DOE/CF-0141
Volume 3 Part 2

Department of Energy

FY 2019 Congressional Budget Request

Energy Efficiency and Renewable Energy
Nuclear Energy
Advanced Research Projects Agency - Energy
Advanced Tech. Vehicles Manufacturing Loan Program
Title 17—Innovative Tech. Loan Guarantee Program
Tribal Energy Loan Guarantee Program
Energy Information Administration

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FUNDING BY APPROPRIATION

($K)

Department of Energy Budget by Appropriation	FY 2017 Enacted	FY 2018 Annualized CR*	FY 2019 Request	FY 2019 Request vs FY 2017 Enacted $	FY 2019 Request vs FY 2017 Enacted %
Energy and Water Development, and Related Agencies					
Energy Programs					
Energy Efficiency and Renewable Energy	2,034,582	2,040,249	695,610	-1,338,972	-65.8%
Electricity Delivery and Energy Reliability	229,585	228,026	0	-229,585	-100.0%
Electricity Delivery	0	0	61,309	+61,309	N/A
Cybersecurity, Energy Security, and Emergency Response	0	0	95,800	+95,800	N/A
Nuclear Energy	1,015,821	1,008,922	757,090	-258,731	-25.5%
Fossil Energy Programs					
Fossil Energy Research and Development	421,154	425,093	502,070	+80,916	+19.2%
Naval Petroleum and Oil Shale Reserves	12,005	14,848	10,000	-2,005	-16.7%
Strategic Petroleum Reserve	222,605	221,485	175,105	-47,500	-21.3%
Northeast Home Heating Oil Reserve	6,497	6,456	10,000	+3,503	+53.9%
Total, Fossil Energy Programs	**662,261**	**667,882**	**697,175**	**+34,914**	**+5.3%**
Uranium Enrichment Decontamination and Decommissioning (D&D) Fund	767,929	763,106	752,749	-15,180	-2.0%
Energy Information Administration	122,000	121,171	115,035	-6,965	-5.7%
Non-Defense Environmental Cleanup	246,762	245,324	218,400	-28,362	-11.5%
Science	5,390,972	5,354,362	5,390,972	0	N/A
Advanced Research Projects Agency - Energy	305,245	303,172	0	-305,245	-100.0%
Nuclear Waste Disposal (30M in DNWF 050)	0	0	90,000	+90,000	N/A
Departmental Administration	120,692	120,009	139,534	+18,842	+15.6%
Inspector General	44,424	44,122	51,330	+6,906	+15.5%
Title 17 - Innovative Technology Loan Guarantee Program	139	16,749	7,000	+6,861	+4,936.0%
Advanced Technology Vehicles Manufacturing Loan Program	3,883	4,966	1,000	-2,883	-74.2%
Tribal Energy Loan Guarantee Program	9,000	8,939	-8,500	-17,500	-194.4%
Total, Energy Programs	**10,953,295**	**10,926,999**	**9,064,504**	**-1,888,791**	**-17.2%**
Atomic Energy Defense Activities					
National Nuclear Security Administration					
Federal Salaries and Expenses	387,366	384,736	422,529	+35,163	+9.1%
Weapons Activities	9,240,739	9,241,675	11,017,078	+1,776,339	+19.2%
Defense Nuclear Nonproliferation	1,879,738	1,885,970	1,862,825	-16,913	-0.9%
Naval Reactors	1,419,792	1,410,455	1,788,618	+368,826	+26.0%
Total, National Nuclear Security Administration	**12,927,635**	**12,922,836**	**15,091,050**	**+2,163,415**	**+16.7%**
Environmental and Other Defense Activities					
Defense Environmental Cleanup	5,404,217	5,368,298	5,630,217	+226,000	+4.2%
Other Defense Activities	781,703	778,676	853,300	+71,597	+9.2%
Defense Nuclear Waste Disposal (90M in 270 Energy)	0	0	30,000	+30,000	N/A
Total, Environmental and Other Defense Activities	**6,185,920**	**6,146,974**	**6,513,517**	**+327,597**	**+5.3%**
Total, Atomic Energy Defense Activities	**19,113,555**	**19,069,810**	**21,604,567**	**+2,491,012**	**+13.0%**
Power Marketing Administrations					
Southeastern Power Administration	0	0	0	0	N/A
Southwestern Power Administration	11,057	10,982	10,400	-657	-5.9%
Western Area Power Administration	94,742	94,099	89,372	-5,370	-5.7%
Falcon and Amistad Operating and Maintenance Fund	232	230	228	-4	-1.7%
Colorado River Basins	-23,000	-22,844	-23,000	0	N/A
Total, Power Marketing Administrations	**83,031**	**82,467**	**77,000**	**-6,031**	**-7.3%**
Federal Energy Regulatory Commission (FERC)	**0**	**0**	**0**	**0**	**N/A**
Subtotal, Energy and Water Development, and Related Agencies	**30,149,881**	**30,079,276**	**30,746,071**	**+596,190**	**+2.0%**
Uranium Enrichment D&D Fund Discretionary Payments	-563,000	-559,177	0	+563,000	+100.0%
Defense EM Funded Uranium Enrichment D&D Fund Contribution	563,000	559,177	0	-563,000	-100.0%
Excess Fees and Recoveries, FERC	-16,645	-9,000	-16,000	+645	+3.9%
Title XVII Loan Guarantee Program Section 1703 Negative Credit Subsidy Receipt	-37,000	-37,000	-44,000	-7,000	-18.9%
Sale of Northeast Gas Reserve	0	0	-77,000	-77,000	N/A
Defense Programs Rescission of Balances (Undistributed)	-43	-43	0	+43	+100.0%
Title 17 Loan Guarantee Program Rescission	-9,000	-8,939	0	+9,000	+100.0%
Total, Funding by Appropriation	**30,087,193**	**30,024,294**	**30,609,071**	**+521,878**	**+1.7%**

