Advanced Research Projects Agency - Energy Annual Report for FY 2017

Report to Congress
September 2018

United States Department of Energy
Washington, DC 20585

Message from the Principal Deputy Director

The Advanced Research Projects Agency-Energy (ARPA-E) maintains a dynamic funding portfolio in which roughly one third of programs turn over annually. ARPA-E supports project teams whose technologies advance the boundaries of science and provides them with the strategic guidance necessary to effectively prepare for the deployment of their technologies.

In Fiscal Year 2017, we continued developing our diverse portfolio of advanced energy technologies. We issued five funding opportunity announcements (FOAs) including one to develop advanced cultivation technologies for marine biomass production (MARINER) and another to develop distributed, natural gas fueled devices that can generate electricity at greater than 70% efficiency (INTEGRATE). Moreover, we announced projects ranging from developing new ways to build semiconductors for high performance, high-powered applications (PNDIODES) to developing innovative electric power converters that save energy (CIRCUITS).

This report is being provided to the following Members of Congress:

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

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

- **The Honorable Cory Gardner**
  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 Greg Walden**
  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 Marc Veasey**
  Ranking Member, House Subcommittee on Energy
  Committee on Science, Space, and Technology

- **The Honorable Richard Shelby**
  Chairman, Senate Committee on Appropriations

- **The Honorable Patrick Leahy**
  Vice Chairman, 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

- **The Honorable Rodney Frelinghuysen**
  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

If you have any questions or need additional information, please contact me or Ms. Melissa Burnison, Assistant Secretary for Congressional and Intergovernmental Affairs, at 202-586-5450.

Sincerely,

Dr. Chris Fall
Acting Director
Advanced Research Projects Agency - Energy

Executive Summary

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

ARPA-E creates options for new paths that accelerate the pace of innovation. These developments help the United States:

- Reduce imports of energy from foreign sources;
- 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 provides America's energy researchers with funding, technical assistance, and commercialization guidance. This report presents a summary of the activities of ARPA-E during Fiscal Year 2017 (FY 2017).

In FY 2017[1], ARPA-E selected projects for seven programs covering a broad array of energy technologies:

- $32 million to create new control technologies that reduce the energy consumption of future vehicles by using connectivity and vehicle automation (NEXTCAR);
- $35 million for technologies that develop new crop breeding approaches for improved root and soil function that will help plants to store more carbon in the ground and absorb nutrients and water more efficiently (ROOTS);
- $35 million to develop technologies that use renewable energy to convert air and water into cost-competitive liquid fuels (REFUEL);
- $25 million for creating innovative components to increase the energy efficiency of datacenters (ENLITENED);
- $6.9 million to develop new ways to build semiconductors for high performance, high-powered applications like aerospace, electric vehicles, and the grid (PNDIODES);

[1] The NEXTCAR, ROOTS, REFUEL, and ENLITENED FOAs were released in FY 2016, with project selections announced in FY 2017. The PNDIODES, MARINER and CIRCUITS FOAs were released in FY 2017, with project selections also announced in FY 2017. 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).

- $30 million to develop innovative electric power converters that save energy and give the United States a critical technological advantage in an increasingly electrified economy (CIRCUITS);
- $22 million to develop technologies capable of providing economically viable, renewable biomass for energy applications without the need for land, fresh water, and synthetic fertilizers (MARINER).

ARPA-E released two additional funding opportunities in FY 2017 with project selections that were ultimately announced in FY 2018:

- $20 million to develop a new class of sensor systems to enable significant energy savings via reduced demand for heating and cooling in residential and commercial buildings (SENSOR);
- $16 million to develop distributed, natural gas fueled devices that can generate electricity at greater than 70% efficiency (INTEGRATE).

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 eighth annual Energy Innovation Summit from February 27 to March 1, 2017. 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 towards deployment. The event drew almost 2,000 attendees and featured over 100 speakers and keynote addresses. At the Summit, ARPA-E announced that as of February 2017, 56 project teams have formed new companies, 68 projects have partnered with other government agencies for further development and an ever increasing number of technologies have already been incorporated into products that are being sold in the market. Additionally, 74 ARPA-E project teams have attracted more than $1.8 billion in private-sector follow-on funding.

In FY 2017, 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 2017

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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 early-stage energy technologies that can be meaningfully advanced with modest funding over a defined period of time. ARPA-E's rigorous program design, competitive project selection process, and hands-on engagement provide America's energy researchers with funding, technical assistance, and market awareness. In FY 2017, ARPA-E thoroughly reviewed all applications and technologies to ensure that funding is provided to areas not currently undertaken by industry, federal agencies, or other DOE applied research and development.

II. Fiscal Year 2017 Appropriation

The Consolidated Appropriations Act, 2017 (P.L. 115-31) included $306 million in FY 2017 funds for ARPA-E.

III. Funding Opportunity Announcements (FOAs)

In FY 2017, ARPA-E released five FOAs. All five FOAs were designed to advance innovative energy technologies in specific program areas.

