to technology and markets—linking knowledge of what science is capable of to what technology can achieve and what the market needs.

ARPA-E is vigilant in its researching, investigating, and coordinating to ensure the agency does not fund any discrete technical idea that is being explored by the private sector or by a different program within DOE. ARPA-E Program Directors will coordinate with other DOE offices and federal agencies, as well as groups outside of government, to identify untapped opportunities.

Before issuing a Funding Opportunity Announcement (FOA) in any particular technology area, ARPA-E studies that area in depth. ARPA-E consults closely with other DOE offices and programs to avoid any duplication or redundancy. ARPA-E engages members of other DOE offices in ARPA-E workshops, defining the FOAs, and the proposal review process. Not every workshop necessarily leads to a program/FOA, but every program/FOA follows from a workshop.

ARPA-E undertook an extensive planning process to create the programs in both its thrusts. The detailed program creation process began with a “deep dive” – a process of thoroughly exploring the aspects of the energy challenges related to transportation – to identify potential topics for program development. From there, ARPA-E Program Directors held technical workshops to gather input from the world’s leading experts about current state-of-the-art technologies and new technological opportunities that lie on the horizon.

ARPA-E has hosted or co-hosted the following five workshops related to transportation:

- Electrical Energy Storage for Vehicles
- Novel Approaches to Direct Solar Fuels Workshop
- Applied Biotechnology for Transportation Fuels: Meeting Today’s Energy Needs by Maximizing Photon Capture
- ARPA-E Critical Materials Technology Workshop
- Tool Development for Transformational Biotechnology Advances

For the Stationary Power Systems thrust, ARPA-E has hosted or co-hosted twelve workshops:

- Grid Scale Energy Storage
- Novel Approaches to Direct Solar Fuels
- Carbon Capture and Conversion
- Advanced Building Energy Technologies
- Energy from Wastewater
- Power Technologies
- \$1/W
- Critical Materials Technology
- Small-Scale Distributed Generation
- Hybrid Energy Storage Module
- Power Electronics in Photovoltaic Systems
- Green Electricity Network Integration

From these workshops, ARPA-E announced its fourth round of funding in April 2011, focused on breakthroughs in rare earth mineral alternatives, in biofuels, thermal storage, grid controls, and solar power electronics.

Advanced Research Projects Agency – Energy  
Funding Profile by Subprogram and Activities

ARPA-E will continue to build on the already strong cooperative relationship with the U.S. Department of Defense to continue to develop advanced clean energy technologies. Advances in innovation are helping to solve our military challenges, protect our troops, and enhance our national security.

### **Strategic Management**

In meeting identified challenges to Transportation Systems, ARPA-E will implement two key strategies to more efficiently and effectively manage the Transportation Systems thrust.

1. ARPA-E will pursue the most promising pathways to increased adoption of alternative liquid fuels production, vehicle electrification, and other technologies with market-oriented performance metrics designed to spur further follow-on funding.
2. ARPA-E’s R&D programs will partner with the private sector, national laboratories, other Federal agencies, and universities to develop advanced technologies.

Three external factors present the strongest impacts to the overall achievement of the Transportation Systems thrust strategic goal:

1. Transportation fleets are relatively long-lived assets (with a current average passenger car expected to be on the road for 11 years) and slow adoption rates for new technologies both mean that the energy and efficiency savings can take a long period of time to accrue.
2. Drop-in replacement technologies can offer more immediate impact but research must be mindful of their cost and the time required for testing and certification.
3. Current transportation patterns and associated land-use patterns are historically slow to change.

In meeting the identified challenges to Stationary Power Systems, ARPA-E will implement two key strategies to more efficiently and effectively manage the Stationary Power Systems thrust.

1. ARPA-E will engage the power generation community to help identify and promote the development of transformational, cost-competitive technologies
2. ARPA-E’s R&D programs will partner with other DOE Offices and programs, the private sector, national laboratories, other Federal agencies

and universities to develop advanced R&D technologies

Three external factors present the strongest obstacles to the overall achievement of the Stationary Power Systems thrust strategic goal:

1. Components of the stationary power system must operate with extremely high and proven reliability, which can slow the adoption of new technologies.
2. The stationary power system is a highly complex, regulated, and inter-connected operation with many stakeholder requirements to be satisfied prior to technology adoption.
3. Adoption of improved efficiency technologies is dependent of economic and environmental factors beyond the scope of DOE R&D programs.