*Note.—A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115–56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution.

Energy Efficiency and Renewable Energy

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Energy Efficiency and Renewable Energy
Proposed Appropriation Language

For Department of Energy expenses including the purchase, construction, and acquisition of plant and capital equipment, and other expenses necessary for energy efficiency and renewable energy activities in carrying out the purpose of the Department of Energy Organization Act (42 U.S.C 7101 et. seq.), including the acquisition or condemnation of any real property or facility or for plant or facility acquisition, construction, or expansion, $695,610,000, to remain available until expended: Provided, that of such amount, $125,110,000 shall be available until September 30, 2020, for program direction.

Note. — A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L.115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution.

Public Law Authorizations
P.L. 93-275, "Federal Energy Administration Act" (1974)
P.L. 93-410, "Geothermal Energy Research, Development, and Demonstration Act" (1974)
P.L. 93-577, "Federal Non-Nuclear Energy Research and Development Act" (1974)
P.L. 94-163, "Energy Policy and Conservation Act" (EPCA) (1975)
P.L. 94-385, "Energy Conservation and Production Act" (ECPA) (1976)
P.L. 94-413, "Electric and Hybrid Vehicle Research, Development and Demonstration Act" (1976)
P.L. 95-91, "Department of Energy Organization Act" (1977)
P.L. 95-618, "Energy Tax Act" (1978)
P.L. 95-619, "National Energy Conservation Policy Act" (NECPA) (1978)
P.L. 95 620, "Power Plant and Industrial Fuel Use Act" (1978)
P.L. 95-238, Title III – "Automotive Propulsion Research and Development Act" (1978)
P.L. 96-512, "Methane Transportation Research, Development and Demonstration Act" (1980)
P.L. 96-294, "Energy Security Act" (1980)
P.L. 100-12, "National Appliance Energy Conservation Act" (1987)
P.L. 100-357, "National Appliance Energy Conservation Amendments" (1988)
P.L. 100-494, "Alternative Motor Fuels Act" (1988)
P.L. 100-615, "Federal Energy Management Improvement Act" (1988)
P.L. 101-218, "Renewable Energy and Energy Efficiency Technology Competitiveness Act" (1989)
P.L. 101-566, "Spark M. Matsunaga Hydrogen Research, Development, and Demonstration Act of 1990"
P.L. 101-575, "Solar, Wind, Waste, and Geothermal Power Production Incentives Act" (1990)
P.L. 102-486, "Energy Policy Act of 1992"
P.L. 104-271, "Hydrogen Future Act of 1996"
P.L. 106-224, "Biomass Research and Development Act" (2000)
P.L. 109-58, "Energy Policy Act of 2005"
P.L. 110-140, "Energy Independence and Security Act of 2007"
P.L. 110-234, "The Food, Conservation, and Energy Act of 2008"
P.L. 111-5, "American Recovery and Reinvestment Act of 2009"