Project selections for three of these FOAs, as well as four FOAs released in FY 2016, were announced in FY 2017. Selections for two FY 2017 FOAs were announced in FY 2018. The focused technology programs created by these solicitations provide a unique bridge from basic science to early-stage technology. They draw from the latest scientific discoveries and will 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 2017[2]						
Program	**Project Selection**	**Project Selection FY**	**FOA Issuance**	**FOA Issuance FY**	**NUMBER OF PROJECTS**	**FUNDING AMOUNT ($ Million)**[2]
NEXTCAR	11/2/2016	FY 2017	4/12/2016	FY 2016	10	$32M
ROOTS	12/15/2016	FY 2017	4/12/2016	FY 2016	10	$35M
REFUEL	12/15/2016	FY 2017	4/26/2016	FY 2016	16	$35M
ENLITENED	6/14/2017	FY 2017	6/10/2016	FY 2016	9	$25M
PNDIODES	6/14/2017	FY 2017	11/2/2016	FY 2017	7	$6.9M
CIRCUITS	8/23/2017	FY 2017	1/18/2017	FY 2017	21	$30M
MARINER	9/19/2017	FY 2017	12/16/2016	FY 2017	18	$22M
SENSOR	11/16/2017	FY 2018	1/18/2017	FY 2017	15	$20M
INTEGRATE	3/13/2018	FY 2018	7/26/2017	FY 2017	8	$16M
Total (Projects Selected)					114	$222M

Summary of FY 2017 Project Selections

In FY 2017, selections were announced for 91 projects across seven technology programs:

On November 2, 2016, ARPA-E announced that ten projects were selected to receive $32 million for **NEXTCAR** (*Next-Generation Energy Technologies for Connected and Automated On-Road Vehicles*).

On December 15, 2016, ARPA-E announced that ten projects were selected to receive $35 million for **ROOTS** *(Rhizosphere Observations Optimizing Terrestrial Sequestration)* and 16 projects were selected to receive $35 million for **REFUEL** *(Renewable Energy to Fuels through Utilization of Energy-Dense Liquids).*

On June 14, 2017, ARPA-E announced that nine projects were selected to receive $25 million for **ENLITENED** *(ENergy-efficient Light-wave Integrated Technology Enabling Networks that Enhance Datacenters)* and seven projects were selected to receive $6.9 million for **PNDIODES** *(Power Nitride Doping Innovation Offers Devices Enabling SWITCHES).*

On August 23, 2017, ARPA-E announced that 21 projects were selected to receive $30 million for **CIRCUITS** *(Creating Innovative and Reliable Circuits Using Inventive Topologies and Semiconductors).*

[2] Funding levels shown in this chart are as of each program's project selection announcement. The final number of projects and final 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 September 19, 2017, ARPA-E announced that 18 projects were selected to receive $22 million for **MARINER** (*MacroAlgae Research Inspiring Novel Energy Resources*).

Throughout FY 2017, ARPA-E continued utilizing **IDEAS** (*Innovative Development in Energy-Related Applied Science*), a rolling open solicitation that allows ARPA-E to quickly support innovative applied energy research that has the potential to lead to new focused programs.

Summary of FY 2018 Project Selections for FOAs Announced in FY 2017

In FY 2017 ARPA-E also issued solicitations for two programs with project selections announced in FY 2018:

On November 16, 2017, ARPA-E announced that 15 projects were selected to receive $20 million for **SENSOR** *(Saving Energy Nationwide in Structures with Occupancy Recognition)*. The FOA was issued on January 18, 2017.

On March 13, 2018 ARPA-E announced that eight projects were selected to receive $16 million for **INTEGRATE** *(Innovative Natural-gas Technologies for Efficiency Gain in Reliable and Affordable Thermochemical Electricity-generation)*. The FOA was issued on July 26, 2017.

Details on the FY 2017 Project Selections

The details of the focused programs with project selections announced during FY 2017 are:[3]

NEXTCAR: *Next-Generation Energy Technologies for Connected and Automated On-Road Vehicles* ($32 million)

The projects that make up ARPA-E's NEXTCAR program are enabling technologies that use connectivity and automation to co-optimize vehicle dynamic controls and powertrain operation, thereby reducing energy consumption of the vehicle. Vehicle dynamic and powertrain control technologies, implemented on a single vehicle basis, across a cohort of cooperating vehicles, or across the entire vehicle fleet, could significantly improve individual vehicle and, ultimately, fleet energy efficiency.

Example NEXTCAR Project: Purdue University – "Enabling High-Efficiency Operation through Next-Generation Control Systems Development for Connected and Automated Class 8 Trucks" – West Lafayette, IN ($5 million). Purdue University, together with its partners, has a multi-pronged approach for the implementation of their heavy-duty diesel truck project, focusing on

[3] Project counts and funding amounts on pages iii-9 (inclusive) reflect information at the time of the project selection announcement. The final number of projects and final 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).

concepts including: transmission and engine optimization; more efficient maintenance of exhaust after-treatment systems using look-ahead information; cloud-based remote engine and transmission recalibration; cloud-based engine and transmission control; and efficient truck platooning. The most promising strategies will be evaluated and refined using a phased approach relying on a combination of simulations, development, and real-world testing.

ROOTS: *Rhizosphere Observations Optimizing Terrestrial Sequestration* ($35 million)
Specialized plant breeds could dramatically and economically reduce the amount of atmospheric carbon dioxide while providing farmers with benefits in soil quality, reduced need for irrigation, and reduced fertilizer use. Improving these plants to increase soil carbon storage represents an untapped opportunity to remove carbon dioxide from the atmosphere with significant additional economic potential. While advances in agriculture have resulted in a ten-fold increase in crop yield over the past century, soil quality has suffered, diminishing its ability to support healthy crops. Through root and soil measurement and modeling to accelerate breeding activities, the ROOTS program aims to develop crops that increase carbon deposition depth and accumulation by 50% while also reducing nitrous oxide emissions by 50% and increasing water productivity by 25%.

