U.S. DEPARTMENT OF
ENERGY

Advanced Research Projects Agency–Energy Annual Report for FY 2015

Report to Congress
October 2016

United States Department of Energy
Washington, DC 20585

Message from the Director

The Advanced Research Projects Agency-Energy (ARPA-E) invests in technologies that could fundamentally change the way we use, generate, and store energy. ARPA-E's mission is to advance energy innovations that will create a more secure, affordable, and sustainable American energy future.

By exploring uncharted territories of energy technology, ARPA-E creates options for entirely new paths that accelerate the pace of innovation. These new developments help our country:

- Reduce its dependence on energy imports;
- Reduce energy related emissions;
- Improve energy efficiency across all sectors of the economy; and
- Ensure it maintains a technological lead in developing and deploying advanced energy technologies.

ARPA-E's rigorous program design, competitive project selection process, and hands-on engagement ensure thoughtful expenditures while empowering America's energy researchers with funding, technical assistance, and market awareness.

Pursuant to statutory requirements, this report is being provided to the following Members of Congress:

- **The Honorable Fred Upton**
  Chairman, House Committee on Energy and Commerce
- **The Honorable Frank Pallone, Jr.**
  Ranking Member, House Committee on Energy and Commerce
- **The Honorable Lamar Smith**
  Chairman, House Committee on Science, Space and Technology
- **The Honorable Eddie Bernice Johnson**
  Ranking Member, House Committee on Science, Space and Technology
- **The Honorable Randy Weber**
  Chairman, House Subcommittee on Energy
  Committee on Science, Space and Technology
- **The Honorable Alan Grayson**
  Ranking Member, House Subcommittee on Energy
  Committee on Science, Space and Technology
- **The Honorable Hal Rogers**
  Chairman, House Committee on Appropriations
- **The Honorable Nita Lowey**
  Ranking Member, House Committee on Appropriations

- **The Honorable Mike Simpson**
  Chairman, House Subcommittee on Energy and Water Development
  Committee on Appropriations

- **The Honorable Marcy Kaptur**
  Ranking Member, House Subcommittee on Energy and Water Development
  Committee on Appropriations

- **The Honorable Lisa Murkowski**
  Chairwoman, Senate Committee on Energy and Natural Resources

- **The Honorable Maria Cantwell**
  Ranking Member, Senate Committee on Energy and Natural Resources

- **The Honorable James E. Risch**
  Chairman, Senate Subcommittee on Energy
  Committee on Energy and Natural Resources

- **The Honorable Joe Manchin III**
  Ranking Member, Senate Subcommittee on Energy
  Committee on Energy and Natural Resources

- **The Honorable Thad Cochran**
  Chairman, Senate Committee on Appropriations

- **The Honorable Barbara Mikulski**
  Vice Chairwoman, Senate Committee on Appropriations

- **The Honorable Lamar Alexander**
  Chairman, Senate Subcommittee on Energy and Water Development
  Committee on Appropriations

- **The Honorable Dianne Feinstein**
  Ranking Member, Senate Subcommittee on Energy and Water Development
  Committee on Appropriations

If you have any questions or need additional information, please contact me or Mr. Brad Crowell, Assistant Secretary for Congressional and Intergovernmental Affairs, at (202) 586-5450.

Sincerely,

Dr. Ellen D. Williams
Director
Advanced Research Projects Agency-Energy

Executive Summary

This report presents a summary of the activities of the Advanced Research Projects Agency-Energy (ARPA-E) during Fiscal Year 2015 (FY 2015).

In FY 2015[1], ARPA-E selected projects for nine new programs covering a broad array of energy technologies, including:

- $30 million for low-cost tools to aid in the future development of fusion power (ALPHA);
- $30 million for new power plant cooling technologies that enable high thermal-to-electric energy conversion efficiency with zero net water dissipation to the atmosphere (ARID);
- $6 million for validation of the performance of ARPA-E-funded grid-storage technologies (CHARGES);
- $30 million for systems for localized thermal management to improve building efficiency (DELTA);
- $25 million for development of generator technologies to enable more affordable and efficient residential Combined Heat and Power (CHP) systems (GENSETS);
- $30 million for low-cost, highly sensitive systems to detect methane emissions (MONITOR);
- $24 million for micro-scale concentrated photovoltaic systems (MOSAIC);
- $30 million to integrate agriculture, information technology and engineering to develop crops that are sustainable, affordable and yield abundant plant feedstocks for bioenergy (TERRA);
- $14.5 million for systems to identify less energy-intense travel options for users using software accessible on smartphones or other communications devices (TRANSNET).

ARPA-E released three additional funding opportunities in FY 2015 with project selections that were ultimately announced in FY 2016. These programs include:

- $125 million for the Agency's third open solicitation (OPEN 2015);

[1] The ALPHA, ARID, DELTA, CHARGES, and MONITOR FOAs were released in FY2014, with project selections announced in FY2015. The GENSETS, MOSAIC, TERRA, and TRANSNET FOAs were released in FY2015, with project selections also announced in FY2015.
Funding levels shown on pages iii-9 (inclusive) are as of each program's Project Selection Announcement. The final number of projects and funding amounts are subject to change based on award negotiations and ongoing program management (see Table 2 of this report for updated data on each program).

- $33 million for technologies that coordinate load and generation on the grid to create a virtual energy storage system (NODES);
- $11 million for realistic, open-access models and data repositories to aid in improving the U.S. electric grid (GRID DATA).

ARPA-E also continued the use of a rolling open solicitation to quickly support innovative applied energy research that has the potential to lead to new focused programs.

In addition to these new programs, ARPA-E hosted the sixth annual Energy Innovation Summit from February 9-11, 2015. The Summit brought together leaders from academia, government, and business to discuss the foremost energy issues, showcase the latest technology innovations, and cultivate relationships to help advance cutting-edge technologies to market. The event drew over 2,100 attendees and featured over 118 speakers and keynote addresses. To date, ARPA-E project teams have formed 30 new companies and 60 ARPA-E projects teams have partnered with other government agencies for further development. Additionally, at least 45 ARPA-E project teams have attracted more than $1.25 billion in private-sector follow-on funding.

