U.S. DEPARTMENT OF ENERGY

Advanced Research Projects Agency-Energy Annual Report for FY 2019

Report to Congress
June 2021

United States Department of Energy
Washington, DC 20585

Message from the Acting 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 the strategic guidance necessary to effectively prepare for the deployment of developed technologies.

In Fiscal Year 2019, the Department continued developing a diverse portfolio of advanced energy technologies. We issued three funding opportunity announcements (FOAs) including one to accelerate the incorporation of machine learning and artificial intelligence into energy technology and product design processes (DIFFERENTIATE). The Department announced projects ranging from developing new technologies for floating, offshore wind turbines using the discipline of control co-design (ATLANTIS) to developing new approaches and technologies for the design and manufacture of high temperature, high pressure, and highly compact heat exchangers and components (HITEMMP).

This report is being provided to:

- **The Honorable Joe Manchin III**
  Chairman, Senate Committee on Energy and Natural Resources

- **The Honorable John Barrasso**
  Ranking Member, Senate Committee on Energy and Natural Resources

- **The Honorable Mazie K. Hirono**
  Chair, Subcommittee on Energy
  Senate Committee on Energy and Natural Resources

- **The Honorable John Hoeven**
  Ranking Member, Subcommittee on Energy
  Senate Committee on Energy and Natural Resources

- **The Honorable Frank Pallone, Jr.**
  Chairman, House Committee on Energy and Commerce

- **The Honorable Cathy McMorris Rodgers**
  Ranking Member, House Committee on Energy and Commerce

- **The Honorable Eddie Bernice Johnson**
  Chairwoman, House Committee on Science, Space, and Technology

- **The Honorable Frank Lucas**
  Ranking Member, House Committee on Science, Space, and Technology

- **The Honorable Jamaal Bowman**
  Chair, Subcommittee on Energy
  House Committee on Science, Space, and Technology

- **The Honorable Randy Weber**
  Ranking Member, Subcommittee on Energy
  House Committee on Science, Space, and Technology

- **The Honorable Patrick Leahy**
  Chairman, Senate Committee on Appropriations

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

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

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

- **The Honorable Rosa DeLauro**
  Chairwoman, House Committee on Appropriations

- **The Honorable Kay Granger**
  Ranking Member, House Committee on Appropriations

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

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

If you have questions or need additional information, please contact me or Ms. Katie Donley, Deputy Director of External Affairs, Office of the Chief Financial Officer, at 202-586-0176, Ms. Elizabeth Noll, Deputy Assistant Secretary for House Affairs or Ms. Rebecca Ward, Legislative Advisor, Office of Congressional and Intergovernmental Affairs, at 202-586-5450.

Sincerely,

Dr. Jennifer Gerbi
Deputy Director for Technology and Acting Director
Advanced Research Projects Agency-Energy

Executive Summary

The Advanced Research Projects Agency-Energy (ARPA-E) funds technologies that have the potential to change the way to 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 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. Each year, ARPA-E thoroughly reviews all applications and technologies so that funding is provided to areas not likely to be undertaken by industry, Federal agencies, or other DOE applied research and development.

This report summarizes ARPA-E's activities during Fiscal Year (FY) 2019. The first program for which projects were selected, across 13 technical areas, was the OPEN 2018 program for over $200 million (the approximate equivalent of six focused programs). In FY 2019[1], ARPA-E selected projects across ***five*** programs covering a broad array of energy technologies:

- $202.8 million to support some of America's top energy innovator's R&D projects as these innovators seek to develop technologies to transform the nation's energy system (OPEN 2018 and related OPEN+ cohorts).[2]
- $29.2 million to develop new approaches and technologies for the design and manufacture of high temperature, high pressure, and highly compact heat exchangers and components (HITEMMP);

[1] The OPEN 2018 (and related OPEN+ cohorts), BREAKERS, and HITEMMP FOAs were released in FY 2018, with project selections announced in FY 2019. The ATLANTIS FOA was released in FY 2019, with project selections also announced in FY 2019. Funding levels shown on pages iv - 13 (inclusive) are as of the date 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). This report includes all FY 2019 programs and projects selected as of March 2020.

[2] In 2018, ARPA-E announced the fourth edition of its OPEN funding solicitation, inviting innovators to send their ideas for disruptive new technologies across the full spectrum of energy applications. While evaluating the thousands of concepts papers submitted, ARPA-E noticed themes emerging around specific technology challenges. The OPEN+ cohorts unite these similarly-themed projects. ARPA-E announced a total of 8 OPEN+ cohorts throughout late 2018 and early 2019. The total sum of $202.8 million includes $122.4 million dollars for the OPEN 2018 program, plus $80.4 million for 8 OPEN+ cohorts. The eight OPEN+ cohorts covered the technology areas of: nuclear, concrete, methane, energy-water technologies, sensors for bioenergy and agriculture, kilovolt devices, data-driven grid, and high-temperature devices.

- $21.1 million to find new ways to harness medium-voltage electricity for application in industry, transportation, on the grid and beyond (BREAKERS);
- $38.0 million to explore new areas of technology (Solicitation on Topics Informing New Program Areas),[3] such as High-Value Methane Pyrolysis, and Downhole Tools to Enable Enhanced Geothermal Systems;[4]
- $26.2 million to develop new technologies for floating, offshore wind turbines using the discipline of control co-design (ATLANTIS).

ARPA-E released two additional funding opportunities in FY 2019 with project selections that were ultimately announced in FY 2020:

- $15.0 million to accelerate the incorporation of machine learning and artificial intelligence into the energy and technology and product design processes (DIFFERENTIATE);
- $13.3 million to explore new areas of technology (Solicitation on Topics Informing New Program Areas), such as High-Value Methane Pyrolysis, and Downhole Tools to Enable Enhanced Geothermal Systems.[5]

In addition to these new programs, ARPA-E hosted the tenth annual Energy Innovation Summit from July 8 to July 11 of 2019. 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 toward deployment. The event drew nearly 1,700 attendees and featured more than 100 speakers and keynote addresses.

According to ARPA-E, as of February 2020, the program had formed 82 companies through its projects, 219 were further developed in partnership with other government agencies for further development, and an increasing number of technologies have been incorporated into

[3] In 2019, ARPA-E announced an ongoing funding opportunity exploring research and development technology areas in the energy technology spectrum that could lead to the development of new ARPA-E program spaces. Thirty-three projects across six topics (Topic A, Extremely Durable Concretes and Cementitious Materials; Topic B, Leveraging Innovations Supporting Nuclear Energy; Topic C, Downhole Tools to Enable Enhanced Geothermal Systems; Topic D, Diagnostic Resource Teams to support the Validation of Potentially Transformative Fusion-Energy Concepts; Topic E, Quantification of Effectiveness of Nutrient Bioextraction by Seaweed; and Topic F, High-Value Methane Pyrolysis) were selected in FY 2019.

[4] This amount is for the Solicitation on Topics Informing New Program Areas funding announcement, Topic H, Establishing Validation Sites for Field-Level Emissions Quantification of Agricultural bioenergy Feedstock Production (SmartFarm).

[5] This amount is for the Solicitation on Topics Informing New Program Areas funding announcement, Topic H, Establishing Validation Sites for Field-Level Emissions Quantification of Agricultural bioenergy Feedstock Production (SmartFarm).

products sold in the market. Additionally, 161 ARPA-E project teams have attracted more than $3.2 billion in private-sector subsequent funding.

In FY 2019, 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 2019

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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. Each year, ARPA-E thoroughly reviews all applications and technologies so that funding is provided to areas not currently undertaken by industry, Federal agencies, or other DOE applied research and development.

II. Fiscal Year 2019 Appropriation

The Consolidated Appropriations Act, 2018 (P.L. 115-141) included $366 million in FY 2019 funds for ARPA-E.