Energy Efficiency and Renewable Energy
($K)

FY 2017 Enacted	FY 2018 Annualized CR*	FY 2019 Request	FY 2019 Requested vs FY 2017 Enacted
2,034,582	2,040,249	695,610	-1,338,972

Overview
American leadership in science and technology is critical to achieving national security, economic growth, and job creation. American ingenuity combined with free-market capitalism have driven, and will continue to drive, tremendous technological breakthroughs. American innovation and invention have fundamentally changed the course of human history, improving the lives of millions of Americans and billions more the world over, making America the economic engine of growth. In spurring future advances, Federal funding of research and development (R&D) programs and research infrastructure plays a crucial supporting role.

The Office of Energy Efficiency and Renewable Energy (EERE) invests in research and development (R&D) as part of the Department of Energy's (DOE) broad portfolio approach to addressing our Nation's energy and environmental challenges. This Budget Request focuses DOE resources toward early-stage R&D and reflects an increased reliance on the private sector to fund later-stage research, development, and commercialization of energy technologies. It emphasizes energy technologies best positioned to support American energy independence and domestic job-growth in the near- to mid-term.

The FY 2019 Budget Request maintains America's leadership in transformative science and emerging energy technologies in sustainable transportation, renewable power, and energy efficiency. Knowledge generated by EERE early-stage R&D enables U.S. industries, businesses, and entrepreneurs to develop and deploy innovative energy technologies and gives them the competitive edge needed to excel in the rapidly changing global energy economy. Industry deployment of these technologies creates jobs, reduces U.S. reliance on imported oil, increases energy affordability, improves energy security and resiliency, ensures environmental responsibility and offers Americans a broader range of energy choices. Some areas of focus include innovative approaches to electric vehicles, including a robust battery material and chemistry program, along with hydrogen fuel cell infrastructure expansion. One area of focus for EERE is energy storage. The Request includes $36 million for battery R&D as well as $90 million for R&D that would research storage technologies in a new initiative "Beyond Batteries". As part of Grid Modernization, "Beyond Batteries" considers energy storage holistically, and focuses on advances in controllable loads, hybrid systems, and new approaches to energy storage, which are essential to increasing the reliability and resilience of our energy systems. Advances in this wide range of energy storage technologies will allow for loads to be combined with generation from all sources to optimize use of existing assets to provide grid services, and increase grid reliability.

EERE works with industry, academia, National Laboratories, and other partners to create technology-specific roadmaps which focus DOE resources on the most fundamental technology challenges. EERE investment strategies fall under three primary areas:
- Early-stage (R&D) to build the knowledge base upon which industry can reduce costs, improve performance, and develop and deploy new materials and manufacturing technologies;
- Limited validation through testing and simulation to provide feedback to R&D; and
- Analysis to support regulatory activities for appliance and equipment standards, building codes, Federal energy management and alternative fuel vehicles.

EERE early-stage research focuses on technology challenges that present a significant degree of scientific or technical uncertainty across a relatively long period, making it unlikely that industry will invest significant R&D on their own. Industry

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typically focuses on near term (2-4 years) investments in marginal improvements to capacity or efficiency, while EERE early-stage R&D focuses on longer-range (5-15 years) transformational technologies, materials, and processes. Thus, this request maintains the most critical core capabilities and infrastructure at DOE National Laboratories related to sustainable transportation, renewable power, and energy efficiency technologies. It proposes cost-shared funding opportunity announcements or competitive solicitations aimed at universities, industry, and entrepreneurs. National Laboratories will be encouraged to form Cooperative Research and Development Agreements (CRADAs) with industry, utilize Agreements for Commercializing Technology (ACT) which recently completed a pilot at the National Renewable Energy Laboratory (NREL), enter into Strategic Partnership Projects (also known as Work for Others) and conduct User Facility calls for university and industry proposals (e.g., Energy Systems Integration Facility at National Renewable Energy Laboratory) to further leverage National Laboratory expertise and infrastructure.