Lastly, ARPA-E continued to focus on providing awardees with practical training and critical business information as part of the Agency's Technology-to-Market program. This support equips projects with a clear understanding of market needs to guide technical development and help projects succeed in the marketplace.

ARPA-E ANNUAL REPORT FOR FISCAL YEAR 2015

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I. Legislative Language

This report is in response to the requirements set forth in the America COMPETES Act, Public Law 110-69, section 5012(g)(1)(2007) as amended, which has been codified as 42 U.S.C. § 16538(h)(1), wherein it is stated:

> *"…the Director shall provide to the relevant authorizing and appropriations committees of Congress a report describing projects supported by ARPA-E during the previous fiscal year."*

ARPA-E focuses on energy technologies that can be meaningfully advanced with a modest investment over a defined period of time. ARPA-E brings together top minds in energy research, development, and commercialization to collaborate and rethink what is possible. ARPA-E's rigorous program design, competitive project selection process, and hands-on engagement, ensure thoughtful expenditures while empowering America's energy researchers with funding, technical assistance, and market awareness. ARPA-E thoroughly reviews all applications and technologies to ensure that investments are made in areas not currently undertaken by industry or other DOE applied research and development investment.

II. Fiscal Year 2015 Appropriation

ARPA-E was appropriated $280 million in FY 2015, pursuant to the Consolidated and Further Continuing Appropriations Act of 2015 (P.L. 113-235, H.R. 83), enacted on December 16, 2014.

III. Funding Opportunity Announcements (FOAs)

In FY 2015, ARPA-E released seven Funding Opportunity Announcements (FOA). Six of these were to advance innovative energy technologies in specific program areas, and one was an Open FOA, the Agency's third open solicitation.

Project selections for four of these FOAs, as well as five FOAs released in FY 2014, were announced in FY 2015. Selections for three FY 2015 FOAs were announced in early FY 2016. The focused technology programs created by these solicitations provide a unique bridge from basic science to early stage technology, drawing from the latest scientific discoveries and help create a viable path to commercial implementation through firm grounding in the economic realities and changing dynamics of the marketplace.

TABLE 1: Summary of ARPA-E FOAs Released and/or Awarded in FY 2015						
Program	**Project Selection**	**Project Selection FY**	**FOA Issuance**	**FOA Issuance FY**	**NUMBER OF PROJECTS**	**FUNDING AMOUNT ($ Million)[2]**
GRID DATA	1/15/2016	FY 2016	6/10/2015	FY 2015	7	$11
NODES	12/11/2015	FY 2016	2/4/2015	FY 2015	12	$33
Open 2015	11/23/2015	FY 2016	1/7/2015	FY 2015	41	$125
MOSAIC	8/24/2015	FY 2015	12/8/2014	FY 2015	11	$24
TRANSNET	7/30/2015	FY 2015	11/10/2014	FY 2015	5	$14.5
GENSETS	6/18/2015	FY 2015	10/16/2014	FY 2015	12	$25
TERRA	6/18/2015	FY 2015	10/1/2014	FY 2015	6	$30
ARID	5/14/2015	FY 2015	9/26/2014	FY 2014	14	$30
ALPHA	5/14/2015	FY 2015	8/24/2014	FY 2014	9	$30
CHARGES	12/8/2014	FY 2015	6/18/2014	FY 2014	2	$6
MONITOR	12/16/2014	FY 2015	4/29/2014	FY 2014	11	$30
DELTA	12/16/2014	FY 2015	4/29/2014	FY 2014	11	$30
Total (Projects Selected)					154	$422

Summary of FY 2015 Project Selections

In FY 2015, selections were announced for 81 projects across nine focused technology programs:

- On December 8, 2014, ARPA-E announced that two projects were selected to receive $6 million for **CHARGES** *(Cycling Hardware to Analyze and Ready Grid-Scale Electricity Storage).*
- On December 16, 2014, ARPA-E announced that 22 projects were selected to receive $60 million: $30 million across 11 projects for **MONITOR** *(Methane Observation Networks with Innovative Technology to Obtain Reductions)* and $30 million across 11 projects for **DELTA** *(Delivering Efficient Local Thermal Amenities).*
- On May 14, 2015, ARPA-E announced 23 projects were selected to receive $60 million: $30 million across 14 projects for **ARID** *(Advanced Research In Dry cooling)* and $30 million across 9 projects for **ALPHA** *(Accelerating Low-cost Plasma Heating and Assembly).*
- On June 18, 2015, ARPA-E announced 18 projects were selected to receive $55 million: $25 million across 12 projects for **GENSETS** *(GENerators for Small Electrical and Thermal Systems)* and $30 million across six projects for **TERRA** *(Transportation Energy Resources from Renewable Agriculture).*

[2] Funding levels shown in this chart are as of each program's Project Selection Announcement. The final number of projects and funding amounts are subject to change based on award negotiations and ongoing program management (see Table 2 of this report for updated data on each program).

- On July 30, 2015, ARPA-E announced five projects were selected to receive $14.5 million for **TRANSET** *(Traveler Response Architecture using Novel Signaling for Network Efficiency in Transportation).*
- On August 24, 2015, ARPA-E announced 11 projects were selected to receive $24 million for **MOSAIC** *(Micro-scale Optimized Solar-cell Arrays with Integrated Concentration).*

Throughout FY 2015, ARPA-E continued utilizing **IDEAS** (*Innovative Development in Energy-Related Applied Science*), a rolling open solicitation that will allow ARPA-E to quickly support innovative applied energy research that has the potential to lead to new focused programs.