III. Funding Opportunity Announcements (FOAs)

In FY 2019, ARPA-E released three FOAs[6] designed to advance innovative energy technologies in specific program areas.

Project selections for two of these FOAs[7], as well as three FOAs[8] released in FY 2018, were announced in FY 2019. Selections for two FY 2019 FOAs[9] occurred in FY 2020. The technology programs created by these solicitations provide a unique bridge from basic science to early-stage technology. This approach draws from the latest scientific discoveries and assists in creating a viable path to commercial implementation through firm grounding in the economic realities and changing dynamics of the marketplace.

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[6] Solicitation on Topics Informing New Program Areas (Topics A-F, Topic H), ATLANTIS, and DIFFERENTIATE FOAs were released in FY 2019.
[7] ATLANTIS and Solicitation on Topics Informing New Program Areas (Topics A-F)
[8] OPEN 2018 and related OPEN+ cohorts, HITEMMP, and BREAKERS
[9] Solicitation on Topics Informing New Program Areas (Topic H) and DIFFERENTIATE

TABLE 1: Summary of ARPA-E FOAs Released and/or Awarded in FY 2019[2]						
Program	**FOA Issuance**	**FOA Issuance FY**	**Project Selection**	**Project Selection FY**	**Number of Projects**	**Funding Amount ($ Million)**[10]
OPEN 2018	12/13/2017	FY 2018	11/15/2018	FY 2019	47	$122.4
OPEN+ (Cohort 1: Nuclear)	12/13/2017	FY 2018	12/06/2018	FY 2019	5	$11.7
OPEN+ (Cohort 2: Concrete)	12/13/2017	FY 2018	12/19/2018	FY 2019	3	$6.1
OPEN+ (Cohort 3: Methane)	12/13/2017	FY 2018	12/19/2018	FY 2019	4	$14.4
OPEN+ (Cohort 4: Energy-Water Technologies)	12/13/2017	FY 2018	01/15/2019	FY 2019	3	$5.2
OPEN+ (Cohort 5: Sensors for Bioenergy and Agriculture)	12/13/2017	FY 2018	01/15/2019	FY 2019	4	$6.0
OPEN+ (Cohort 6: Kilovolt Devices)	12/13/2017	FY 2018	02/07/2019	FY 2019	4	$13.7
OPEN+ (Cohort 7: Data-Driven Grid)	12/13/2017	FY 2018	02/14/2019	FY 2019	4	$14.6
OPEN+ (Cohort 8: High Temperature Devices)	12/13/2017	FY 2018	03/22/2019	FY 2019	3	$8.7
HITEMMP	8/9/2018	FY 2018	3/22/2019	FY 2019	15	$29.2
BREAKERS	9/12/2018	FY 2018	2/6/2019	FY 2019	8	$21.1
Solicitation on Topics Informing New Program Areas[11] **(Topic A)**	12/20/2018	FY 2019	05/09/2019	FY 2019	12	$14.1

[10] Funding levels shown in this chart are as of the date 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).

[11] The Solicitation on Topics Informing New Program Areas is a Funding Opportunity Announcement (FOA) consisting of seven topic area cohorts (Topic A, Extremely Durable Concretes and Cementitious Materials; Topic B, Leveraging Innovations Supporting Nuclear Energy; Topic C, Downhole Tools to Enable Enhanced Geothermal Systems; Topic D, Diagnostic Resource Teams to support the Validation of Potentially Transformative Fusion-Energy Concepts; Topic E, Quantification of Effectiveness of Nutrient Bioextraction by Seaweed; Topic F, High-Value Methane Pyrolysis; and Topic H, Establishing Validation Sites for Field-Level Emissions Quantification of Agricultural Bioenergy Feedstock Production (SmartFarm). Topics A-E were selected in FY 2019 and Topic F was selected in FY 2020.

TABLE 1: Summary of ARPA-E FOAs Released and/or Awarded in FY 2019[2]						
Program	**FOA Issuance**	**FOA Issuance FY**	**Project Selection**	**Project Selection FY**	**Number of Projects**	**Funding Amount ($ Million)**[10]
Solicitation on Topics Informing New Program Areas (Topic B)	12/20/2018	FY 2019	05/30/2019	FY 2019	4	$7.5
Solicitation on Topics Informing New Program Areas (Topic C)	12/20/2018	FY 2019	05/15/2019	FY 2019	2	$2.0
ATLANTIS	2/01/2019	FY 2019	05/30/2019	FY 2019	13	$26.2
Solicitation on Topics Informing New Program Areas (Topic D)	02/13/2019	FY 2019	07/03/2019	FY 2019	7	$6.8
Solicitation on Topics Informing New Program Areas (Topic E)	03/12/2019	FY 2019	07/24/2019	FY 2019	4	$1.2
Solicitation on Topics Informing New Program Areas (Topic F)	05/26/2019	FY 2019	09/26/2019	FY 2019	4	$6.4
DIFFERENTIATE	4/05/2019	FY 2019	11/19/2019	FY 2020	23	$15.0
Solicitation on Topics Informing New Program Areas (Topic H)	09/19/2019	FY 2019	01/09/2020	FY 2020	5	$13.3
Total (Projects Selected)					**174**	**$345.6**

Summary of FY 2019 Project Selections

In FY 2019, selections were announced for 146 projects across five programs:

From November 15, 2018 through March 22, 2019, ARPA-E announced that 77 projects were selected to receive $202.8 million for **OPEN 2018 and its 8 related OPEN+ cohorts**.

On March 22, 2019, ARPA-E announced that 15 projects were selected to receive $29.2 million for **HITEMMP** *(High Intensity Thermal Exchange through Materials and Manufacturing Processes).*

On February 6, 2019, ARPA-E announced that eight projects were selected to receive $21.1 million for **BREAKERS** *(Building Reliable Electronics to Achieve Kilovolt Effective Ratings Safely).*

From May 9 through September 26, 2019, ARPA-E announced that 33 projects were selected to receive $38 million for **Solicitation on Topics Informing New Program Areas (Topics A – F)**.

On May 30, 2019, ARPA-E announced that 13 projects were selected to receive $26.2 million for **ATLANTIS** *(Aerodynamic Turbines Lighter and Afloat with Nautical Technologies and Integrated Servo-control).*

Summary of FY 2020 Project Selections for FOAs Announced in FY 2019

In FY 2019 ARPA-E issued solicitations for two programs with 28 project selections announced in FY 2020:

On November 19, 2019, ARPA-E announced that 23 projects were selected to receive $15.0 million for **DIFFERENTIATE** *(Design Intelligence Fostering Formidable Energy Reduction and Enabling Numerous Totally Impactful Advanced Technology Enhancements)*. The FOA was issued on April 5, 2019.

On January 9, 2020, ARPA-E announced that five projects were selected to receive $13.3 million for **Solicitation on Topics Informing New Program Areas (Topic H).** The FOA was issued on September 19, 2019.

Details on the FY 2019 Project Selections
The details of the focused programs with project selections announced during FY 2019 are:[12]

OPEN 2018 and related OPEN+ Cohorts ($202.8 million)
In 2018, ARPA-E issued its fourth open funding opportunity, designed to catalyze transformational breakthroughs across the entire spectrum of energy technologies. ARPA-E received thousands of concept papers for OPEN 2018, which hundreds of scientists and engineers reviewed over the course of several months. ARPA-E selected 47 projects for its OPEN 2018 program, and awarded $122.4 million in federal funding to the projects. OPEN 2018 projects cut across ten technology areas: building efficiency, distributed generation, electrical efficiency, grid, grid storage, manufacturing efficiency, resource efficiency, transportation fuels, transportation energy conversion, and transportation vehicles.