### **Major Priorities and Assumptions**

ARPA-E's mission is to aid the development of transformational and disruptive energy technologies – technologies that hold the potential to radically shift the nation's energy reality.

Transportation Systems thrust: Specific goals in the outyears include making substantial progress in the areas of:

- Batteries and systems for electric vehicles
- Sustainable and market-competitive transportation fuels from domestic resources
- Information technology related to transportation
- Cost-effective power generation/propulsion systems
- Natural gas conversion and/or compression/storage for transportation systems

Stationary Power Systems thrust: In order to achieve the President's challenge of generating 80% of America's electricity from clean energy sources by 2035, specific goals in the outyears include making substantial progress in the areas of:

- Stationary Power
- Electrical Infrastructure
- End Use Efficiency
- Embedded Efficiency

### **Program Goals and Funding**

ARPA-E has established a goal for its program management, to fulfill its statutory mission of transformational energy research. The goal of ARPA-E shall be:

- (A) to enhance the economic and energy security of the United States through the development of energy technologies that result in—
  - (i) reductions of imports of energy from foreign sources;
  - (ii) reductions of energy-related emissions, including greenhouse gases; and
  - (iii) improvement in the energy efficiency of all economic sectors; and
- (B) to ensure that the United States maintains a technological lead in developing and deploying advanced energy technologies.



**Goal Areas by Subprogram**

ARPA-E Projects  
     Transportation Systems  
     Stationary Power Systems  
 Subtotal, ARPA-E Projects

<u>Goal Area: Fulfill Statutory Mission</u>	
	100%
	100%
	100%

**Explanation of Funding AND/OR Program Changes**

(Dollars in Thousands)

FY 2012 Enacted	FY 2013 Request	FY 2013 Request vs FY 2012 Enacted
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ARPA-E Projects. The FY 2013 request for ARPA-E projects is a 27 percent increase over the enacted FY 2012 level. This increase underscores the Administration’s commitment to invest in innovation. The increase in funding will enable ARPA-E to fund more projects that could lead to game-changing, transformative technologies.

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

In FY 2013, ARPA-E is placing a particular priority on Transportation Systems, including advanced manufacturing and vehicles research and development.

Total, ARPA-E Projects

255,000	325,000	+70,000
<u>255,000</u>	<u>325,000</u>	<u>+70,000</u>

**Transportation Systems  
Comparable Funding Profile by Activity**

(Dollars in Thousands)

	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
Transportation Systems	60,610	142,887	184,325
Total, Transportation Systems	60,610	142,887	184,325

**Overview**

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

In 2010, the U.S. consumed 19.2 million barrels of petroleum per day, about 50 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 28 percent of U.S. CO<sub>2</sub> emissions. 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 and vehicles.

Some broad goals and benefits of the Transportation Systems thrust include development and batteries and energy storage systems, development of competitively-priced transportation fuels, novel uses of information technology to improve energy efficiency, and unexplored uses of natural gas.

ARPA-E's efforts in the transportation system area seek to diversify fuel choices in the transportation sector away from a nearly exclusive reliance on oil, improve vehicle efficiency, develop and improve alternative transportation technologies.

**Explanation of Funding Changes (Comparable)**

(Dollars in Thousands)

	FY 2012 Enacted	FY 2013 Request	FY 2013 Request vs FY 2012 Enacted
Transportation Systems. Though exact allocations between thrusts will depend on the applications received, ARPA-E anticipates the funding level for the Transportation Systems thrust to be as shown. The increase reflects the priority ARPA-E is placing on Transportation Systems, including advanced manufacturing and vehicles research and development.	142,887	184,325	+41,438
Total, Transportation Systems	142,887	184,325	+41,438

**Funding and Activity Schedule**

In FY 2013 ARPA-E is placing an increased priority and focus on Transportation Systems, including advanced manufacturing for this sector and vehicles research and development. ARPA-E will continue to invest in the transportation sector, in both alternative domestic sources of sustainable fuels and electrification of vehicles. ARPA-E believes there are critical "white spaces" within the field of transportation systems where

neither the private sector nor other areas within the Department are exploring, largely due to the increased-risk early-stage nature of the research and the relative financial uncertainty.

ARPA-E's model seeks to find new and timely opportunities, often soon after they emerge. While the goals of specific FOAs will be informed by technical

stakeholder input closer to the announcement of the Funding Opportunities, ARPA-E is planning on investing in the following areas related to transportation systems. ARPA-E plans to renew its investment in Electrofuels, which will select for successful technologies capable of advancing to mid-stage technology readiness pilot scale. ARPA-E will continue to expand support for novel approaches. Future programs would build on the ARPA-E Electrofuels Program, which considers non-photosynthetic autotrophic biological approaches to convert energy resources and carbon dioxide directly into fuel. Successful Electrofuels approaches will be improved to increase energy conversion efficiency and lower cost, subject to rigorous techno-economic analysis to ensure cost-effective deployment, and scale-up to de-risk commercial investment.