Summary of FY 2016 Project Selections for FOAs Announced in FY 2015

In FY 2015 ARPA-E also issued solicitations for three programs with project selections announced in early FY 2016:

- On November 23, 2015, ARPA-E announced 41 projects were selected to receive $125 million for **OPEN 2015**.
- On December 11, 2015, ARPA-E announced 12 projects were selected to receive $33 million for **NODES** *(Network Optimized Distributed Energy Systems).*
- On January 15, 2016, ARPA-E announced 7 projects were selected to receive $11 million for **GRID DATA** *(Generating Realistic Information for the Development of Distribution and Transmission Algorithms).*

Details on the FY 2015 Project Selections

The details of the focused programs with project selections announced during FY 2015 are:[3]

- **ALPHA:** ***Accelerating Low-cost Plasma Heating and Assembly*** **($30 million)**
    - ALPHA will develop the tools to build foundations for new pathways toward fusion power. ALPHA is focused on approaches in the intermediate ion density regime between lower density magnetic confinement fusion (MCF) and higher density inertial confinement fusion (ICF). This intermediate density regime is not as well explored as the more mature MCF and ICF approaches, and it may offer new opportunities for fusion reactors with energy and power requirements that are compatible with low-cost technologies such as pulsed power or piston-driven compression. The ALPHA program will provide $30 million to support nine project teams in creating technologies designed to explore the intermediate

[3] Project counts and funding amounts on pages iii-9 (inclusive) reflect information at the time of the project selection announcement. Final number of projects and funding amounts are subject to change based on contract negotiations and ongoing program management (see Table 2 of this report for updated data on each program).

density regime and provide the basis for the development of fusion power at a lower cost than technologies available today.

- ***Example ALPHA Project: Helion Energy, Inc. – "Staged Magnetic Compression of FRC Targets to Fusion Conditions" – Redmond, WA ($4.0 million).*** Helion Energy, Inc. will investigate staged magnetic compression of field-reversed configuration (FRC) plasmas, building on past successes to develop a prototype that can attain higher temperatures and fuel density than previously possible. The team will use these results to assess the viability of scaling to a power reactor, which if successful would offer the benefits of simple linear geometry, attractive scaling, and compatibility with modern pulsed power electronics.

- **ARID:** ***Advanced Research In Dry cooling*** **($30 million)**
  - ARID will fund transformative new power plant cooling technologies that enable high thermal-to-electric energy conversion efficiency with zero net water dissipation to the atmosphere. The program plans to provide $30 million to support 14 project teams in developing innovative, ultra-high-performance air-cooled heat exchangers, supplemental cooling systems, and/or cool-storage systems that can cost-effectively and efficiently reject waste heat. ARPA-E project teams will work to design kilowatt-scale testing prototypes to help ensure the technologies can scale up to megawatt-cooling capacity without significant performance loss. If successful, these new cooling technologies could significantly reduce water usage at thermoelectric plants without sacrificing a plant's performance or increasing its cooling costs.
  - ***Example ARID Project: the University of Colorado at Boulder – "Radiative Cooled-Cold Storage Modules and Systems (RadiCold)" - Boulder, CO ($3.0 million):*** The University of Colorado at Boulder will develop radiative cool storage modules and a system called RadiCold to enable efficient, low-cost supplementary cooling for power plants. A metal-coated micro-structured thermoplastic polymethylpentene (TPX) surface reflects sunlight and allows radiative cooling for both day- and night-time operation. A passive, single-phase thermosyphon will collect cool water in a local storage unit beneath the RadiCold surface, and a low power-consumption pipe network will collect the cool water from local storage modules into a central storage system. Roll-to-roll manufacturing technology for the micro-structured TPX thin film will enable effective radiative cooling at a low cost.

- **CHARGES: Cycling Hardware to Analyze and Ready Grid-Scale Electricity Storage ($6 million)**
  - Through CHARGES, ARPA-E project teams working on grid-storage innovations will have a way to evaluate their technologies in both controlled environments and under realistic grid operating conditions early in their development cycle. Further, this testing and validation will provide grid operators and utilities with

reliable information about the performance characteristics, operating requirements, and life expectancy of emerging technologies.

- ***Example CHARGES Project: University of California, San Diego (UCSD) – "Advanced Energy Storage Modeling, Performance Evaluation and Testing" – San Diego, CA ($3 million):*** UCSD, home to one of the country's largest microgrids, will develop energy storage load profiles and duty cycles. UCSD will then test cells and modules from ARPA-E-funded battery developers in its laboratory and assist the ARPA-E developers in resolving issues and enhancing the performance of their technologies. Those technologies that perform well in laboratory testing using the selected duty cycles will then be deployed for extended testing on UCSD's microgrid.

- **DELTA: Delivering Efficient Local Thermal Amenities ($30 million)**
  - DELTA will develop localized heating and cooling systems and devices to expand temperature ranges within buildings. DELTA projects will develop technologies that can regulate temperatures focused on a building's occupants and not the overall building. This localization of thermal management will enable facilities to operate in wider temperature ranges while still ensuring occupant comfort, which would dramatically reduce the building's energy consumption and associated emissions.
  - ***Example DELTA Project: Syracuse University – "Micro-Environmental Control System" - Syracuse, NY ($3.2 million):*** Syracuse University will develop a near-range micro-environmental control system transforming the way office buildings are thermally conditioned to improve occupant comfort. The system leverages a high-efficiency micro-scroll compressor in a micro vapor compression system, whose evaporator is embedded in a phase-change material. This material will store the cooling produced by the micro vapor compression system at night, releasing it as a cool breeze to make occupants more comfortable during the day. This micro-environmental control system could save more than 15 percent of the energy provided for heating and cooling.

- **GENSETS: GENerators for Small Electrical and Thermal Systems ($25 million)**
  - GENSETS will accelerate the development of generator technologies to enable more affordable and efficient residential Combined Heat and Power (CHP) systems. Compared to conventional electricity generation and transmission, CHP captures the otherwise wasted heat and makes it available for useful application. By making CHP affordable for home use, this heat can be used for water and home heating, reducing the residents' energy costs. GENSETS project teams will develop advanced generators to produce electricity from piped-in natural gas while using the 'waste' heat to reduce the energy used by furnaces and water heaters. Widespread adoption of CHP systems in the residential sector would lead

to significant energy savings, along with increased reliability for residential power supply and a large reduction in CO2 emissions.