Example ROOTS Project: Texas A&M AgriLife Research – "A Field-Deployable Magnetic Resonance Imaging Rhizotron for Modeling and Enhancing Root Growth and Biogeochemical Function" – College Station, TX ($4 million). The Texas A&M AgriLife Research team will develop a low-cost, portable magnetic resonance imaging (MRI) system for field imaging of root architecture and soil water distribution. The system will provide high spatial resolution and allow for dynamic tracking of water movement in roots and soil. This will allow identification of plant roots with improved nutrient uptake and quantification of plant available water in the soil. The aboveground design of the imaging system will allow for easier, less invasive set up and use. The team will leverage its partners' world-class expertise in sorghum genetics and breeding, as well as cutting edge biomedical engineering and physics capabilities.

REFUEL: *Renewable Energy to Fuels Through Utilization of Energy-Dense Liquids* ($35 million)
Most liquid fuels used in transportation today are derived from petroleum and burned in internal combustion engines. While these energy-dense fuels are currently economical, they are highly carbon intensive. Additionally, the United States remains partially reliant on imported petroleum. Projects in the REFUEL program seek to develop scalable technologies for converting electrical energy from renewable sources into energy-dense carbon-neutral liquid fuels (CNLFs) and back into electricity or hydrogen on demand. These projects could accelerate the shift to domestically produced transportation fuels, improving U.S. economic and energy security and reducing energy emissions.

Example REFUEL Project: Storagenergy Technologies, Inc. – "High Rate Ammonia Synthesis by Intermediate Temperature Solid-State Alkaline Electrolyzer" – Salt Lake City, UT ($2.5 million).
The Storagenergy Technologies team will build a system to produce ammonia from water and

nitrogen. Storagenergy's innovation relies on a cell containing an electrolyte made from a solid composite and nanostructured catalysts for nitrogen reduction reactions. If successful, the team will create a cell capable of producing ammonia at temperatures between 100 and 300 °C without the need for separate hydrogen production, thus decreasing feedstock costs.

ENLITENED: ***ENergy-efficient Light-wave Integrated Technology Enabling Networks that Enhance Datacenters*** **($25 million)**
The explosive growth of the internet has increased the amount of energy consumed by the information communications technology sector, especially from datacenters where information in the "cloud" is stored and processed. There are many approaches to improve how datacenters use energy effectively, but ultimately, the metal interconnects currently used to transmit information between devices within a datacenter will limit efficiency gains. The ENLITENED program seeks an entirely new approach to improving datacenter energy efficiency. Project teams will develop novel network topologies enabled by integrated photonics technologies, which use light instead of electricity to transmit information.

Example ENLITENED Project: University of California, San Diego – "Lightwave Energy Efficient Datacenter (LEED)" – La Jolla, CA ($3.8 million). The University of California, San Diego team will develop (1) a unique, scalable energy-efficient architecture that is based on the distributed control of light-based circuit-switches; (2) a large-port-count low-loss optical switch technology that routes information carried as light waves; (3) packaged, scalable, energy-efficient optical interconnect technology designed for the optical switch that does not require optical amplification. By combining these three technologies, the team hopes to create a highly scalable, easily controllable, energy-efficient network architecture for datacenters.

PNDIODES: ***Power Nitride Doping Innovation Offers Devices Enabling SWITCHES*** **($6.9 million)**
The PNDIODES program seeks to develop transformational advances in the process of selective area doping in the wide-bandgap (WBG) semiconductor, gallium nitride (GaN), and its alloys. WBG semiconductors have applications similar to today's popular semiconductors, but with properties that allow them to operate at much higher voltages, frequencies, and temperatures than these traditional materials. The doping process consists of adding a specific impurity to a semiconductor to change its electrical properties—altering its physical makeup to achieve performance characteristics that are useful for electronics. Developing a reliable and usable doping process that can be applied to specific regions of the semiconductor GaN and its alloys remains an important obstacle in the fabrication of power electronics devices using this technology. The PNDIODES program aims to fill technological gaps in the area of selective area doping, further advancing the field by addressing the problem of producing sufficiently high quality and reliably doped regions in GaN and its alloys to create viable high-power, high-performance transistors.

Example PNDIODES Project: Arizona State University – "Effective Selective Area Doping for GaN Vertical Power Transistors Enabled by Innovative Materials Engineering" – Tempe, AZ

($1.5 million). The Arizona State University team will develop a new fabrication process and determine the opportunities to solve the challenges of selective area growth for doping in GaN materials. The team will also conduct a materials study and investigate several issues related to GaN selective area epitaxial growth. If successful, this project will demonstrate generally usable p-n junctions for vertical GaN power devices that meet PNDIODES program targets of high power, high-performance power conversion for a wide array of applications

CIRCUITS: ***Creating Innovative and Reliable Circuits Using Inventive Topologies and Semiconductors*** **($30 million)**
The CIRCUITS program seeks to accelerate the development and deployment of a new class of efficient, lightweight, and reliable power converters, based on wide-bandgap (WBG) semiconductors. Projects will establish the building blocks of this class of power converter by advancing higher efficiency designs that exhibit enhanced reliability and superior total cost of ownership. In addition, a reduced form factor (size and weight) will drive adoption of higher performance and more efficient power converters relative to today's state-of-the-art systems. CIRCUITS projects will build on earlier ARPA-E programs by designing circuit topologies optimally suited for WBG attributes to maximize overall electrical system performance. Innovations stemming from the program have the potential to affect high-impact applications wherever electrical power is generated or used, including the grid, solar and wind power systems, datacenters, and consumer electronics.