Similarly, ARPA-E aims to invest in new approaches to biofuels. ARPA-E will explore what has limited the use of biological system in augmenting energy supplies and how those limitations can be overcome to leverage biology for transformational improvements in energy conversion. This may include developing different approaches to renewable methane, which aims to turn whole biomass into methane; new technologies to lower the cost and improve performance of bioreactors; and, biomanufacturing.

ARPA-E plans to expand its support of electric vehicle technologies. Development of those batteries and systems would allow electric vehicles to have a range of 300-500 miles, and be less expensive than cars based on internal combustion engines. 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 would be to overcome "range anxiety" (>300 miles driving range) and simultaneously deliver sufficient power for acceleration. Low-cost, high-efficiency, user-friendly vehicle charging technology would also be targeted, including "fast charging" systems that transfer an order of magnitude more energy into electric vehicles over short durations (5-15 minutes) than current state of the art systems 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. In this program, ARPA-E will support game-changing technologies that range from devices to double the minimum range of today's electric cars, to high risk batteries (e.g. lithium-air, lithium-sulfur,

and magnesium ion) that could allow a car to travel up to 500-miles on a single charge.

ARPA-E is interested in investing in the development of sustainable and market-competitive transportation fuels using domestic resources such as natural gas or a combination of carbon dioxide and hydrogen. ARPA-E will explore unique approaches for the conversion of natural gas into energy-dense, infrastructure-compatible liquid fuels for transportation. ARPA-E is interested in supporting the exploration of methane conversion protocols, including biological routes through methanotrophic systems, to convert natural gas to gasoline and diesel cleanly and efficiently.

Rare earths are naturally-occurring minerals with unique magnetic properties that are used in many emerging energy technologies. ARPA-E seeks to fund early-stage technology alternatives that reduce or eliminate the dependence on rare earth materials by developing substitutes for electric vehicle motors. This aims to continue and further develop the work being funded under ARPA-E's Rare Earth Alternatives in Critical Technologies (REACT) program.

ARPA-E seeks to fund technology alternatives for several candidate biofuel crops, and this aims to continue and further develop the work being funded under ARPA-E's Plants Engineered To Replace Oil (PETRO) program.

Fiscal Year	Activity	Funding (Dollars in Thousands)
FY 2011	<p>In FY 2011, ARPA-E invested in innovations in:</p> <ul style="list-style-type: none"> <li>• Technologies that optimize the biochemical processes of energy capture and conversion to develop robust, farm-ready crops that deliver more energy per acre with less processing prior to the pump.</li> <li>• Cost-effective thermal energy storage technologies for HVAC systems that use thermal storage to dramatically improve the driving range of electric vehicles.</li> <li>• Early-stage technology alternatives that reduce or eliminate the dependence on rare earth materials by developing substitutes for electric vehicle motors.</li> </ul>	60,610
FY 2012	<p>In FY 2012, ARPA-E is planning on investing in innovations in:</p> <ul style="list-style-type: none"> <li>• Unique approaches for the conversion of natural gas into energy-dense, infrastructure-compatible liquid fuels for transportation.</li> <li>• Novel and low-cost natural gas compression and storage technologies enabling widespread adoption of natural gas fueled vehicles.</li> <li>• A Broad Funding Opportunity Announcement open to all energy ideas and technologies and focused on applicants who already had well-formed research and development plans for potentially high-impact concepts or new technologies.</li> </ul>	142,887 (Estimated pending award selection)
FY 2013	<p>In FY 2013, ARPA-E is planning to invest in innovations in:</p> <ul style="list-style-type: none"> <li>• Technologies that overcome limitations in traditional biological systems to dramatically increase biofuel production for transportation.</li> <li>• Batteries and systems for electric vehicles that aim to have a range of 300-500 miles while costing less than cars based on internal combustion engines.</li> <li>• Early-stage technology alternatives that reduce or eliminate the dependence on rare earth materials by developing substitutes for electric vehicle motors.</li> <li>• Novel cost-effective power generation or propulsion systems that have significantly higher efficiency than today's internal combustion engines. This will maximize the use of transportation fuels.</li> <li>• 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.</li> </ul>	184,325