After announcing its OPEN 2018 project selections, ARPA-E unveiled its selection of mini programs, called OPEN+ cohorts. These cohorts were inspired by the high-quality applications DOE received as a result of the OPEN 2018 solicitation and unite similarly themed projects.

[12] Project counts and funding amounts on pages iv - 13 (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).

ARPA-E announced a total of eight OPEN+ cohorts from late 2018 through early 2019 representing the technology areas of: nuclear, concrete, methane, energy-water technologies, sensors for bioenergy and agriculture, kilovolt devices, data-driven grid, and high-temperature devices.

Example OPEN 2018 Project: AltaRock Energy – "Millimeter-Wave Technology Demonstration for Geothermal Direct Energy Drilling" – Seattle, WA ($3.8 million).
AltaRock Energy will overcome technical limitations to deep geothermal drilling by replacing mechanical methods with a Millimeter Wave (MMW)—directed energy technology to melt and vaporize rocks for removal. This approach could increase drilling speed by 10 times or more, reducing costs while reaching higher temperatures and greater depths than those achievable with the best current and proposed mechanical technologies. Project R&D will include benchtop testing as well as larger scale demonstrations of directed MMW drilling at unprecedented borehole lengths and power levels. A detailed modeling and simulations campaign carried out with the experimental work will provide the basis for the design of larger, commercial-scale systems.

Example OPEN+ (Cohort 1) Project: Carnegie Mellon University – "Additive Manufacturing of Spacer Grids for Nuclear Reactors" – Pittsburgh, PA ($1 million).
Carnegie Mellon will combine its expertise in additive manufacturing (AM) with Westinghouse's know-how in nuclear reactor component fabrication to develop a novel design and AM process for nuclear reactor spacer grids. Spacer grids are used to provide mechanical support to nuclear fuel rods within a reactor and reduce vibration, and are a particularly difficult component to manufacture. The team will alter the traditional AM process, including utilizing nonstandard powders to optimize performance and reduce cost. Because of the difficulty of printing spacer grids, the effect would be significant if the team is successful – it could pave the way for other reactor components to be additively manufactured. The ability to cost-effectively manufacture nuclear reactor components using AM could enable the rapid deployment of advanced reactors.

HITEMMP: *High Intensity Thermal Exchange through Materials, and Manufacturing Processes* ($29.2 million)
The projects that comprise ARPA-E's HITEMMP (High Intensity Thermal Exchange through Materials and Manufacturing Processes) program will develop new approaches and technologies for the design and manufacture of high temperature, high pressure, efficient, and highly compact heat exchangers. Heat exchangers are critical to efficient thermal energy exchange in numerous industrial applications and everyday life, with valuable applications in electricity generation, transportation, petrochemical plants, waste heat recovery, and much more. HITEMMP projects target heat exchangers capable of operating for tens of thousands of hours in temperatures and pressures exceeding 800°C and 80 bar (1472°F and1,160 psi,)

respectively. This new class of hardware, designed and manufactured using novel techniques, topologies, and materials, would facilitate far greater exchanger efficiency, boosting the performance of many important industrial processes.

Example HITEMMP Project: General Electric – "Ultra Performance Heat Exchanger Enabled by Additive Technology (UPHEAT)" – Fairfield, CT ($2.5 million).
The GE-led team will develop a metallic-based, ultra-performance heat exchanger enabled by additive manufacturing technology and capable of operation at 900°C (1652°F) and 250 bar (3626 psi). The team will optimize heat transfer versus thermomechanical load using new micro-trifurcating core structures and manifold designs. The team will leverage a novel, high-temperature capable, crack-resistant nickel superalloy, designed specifically for additive manufacturing. When completed, the heat exchanger could facilitate increased thermal efficiency of indirect heated power cycles such as supercritical carbon dioxide (sCO_2) Brayton power generation, reducing energy consumption and emissions.

BREAKERS: *Building Reliable Electronics to Achieve Kilovolt Effective Ratings Safely* ($21 million)
Recent advances in hardware for handling direct current (DC) electricity have created an opportunity to greatly improve the efficiency, security, and safety of the U.S. power system while supporting new industries and grid design options. There remains a significant technology gap in the safety and protection mechanisms required to mitigate potentially damaging faults in these systems. The projects that comprise ARPA-E's BREAKERS (Building Reliable Electronics to Achieve Kilovolt Effective Ratings Safely) program will develop novel technologies for medium voltage direct current (MVDC) circuit breakers, applicable to markets including electrified transportation, MVDC grid distribution, renewable interconnections, and offshore oil, gas, and wind production. Project teams will either develop transformational improvements to conventional DC circuit breakers (i.e., mechanical, solid state, hybrid) or construct circuit breakers based on completely novel designs. These systems must achieve program goals of handling a voltage between 1 - 100 kV DC and power above 1 MW at extremely high efficiencies and fast response times.

Example BREAKERS Project: Georgia Tech Research Corporation – "EDISON – Efficient DC Interrupter with Surge Protection" – Atlanta, GA ($3.3 million).
Georgia Tech is developing a novel hybrid direct current (DC) circuit breaker that could enable multi-terminal DC power systems. The breaker's mechanical switch enables switching speeds 10 times faster than existing technology, severing the mechanical linkage, while the power electronics-based circuit handles the fault current. A new configuration of the fast switch and solid-state devices/circuits will reduce steady-state losses compared with state-of-the-art hybrid circuit breakers. A new control scheme dramatically reduces the peak fault current levels, enabling more compact packaging and increasing reliability.

Solicitation on Topics Informing New Program Areas ($38 million)
In 2019, ARPA-E announced an ongoing funding opportunity for a range of the most innovative and unconventional ideas across the energy technology spectrum, exploring high-risk R&D that could lead to the development of disruptive technologies. The topics explored under this opportunity are not part of existing ARPA-E programs, and if successful could establish new program areas for ARPA-E to further explore. Thirty-three projects across six topics (Topic A, Extremely Durable Concretes and Cementitious Materials; Topic B, Leveraging Innovations Supporting Nuclear Energy; Topic C, Downhole Tools to Enable Enhanced Geothermal Systems; Topic D, Diagnostic Resource Teams to support the Validation of Potentially Transformative Fusion-Energy Concepts; Topic E, Quantification of Effectiveness of Nutrient Bioextraction by seaweed; and Topic F, High Value Methane Pyrolysis) were selected in FY 2019.

Example Solicitation on Topics Informing New Program Areas (Topic F) Project: Stanford University – "Co-Synthesis of Hydrogen and High-Value Carbon Products from Methane Pyrolysis" – Stanford, CA ($1.4 million).
Stanford University will design a process for catalytic pyrolysis of methane into high-value carbon nanotubes and hydrogen (H_2) at the low cost goal of $1/kg at large scale, without any carbon dioxide (CO_2) emissions. This project will synthesize high-performance, nano-controlled pyrolysis catalysts with structural features that enable efficient catalyst regeneration and separation of solid crystalline carbon. The carbon nanotubes can be used in a wide range of applications from batteries to carbon-fiber composites. Low-cost, CO_2-free hydrogen can be used to decarbonize multiple large industries such as refinery and petrochemicals, ammonia production, steel, concrete, and transportation.

ATLANTIS: *Aerodynamic Turbines Lighter and Afloat with Nautical Technologies and Integrated Servo-control* ($26 million)
Accessible U.S. offshore wind is estimated at more than 25 quads per year (a quad is one quadrillion BTUs, equivalent to 45 million tons of coal, 1 trillion cubic feet of natural gas, or 170 million barrels of crude oil). Nearly 60 percent of that wind energy--the equivalent of the entire U.S. annual electricity consumption--blows across waters more than 200 feet deep, an area that cannot be economically accessed today. Floating offshore wind turbine (FOWT) technology has tremendous promise to access wind resources in these areas, since the current state of the art for FOWT is too massive and expensive for practical deployment. ATLANTIS seeks to design radically new FOWTs by maximizing their rotor-area-to-total-weight ratio while maintaining or ideally increasing turbine generation efficiency; build a new generation of computer tools to facilitate FOWT design, and collect real data from full and lab-scale experiments to validate the FOWT designs and computer tools. The program encourages the application of control co-design (CCD) methodologies that integrate all relevant engineering disciplines at the start of the design process, with feedback control and dynamic interaction principles as the primary drivers of the design. CCD methodologies enable designers to analyze the interactions of FOWTs' aero-, hydro-, elastic-, electric-, economic-, and servo-system dynamics, and propose solutions that permit optimal FOWT designs not achievable otherwise.