Example CIRCUITS Project: Imagen Energy, LLC – "1200V SiC-Based Extremely Compact, 500 kW, 2000Hz Inverter for High Speed Permanent Magnet Synchronous Machine (PMSM) Applications" – New Berlin, WI ($0.8 million). Imagen and its project team will develop a SiC-based compact motor drive system to efficiently control high power (greater than 500 kW), high performance permanent magnet electric motors operating at extremely high speed (greater than 20,000 rpm). Imagen Energy's design seeks to address a major roadblock in operating electric motors at high speed, namely overcoming large back electromotive forces (BEMF). If successful, the project team will demonstrate a motor drive capable of handling large BEMF and increase motor system efficiency over a broad range of operating speeds.

MARINER: ***Macroalgae Research Inspiring Novel Energy Resources*** **($22 million)**
The MARINER program seeks to develop the tools to enable the United States to become a global leader in the production of marine biomass. MARINER project teams aim to develop technologies capable of providing economically viable, renewable biomass for energy applications without the need for land, fresh water, and synthetic fertilizers. Such technologies include integrated cultivation and harvesting systems, advanced component technologies, computational modeling tools, aquatic monitoring tools, and advanced breeding and genetic tools. Successful technologies could help greatly reduce the capital and operational expenses related to macroalgae production and enable significant increases in farm size and potential areas of deployment.

Example MARINER Project: University of Alaska, Fairbanks – "Development of Scalable Coastal & Offshore Macroalgal Farming" – Fairbanks, AK (0.5 million). The University of Alaska Fairbanks team will develop replicable scale model farms capable of the cost-effective production of sugar kelp, a type of seaweed. The project aims to reduce capital cost using purpose-built designs while simplifying installation and production to lower operational expenses. The team seeks to integrate the entire farming process, including seed production, outplanting, grow-out, harvest, and re-seeding. A particular emphasis will be on the development of cost-effective harvesting methods based on technologies applied in the commercial fishing industry. Test deployments for the integrated system are planned for locations in Alaska and New England.

Table 2 on the following page summarizes ARPA-E's programs to date. A full list of the projects selected during FY 2017 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	$49
	Agile Delivery of Electrical Power Technology (ADEPT)	14	$38
	Building Energy Efficiency Through Innovative Thermodevices (BEETIT)	17	$39
	Grid-Scale Rampable Intermittent Dispatchable Storage (GRIDS)	16	$44
	Plants Engineered To Replace Oil (PETRO)	10	$56
	High Energy Advanced Thermal Storage (HEATS)	15	$39
	Rare Earth Alternatives in Critical Technologies (REACT)	14	$40
	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	$45
	Advanced Management and Protection of Energy Storage Devices (AMPED)	15	$36
	OPEN 2012	66	$179
	Innovative Development in Energy-related Applied Science (IDEAS)	53	$25
	Robust Affordable Next Generation Energy Storage Systems (RANGE)	22	$46
	Reducing Emissions using Methanotrophic Organisms for Transportation Energy (REMOTE)	16	$46
	Modern Electro/Thermochemical Advancements for Light metals Systems (METALS)	19	$50
	Full-Spectrum Optimized Conversion and Utilization of Sunlight (FOCUS)	14	$38

[4] Funding levels shown in this chart are as of February 2018 unless otherwise stated. CIRCUITS, MARINER, SENSOR, and INTEGRATE project counts and funding amounts reflect information at the time of selection. Final number of projects and funding amounts are subject to change based on award negotiations.

	Strategies for Wide Bandgap, Inexpensive Transistors for Controlling High Efficiency Systems (SWITCHES) & SBIR/STTR	14	$37
	Reliable Electricity Based on ELectrochemical Systems (REBELS)	13	$37
	Cycling Hardware to Analyze and Ready Grid-Scale Electricity Storage (CHARGES)	2	$7
	Delivering Efficient Local Thermal Amenities (DELTA)	11	$30
	Methane Observation Networks with Innovative Technology to Obtain Reductions (MONITOR)	11	$32
	Accelerating Low-cost Plasma Heating and Assembly (ALPHA)	9	$32
	Advanced Research In Dry cooling (ARID)	15	$34
	GENerators for Small Electrical and Thermal Systems (GENSETS)	11	$27
	Transportation Energy Resources from Renewable Agriculture (TERRA)	6	$36
	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	$26
	GENerators for Small Electrical and Thermal Systems Small Business Innovation Research / Small Business Technology Transfer (GENSETS SBIR / STTR)	3	$7
	OPEN 2015	39	$123
	Network Optimized Distributed Energy Systems (NODES)	12	$34
	Generating Realistic Information for the Development of Distribution and Transmission Algorithms (GRID DATA)	7	$11
	Single-Pane Highly Insulating Efficient Lucid Design (SHIELD)	14	$31
	MONITOR Test Site	1	$4
	Integration and Optimization of Novel Ion-Conducting Solids (IONICS)	16	$37
FY 2016 FOA / FY 2017 Project Selection	Next-Generation Energy Technologies for Connected and Automated On-Road Vehicles (NEXTCAR)	11	$35
	Rhizosphere Observations Optimizing Terrestrial Sequestration (ROOTS)	10	$35
	Renewable Energy to Fuels Through Utilization of Energy-Dense Liquids (REFUEL)	12	$24
	Renewable Energy to Fuels Through Utilization of Energy-Dense Liquids Small Business Innovation Research / Small Business Technology Transfer (REFUEL SBIR / STTR)	4	$8