**Stationary Power Systems  
Comparable Funding Profile by Subprogram and Activity**

(Dollars in Thousands)

	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
Stationary Power Systems	100,000	104,000	130,000
Total, Stationary Power Systems	100,000	104,000	130,000

Stationary Power Systems  
Total, Stationary Power Systems

**Overview**

The ARPA-E Stationary Power Systems thrust supports high-impact technologies that are not related to transportation. Some of these fields include: power electronics, solar, wind, osmotic power, smart grid technologies, natural gas, geothermal, and waste heat capture. To accomplish its mission and address the scientific challenges outlined below, ARPA-E's Stationary Power Systems is organized into four portfolios: Stationary Power, Electrical Infrastructure, End Use Efficiency, and Embedded Efficiency.

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

In its Stationary Power Systems thrust ARPA-E is focusing on creating a diverse array of technological options that

would reduce energy demand and green house gas emissions, create low-cost power generation from traditional and renewable sources, provide greater reliability and security in the delivery of electricity and provide a secure energy foundation for the future.

Some broad goals and benefits of the Stationary Power Systems thrust 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; low-cost electrical storage; 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; and energy efficiency.

ARPA-E's efforts in the stationary power systems thrust seek to develop clean and efficient power generation through new sources and new production and delivery hardware, increase energy efficiency, and reduce the energy used in manufacturing goods.

**Explanation of Funding Changes (Comparable)**

(Dollars in Thousands)

FY 2012 Enacted	FY 2013 Request	FY 2013 Request vs FY 2012 Enacted
104,000	130,000	+26,000
104,000	130,000	+26,000

Stationary Power Systems. Though exact allocations between thrusts will depend on the applications received, ARPA-E anticipates the funding level for the Stationary Power Systems thrust to be as shown.

Total, Stationary Power Systems

104,000	130,000	+26,000
104,000	130,000	+26,000

### **Funding and Activity Schedule**

The broad field of Stationary Power Systems offers many ripe opportunities for critical research and development. ARPA-E believes there are critical “white spaces” within the field where neither the private sector nor other areas within the DOE are exploring, largely due to the increased-risk early-stage nature of the research and the inherent financial uncertainty.

ARPA-E is planning on investing in the following key areas of Stationary Power Systems:

Conventional power generation facilities – both nuclear and fossil-fuel fired – present extraordinarily harsh conditions under which construction materials must survive and perform. 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.

The salt concentration gradient where freshwater rivers reach saltwater oceans can be harnessed to create electricity. ARPA-E will consider programs in advanced membranes and osmotic power generation strategies to simultaneously produce electricity and improve desalination efficiency.

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. 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.

Natural gas (methane) currently provides 29% of U.S. energy, and is a clean, lower carbon, energy source. While natural gas combined cycle (NGCC) plants have demonstrated efficiencies of 60% that are superior to coal-fired power plants, ARPA-E will explore programs that convert natural gas into electricity with even higher efficiency than a NGCC plant.

Advanced Research Projects Agency – Energy  
Funding Profile by Subprogram and Activity  
Stationary Power Systems

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. 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.

Critical materials are important to many technologies in the energy sector. ARPA-E aims to identify transformational, early-stage applied research and development approaches to address the technical challenges associated with reducing or eliminating the use of critical materials. Specifically, ARPA-E is interested in exploring potentially disruptive wind generators.

Fiscal Year	Activity	Funding (Dollars in Thousands)
FY 2011	<p>In FY 2011, ARPA-E invested in innovations in:</p> <p>Integrating advanced power electronics into solar panels and solar farms to extract and deliver energy more efficiently. Specifically, ARPA-E aims to invest in key advances in magnetics, semiconductor switches, and charge storage, which could reduce power conversion costs by up to 50 percent for utilities and 80 percent for homeowners</p> <p>Novel control software and high-voltage hardware to reliably control the grid network, specifically: 1) cost-optimizing controls able to manage sporadically available sources, such as wind and solar, alongside coal and nuclear, and 2) resilient power flow control hardware – or the energy equivalent of an internet router – to enable automated, real-time control of grid components.</p> <p>Early-stage technology alternatives that reduce or eliminate the dependence on rare earth materials by developing substitutes for wind generators.</p> <p>Revolutionary cost-effective thermal energy storage technologies in two 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 and 2) fuel produced from the sun’s heat.</p>	100,000
FY 2012	<p>In FY 2012, ARPA-E is planning on investing in innovative technologies to address the following challenges:</p> <p>Hybrid Energy Storage Modules (HESM) that couple and optimize attributes of different energy storage technologies with real-time sensory, analysis, and control techniques to increase efficiency, capacity utilization, reliability, and lifetime across transportation and stationary applications. This FOA was developed jointly with the Department of Defense.</p> <p>A Broad Funding Opportunity Announcement open to all energy ideas and technologies and focused on applicants who already had well-formed research and development plans for potentially high-impact concepts or new technologies.</p>	104,000 (Exact amount unknown until projects are selected)
FY 2013	<p>In FY 2013, ARPA-E is planning to invest in innovative technologies to address the following challenges:</p> <p>Develop clean and efficient power generation technologies that are cost-competitive with today’s resources.</p> <p>Develop robust and efficient hardware/software for the future of power transmission, distribution, and end-use.</p> <p>Increase end-use energy efficiency in residential and commercial sectors.</p> <p>Create higher-performing and less energy intensive manufactured goods and services</p> <p>Engage the energy community to develop the next generation of energy technology leadership.</p>	130,000