Example ATLANTIS Project: Rutgers University – "Computationally Efficient Control Co-Design Optimization Framework with Mixed-Fidelity Fluid and Structure Analysis" – New Brunswick, NJ ($1.5 million).

Rutgers University will lead a multidisciplinary team in developing a computationally efficient CCD optimization software framework for FOWT design. This effort will focus on developing a high-fidelity modular computational framework for the modeling, optimization, and control of primary structures coupled to the surrounding air, water, and actuator dynamics. The proposed framework will integrate traditional aeroelastic models with higher fidelity simulation tools. This project will yield a modular and open-source framework that will be available to the other ATLANTIS teams to support the broad mission of the program.

Table 2 summarizes ARPA-E's programs to date. A full list of the projects selected during FY 2019 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)[13]**
EXISTING PROGRAMS	OPEN 2009	41	$174.0
	Batteries for Electrical Energy Storage in Transportation (BEEST)	12	$38.0
	Innovative Materials and Processes for Advanced Carbon Capture Technologies (IMPACCT)	15	$40.0
	Electrofuels	13	$48.0
	Agile Delivery of Electrical Power Technology (ADEPT)	14	$38.0
	Building Energy Efficiency Through Innovative Thermodevices (BEETIT)	17	$38.0
	Grid-Scale Rampable Intermittent Dispatchable Storage (GRIDS)	15	$40.0
	Plants Engineered To Replace Oil (PETRO)	10	$56.0
	High Energy Advanced Thermal Storage (HEATS)	15	$37.0
	Rare Earth Alternatives in Critical Technologies (REACT)	14	$39.0
	Green Electricity Network Integration (GENI)	15	$43.0
	Solar Agile Delivery of Electrical Power Technology (Solar ADEPT)	7	$12.0
	Methane Opportunities for Vehicular Energy (MOVE)	13	$42.0
	Advanced Management and Protection of Energy Storage Devices (AMPED)	15	$34.0
	OPEN 2012	66	$171.0
	Innovative Development in Energy-related Applied Science (IDEAS)	59	$28.0
	Robust Affordable Next Generation Energy Storage Systems (RANGE)	22	$45.0
	Reducing Emissions using Methanotrophic Organisms for Transportation Energy (REMOTE)	16	$48.0
	Modern Electro/Thermochemical Advancements for Light metals Systems (METALS)	19	$45.0
	Full-Spectrum Optimized Conversion and Utilization of Sunlight (FOCUS)	14	$35.0

[13] Funding levels shown in this chart are as of March 2020 unless otherwise stated. OPEN 2018, HITEMMP, Solicitation on Topics Informing New Program Areas, ATLANTIS, DIFFERENTIATE, and BREAKERS 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.

TABLE 2: ARPA-E PROGRAMS TO DATE			
PROGRAM NAME		**NUMBER OF PROJECTS**	**FUNDING AMOUNT ($ Million)[13]**
	Strategies for Wide Bandgap, Inexpensive Transistors for Controlling High Efficiency Systems (SWITCHES) & SBIR/STTR	14	$36.0
	Reliable Electricity Based on Electrochemical Systems (REBELS)	13	$37.0
	Cycling Hardware to Analyze and Ready Grid-Scale Electricity Storage (CHARGES)	2	$6.5
	Delivering Efficient Local Thermal Amenities (DELTA)	11	$32.0
	Methane Observation Networks with Innovative Technology to Obtain Reductions (MONITOR)	12	$39.0
	Accelerating Low-cost Plasma Heating and Assembly (ALPHA)	9	$31.0
	Advanced Research In Dry cooling (ARID)	15	$33.0
	GENerators for Small Electrical and Thermal Systems (GENSETS)	14	$37.0
	Transportation Energy Resources from Renewable Agriculture (TERRA)	6	$38.0
	Traveler Response Architecture using Novel Signaling for Network Efficiency in Transportation (TRANSNET)	5	$15.0
	Micro-scale Optimized Solar-cell Arrays with Integrated Concentration (MOSAIC)	11	$26.0
	OPEN 2015	39	$124.0
	Network Optimized Distributed Energy Systems (NODES)	12	$35.0
	Generating Realistic Information for the Development of Distribution and Transmission Algorithms (GRID DATA)	7	$11.0
	Single-Pane Highly Insulating Efficient Lucid Design (SHIELD)	14	$27.0
	Integration and Optimization of Novel Ion-Conducting Solids (IONICS)	16	$37.0
	Next-Generation Energy Technologies for Connected and Automated On-Road Vehicles (NEXTCAR)	11	$35.0
	Rhizosphere Observations Optimizing Terrestrial Sequestration (ROOTS)	10	$36.0
	Renewable Energy to Fuels Through Utilization of Energy-Dense Liquids (REFUEL)	16	$33.0
	Energy-Efficient Light-Wave Integrated Technology Enabling Networks that Enhance Datacenters (ENLITENED)	9	$25.0
	Power Nitride Doping Innovation Offers Devices Enabling SWITCHES (PNDIODES)	7	$6.9

TABLE 2: ARPA-E PROGRAMS TO DATE			
PROGRAM NAME		**NUMBER OF PROJECTS**	**FUNDING AMOUNT ($ Million)[13]**
	Creating Innovative and Reliable Circuits Using Inventive Topologies and Semiconductors (CIRCUITS)	21	$30.0
	Macroalgae Research Inspiring Novel Energy Resources (MARINER)	18	$22.0
	Saving Energy Nationwide in Structures with Occupancy Recognition (SENSOR)	15	$20.0
	Innovative Natural-gas Technologies for Efficiency Gain in Reliable and Affordable Thermochemical Electricity-generation (INTEGRATE)	8	$16.0
	Modeling-Enhanced Innovations Trailblazing Nuclear Energy Reinvigoration (MEITNER)	6	$14.0
	Duration Addition to electricity Storage (DAYS)	10	$28.0
FY 2018 FOA / FY 2019 SELECTIONS	Building Reliable Electronics to Achieve Kilovolt Effective Ratings Safely (BREAKERS)	8	$21.1
	High Intensity Thermal Exchange through Materials and Manufacturing Processes (HITEMMP)	15	$29.2
	OPEN 2018 (and related OPEN+ cohorts)	77	$202.8
FY 2019	Aerodynamic Turbines Lighter and Afloat with Nautical Technologies and Integrated Servo-control (ATLANTIS)	13	$26.2
	Solicitation on Topics Informing New Program Areas (Topics A-F)	33	$38.0
FY 2019 FOA / FY 2020 SELECTION	Design Intelligence Fostering Formidable Energy Reduction and Enabling Numerous Totally Impactful Advanced Technology Enhancements (DIFFERENTIATE)	23	$15.0
	Solicitation on Topics Informing New Program Areas (Topic H)	5	$13.3
	TOTAL	**917**	**$2,227**

IV. ARPA-E Energy Innovation Summit

The tenth annual ARPA-E Energy Innovation Summit took place July 8-11, 2019, in Denver, Colorado. 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 toward deployment.