After four decades of investment in American innovation, EERE-sponsored R&D has made enormous strides toward cost competitiveness in transportation, energy efficiency and renewable power technologies. Since 2010, adoption of technologies developed with EERE R&D funding has resulted in significant cost reductions across the renewable energy and energy efficiency sectors. For example, between 2010 and 2016, the cost to utilities of power purchase agreements (PPAs) for utility scale photovoltaic electricity decreased by 74 percent,[1] and the cost for wind PPAs decreased by 64 percent.[2] Over the same period, modeled battery costs for electric vehicles have dropped by 67 percent[3] and the cost to generate light from light-emitting diodes (LEDs) has dropped by 82 percent.[4]

These cost declines have enabled subsequent market uptake and can be traced to previous EERE investments in early-stage research, and EERE is committed to continuing in its role as a global leader in enabling the development of the next generation of energy technologies.

Major Changes in the FY 2019 Budget Request

In developing the FY 2019 budget, EERE prioritized early-stage R&D to support the Administration's R&D priority areas, particularly Security, Prosperity and Energy Dominance. EERE will spend $695.6 million focused on early-stage research to strengthen our knowledge and understanding of promising technologies, with the potential to enable American consumers and businesses to increase energy productivity, reduce the cost of renewable power, and adopt more affordable and secure transportation options. EERE will also conduct rigorous analyses and evaluations of its portfolio, and achieve the greatest possible impact in each of its three sectors (Sustainable Transportation, Renewable Power, and Energy Efficiency).

The continued shift toward an increased focus on early-stage R&D provides an opportunity to move EERE towards a more efficient organization and operation. During FY 2018, staff and associated functions from the EERE Office of Strategic Programs will be centralized within DOE corporate offices, including International Affairs and Public Affairs within Departmental Administration and the Office of Technology Transitions in an effort to eliminate redundancies and increase efficiencies across the department. Therefore, no funds are requested for Strategic Programs within the EERE account in FY 2019.

Similarly, as resources are shifted toward early-stage R&D, the Weatherization Assistance Program and State Energy Program Grants are terminated in FY 2019. Therefore, no funds are requested in this Budget Request for the Weatherization and Intergovernmental Program.

Program Direction funding enables EERE to efficiently and transparently maintain and support a world-class, technology-focused Federal workforce to manage the wide range of projects and activities funded through the EERE programs. The FY 2019 Budget Request for Program Direction provides sufficient resources for program and project management, oversight

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[1] Utility Scale Solar 2016, (LBNL) https://emp.lbl.gov/utility-scale-solar.
[2] 2016 Wind Technologies Market Report (LBNL), https://emp.lbl.gov/wind-technologies-market-report.
[3] Assessment of Vehicle Sizing, Energy Consumption, and Cost through Large-Scale Simulation of Advanced Vehicle-Technologies. (ANL) 2016 http://www.ipd.anl.gov/anlpubs/2016/04/126422.pdf.
[4] Adoption of Light-Emitting Diodes in Common Lighting Applications, 2016, (EERE) https://energy.gov/sites/prod/files/2017/08/f35/led-adoption-jul2017_0.pdf; supplemented with data from Navigant.

activities, contract administration, workforce management, IT support, stewardship of the NREL, and headquarters and field site non-laboratory facilities and infrastructure. Of EERE's current portfolio of approximately 2,500 multi-year (3-5 year) projects, at least two-thirds will remain active in 2019.

In keeping with the direction to generate efficiencies and reduce the cost of government, and to align with reductions in technology program budgets, the department proposes to reduce EERE-funded Full-Time Equivalents by approximately 30 percent from the FY 2017 level. The specific reduction will be adjusted as needed, dependent on the timing of appropriations, in order to fully account for associated severance payments. Remaining staff will ensure continuity of the essential oversight activities for EERE's project portfolio and maintaining proper stewardship of taxpayer dollars. A limited amount of staff will remain in the Weatherization and Intergovernmental Program to provide required oversight of existing projects. Due to the reduced financial assistance project and grant workload in FY 2019, EERE will consolidate procurement and project management functions at the Golden Field Office, allowing for the elimination of staff support at the National Energy Technology Laboratory (NETL).