	Energy-Efficient Light-Wave Integrated Technology Enabling Networks that Enhance Datacenters (ENLITENED)	9	$24
FY2017 FOA / FY 2017 Project Selection	Power Nitride Doping Innovation Offers Devices Enabling SWITCHES (PNDIODES)	7	$6.9
	Creating Innovative and Reliable Circuits Using Inventive Topologies and Semiconductors (CIRCUITS)	19	$27
	Creating Innovative and Reliable Circuits Using Inventive Topologies and Semiconductors Small Business Innovation Research / Small Business Technology Transfer (CIRCUITS SBIR / STTR)	2	$4
	Macroalgae Research Inspiring Novel Energy Resources (MARINER)	18	$22
FY2017 FOA / FY 2018 Project Selection	Saving Energy Nationwide in Structures with Occupancy Recognition (SENSOR)	11	$15
	Saving Energy Nationwide in Structures with Occupancy Recognition Small Business Innovation Research / Small Business Technology Transfer (SENSOR SBIR / STTR)	4	$5
	Innovative Natural-gas Technologies for Efficiency Gain in Reliable and Affordable Thermochemical Electricity-generation (INTEGRATE)	8	$16
	Total To Date	722	$1.9B

IV. ARPA-E Energy Innovation Summit

The eighth annual ARPA-E Energy Innovation Summit took place February 27 to March 1, 2017 at the Gaylord National Convention Center in National Harbor, Maryland. The Summit convened leaders from academia, business, and government to discuss the foremost energy issues, showcased cutting-edge energy technologies, and facilitated relationships to help move technologies towards deployment.

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 energy technologies displayed in the Technology Showcase were demonstrated publicly for the first time.

ARPA-E Energy Innovation Summit Highlights

- Nearly 2,000 registered attendees from 45 states and 16 countries
- Technology Showcase displaying more than 280 breakthrough energy technologies from ARPA-E awardees and other innovative companies
- Panel discussions and networking sessions that enabled participants to meet with ARPA-E program directors, global industry leaders, and energy technologists
- Over 100 expert speakers and keynote addresses, including leaders from government, business, and academia
- Attendance and comments by a bipartisan group of U.S. senators and representatives
- Announcement that as of early 2017, ARPA-E had recognized several notable accomplishments, including:
    - At least 56 ARPA-E project teams have formed new companies to advance their technologies
    - 68 ARPA-E project teams have partnered with other government agencies for further development
    - 74 ARPA-E project teams have attracted more than $1.8 billion in private-sector follow-on funding.

V. Conclusion

In FY 2017, ARPA-E announced project selections for seven focused programs. The programs created through these solicitations cover a wide range of technical areas:[5]

- NEXTCAR: development of new control technologies to reduce the energy consumption of future vehicles by using connectivity and vehicle automation;
- ROOTS: development of new crop breeding approaches for improved root and soil function that will help plants to store more carbon in the ground and absorb nutrients and water more efficiently;
- REFUEL: development of technologies that use renewable energy to convert air and water into cost-competitive liquid fuels;
- ENLITENED: development of innovative components to increase the energy efficiency of datacenters;
- PNDIODES: development of new ways to build semiconductors for high performance, high-powered applications like aerospace, electric vehicles and the grid;
- CIRCUITS: development of innovative electric power converters that save energy;
- MARINER: development of technologies capable of providing economically viable, renewable biomass for energy applications without the need for land, fresh water, and synthetic fertilizers.

As directed by its statutory authorization,[6] ARPA-E entered into a contract with the National Academy of Sciences (NAS) in October 2014 to "conduct an evaluation of how well ARPA-E is achieving the goals and mission of ARPA-E." The NAS report was released in June 2017. It found that ARPA-E "is successfully enhancing the economic and energy security of the United States by funding transformational activities, white space (technology areas that are novel or underexplored and unlikely to be addressed by the private sector or by other federal research programs), and feasibility studies to open up new technological directions and evaluate the technical merit of potential directions."[7]

At the 2017 ARPA-E Energy Innovation Summit, the Agency convened a diverse group of energy experts and industry leaders focused on advancing the next generation of breakthrough energy

[5] The NEXTCAR, ROOTS, REFUEL, and ENLITENED FOAs were released in FY 2016, with project selections announced in FY 2017. The PNDIODES, CIRCUITS, and MARINER FOAs were released in FY 2017, with project selections also announced in FY 2017.

[6] Public Law 110-69, section 5012(k)(2007) as amended, which has been codified as 42 U.S.C. § 16538(l)

[7] The National Academies of Sciences, Engineering, and Medicine. (2017, June 13). *ARPA-E Making Progress Toward Achieving Mission, Says New Assessment* [Press Release]. Retrieved from: http://www8.nationalacademies.org/onpinews/newsitem.aspx?RecordID=24778

technologies. The Summit brought together leaders with unique perspectives, experiences, and ideas with the shared goal of revolutionizing the American approach to energy innovation.