Throughout the three-day event, attendees also had the opportunity to explore the Technology Showcase, which featured ARPA-E awardees and a highly select 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 1,700 registered attendees from 47 states and 16 countries
- Technology Showcase displaying nearly 300 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
- More than 100 expert speakers and keynote addresses, including leaders from government, business, and academia

V. Conclusion

In FY 2019, ARPA-E announced project selections for **five** focused programs. The programs created through these solicitations cover a wide range of technical areas:[14]

- OPEN 2018 and related OPEN+ Cohorts: supporting some of America's top energy innovators' R&D projects as these innovators seek to develop technologies to transform the nation's energy system;[15]
- HITEMMP: development of new approaches and technologies for the design and manufacture of high-temperature, high pressure, and highly compact heat exchangers and components;
- BREAKERS: finding new ways to harness medium-voltage electricity for application in industry, transportation, on the grid, and beyond;

[14] OPEN 2018 and its related OPEN+ cohorts, HITEMMP, and BREAKERS FOAs were announced in FY 2018 and selected in FY 2019. ATLANTIS and Topics A – F of the Solicitation on Topics Informing New Program Areas FOAs were announced and selected in FY 2019.

[15] ARPA-E announced a total of eight OPEN+ cohorts throughout late 2018 and early 2019. The eight OPEN+ cohorts covered the technology areas of: nuclear, concrete, methane, energy-water technologies, sensors for bioenergy and agriculture, kilovolt devices, data-driven grid, and high temperature devices.

- Solicitation on Topics Informing New Program Areas: exploring new areas of technology;[16] and
- ATLANTIS: development of new technologies for floating, offshore wind turbines using the discipline of control co-design.

In FY 2019, ARPA-E announced FOAs for **three** focused programs. The programs created through these solicitations cover a wide range of technical areas:

- ATLANTIS: development of new technologies for floating, offshore wind turbines using the discipline of control co-design.
- Solicitation on Topics Informing New Project Areas: exploring new areas of technology;[17] and
- DIFFERENTIATE: accelerating the incorporation of machine learning and artificial intelligence into energy technology and product design processes.

At the 2019 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 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[18] 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, improve energy efficiency across all sectors of the

[16] Thirty-three projects across six topics (Topic A, Extremely Durable Concretes and Cementitious Materials; Topic B, Leveraging Innovations Supporting Nuclear Energy; Topic C, Downhole Tools to Enable Enhanced Geothermal Systems; Topic D, Diagnostic Resource Teams to support the Validation of Potentially Transformative Fusion-Energy Concepts; Topic E, Quantification of Effectiveness of Nutrient Bioextraction by Seaweed; and Topic F, High-Value Methane Pyrolysis) were selected in FY 2019. Topic H, Establishing Validation Sites for Field-Level Emissions Quantification of Agricultural Bioenergy Feedstock Production (SmartFarm), was announced in FY 2019 and selected in FY 2020.

[17] Thirty-four projects across six topics (Topic A, Extremely Durable Concretes and Cementitious Materials; Topic B, Leveraging Innovations Supporting Nuclear Energy; Topic C, Downhole Tools to Enable Enhanced Geothermal Systems; Topic D, Diagnostic Resource Teams to support the Validation of Potentially Transformative Fusion-Energy Concepts; Topic E, Quantification of Effectiveness of Nutrient Bioextraction by Seaweed; and Topic F, High-Value Methane Pyrolysis) were selected in FY 2019. Topic H, Establishing Validation Sites for Field-Level Emissions Quantification of Agricultural Bioenergy Feedstock Production (SmartFarm), was announced in FY 2019 and selected in FY 2020.

[18] 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)

U.S. economy, and maintain the United States' technological lead in the development and deployment of advanced energy technologies.

In FY 2019, 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 2019

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
OPEN 2018	Aquanis, Inc.	Active Aerodynamic Load Control for Wind Turbines	East Greenwich, RI	$3,515,113
OPEN 2018	University of Illinois Urbana-Champaign	Megawatt-Scale Power-Electronic-Integrated Generator with Controlled DC Output	Champaign, IL	$2,056,280
OPEN 2018	Zap Energy, Inc.	Electrode Technology Development for the Sheared-Flow Stabilized Z-Pinch Fusion Reactor	Seattle, WA	$6,767,334
OPEN 2018	3M Company	Passive Radiative Cooling Film	St. Paul, MN	$2,776,899
OPEN 2018	Massachusetts Institute of Technology	CARBONHOUSE: Towards a Carbon Ontology - Ultra Low Footprint Buildings Using Gas-Pyrolysis Hydrocarbons	Cambridge, MA	$3,726,606
OPEN 2018	Arizona State University	Sensor Enabled Modeling of Future Distribution Systems with Distributed Energy Resources	Tempe, AZ	$2,800,000
OPEN 2018	CTFusion, LLC	HIT-TD: Plasma Driver Technology Demonstration for Economical Fusion Power Plants	Seattle, WA	$3,000,000
OPEN 2018	Georgia Tech Research Corporation	Resilient, Cyber Secure Centralized Substation Protection	Atlanta, GA	$2,351,000
OPEN 2018	Princeton Fusion Systems	Novel RF Plasma Heating for Low-Radioactivity Compact Fusion Devices	Plainsboro, NJ	$1,250,000
OPEN 2018	University of Michigan	Overcoming the Technical Challenges of Coordinating Distributed Load Resources at Scale	Ann Arbor, MI	$2,800,000

OPEN 2018	Harvard University	GaN NMR Spectrometer Integrated Circuits towards Broadly Distributed On-line Monitoring and Management of Subsurface Oil/Gas Reservoirs and Downstream	Cambridge, MA	$1,683,819
OPEN 2018	Hewlett Packard Enterprise	Ultra-Energy-Efficient Integrated DWDM (Dense Wavelength Division Multiplexing) Optical Interconnect	Palo Alto, CA	$3,506,711
OPEN 2018	Qromis, Inc.	P-Type Gallium Nitride Doping by Controlled Magnesium Diffusion	Santa Clara, CA	$773,368
OPEN 2018	Sonrisa Research, Inc.	A New Class of SiC Power MOSFETS with Record-Low Resistance	Santa Fe, NM	$1,369,282
OPEN 2018	Stanford University	Exploring the Limits of Cooling for Extreme Heat Flux Applications: Data Centers and Power Electronics	Stanford, CA	$1,302,264
OPEN 2018	State University of New York Polytechnic Institute	Smart SiC Power Integrated Circuits (Scalable, Manufacturable, and Robust Technology for SIC Power Integrated Circuits)	Albany, NY	$2,103,459
OPEN 2018	University of California-Santa Barbara	FRESCO: Frequency Stabilized Coherent Optical Low-energy Wavelength Division Multiplexing (WDM) DC Interconnects	Santa Barbara, CA	$3,750,000
OPEN 2018	University of Colorado Boulder	University of Colorado Boulder	Boulder, CO	$2,500,000
OPEN 2018	Sandia National Laboratories	Transformers for a Modernized Grid	Albuquerque, NM	$1,200,000
OPEN 2018	PingThings, Inc.	A National Infrastructure for Artificial Intelligence on the Grid	El Segundo, CA	$6,250,000
OPEN 2018	Siemens Corporation Corporate Technology	Renew100 - Reliable Power System Operation with 100% Renewable Generation	Princeton, NJ	$3,000,000
OPEN 2018	University of Minnesota	Rapidly Viable Sustained Grid	Twin Cities, MN	$3,864,840
OPEN 2018	University of Wisconsin-Madison	A Persistence Meter for Nimble Alarming Using Ambient Synchrophasor Data	Madison, WI	$648,396