Highlights of the FY 2019 Budget Request

- **Sustainable Transportation ($163,500,000)** — EERE's sustainable transportation portfolio supports comprehensive and analysis-based, early-stage research strategies that ultimately enable industry to accelerate the development and widespread use of a variety of promising sustainable transportation technologies. Broadly, transportation programs within EERE pursue four key parallel solution pathways: (1) fuel diversification, replacing conventional fuels with cost-competitive, domestically produced alternatives; (2) vehicle efficiency, using less fuel to move people and freight; (3) energy storage, delivering durable, reliable, resilient and affordable energy storage technology R&D across sectors, and (4) improving the overall energy efficiency and efficacy of the transportation or mobility system. The pathways and activities also include those necessary to address statutory requirements and the supporting advanced data-driven, technical, economic, and interdisciplinary systems analyses critical to informing R&D investment priorities.

    - **Vehicle Technologies:** The Budget Request provides $68,500,000 in FY 2019 funding to support early-stage R&D to generate knowledge upon which industry can develop and deploy innovative energy technologies for more affordable, secure and reliable transportation of people and goods across America. Vehicle Technologies will focus on research that industry either does not have the technical capability to undertake or is too far from market realization to merit sufficient industry focus and critical mass. Within Battery and Electrification Technologies, Advanced Battery R&D will explore new battery materials, high-power fast-charging methods, innovative chemistries beyond lithium ion technology and advanced cell technologies. These topics have the potential to reduce the cost of electric vehicle batteries by more than half, to less than $100/kWh (ultimate goal is $80/kWh), increase range to 300 miles, and decrease charge time to 15 minutes or less. Building upon recent work, Energy Efficient Mobility Systems (EEMS) will continue to create new ideas and knowledge focused on pathways to significantly improve transportation system efficiency leading to greater energy productivity in moving people and goods. EEMS research will include the application of new computational models and simulation capabilities to create and test new theories that use vehicle connectivity and automation to improve energy efficiency including; vehicle autonomy, big data tools, machine/deep-learning and artificial intelligence, as well as new scientific approaches that improve mobility decision making and increase transportation choices at both the individual and system level. In Advanced Engine and Fuel Technologies, research will continue to advance and improve our understanding of, and ability to, increase combustion efficiency, generating knowledge and insight necessary for industry to develop the next generation of engines and fuels capable of improving passenger vehicle fuel economy 35 percent by 2030 from a 2015 baseline. In Materials Technology, research will focus on novel approaches to build lightweight, multi-material structures, and on creating new materials that can meet the extreme temperatures and pressures (e.g., high compression engines) that the next generation of vehicle engines will require.

    - **Bioenergy Technologies:** The Budget Request provides $37,000,000 in FY 2019 to support early-stage R&D that bolsters the body of scientific and engineering knowledge enabling industry to develop and deploy high-performing drop-in biofuels at $3 per gallon gasoline equivalent, which includes high-value co-production of renewable chemicals and materials. Domestically-produced renewable biomass, and its subsequent conversion to bioenergy and bioproducts, offers a tremendous opportunity to create American jobs across the supply chain, boost economic growth, and encourage investment across the Nation. The program's early-stage, laboratory-based R&D emphasizes advanced technologies to produce renewable gasoline, diesel, and jet fuels from non-food sources. Consortium-supported research focus areas include: (1) detailed understanding and optimization of the physics and chemistry of each feedstock and preprocessing steps necessary for high conversion rates; (2) identification and molecular characterization of high performing algal strains; and (3) development of engineered organisms and novel catalysts. In collaboration with the Advanced Engine and Fuel Technologies sub-program, Bioenergy will explore the co-optimization of fuels and engines enabling the development of bio-based fuels/additives that have the potential for a 35 percent fuel economy gain (25 percent from advanced engine research and 10 percent from co-optimization with biofuels) by 2030 compared to 2015 gasoline vehicles.