The statutory goals of ARPA-E are to enhance the economic and energy security of the United States through the development of technologies that reduce imports of energy from foreign sources, reduce energy-related emissions, and improve energy efficiency across all sectors of the U.S. economy; and to ensure the United States maintains a technological lead in the development and deployment of advanced energy technologies.

In FY 2017, ARPA-E program directors provided awardees with technical guidance and developed new programs by engaging diverse communities to identify gaps where ARPA-E funding 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 business information to equip awardees with a clear understanding of market needs to guide technical development.

VI. Appendix I: Projects Selected in FY 2017

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
NEXTCAR	General Motors	InfoRich VD&PT Controls	Detroit, MI	$4,199,999
NEXTCAR	University of Delaware	Simultaneous Optimization of Vehicle and Powertrain Operation Using Connectivity and Automation	Newark, DE	$3,357,191
NEXTCAR	University of California, Riverside	An Innovative Vehicle-Powertrain Eco-Operation System for Efficient Plug-in Hybrid Electric Buses	Riverside, CA	$2,799,999
NEXTCAR	Purdue University	High-Efficiency Control System for Connected and Automated Class 8 Trucks	West Lafayette, IN	$4,770,000
NEXTCAR	University of Michigan	Integrated Power and Thermal Management for Connected and Automated Vehicles (iPTM-CAV) through Real-Time Adaptation and Optimization	Ann Arbor, MI	$1,600,000
NEXTCAR	Pennsylvania State University	Maximizing Vehicle Fuel Economy through the Real-Time, Collaborative, and Predictive Co-Optimization of Routing, Speed, and Powertrain Control	University Park, PA	$3,000,000
NEXTCAR	Ohio State University	Fuel Economy Optimization with Dynamic Skip Fire in a Connected Vehicle	Columbus, OH	$4,999,211
NEXTCAR	Southwest Research Institute	Model Predictive Control for Energy-Efficient Maneuvering of Connected Autonomous Vehicles	San Antonio, TX	$2,899,934
NEXTCAR	Michigan Technological University	Connected and Automated Control for Vehicle Dynamics and Powertrain Operation on a Light-Duty Multi-Mode Hybrid Electric Vehicle	Houghton, MI	$2,801,389
NEXTCAR	University of California, Berkeley	Predictive Data-Driven Vehicle Dynamics and Powertrain Control: from ECU to the Cloud	Berkeley, CA	$3,329,716

NEXTCAR	University of Minnesota	Cloud Connected Delivery Vehicles: Boosting Fuel Economy using Physics-Aware Spatiotemporal Data Analytics and Realtime Powertrain Control	Minneapolis, MN	$1,399,999
ROOTS	Lawrence Berkeley National Laboratory	Integrated Imaging and Modeling Toolbox for Accelerated Development of Root-focused Crops at Field Scales	Berkeley, CA	$2,299,999
ROOTS	UHV Technologies, Inc.	Low Cost X-Ray CT System for in-situ Imaging of Roots	Lexington, KY	$2,000,000
ROOTS	University of Florida	Rays for Roots – Integrating Backscatter X-Ray Phenotyping, Modelling, and Genetics to Increase Carbon Sequestration	Gainesville, FL	$6,359,996
ROOTS	Texas A&M University	A Field-Deployable Magnetic Resonance Imaging Rhizotron for Modeling and Enhancing Root Growth and Biogeochemical Function	College Station, TX	$3,068,969
ROOTS	Stanford University	Thermoacoustic Root Imaging, Biomass Analysis, and Characterization	Stanford, CA	$2,000,000
ROOTS	Pennsylvania State University	DEEPER: An Integrated Phenotyping Platform for Deeper Roots	University Park, PA	$7,000,000
ROOTS	Sandia National Laboratory	Multi-Modal Monitoring of Plant Roots for Drought & Heat Tolerance in the US Southwest	Albuquerque, NM	$2,399,952
ROOTS	Lawrence Berkeley National Laboratory	Associated Particle Imaging (API) for Non-invasive Determination of Carbon Distribution in Soil	Berkeley, CA	$2,299,999
ROOTS	Iowa State University	High-throughput, High-resolution Phenotyping of Nitrogen Use Efficiency Using Coupled In-plant and In-soil Sensors	Ames, IA	$1,099,513
ROOTS	Colorado State University	Root Genetics in the Field to Understand Drought Adaptation and Carbon Sequestration	Fort Collins, CO	$6,019,238
REFUEL	Giner Inc.	High-Efficiency Ammonia Production from Water and Nitrogen	Newton, MA	$1,499,186