OPEN 2018	Massachusetts Institute of Technology	Thermal Energy Grid Storage (TEGS) Using Multi-Junction Photovoltaics (MPV)	Cambridge, MA	$1,500,000
OPEN 2018	Southwest Research Institute	Grid-Scale Electricity Storage at Lowest Possible Cost: Enabled by Pumped Heat Electricity Storage	San Antonio, TX	$2,000,000
OPEN 2018	Arizona State University	Mining Air for Fuels and Fine Chemicals (MAFF)	Tempe, AZ	$4,733,494
OPEN 2018	Colorado School of Mines	Efficient Hydrogen and Ammonia Production via Process Intensification and Integration	Golden, CO	$2,047,676
OPEN 2018	Otherlab, Inc.	Hydraulically Actuated Near-Isothermal Compressor	San Francisco, CA	$500,000
OPEN 2018	Palo Alto Research Center, Inc.	Palo Alto Research Center, Inc.	Palo Alto Research Center, Inc.	$1,286,018
OPEN 2018	Syzygy Plasmonics, Inc.	Photocatalytic Ammonia Decomposition for Hydrogen Production	Houston, TX	$750,000
OPEN 2018	Via Separations	Scalable Graphene Oxide Membranes for Energy-Efficient Chemical Separations	Cambridge, MA	$2,850,000
OPEN 2018	United Technologies Research Center	SCOTTIE - Systematic Communication Objectives and Telecommunications Technology Investigations and Evaluation	East Hartford, CT	$2,234,134
OPEN 2018	Achates Power, Inc.	Highly Efficient Opposed Piston Engine for Hybrid Vehicles ("HOPE-Hybrid")	San Diego, CA	$2,000,000
OPEN 2018	Advanced Magnet Lab, Inc.	Homopolar Machines Enabled with Brushless Field Electron Emission Current Transfer	Melbourne, FL	$541,184
OPEN 2018	Georgia Tech Research Corporation	High Power Density Compact Drive Integrated Motor for Electric Transportation	Atlanta, GA	$2,982,389
OPEN 2018	Ecolectro, Inc.	Modular Ultrastable Alkaline Exchange Ionomers to Enable High-performance Fuel Cells and Electrolyzer Systems	Ithaca, NY	$1,700,000
OPEN 2018	Ionic Materials, Inc.	Novel Polymer-enhanced Rechargeable Aluminum-Alkaline Battery Technology	Woburn, MA	$2,000,000
OPEN 2018	Lawrence Berkeley National Laboratory	Metal-Supported SOFCs for Ethanol-Fueled Vehicles	Berkeley, CA	$3,170,000

OPEN 2018	Pinnacle Engines	Design and Demonstration of an Electrification-Enabled Full-Featured Opposed Piston 4-Stroke Engine for Hybrid and Range Extender Applications	San Carlos, CA	$8,000,000
OPEN 2018	Sila Nanotechnologies, Inc.	Drop-In Replacement Materials from Abundant Resources to Double Energy in EV Batteries	Alameda, CA	$3,100,000
OPEN 2018	Los Alamos National Laboratory	Stable Diacid Coordinated Quaternary Ammonium Polymers for 80-230 °C Fuel Cells	Los Alamos, NM	$2,900,000
OPEN 2018	University of California, San Diego	Low-Cost, Easy-to-integrate, and Reliable Grid Energy Storage System with 2nd Life Lithium Batteries	La Jolla, CA	$1,894,705
OPEN 2018	University of Delaware	Advanced Alkaline Membrane H_2/Air Fuel Cell System with Novel Technique for Air CO_2 Removal	Newark, DE	$1,979,998
OPEN 2018	Vanderbilt University	Bipolar Membranes with an Electrospun 3D Junction	Nashville, TN	$965,000
OPEN 2018	Kampachi Farms, LLC	KRUMBS–Kyphosid Ruminant Microbial Bioconversion of Seaweeds	Kona, HI	$3,341,894
OPEN 2018	University of Maryland	Superstrong, Low-cost Wood for Lightweight Vehicles	College Park, MD	$3,600,000
OPEN 2018	Supercool Metals, LLC	Thermoplastic Forming of Bulk Metallic Glasses for Energy Efficiency in Transportation	New Haven, CT	$3,323,373
OPEN+ (Cohort 1)	Carnegie Mellon University	Additive Manufacturing of Spacer Grids for Nuclear Reactors	Pittsburgh, PA	$1,000,000
OPEN+ (Cohort 1)	Lawrence Berkeley National Laboratory	MEMS RF Accelerators for Nuclear Energy and Advanced Manufacturing	Berkeley, CA	$3,600,000
OPEN+ (Cohort 1)	Los Alamos National Laboratory	Advanced Manufacturing of Embedded Heat Pipe Nuclear Hybrid Reactor	Los Alamos, NM	$3,552,295
OPEN+ (Cohort 1)	Massachusetts Institute of Technology	Multimetallic Layered Composites (MMLCs) for Rapid, Economical Advanced Reactor Deployment	Cambridge, MA	$1,694,034
OPEN+ (Cohort 1)	University of Wisconsin-Madison	Accelerated Materials Design for Molten Salt Technologies Using Innovative High-Throughput Methods	Madison, WI	$1,861,820

OPEN+ (Cohort 2)	Neuvokas Corporation	Energy Efficient, Incrementally Scalable, Continuous Basalt Fiber Filament-forming Extrusion Bushing	Ahmeek, MI	$2,000,000
OPEN+ (Cohort 2)	Rutgers University	Microbial Curing of Cement for Energy Applications	New Brunswick, NJ	$2,932,154
OPEN+ (Cohort 2)	University of Virginia	Carbonation-Enabled Mineralization to Engender Novel Technology	Charlottesville, VA	$1,186,934
OPEN+ (Cohort 3)	Rice University	Converting Hydrocarbons to Recyclable Materials for Metal Replacement with Positive Hydrogen Output	Houston, TX	$3,300,000
OPEN+ (Cohort 3)	Nanocomp Technologies, Inc.	High Value, Energy Saving Carbon Products and Clean Hydrogen Gas from Methane	Merrimack, NH	$3,479,624
OPEN+ (Cohort 3)	ETCH, Inc.	Carbon Dioxide-Free Hydrogen and Solid Carbon from Natural Gas via Metal Salt Intermediates	Chevy Chase, MD	$3,690,304
OPEN+ (Cohort 3)	Palo Alto Research Center, Inc.	High-Throughput Methane Pyrolysis for Low-Cost Hydrogen	Palo Alto, California	$3,946,542
OPEN+ (Cohort 4)	Columbia University	Expanding the Boundaries of Autotrophic Nitrogen Removal for Energy-Efficient Clean Water Production	New York, NY	$1,620,136
OPEN+ (Cohort 4)	Oregon State University	Freshwater Recovery System for Hydraulic Fracturing (FRESH-Frac) Using a Thermally-Actuated NozzleDemister	Corvallis, OR	$2,972,000
OPEN+ (Cohort 4)	University of Oklahoma	An Innovative Zero-Liquid Discharge Intermediate-Cold-Liquid Eutectic-Freeze Desalination System	Norman, OK	$608,333
OPEN+ (Cohort 5)	Geegah LLC	Integrated Gigahertz Ultrasonic Imager for Soil: Towards Targeted Water and Pesticide Delivery for Biomass Productions	Ithaca, NY	$500,000
OPEN+ (Cohort 5)	Northeastern University	Zero-Power Wireless Infrared Digitizing Sensors for Large Scale Energy-Smart Farm	Boston, MA	$1,630,925
OPEN+ (Cohort 5)	University of Colorado, Boulder	Precision Agriculture using Networks of Degradable Analytical Sensors (PANDAS)	Boulder, CO	$1,690,415