- The program will provide $25 million to support 12 project teams to design, build and test improved natural gas-powered generators for residential use. These generators can supply the majority of a household's electricity while producing thermal energy for space and water heating. To make small-scale CHP systems more economical and to stimulate widespread adoption, the GENSETS program aims to develop one kilowatt systems that are affordable, efficient and durable. The selected project teams are grouped into four areas of technology focus: internal combustion engines, Stirling engines, microturbines, and solid state devices.
- ***Example GENSETS Project: Brayton Energy – "1kW Recuperated Brayton-Cycle Engine Using Positive-Displacement Components" - Hampton, N.H. ($2.4 million):*** Brayton Energy will lead a team in developing a high efficiency microturbine CHP system that employs a thermodynamic cycle commonly used for large scale turbines. The key innovation for making an effective microturbine is to adapt this technology to use a lower input pressure. This will improve durability and increase efficiency by enabling use of a larger screw compressor for low viscous losses. The planned device also includes a silicon nitride screw expander, which enables high temperature operation. Brayton Energy will use its patented intake air recuperator and existing ultra-low emissions combustor to complete the CHP system.

- **MONITOR: Methane Observation Networks with Innovative Technology to Obtain Reductions ($30 million)**
  - MONITOR focuses on reducing methane emissions associated with energy production to build a more sustainable energy future. MONITOR projects will develop low-cost, highly sensitive systems that detect and measure methane associated with the production and transportation of oil and natural gas.
  - ***Example MONITOR Project: Bridger Photonics, Inc – "Mobile LiDAR Sensors for Methane Leak Detection" – Bozeman, MT ($1.5 million):*** Bridger Photonics will develop a light-detection and ranging (LiDAR) system capable of rapid and precise methane measurements resulting in 3D topographic information about potential leak locations. A novel near-infrared fiber laser will enable long range detection with high sensitivity and can be deployed on a range of mobile platforms to survey multiple sites per day. This mobile LiDAR system will dramatically reduce the cost of identifying, quantifying, and locating methane leaks compared to currently available technologies.

- **MOSAIC: Micro-scale Optimized Solar-cell Arrays with Integrated Concentration ($24 million)**

- MOSAIC aims to develop new solar modules with the high performance of concentrated photovoltaic (CPV) technologies, but at a cost and profile similar to commonly used flat-plate PV. Although CPV is much more efficient than flat-plate PV, CPV has not been widely adopted due to its high cost, large size, and expensive solar tracking systems. MOSAIC project teams will address these limitations by designing micro-scale CPV systems that can be integrated into flat-plate solar panels. These micro-CPV technologies will use thousands of small lenses to concentrate sunlight onto an array of micro-PV cells to achieve a higher solar-to-electricity conversion. By exploiting micro-CPV techniques, the teams aim to reduce system costs and dramatically improve flat-plate PV efficiency – and thereby expand the market and geographic areas in which these technologies can operate successfully.

- ***Example MOSAIC Project: Semprius, Inc. – "Micro-Scale Ultra-High Efficiency CPV/Diffuse Hybrid Arrays Using Transfer Printing" - Durham, NC ($2.9 million):*** Semprius and its partners will design a CPV module that integrates two types of solar cells to efficiently capture diffuse and direct sunlight. The team will create six-junction PV cells that exceed the efficiency of even the highest performing PV cells on the market today. Arrays of these six-junction PV cells will convert direct sunlight to electricity, while low-cost single-junction solar cells will efficiently convert diffuse sunlight. Semprius will use its expertise in cost-effective micro-transfer printing to fabricate and assemble the six-junction microcells. In addition to the cost benefits of micro-transfer printing, the team will utilize less expensive optics to reduce the cost of the system. By integrating cells that capture diffuse sunlight, Semprius' innovation could expand the use of high-efficiency CPV in regions with low direct sunlight.

- **TERRA: Transportation Energy Resources from Renewable Agriculture ($30 million)**
  - TERRA uniquely integrates agriculture, information technology and engineering to address major global challenges in developing crops that are sustainable, affordable and yield abundant plant feedstocks for bioenergy. The program will encourage systems that couple large scale physical and genetic characterization with advanced algorithms to accelerate the year-over-year yield gains of traditional plant breeding and the discovery of crop traits that improve water productivity, nutrient use and our ability to mitigate greenhouse gases. The TERRA program provides $30 million to support six project teams in the development of improved varieties of sorghum, a crop used to produce biofuel, by developing improved plant remote sensing, analysis and breeding methods.
  - TERRA project teams will address the limitations surrounding crop phenotyping (identifying and measuring the physical characteristics of plants) and genotyping (decoding the DNA of a plant), which are both manual and time-intensive

processes. Project teams will develop mobile platforms with sensory systems to observe and record the characteristics of plants and create advanced algorithms to analyze data and predict plant growth potential. Additionally, the TERRA program will fund the creation of a large public database comprised of sorghum genotypes and field phenotypes. This database will provide the greater community of plant physiologists, bioinformaticians and geneticists with the knowledge to improve sorghum and bioenergy crops.

- ***Example TERRA Project: University of Illinois, Urbana-Champaign – "Mobile Energy-Crop Phenotyping Platform" - Urbana-Champaign, IL ($3.1 million):*** The University of Illinois at Urbana-Champaign, with its partners Cornell University and Signetron Inc., will develop small-scale, automated ground rovers with the distinct capability to travel within the crops between rows. Phenotyping platforms will measure crop growth via 3-D reconstruction of plants and stands, and assess physiological indicators of performance using reflectance and LiDAR (laser light detection and ranging) sensors. The team will also use sophisticated biophysical growth models and DNA-sequencing technologies to develop innovative methods for accelerating improvement of energy sorghum and identifying key genes controlling plant performance.