REFUEL	Sustainable Innovations LLC	Electricity From an Energy-Dense Carbon-Neutral Energy Carrier	East Hartford, CT	$1,200,000
REFUEL	FuelCell Energy, Inc.	Protonic Ceramics for Energy Storage and Electricity Generation with Ammonia	Danbury, CT	$3,100,000
REFUEL	Molecule Works Inc.	Novel Electrochemical Membrane Reactor for Synthesis of Ammonia from Air and Water at Low Temperature and Low Pressure	Richland, WA	$2,300,000
REFUEL	Opus 12 Incorporated	Renewable Electricity-Powered Carbon Dioxide Conversion to Ethanol for Storage and Transportation	Berkeley, CA	$1,903,255
REFUEL	Wichita State University	Alkaline Membrane-Based Ammonia Electrosynthesis with High Efficiency for Renewable and Scalable Liquid-Fuel Production	Wichita, KS	$855,000
REFUEL	Chemtronergy, LLC.	Cost-effective, Intermediate-temperature Fuel Cell for Carbon-free Power Generation	Salt Lake City, UT	$1,099,999
REFUEL	Gas Technology Institute	A Novel Catalytic Membrane Reactor for DME Synthesis from Renewable Resources	Des Plaines, IL	$2,300,000
REFUEL	Bettergy Corp.	Low Temperature Ammonia Cracking Membrane Reactor for Hydrogen Generation	Peekskill, NY	$1,524,606
REFUEL	West Virginia University Research Corporation	Renewable Energy to Fuels Through Microwave-Plasma Catalytic Synthesis of Ammonia	Morgantown, WV	$1,250,000
REFUEL	Research Triangle Institute	Innovative Renewable Energy-based Catalytic Ammonia Production	Research Triangle Park, NC	$3,111,904
REFUEL	SAFCell, Inc.	Distributed Electrochemical Production and Conversion of Carbon-Neutral Ammonia	Pasadena, CA	$3,000,000
REFUEL	University of Delaware	Direct Ammonia Fuel Cells for Transport Applications	Newark, DE	$2,500,000
REFUEL	Rensselaer Polytechnic Institute	A Novel Hollow Fiber Membrane Reactor for High Purity Hydrogen Generation from Thermal Catalytic Ammonia Decomposition	Troy, NY	$1,599,999
REFUEL	University of Minnesota	Small Scale Ammonia Synthesis Using Stranded Wind Energy	Minneapolis, MN	$2,900,000

REFUEL	Storagenergy Technologies, Inc.	High Rate Ammonia Synthesis by Intermediate Temperature Solid-State Alkaline Electrolyzer	Salt Lake City, UT	$2,523,547
ENLITENED	Columbia University	PINE: Photonic Integrated Networked Energy efficient Datacenters	New York, NY	$3,900,000
ENLITENED	University of California, Santa Barbara	Intelligent Reduction of Energy through Photonic Integration for Datacenters (INTREPID)	Santa Barbara, CA	$4,400,000
ENLITENED	University of California, Berkeley	IceNet for FireBox	Berkeley, CA	$2,000,000
ENLITENED	IBM T. J. Watson Research Center	Optical Network using Rapid Amplified Multi-wavelength Photonic Switches (ONRAMPS)	Yorktown Heights, NY	$2,424,000
ENLITENED	Ayar Labs, Inc.	LytBit: An In-Rack Optical Communications System	San Francisco, CA	$1,999,999
ENLITENED	Massachusetts Institute of Technology	Seamless Hybrid-integrated Interconnect NEtwork (SHINE)	Cambridge, MA	$1,258,661
ENLITENED	IBM T. J. Watson Research Center	Multi-Wavelength Optical Transceivers Integrated on Node	Yorktown Heights, NY	$3,382,954
ENLITENED	University of Southern California	System Testbed, Evaluation, and Architecture Metrics: STEAM	Los Angeles, CA	$1,000,000
ENLITENED	University of California, San Diego	LEED: A Lightwave Energy-Efficient Datacenter	La Jolla, CA	$3,800,000
PNDIODES	Adroit Materials Inc.	Selective Area Doping for Nitride Power Devices	Raleigh, NC	$700,000
PNDIODES	Arizona State University	Effective Selective Area Doping for GaN Vertical Power Transistors Enabled by Innovative Materials Engineering	Tempe, AZ	$1,499,989
PNDIODES	The Research Foundation for State University of New York, on behalf of SUNY Polytechnic Institute	Demonstration of PN-junctions by Implant and Growth techniques for GaN	Albany, NY	$720,000
PNDIODES	JR2J, LLC	Laser Spike Anneal Technology for the Activation of Implanted Dopants in Gallium Nitride	Ithaca, NY	$647,749
PNDIODES	Sandia National Laboratory	High Voltage Re-grown GaN P-N Diodes Enabled by Defect and Doping Control	Albuquerque, NM	$1,894,700

PNDIODES	University of Missouri	High quality GaN FETs through Transmutation Doping and Low Temperature Processing	Columbia, MO	$249,999
PNDIODES	Yale University	Regrowth and Selective Area Growth of GaN for Vertical Power Electronics	New Haven, CT	$1,149,999
CIRCUITS[8]	Cree Fayetteville, Inc.	Smart, Compact, Efficient 500kW DC Fast Charger	Fayetteville, AR	$1,911,984
CIRCUITS	Eaton Corporation	SiC-Based Wireless Power Transformation for Data Centers & Medium-Voltage Applications	Menomonee Falls, WI	$1,988,270
CIRCUITS	Empower Semiconductor	Resonant Voltage Regulator Architecture Eliminates 30-50% Energy Consumption of Digital ICs	Fremont, CA	$986,000
CIRCUITS	Georgia Institute of Technology	Grid-Connected Modular Soft-Switching Solid State Transformers	Atlanta, GA	$1,519,636
CIRCUITS	Illinois Institute of Technology	Wide Bandgap Solid State Circuit Breakers for AC and DC Microgrids	Chicago, IL	$418,688
CIRCUITS	Imagen Energy LLC	1200 V SiC Based Extremely Compact, 500 kW, 2000 Hz Inverter for High Speed Permanent Magnet Synchronous Machine (PMSM) Applications	New Berlin, WI	$847,888
CIRCUITS	Infineon Technologies Americas Corp.	Low Cost e-mode GaN HEMT Gate Driver IC: Enables Revolutionary Energy Savings in Variable Speed Drives for Appliance Motors	El Segundo, CA	$924,392
CIRCUITS	Marquette University	Advanced Parallel Resonant 1MHz, 1MW, Three Phase AC to DC Ultra-Fast EV Charger	Milwaukee, WI	$632,437
CIRCUITS	Northeastern University	A Universal Converter for DC, Single-phase AC, and Multi-phase AC Systems	Boston, MA	$628,205
CIRCUITS	Opcondys, Inc.	A Bidirectional, Transformerless Converter Topology for Grid-tied Energy Storage Systems	Manteca, CA	$3,061,449

[8] CIRCUITS and MARINER funding levels reflect information at the time of selection. Final number of projects and funding amounts are subject to change based on award negotiations.