  - **Hydrogen and Fuel Cell Technologies:** The Budget Request provides $58,000,000 in FY 2019 to support early-stage R&D to investigate novel hydrogen and fuel cell technologies that could enable American energy independence, resilience, and domestic job growth through industry development and deployment. To be cost competitive with vehicles powered by gasoline and an internal combustion engine on a cents-per-mile driven basis, the cost of hydrogen delivered from domestic resources needs to be less than $4/gge (untaxed), and the cost of a durable fuel cell system needs to be less than $40/kW. In FY 2019, research will emphasize the acceleration of materials breakthroughs by National Laboratory consortia that bring together world-class capabilities from multiple laboratories, while leveraging the results of ongoing projects with university and industry partners using prior year funding. Key areas of research include: platinum-free catalysts; high performance durable membranes and electrodes; materials for hydrogen production, storage, and transmission; and understanding the infrastructure necessary to accomplish H2@Scale — a vision of cost-competitive, domestically sourced and produced hydrogen used across multiple sectors.

- **Renewable Power ($175,000,000**) — Through its Renewable Power portfolio, EERE will perform early-stage research to enable solar, wind, water, and geothermal industries to develop and ultimately deploy low-cost novel power generation technologies. The overarching objective of the Renewable Power portfolio is to lower costs and improve the reliability of renewable energy technologies, which would enable the adoption of affordable renewable energy options, allow for regional optimization, maximize the use of domestic resources, and contribute to a resilient, reliable, and secure electricity grid. The Renewable Power technology sector pursues three key parallel solution pathways: (1) Technology Innovation; (2) Validation and Analysis; and (3) Systems Integration, including efforts coordinated through the Grid Modernization Initiative. Through investments in DOE labs, industry, and academia, EERE's Renewable Power technology offices will continue to lead the world in developing domestic, clean, reliable energy choices in power generation, which strengthen the U.S. economy while increasing energy security.

  - **Solar Energy:** The Budget Request provides $67,000,000 in FY 2019 to support the DOE's goal of making solar power one of the least expensive forms of electricity by enabling cost reductions toward the 2030 target of $0.03/kWh for utility-scale solar power without subsidies. Funding will support early-stage R&D at the National Laboratories, in partnership with academia and industry, with a focus on increasing the reliability and decreasing the cost of next-generation photovoltaics and concentrating solar power technologies. In addition, the program will advance the state of knowledge necessary for industry to develop more reliable, on-demand solar technologies that can be more effectively integrated into the electric grid. Key areas of research include: grid reliability, PV efficiency, energy yield and storage, material durability, power electronics, microgrid integration, and next generation concentrating solar power. Funding will also support analytics and modeling of power system integrity and potential cybersecurity issues related to integrating increasing amounts of solar power on the electric grid. National Laboratory research also supports the development of experimental test and evaluation standards. The program will also perform some research at universities in coordination with the Office of Science and the National Science Foundation.

  - **Wind Energy:** The Budget Request provides $33,000,000 in FY 2019 to support fundamental, early-stage R&D, and related testing that builds the knowledge base upon which industry can develop and deploy novel technologies. FY 2019 activities will focus on applying high-performance computing to analyze wind technology challenges and investigate fundamental systems-level interactions influenced by atmospheric conditions, variable terrain, and machine-to-machine wake interactions. Continuing R&D will focus on the scientific challenges associated with the design and manufacturing of low-specific power rotors for tall wind applications, aimed at enabling industry improvement of wind plant capacity factors by as much as 10 percent, and mitigating challenges associated with aerodynamic and gravitational loading. Funding will continue to advance collaboration with Department of Defense, Federal Aviation Administration, Department of Homeland Security, and other agencies to complete a suite of wind turbine radar interference mitigation algorithms for long-range and terminal radar systems. R&D will explore long-term challenges related to reliably integrating increasing amounts of wind power on the electric grid, including secure and reliable hybrid system concepts, new energy storage technologies, and control strategies, as well as technologies to reduce environmental and community impacts, all to achieve necessary cost reductions, improved grid reliability, and reduction of regulatory burdens.