- **TRANSNET: Traveler Response Architecture using Novel Signaling for Network Efficiency in Transportation ($14.5 million)**
  - TRANSNET systems will identify less energy-intense travel options for users using software accessible on smartphones or other communications devices and provide the most efficient transportation choices for travelers and commuters. To develop the software, project teams will use currently available data to simulate the transportation network of a U.S. urban region and quantify how much energy is used in various transportation patterns. The teams will also design control architectures to quantify energy reductions, identify user preferences and provide information needed to encourage a traveler to adopt efficient choices. If successful, TRANSNET projects will provide travelers information and signals to pursue more efficient travel, leading to less traffic, lower fuel consumption and emissions and more productive transportation networks.
  - ***Example TRANSNET Project: Georgia Tech Research Corporation – "Network Performance Monitoring and Distributed Simulation to Improve Transportation Energy Efficiency" - Atlanta, GA ($3.0 million):*** Researchers at the Georgia Institute of Technology will combine real-time analysis of transportation network data with distributed simulation modeling to provide drivers with information designed to reduce energy consumption as they travel. The team's system model will use a variety of data including: real-time traffic monitoring of the Atlanta metro area provided by regional transportation systems; origin-destination patterns and highway speeds collected from cellular networks and provided through a partnership with AirSageTM; and real-time data on speed

levels collected from 60,000 volunteers using a smartphone app. The researchers will use pattern recognition algorithms to identify traffic accidents and recurrent congestion and predict how traffic will respond. The team's control architecture will communicate with users via the app, providing suggestions for altering departure times, routes and/or modes of transport to reduce energy consumption, without increasing the time or cost of the trip. The system will evaluate trips and provide travelers with useful information designed to incentivize energy efficiency.

Table 2 on the following page summarizes ARPA-E's programs to date. A full list of the projects selected during FY 2015 can be found in Appendix I. Additional information related to these projects is on ARPA-E's website: http://arpa-e.energy.gov.

TABLE 2: ARPA-E PROGRAMS TO DATE			
PROGRAM NAME		**NUMBER OF PROJECTS**	**FUNDING AMOUNT ($ Million)[4]**
EXISTING PROGRAMS	OPEN 2009	41	$176
	Batteries for Electrical Energy Storage in Transportation (BEEST)	12	$39
	Innovative Materials and Processes for Advanced Carbon Capture Technologies (IMPACCT)	15	$41
	Electrofuels	13	$47
	Agile Delivery of Electrical Power Technology (ADEPT)	14	$38
	Building Energy Efficiency Through Innovative Thermodevices (BEETIT)	17	$37
	Grid-Scale Rampable Intermittent Dispatchable Storage (GRIDS)	16	$44
	Plants Engineered to Replace Oil (PETRO)	10	$55
	High Energy Advanced Thermal Storage (HEATS)	15	$39
	Rare Earth Alternatives in Critical Technologies (REACT)	14	$39
	Green Electricity Network Integration (GENI)	15	$44
	Solar Agile Delivery of Electrical Power Technology (Solar ADEPT)	7	$14
	Methane Opportunities for Vehicular Energy (MOVE)	13	$43
	Advanced Management and Protection of Energy Storage Devices (AMPED)	14	$32
	OPEN 2012	67	$172
	Innovative Development in Energy-related Applied Science (IDEAS)	22	$10
	Robust Affordable Next Generation Energy Storage Systems (RANGE)	22	$38
	Reducing Emissions using Methanotrophic Organisms for Transportation Energy (REMOTE)	15	$39
	Modern Electro/Thermochemical Advancements for Light-metal Systems (METALS)	19	$42
	Full-Spectrum Optimized Conversion and Utilization of Sunlight (FOCUS)	13	$36
	Strategies for Wide Bandgap, Inexpensive Transistors for Controlling High Efficiency Systems (SWITCHES) & SBIR/STTR	14	$31

[4] Funding levels shown in this chart are as of February 2016 unless otherwise stated. Open 2015, NODES, and GRID DATA project counts and funding amounts reflect information at the time of announcement. Final number of projects and funding amounts are subject to change based on award negotiations.

	Reliable Electricity Based on ELectrochemical Systems (REBELS)	13	$34
FY 2015 PROJECT SELECTIONS	Cycling Hardware to Analyze and Ready Grid-Scale Electricity Storage (CHARGES)[5]	2	$7
	Delivering Efficient Local Thermal Amenities (DELTA)	11	$30
	Methane Observation Networks with Innovative Technology to Obtain Reductions (MONITOR)	11	$31
	Accelerating Low-cost Plasma Heating and Assembly (ALPHA)	9	$32
	Advanced Research In Dry cooling (ARID)	14	$30
	GENerators for Small Electrical and Thermal Systems (GENSETS)	12	$27
	Transportation Energy Resources from Renewable Agriculture (TERRA)	6	$30
	Traveler Response Architecture using Novel Signaling for Network Efficiency in Transportation (TRANSNET)	5	$15
	Micro-scale Optimized Solar-cell Arrays with Integrated Concentration (MOSAIC)	11	$24
FOA ISSUED IN FY2015 WITH FY 2016 PROJECT SELECTION	Open 2015	41	$125
	Network Optimized Distributed Energy Systems (NODES)	12	$33
	Generating Realistic Information for the Development of Distribution and Transmission Algorithms (GRID DATA)	7	$11
	Total To Date[6]	542	$1,485

[5] The ALPHA, ARID, CHARGES, DELTA, and MONITOR FOAs were issued in FY 2014, with project selections announced in FY 2015. The GENSETS, MOSAIC, TERRA, and TRANSNET FOAs were issued in FY 2015, with project selections also announced in FY 2015. The Open 2015, NODES, and GRID DATA FOAs were issued in FY 2015, with project selections announced in FY 2016.

[6] As of early February, 2016 including estimated values for selected projects within the Open 2015, NODES, and GRID DATA programs.