CIRCUITS	Teledyne Scientific Company	SiC-Based Direct AC-AC Power Converter for Motor Drives	Thousand Oaks, CA	$1,602,275
CIRCUITS	United Technologies Research Center	Power Conversion Through Novel Current Source Matrix Converter (MxC)	East Hartford, CT	$1,899,939
CIRCUITS	United Technologies Research Center	Ultra-dense Power Converters for Advanced Electrical Systems	East Hartford, CT	$1,583,576
CIRCUITS	University of Arkansas	Reliable, High Power Density Inverters for Heavy Equipment Applications	Fayetteville, AR	$2,163,630
CIRCUITS	University of Colorado, Boulder	A High-voltage, High-reliability Scalable Architecture for Electric Vehicle Power Electronics	Boulder, CO	$2,430,591
CIRCUITS	University of Illinois at Chicago	Universal Battery Supercharger	Chicago, IL	$1,047,719
CIRCUITS	University of Illinois at Urbana-Champaign	Enabling Ultra-compact, Lightweight, Efficient, and Reliable 6.6 kW On-board Bi-directional Electric Vehicle Charging with Advanced Topology and Control	Champaign, IL	$1,737,545
CIRCUITS	University of Illinois at Urbana-Champaign	Extreme Efficiency 240 VAC to Load Data Center Power Delivery Topologies and Control	Champaign, IL	$780,926
CIRCUITS	University of Wisconsin-Madison	WBG-Enabled Current-Source Inverters for Integrated PM Machine Drives	Madison, WI	$1,031,315
CIRCUITS	Virginia Polytechnic Institute and State University	High Power Density 10-kV SiC-MOSFET-based Modular, Scalable Power Converters for Medium-voltage Applications	Blacksburg, VA	$2,344,467
CIRCUITS	Virginia Polytechnic Institute and State University	Single DC Source Based Cascaded Multilevel Inverter	Blacksburg, VA	$1,048,939
MARINER	Catalina Sea Ranch	Design of Large Scale Macroalgae Systems	San Pedro, CA	$449,772
MARINER	Fearless Fund	Ocean Energy from Macroalgae (OEM): Ranching Sargassum	Washington, DC	$500,000
MARINER	Kampachi Farms, LLC	Blue Fields: Single Point Mooring Array for High-Yield Macroalgae Culture	Kailua-Kona, HI	$500,000

MARINER	Marine Biological Laboratory	Development of Techniques for Tropical Seaweed Cultivation	Woods Hole, MA	$500,000
MARINER	Pacific Northwest National Laboratory	Nautical Offshore Macroalgal Autonomous Device (NOMAD)	Richland, WA	$500,000
MARINER	Trophic, LLC	Continuous, High-Yield Kelp Production	Albany, CA	$500,000
MARINER	University of Southern Mississippi	AdjustaDepth – Adjustable Depth Seaweed Growth System	Hattiesburg, MS	$500,000
MARINER	University of Southern Mississippi	SeaweedPaddock Pelagic Sargassum Ranching	Hattiesburg, MS	$500,000
MARINER	University of Alaska Fairbanks	Development of Scalable Coastal & Offshore Macroalgal Farming	Fairbanks, AK	$500,000
MARINER	C.A. Goudey and Associates	Autonomous Tow Vessels for Offshore Macroalgae Farming	Newburyport, MA	$406,549
MARINER	Makai Ocean Engineering, Inc.	Modeling the Performance and Impact of Macroalgae Farming	Honolulu, HI	$995,978
MARINER	Pacific Northwest National Laboratory	Multi-resolution, Multi-scale Modeling for Scalable Macroalgae Production	Richland, WA	$2,025,986
MARINER	University of California, Irvine	MacroAlgae Cultivation MODeling System (MACMODS)	Irvine, CA	$1,815,529
MARINER	University of New England	Validated, Finite Element Modeling Tool for Hydrodynamic Loading and Structural Analysis of OceanDeployed Farms	Biddeford, ME	$1,321,039
MARINER	University of California, Santa Barbara	Scalable Aquaculture Monitoring System (SAMS)	Santa Barbara, CA	$2,003,894
MARINER	Woods Hole Oceanographic Institution	Integrated Monitoring of Macroalgae Farms Using Acoustics and UUV Sensing	Woods Hole, MA	$2,063,170
MARINER	University of Wisconsin-Milwaukee	Genome-wide Association Studies for Breeding M. Pyrifera	Milwaukee, WI	$2,820,128
MARINER	Woods Hole Oceanographic Institution	Integrated Seaweed Hatchery and Selective Breeding Technologies for Scalable Offshore Seaweed Farming	Woods Hole, MA	$3,704,276