OPEN+ (Cohort 5)	University of Utah	Low-Cost Wireless Chemical Sensor Networks for Early Detection of Invasive Parasitics in Biofuel Crops	Salt Lake City, UT	$2,164,314
OPEN+ (Cohort 6)	GE Global Research	Advanced Medium Voltage SiC-SJ FETs with Ultra-Low On-Resistance	Niskayuna, NY	$3,090,746
OPEN+ (Cohort 6)	The Ohio State University	GaN MOCVD Growth on Native Substrates for High Voltage (15-20 kV) Vertical Power Devices	Columbus, OH	$2,211,712
OPEN+ (Cohort 6)	Sandia National Laboratories	20 kV Gallium Nitride pn Diode Electro-Magnetic Pulse Arrestor for Grid Reliability	Albuquerque, NM	$5,415,000
OPEN+ (Cohort 6)	Virginia Tech	20-kV GaN Switch Technology Demonstrated in High-Efficiency Medium-Voltage Building Block	Blacksburg, VA	$3,000,000
OPEN+ (Cohort 7)	ABB Inc.	Economical Data-fused Grid Edge Processor (EDGEPRO) for Future Distribution Grid Control Applications	Cary, NC	$2,302,897
OPEN+ (Cohort 7)	GridBright, Inc.	Secure Grid Data Exchange Using Cryptography, Peer-to-Peer Networks, and Blockchain Ledgers	Alamo, CA	$2,500,000
OPEN+ (Cohort 7)	Pacific Northwest National Laboratory	High-Performance Adaptive Deep-Reinforcement-Learning-based Real-Time Emergency Control (HADREC) to Enhance Power Grid Resilience in Stochastic Environments	Richland, WA	$3,500,000
OPEN+ (Cohort 7)	PingThings, Inc	A National Infrastructure for Artificial Intelligence on the Grid	El Segundo, CA	$6,250,000
OPEN+ (Cohort 8)	Brayton Energy	Efficient and Low-Cost Brayton Cycle for Residential and Remote Power Applications	Hampton, NH	$1,000,000
OPEN+ (Cohort 8)	Creare, LLC	Closed-Loop 5-kWe Brayton-Cycle Microturbine with 38% Efficiency: Advanced Generator Technology Designed for Inexpensive Mass Production	Hanover, NH	$2,999,901
OPEN+ (Cohort 8)	Pennsylvania State University	Integration of Sensors through Additive Manufacturing Leading to Increased Efficiencies of Gas Turbines for Power Generation and Propulsion	University Park, PA	$4,703,906

HITEMMP	Michigan State University	Heat-Exchanger Intensification through Powder Processing and Enhanced Design (HIPPED)	East Lansing, MI	$2,300,000
HITEMMP	Missouri University of Science and Technology	UHT-CAMANCHE: Ultra-High Temperature Ceramic Additively Manufactured Compact Heat Exchangers	Rolla, MO	$1,457,000
HITEMMP	Michigan Technological University	High-Density SSiC 3D-Printed Lattices for Compact HTHP Aero-Engine Recuperators	Houghton, MI	$1,846,000
HITEMMP	Carnegie Mellon University	High Energy Density Modular Heat Exchangers through Design, Materials Processing, and Manufacturing Innovations	Pittsburgh, PA	$2,400,000
HITEMMP	The Ohio State University	Additively Manufactured High Efficiency and Low-Cost sCO2 Heat Exchangers	Columbus, OH	$1,500,000
HITEMMP	Thar Energy LLC	High Temperature, High Pressure, and High Performance Compact Heat Exchanger –	Pittsburgh, PA	$2,000,000
HITEMMP	Massachusetts Institute of Technology	Multiscale Porous High-Temperature Heat Exchanger Using Ceramic Co-Extrusion	Cambridge, MA	$1,715,000
HITEMMP	University of California-Los Angeles	SHOTEAM: Superalloy Heat Exchangers Optimized For Temperature Extremes and Advanced Manufacturability	Los Angeles, CA	$2,200,000
HITEMMP	Vacuum Process Engineering, Inc	Compact Diffusion Bonded Printed-Circuit Heat Exchanger Development Using Nickel Superalloys for Highly Power Dense and Efficient Modular Energy Production Systems	Sacramento, CA	$2,279,000
HITEMMP	International Mezzo Technologies	Supercritical CO_2 Micro Tube Recuperator: Manufacturing, Testing and Laser Weld Qualification	Baton Rouge, LA	$1,640,000
HITEMMP	CompRex, LLC	Compact Heat Exchanger for High Temperature High Pressure Applications Using Advanced Cermet	De Pere, WI	$1,455,000
HITEMMP	General Electric Company, GE Global Research	Ultra Performance Heat Exchanger Enabled by Additive Technology (UPHEAT)	Niskayuna, NY	$2,500,000
HITEMMP	The Boeing Company	Highly Compact Metallic Heat Exchangers for Extreme Environments	Huntington Beach, CA	$2,397,756

HITEMMP	United Technologies Research Center (UTRC)	Additive, Topology-Optimized Ultra-Compact Heat Exchanger	East Hartford, CT	$2,100,000
HITEMMP	United Technologies Research Center (UTRC)	Low-Cost Glass Ceramic-Matrix Composite Heat Exchanger	East Hartford, CT	$1,400,000
BREAKERS	Drexel University	Resonant Solid State Breaker Based on Wireless Coupling in MVDC Systems	Philadelphia, PA	$500,000
BREAKERS	Eaton Corporation	DC Wide Bandgap Static Circuit Breaker	Arden, NC	$3,760,000
BREAKERS	Eaton Corporation	Ultra-Efficient Intelligent MVDC Hybrid Circuit Breaker	Menomonee Falls, WI	$4,413,913
BREAKERS	GE Global Research	Inline Gas Discharge Tube Breaker for Meshed MVDC Grids	Niskayuna, NY	$4,350,686
BREAKERS	Georgia Tech Research Corporation	EDISON – Efficient DC Interrupter with Surge Protection	Atlanta, GA	$3,000,000
BREAKERS	Marquette University	Ultra-Fast Resonant DC Breaker	Milwaukee, WI	$500,000
BREAKERS	The Ohio State University	T-Type Modular DC Circuit Breaker (T-Breaker) for Future DC Networks	Columbus, OH	$2,309,950
BREAKERS	Sandia National Laboratories	ARC-SAFE: Accelerated Response semiconducting Contactors and Surge Attenuation for DC Electrical Systems	Albuquerque, NM	$2,250,000
Solicitation on Topics Informing New Program Areas (Topic A)	The Regents of the University of California	Low-Temperature Architected Cementation Agents (LAMINAE)	Los Angeles, CA	$2,000,000
Solicitation on Topics Informing New Program Areas (Topic A)	The Regents of the University of Michigan	Development of an extremely durable concrete (EDC) - a novel approach coupling chemistry and autogenous crack width control	Ann Arbor, MI	$1,377,690.26
Solicitation on Topics Informing New Program Areas (Topic A)	University of California, San Diego	Extremely durable and low-cost concrete: ultralow binder content and ultrahigh tensile ductility	La Jolla, CA	$1,499,146

Solicitation on Topics Informing New Program Areas (Topic A)	Georgie Institute of Technology	Development of an advanced ultrasonic phased array for the characterization of thick, reinforced concrete components	Atlanta, GA	$867,261
Solicitation on Topics Informing New Program Areas (Topic A)	University of Kentucky	Belite cement, and concretes; novel low-energy approaches to making concrete extremely durable	Lexington, KY	$1,401,064.71
Solicitation on Topics Informing New Program Areas (Topic A)	University of Florida	Boron concrete for active formation of Lithium as mitigation of neutron-induced expansion and passive neutron absorption	Gainesville, FL	$1,079,999.17
Solicitation on Topics Informing New Program Areas (Topic A)	University of Colorado Boulder	Geopolymer cements: resistance-engineered sewer infrastructure for longevity using innovative, energy-efficient, synthesis techniques (RESILIENT)	Boulder, CO	$1,205,353
Solicitation on Topics Informing New Program Areas (Topic A)	Carnegie Mellon University	Integrated design of chemical admixture systems for ultradurable, low CO2 alternative binder chemistries via machine learning	Pittsburgh, PA	$566,370
Solicitation on Topics Informing New Program Areas (Topic A)	Washington State University	Biopolymer modified cementitious systems with radically superior strength and durability	Pullman, WA	$644,116
Solicitation on Topics Informing New Program Areas (Topic A)	Oregon State University	Development of thermodynamic and kinetic tools and testing procedures for enhanced durability of concrete containing industrial by-products	Corvallis, OR	$1,305,798
Solicitation on Topics Informing New Program Areas (Topic A)	University of Utah	Self-sustaining cementitious systems in roman reactive glass concretes	Salt Lake City, UT	$1,430,556