IV. ARPA-E Energy Innovation Summit

The sixth annual ARPA-E Energy Innovation Summit took place February 24-26, 2015 at the Gaylord National Convention Center at the National Harbor in Maryland. The Summit convenes thought leaders from academia, business, and government to discuss the foremost energy issues, showcase cutting-edge energy technologies, and facilitate relationships to help move technologies into the market. The unique combination of leaders, investors, and innovators at the Summit makes it the ideal forum for developing energy solutions that will enable the United States to maintain a global technological lead in advanced energy technology.

Throughout the three-day event, attendees also had the opportunity to explore the Technology Showcase which featured ARPA-E awardees and a highly selective group of other companies, stakeholders, and research organizations. Many of the transformational energy technologies displayed in the Technology Showcase were demonstrated publically for the first time.

ARPA-E Energy Innovation Summit Highlights

- Over 2,100 registered attendees from across the United States and over 20 countries
- Technology Showcase displaying more than 280 breakthrough energy technologies from ARPA-E awardees and other innovative companies
- Dynamic panel discussions and networking sessions that enabled participants to meet with ARPA-E Program Directors, global industry leaders and energy technologists
- Over 118 expert speakers and keynote addresses, including leaders from government, business, and academia
- Attendance and comments by a bipartisan group of United States senators and representatives
- Announcement that as of early 2015, ARPA-E had recognized several notable preliminary indicators of success, including:
    - At least 30 ARPA-E project teams have formed new companies to advance their technologies
    - Several ARPA-E awardees have announced strategic partnerships with established industry participants, ranging from jointly developing a demonstration site to being acquired by a larger company
    - Over 37 ARPA-E project teams have partnered with other government agencies for further development
    - 34 ARPA-E project teams have attracted more than $850 million in private-sector follow-on funding.

V. Conclusion

In FY 2015, ARPA-E announced project selections for nine focused programs supporting the development of high-potential, high-impact energy technologies. The programs created through these solicitations cover a wide range of technical areas:[7]

- ALPHA: Low-cost tools to aid in the future development of fusion power;
- ARID: New power plant cooling technologies that enable high thermal-to-electric energy conversion efficiency with zero net water dissipation to the atmosphere;
- CHARGES: Validation of the performance of ARPA-E-funded grid-storage technologies;
- DELTA: Systems for localized thermal management to improve building efficiency;
- GENSETS: Development of generator technologies to enable more affordable and efficient residential Combined Heat and Power (CHP) systems;
- MONITOR: Low-cost, highly sensitive systems to detect methane emissions;
- MOSAIC: Micro-scale concentrated photovoltaic systems;
- TERRA: Integration of agriculture, information technology, and engineering to develop crops that are sustainable, affordable and yield abundant plant feedstocks for bioenergy;
- TRANSNET: Systems to identify less energy-intense travel options for users using software accessible on smartphones or other communications devices.

As directed by its statutory authorization,[8] ARPA-E entered into a contract with the National Academy of Sciences in October 2014 to "conduct an evaluation of how well ARPA-E is achieving the goals and mission of ARPA-E." ARPA-E has and will continue to actively engage with the National Academies *ad hoc* committee preparing this report. [9]
As of February 2016, ARPA-E has invested over $1.3 billion across more than 475 projects through 30 focused programs and three open funding solicitations (OPEN 2009, OPEN 2012, and Open 2015).[10]

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[7] The ALPHA, ARID, CHARGES, DELTA, and MONITOR, FOAs were released in FY 2014, with project selections announced in FY 2015. The GENSETS, MOSAIC, TERRA, and TRANSNET FOAs were released in FY 2015, with project selections also announced in FY 2015.
[8] Public Law 110-69, section 5012(k)(2007) as amended, which has been codified as 42 U.S.C. § 16538(l)
[9] More information on the report being prepared by the National Academies is available on their website. As of February 2016, the National Academies expects the study to be published in January 2017. http://sites.nationalacademies.org/PGA/step/ARPA-E_Evaluation/index.htm
[10] This statement does not include selected projects which have not yet completed contracting as of early February, 2016 (i.e. several projects within the Open 2015, NODES, and GRID DATA programs). Estimated values for these programs are included in Table 2.

At the 2015 ARPA-E Energy Innovation Summit, the Agency convened a diverse and influential group of energy experts and industry leaders focused on advancing the next generation of breakthrough energy technologies. The Summit brought together leaders with unique perspectives, experiences, and ideas with the shared goal of revolutionizing the American approach to energy innovation.

ARPA-E catalyzes transformational energy technologies that could create a more secure, affordable, and sustainable American future by advancing high-potential, high-impact energy projects that are too early for private sector investment. The goals of ARPA-E are to enhance the economic and energy security of the United States through the development of 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 has created a unique, nimble, and adaptive structure that allows the Agency to quickly develop and execute programs, recruit a highly talented and experienced technical team, and provide awardees with technical assistance and market awareness to help projects succeed. ARPA-E Program Directors provide awardees with technical guidance and develop new programs by engaging diverse communities to identify gaps where investment by ARPA-E could lead to transformational technologies enabling entirely new ways to generate, store, and use energy. The ARPA-E technology-to-market program provides practical training and critical business information to equip awardees with a clear understanding of market needs to guide technical development and help projects succeed.

Throughout FY 2015, ARPA-E has continued to demonstrate its dedication to supporting transformational projects. These breakthrough energy technologies present opportunities to revolutionize the ways we generate, store, distribute, and utilize energy in the United States.

VI. Appendix I: Projects Selected in FY 2015

Data below are as of the dates on which project selections were publicly announced: December 8, 2014 (CHARGES); December 16, 2014 (MONITOR & DELTA); May 14, 2015 (ARID & ALPHA); June 18, 2015 (GENSETS & TERRA); July 30, 2015 (TRANSNET); and August 24, 2015 (MOSAIC).

Additional information on these projects is available on the ARPA-E website: http://arpa-e.energy.gov.