**Program Direction  
Funding Profile by Category**

(Dollars in Thousands)

	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
Headquarters			
Salary & Benefits	3,600	6,650	7,875
Travel	800	900	1,500
Support Services	9,200	10,650	13,200
Other Related Expenses	400	1,800	2,425
Total, Headquarters	14,000	20,000	25,000
Full Time Equivalents	22	38	40

**Overview**

Program Direction provides the Federal staffing resources and associated costs required to provide overall direction and execution of the ARPA-E mission. This budget provides for salaries and benefits of federal staff, federal staff and contractor travel; and support services contracts that provide technical advisory and

assistance services. This budget further provides funding for other related expenses, including leased office space and for the DOE Working Capital Fund.

**Explanation of Funding AND/OR Program Changes**

(Dollars in Thousands)

FY 2012 Enacted	FY 2013 Request	FY 2013 Request vs FY 2012 Enacted
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**Salaries and Benefits**

Increase associated with the growth of federal staff reflects ARPA-E's commitment to the President's initiative to optimize the workforce and reclaim federal responsibilities. Increased federal staff includes additional Program Directors and other technical and professional staff.

6,650                      7,875                      +1,225

**Travel**

ARPA-E performs significant oversight and diligence on its performers with multiple site visits per year by the Program Director, and this increase reflects more travel to an increased number of 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. Travel also includes performer community meetings which bring together performers from similar or complimentary technology areas for collaboration.

900                              1,500                              +600

**Support Services**

ARPA-E expects to initiate support to approximately 100 new projects in FY 2013, a nearly 50 percent increase over the number of projects through FY 2012, but the support services funding level will only increase 33 percent. This reflects ARPA-E's commitment to the President's initiative to optimize the workforce and reclaim federal responsibilities.

10,650                      13,200                      +2,550

(Dollars in Thousands)

FY 2012 Enacted	FY 2013 Request	FY 2013 Request vs FY 2012 Enacted
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**Other Related Expenses**

The increase reflects primarily an increase in the amount of leased space, as well as increased costs commensurate with increased federal staff. DOE is working to achieve economies of scale through an enhanced WCF. The WCF increase covers certain shared, enterprise activities including enhanced cyber security architecture, employee health and testing services, and consolidated training and recruitment initiatives.

	1,800	2,425	+625
Total Funding Change, Program Direction	20,000	25,000	+5,000

**Support Services by Category**

(Dollars in Thousands)

FY 2012 Enacted	FY 2013 Request	FY 2013 Request vs FY 2012 Enacted
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## Support Services

Management and Technical Services

Administrative Services

Total, Support Services

6,200	7,650	+1,450
4,450	5,550	+1,100
10,650	13,200	+2,550

**Other Related Expenses by Category**

(Dollars in Thousands)

FY 2012 Enacted	FY 2013 Request	FY 2013 Request vs FY 2012 Enacted
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## Other Related Expenses

Other Services

DOE/COE

Working Capital Fund

Total, Other Related Expenses

50	100	+50
300	400	+100
1,450	1,925	+475
1,800	2,425	+625

**Scientific Employment**

	FY 2011 Actual	FY 2012 Estimate	FY 2013 Estimate
# of University Grants	30	35	40
Average Size per year (\$000)	2,110	2,500	2,850
# Permanent PhD's (FTEs)	11	15	19
# Postdoctoral Associates (FTEs)	5	7	9
# Graduate Students (FTEs)	0	0	0