Solicitation on Topics Informing New Program Areas (Topic A)	C-Crete Technologies	Irradiation, heat, and corrosion resistant hexagonal boron Nitride-cement coating for mitigating aging and irradiation effects in nuclear power plants	Stafford, TX	$750,000
Solicitation on Topics Informing New Program Areas (Topic B)	National Energy Technology Laboratory	Distributed nuclear reactor core monitoring with single-crystal harsh-environment optical fibers	Morgantown, WV	$2,027,499
Solicitation on Topics Informing New Program Areas (Topic B)	Southern Research Institute	Machine learning for automated maintenance of future MSR	Birmingham, AL	$2,059,661
Solicitation on Topics Informing New Program Areas (Topic B)	North Carolina State University	A data-driven approach to high precision construction and reduced overnight cost and schedule	Raleigh, NC	$1,584,842
Solicitation on Topics Informing New Program Areas (Topic B)	Idaho National Laboratory	Next-generation metal fuel	Idaho Falls, ID	$1,800,000
Solicitation on Topics Informing New Program Areas (Topic C)	Lawrence Livermore National Laboratory	Next Generation High-Temperature Optical Fibers	Livermore, CA	$800,000
Solicitation on Topics Informing New Program Areas (Topic C)	Fervo Energy Company	SOLVE EGS: Surface OrbitaL Vibrator for Evaluation of Enhanced Geothermal Systems	Berkeley, CA	$1,180,000
Solicitation on Topics Informing New Program Areas (Topic D)	Lawrence Livermore National Laboratory	Absolute Neutron Rate Measurement and Non-Thermal/Thermonuclear Fusion Differentiation	Livermore, CA	$1,326,530

Solicitation on Topics Informing New Program Areas (Topic D)	Los Alamos National Laboratory	Portable Neutron and Soft X-Ray Diagnostics for Transformative Fusion-Energy Concepts	Los Alamos, NM	$630,000
Solicitation on Topics Informing New Program Areas (Topic D)	Oak Ridge National Laboratory	A portable diagnostic package for spectroscopic measurement of key plasma parameters in transformative fusion energy devices	Oak Ridge, TN	$1,106,000
Solicitation on Topics Informing New Program Areas (Topic D)	University of Rochester	LLE Diagnostic Resource Team for the Advancement of Innovative Fusion Concepts	Rochester, NY	$1,000,000
Solicitation on Topics Informing New Program Areas (Topic D)	University of California, Davis	Electron Density Profile Measurements using USPR	Davis, CA	$443,863
Solicitation on Topics Informing New Program Areas (Topic D)	Lawrence Livermore National Laboratory	A Portable Optical Thomson Scattering System	Livermore, CA	$2,000,000
Solicitation on Topics Informing New Program Areas (Topic D)	Princeton Plasma Physics Laboratory	A Portable Energy Diagnostic for Transformative ARPA-E Fusion Energy R&D	Princeton, NJ	$290,000
Solicitation on Topics Informing New Program Areas (Topic E)	Bigelow Laboratory for Ocean Sciences	Cost-effective and benchmarked industry standards to quantify nutrient bioextraction by seaweed	East Boothbay, ME	$299,730
Solicitation on Topics Informing New Program Areas (Topic E)	Pacific Northwest National Laboratory	Quantifying Nitrogen Bioextraction by Seaweed Farms-- A Real-time Modeling-Monitoring Case Study in Hood Canal, WA	Richland, WA	$294,107

Solicitation on Topics Informing New Program Areas (Topic E)	San Diego State University Research Foundation	Using seaweed farms to remove excess nutrients from estuarine waterways	San Diego, CA	$299,999
Solicitation on Topics Informing New Program Areas (Topic E)	The University of Connecticut	Assessing kelp nutrient bioextraction capacity in aquaculture farms in the US with implications for conservation and management	Storrs, CA	$299,994
Solicitation on Topics Informing New Program Areas (Topic F)	Johns Hopkins University	Electrothermal Conversion of Methane into Hydrogen and High-Value Carbon Fibers	Baltimore, MD	$1,500,000
Solicitation on Topics Informing New Program Areas (Topic F)	Stanford University	Co-synthesis of Hydrogen and High-value Carbon Products from Methane Pyrolysis	Stanford, CA	$1,465,139
Solicitation on Topics Informing New Program Areas (Topic F)	C-ZERO LLC	Molten-Salt Methane Pyrolysis Optimization Through in-situ Carbon Characterization and Reactor Design	Santa Barbara, CA	$1,997,969
Solicitation on Topics Informing New Program Areas (Topic F)	Northwestern University	Direct Methane Pyrolysis to Hydrogen and Silicon Carbide (DMPH2SiC)	Evanston, IL	$1,426,820
ATLANTIS	Sandia National Laboratories	ARCUS Vertical-Access Wind Turbine	Albuquerque, NM	$2,505,098
ATLANTIS	General Electric Company, GE Research	Design and Develop Optimized Controls for a Lightweight 12 MW Wind Turbine on an Actuated Tension Leg Platform	Niskayuna, NY	$2,800,000
ATLANTIS	Principle Power Inc.	DIGIFLOAT: Development, Experimental Validation and Operation of a DIGItal Twin Model for Fullscale FLOATing Wind Turbines	Emeryville, CA	$3,600,000

ATLANTIS	The University of Texas at Dallas	A Low-Cost Floating Offshore Vertical Axis Wind System	Richardson, TX	$3,000,000
ATLANTIS	The University of Massachusetts	A Co-Simulation Platform for Off-Shore Wind Turbine Simulations	Amherst, MA	$1,175,252
ATLANTIS	National Renewable Energy Laboratory	USFLOWT: Ultraflexible Smart FLoating Offshore Wind Turbine	Golden, CO	$1,500,000
ATLANTIS	National Renewable Energy Laboratory	Wind Energy with Integrated Servo-control (WEIS): A Toolset to Enable Controls Co-Design of Floating Offshore Wind Energy Systems	Golden, CO	$2,708,864
ATLANTIS	National Renewable Energy Laboratory	The FOCAL Experimental Program	Golden, CO	$1,529,923
ATLANTIS	Otherlab	AIKIDO - Advanced Inertial and Kinetic energy recovery through Intelligent (co)-Design Optimization	San Francisco, CA	$2,614,145
ATLANTIS	WS Atkins	Scale Model Experiments for Co-Designed FOWTs Supporting a High-Capacity (15MW) Turbine	Houston, TX	$1,560,660
ATLANTIS	Rutgers University, The State University of New Jersey	Computationally Efficient Atmospheric-Data-Driven Control Co-Design Optimization Framework with Mixed-Fidelity Fluid and Structure Analysis	Piscataway, NJ	$1,356,872
ATLANTIS	The University of Central Florida	Model-Based Systems Engineering and Control Co-Design of Floating Offshore Wind Turbines	Orlando, FL	$487,777
ATLANTIS	The University of Maine	Ultra-light Concrete Floating Offshore Wind Turbine with NASA-developed Response Mitigation Technology	Orono, ME	$1,398,202