PROGRAM	LEAD ORGANIZATION	PROJECT TITLE	LOCATION	ARPA-E FUNDING [11] (Million $)
CHARGES	Det Norske Veritas (DNV GL)	Third Party Valuation of Grid and Microgrid Energy Storage Technologies	Katy, TX	$2.9
CHARGES	University of California, San Diego (UCSD)	Advanced Energy Storage Modeling, Performance Evaluation and Testing	San Diego, CA	$3.0
MONITOR	Aeris Technologies	Miniaturized Tunable Laser Spectrometer for Methane Leak Detection	Redwood City, CA	$2.4
MONITOR	Bridger Photonics, Inc.	Mobile LiDAR Sensors for Methane Leak Detection	Bozeman, MT	$1.5
MONITOR	Duke University	Miniaturized Coded Aperture Mass Spectrometer for Methane Sensing	Durham, NC	$2.9
MONITOR	General Electric Company	Microstructured Optical Fiber for Methane Sensing	Niskayuna, NY	$1.4
MONITOR	IBM	On-Chip Optical Sensors and Network for Methane Leak Detection	Yorktown Heights, NY	$4.5
MONITOR	LI-COR	Fixed Cavity Mode Spectrometer for Methane Leak Detection	Lincoln, NE	$2.7
MONITOR	Maxion Technologies, Inc	Tunable Mid-infrared Laser for Methane Sensing	Jessup, MD	$1.9
MONITOR	Palo Alto Research Center	Printed Carbon Nanotube Sensors for Methane Leak Detection	Palo Alto, CA	$3.4

[11] Figures represent funding amounts at the time of project announcements. Final amounts are subject to change based on award negotiations. Please see the ARPA-E's website for updated information: http://arpa-e.energy.gov/.

MONITOR	Physical Sciences, Inc.	UAV-based Laser Spectroscopy for Methane Leak Detection	Andover, MA	$3.0
MONITOR	Rebellion Photonics	Portable Imaging Spectrometer for Methane Leak Detection	Houston, TX	$4.3
MONITOR	The University of Colorado	Frequency Comb-based Methane Sensing	Boulder, CO	$2.1
DELTA	Cornell University	Thermoregulatory Clothing System for Building Energy Saving	Ithaca, NY	$3.0
DELTA	Otherlab	Passive Thermo-Adaptive Textiles with Laminated Polymer Bimorphs	San Francisco, CA	$1.8
DELTA	SRI International	Wearable Electroactive Textile for Physiology-based Thermoregulation	Menlo Park, CA	$3.9
DELTA	Stanford University	Photonic Structure Textiles for Localized Thermal Management	Stanford, CA	$2.4
DELTA	State University of New York at Stony Brook	Electroactive Smart Air-Conditioner VEnt Registers (eSAVER) for Improved Personal Comfort and Reduced Electricity Consumption	Stony Brook, NY	$2.1
DELTA	Syracuse University	Micro-Environmental Control System	Syracuse, NY	$3.2
DELTA	University of California at Berkeley	Heating and Cooling the Human Body with Wirelessly Powered Devices	Berkeley, CA	$2.6
DELTA	University of California at Irvine	Thermocomfort Cloth Inspired by Squid Skin	Irvine, CA	$2.4
DELTA	University of California at San Diego	Adaptive Textiles Technology with Active Cooling & Heating (ATTACH)	San Diego, CA	$2.6
DELTA	University of Maryland	Meta-Cooling Textile with Synergetic Infrared Radiation and Air Convection for Bidirectional Thermoregulation	College Park, MD	$3.1
DELTA	University of Maryland	Robotic Personal Conditioning Device	College Park, MD	$2.6
ARID	Advanced Cooling Technologies, Inc.	Heat-Pipe PCM Based Cool Storage for Air-Cooled Systems	Lancaster, PA	$3.2
ARID	Applied Research Associates, Inc.	Active Cooling Thermally Induced Vapor-Polymerization Effect (ACTIVE)	Panama City, FL	$2.2

ARID	Colorado State University	Ultra-Efficient Turbo-Compression Cooling	Fort Collins, CO	$1.9
ARID	Electric Power Research Institute, Inc.	Indirect Dry Cooling Using Recirculating Encapsulated Phase-Change Materials	Palo Alto, CA	$3.0
ARID	General Electric Company – GE Global Research	A Low-Cost Heat Pump with Advanced Refrigerant/Absorbent Separation	Niskayuna, NY	$1.1
ARID	Palo Alto Research Center	Metamaterials-Enhanced Passive Radiative Cooling Panels	Palo Alto, CA	$1.0
ARID	SRI International	Spectrally-Tuned All-Polymer Technology for Inducing Cooling (STATIC) Radiative Cooling for Cold Storage	Menlo Park, CA	$0.7
ARID	Stony Brook University	Condensing Flue Gas Water Vapor for Cool Storage	Stony Brook, NY	$2.5
ARID	TDA Research, Inc.	Novel Desiccant Cycle for Flue Gas Water Recovery and Cool Storage	Wheat Ridge, CO	$1.7
ARID	University of Cincinnati	Enhanced Air-Cooling System with Optimized Asynchronously Cooled Thermal Energy Storage	Cincinnati, OH	$3.4
ARID	University of Colorado at Boulder	Radiative Cooled-Cold Storage Modules and Systems (RadiCold)	Boulder, CO	$3.0
ARID	University of Maryland	Novel Microemulsion Absorption Systems for Supplemental Power Plant Cooling	College Park, MD	$3.0
ARID	University of Maryland	Novel Polymer Composite Heat Exchanger for Dry Cooling of Power Plants	College Park, MD	$2.0
ARID	University of Wisconsin	Optimized Air-Side Heat Transfer Surfaces Via Advanced Additive Manufacturing-	Madison, WI	$1.2
ALPHA	California Institute of Technology	Prototype Tools to Establish the Viability of the Adiabatic Heating and Compression Mechanisms Required for Magnetized Target Fusion	Pasadena, CA	$0.8
ALPHA	Helion Energy, Inc.	Staged Magnetic Compression of FRC Targets to Fusion Conditions	Redmond, WA	$4.0

ALPHA	Lawrence Berkeley National Laboratory	MEMS Based Ion Beam Drivers for Magnetized Target Fusion	Berkeley, CA	$2.2
ALPHA	Los Alamos National Laboratory	Spherically Imploding Plasma Liners as a Standoff Magneto-Inertial-Fusion Driver	Los Alamos, NM	$5.5
ALPHA	Magneto-Inertial Fusion Technologies, Inc.	Staged Z-pinch Target for Fusion	Santa Ana, CA	$4.3
ALPHA	NumerEx, LLC	Stabilized Liner Compressor (SLC) for Low-Cost Fusion	Albuquerque, NM	$4.0
ALPHA	Sandia National Laboratories	Demonstrating Fuel Magnetization and Laser Heating Tools for Low-Cost Fusion Energy	Albuquerque, NM	$3.8
ALPHA	Swarthmore College	Plasma Accelerator on the Swarthmore Spheromak Experiment	Swarthmore, PA	$0.5
ALPHA	University of Washington	Development of a Compact Fusion Device based on the Flow Z-Pinch	Seattle, WA	$4.8
GENSETS	Aerodyne Research, Inc.	Single-cylinder Two-stroke Free-Piston Internal Combustion Generator	Billerica, MA	$2.6
GENSETS	Brayton Energy	1kW Recuperated Brayton-Cycle Engine Using Positive-Displacement Components	Hampton, NH	$2.4
GENSETS	Georgia Institute of Technology	High Efficiency Generator Based on Sodium Thermo-Electro-Chemical Conversion (Na-TEC)	Atlanta, GA	$1.0
GENSETS	Infinia Technology Corporation	Sustainable Economic mCHP Stirling (SEmS) Generator	Richland, WA	$3.7
GENSETS	Mahle Powertrain	Advanced Lean Burn Micro-CHP Genset	Farmington Hills, MI	$2.5
GENSETS	Metis Design Corp	Advanced Microturbine Engine for Residential Generation	San Francisco, CA	$1.0
GENSETS	NanoConversion Technologies, Inc.	High-efficiency Thermoelectric Generator-	San Jose, CA	$1.5
GENSETS	Sunpower, Inc.	Free Piston Stirling Engine Based 1kW Generator	Athens, OH	$3.5
GENSETS	Temple University	Advanced Stirling Power Generation System for Combined Heat and Power	Philadelphia, PA	$1.0
GENSETS	Tour Engine, Inc.	High Efficiency Split-Cycle Engine for Residential Generators	San Diego, CA	$1.0

GENSETS	West Virginia University Research Corporation	Oscillating Linear Engine and Alternator	Morgantown, WV	$2.0
GENSETS	Wisconsin Engine Research Consultants (WERC), LLC	Spark-Assisted HCCI Residential Generator	Madison, WI	$2.6
TERRA	Clemson University	Breeding High Yielding Bioenergy Sorghum for the New Bioenergy Belt	Clemson, SC	$6.0
TERRA	Donald Danforth Plant Science Center	A Reference Phenotyping System for Energy Sorghum	St. Louis, MO	$8.0
TERRA	Pacific Northwest National Laboratory	Consortium for Advanced Sorghum Phenomics (CASP)	Richland, WA	$3.3
TERRA	Purdue University	Automated Sorghum Phenotyping and Trait Development Platform	West Lafayette, IN	$6.5
TERRA	Texas A&M AgriLife Research	Automated Phenotyping System for Genetic Improvement of Energy Crops	College Station, TX	$3.1
TERRA	University of Illinois at Urbana-Champaign	Mobile Energy-Crop Phenotyping Platform (MEPP)	Champaign, IL	$3.1
TRANSNET	Georgia Tech Research Corporation	Network Performance Monitoring and Distributed Simulation to Improve Transportation Energy Efficiency	Atlanta, GA	$3.0
TRANSNET	Massachusetts Institute of Technology	Mobility Electronic Market for Optimized Travel (MeMOT)	Cambridge, MA	$4.0
TRANSNET	National Renewable Energy Laboratory	The Connected Traveler: A Framework to Reduce Energy Use in Transportation	Golden, CO	$1.6
TRANSNET	Palo Alto Research Center	Collaborative Optimization and Planning for Transportation Energy Reduction (COPTER)	Palo Alto, CA	$2.2
TRANSNET	University of Maryland at College Park	Integrated, Personalized, Real-Time Traveler Information and Incentive Technology for Optimizing Energy Efficiency in Multimodal Transportation Systems	College Park, MD	$3.8
MOSAIC	California Institute of Technology	Micro-Optical Tandem Luminescent Solar Concentrator	Pasadena, CA	$3.0
MOSAIC – SBIR	Glint Photonics, Inc.	Stationary Wide-Angle Concentrator PV System	Burlingame, CA	$1.7

MOSAIC	Massachusetts Institute of Technology	Integrated Micro-Optical Concentrator Photovoltaics with Lateral Multijunction Cells	Cambridge, MA	$3.5
MOSAIC	Massachusetts Institute of Technology	Wafer-Level Integrated Concentrating Photovoltaics	Cambridge, MA	$1.2
MOSAIC	Palo Alto Research Center	Micro-Chiplet Printer for MOSAIC	Palo Alto, CA	$1.5
MOSAIC	Panasonic Boston Laboratory	Low Profile CPV Panel with Sun Tracking for Rooftop Installation	Newton, MA	$2.1
MOSAIC	The Pennsylvania State University	Wide-Angle Planar Microtracking Microcell CPV	University Park, PA	$2.9
MOSAIC	Semprius, Inc.	Micro-Scale Ultra-High Efficiency CPV/Diffuse Hybrid Arrays Using Transfer Printing	Durham, NC	$2.9
MOSAIC	Sharp Laboratories of America	A High-Efficiency Flat Plate PV with Integrated Micro-PV atop a 1-Sun Panel	Camas, WA	$2.7
MOSAIC	Texas A&M University Engineering Experiment Station	Waveguiding Solar Concentrator	College Station, TX	$1.0
MOSAIC	University of Rochester	Planar Light Guide Concentrated Photovoltaics	Rochester, NY	$1.5