- **Water Power:** The Budget Request provides $45,000,000 in FY 2019 to support early-stage R&D exploring novel concepts and approaches to capturing hydropower and marine hydrokinetic energy resources. The program invests in hydropower technology R&D for innovative standardized and modular approaches to hydropower development that can lower overall project costs versus traditional projects at greenfield sites and non-powered dams. The program will continue its focus on hydropower and PSH's roles in grid reliability and resiliency by continuing to support innovative PSH technologies and conducting new research to evaluate the specific grid resiliency services provided by hydropower and/or PSH. It will also support the development of innovative environmental mitigation technologies and new research to inform licensing studies and requirements in order to reduce the time, cost and uncertainty of hydropower licensing. In marine and hydrokinetics (MHK), the program will support R&D to enable improvements in controls, structures, materials and power take-offs for early-stage wave, tidal and ocean current technologies, ultimately leading to reduced costs and increased competitiveness of marine energy devices. Through its partnerships with the Navy and with university-National Laboratory collaborations, the program will validate reliability of marine energy technologies and the value of integrating energy from prototype devices into the electric grid. Monitoring of open water tests and continued analysis and dissemination of the results of new research is also supported to reduce perceived environmental risk and the time associated with device permitting.

- **Geothermal Technologies:** The Budget provides $30,000,000 in FY 2019 to support Geothermal Technologies' early-stage R&D. Within Enhanced Geothermal Systems (EGS), the program will continue implementation of the Frontier Observatory for Research in Geothermal Energy (FORGE) to advance Phase 3 field operations at the FORGE site. The EGS Collab effort, which brings together a team comprised of National Laboratories, academia, and industry to conduct early-stage R&D that explores the fundamental relationships between seismicity, stress state, and permeability to validate and verify models, will continue into FY 2019. These models will serve as the basis for the design of the FORGE stimulations. The Hydrothermal subprogram will address subsurface stress, focusing on subsurface stress measurement and simulation to enable the collection of stress data at reservoir scale to understand fracture propagation, permeability distribution, reservoir management, fluid production, and wellbore integrity. The Budget Request also supports improving grid reliability and resilience through the Beyond Batteries Initiative focusing on subsurface thermal energy storage, thermal management of reservoirs, and evaluation of geothermal's potential to respond to electrical demand fluctuations. Combined efforts will strengthen the body of knowledge necessary to enable industry to achieve a cost target of $0.06/kWh by 2030 from newly developed geothermal systems, and support enhanced grid reliability and resiliency through analyses focused on improving the ability for geothermal power to be operated flexibly and provide essential grid reliability services.

- **Energy Efficiency ($142,000,000**) — EERE's energy efficiency portfolio will build on the considerable progress made over the last 40 years and pursue early-stage R&D targeted at high impact technology areas such as advanced lighting, space heating and cooling, building envelopes, and manufacturing materials and processes. The overall goal of the energy efficiency portfolio is to strengthen the body of knowledge that enables businesses, industry, and the Federal Government to improve the affordability, energy productivity, and resiliency of our homes, buildings, and manufacturing sectors. The knowledge outputs of this research can support a foundation for economic growth and job creation as businesses, consumers, and energy managers develop and deploy new energy-efficiency and manufacturing technologies and best practices.

- **Advanced Manufacturing:** The Budget Request provides $75,000,000 in FY 2019 to support early-stage applied R&D focused on advancing and creating new understanding of underlying technologies, materials, and processes relevant to the productive use of energy in manufacturing, as well as the competitive manufacturing of energy related products, with additional emphasis on alternative approaches to energy storage and the intersection between manufacturing and the energy grid. The Budget for Advanced Manufacturing reasserts the proper role of the Federal Government by reflecting an increased reliance on the private sector to fund later-stage research, development, and commercialization of energy technologies and focusing funding toward early-stage R&D. By fostering collaboration between National Laboratories, universities and companies (for-profit and not-for-profit), this Budget Request will enhance the foundational knowledge base in materials and manufacturing processes, focusing on research challenges that present a significant degree of scientific or technical uncertainty and are beyond the horizon in terms of commercialization, making it unlikely that industry will pursue independently.

- **Federal Energy Management Program:** The Budget Request provides $10,000,000 in FY 2019 to support Federal Energy Management Program's core activities of catalyzing and assisting Federal agencies to both meet energy-related goals and provide Federal energy leadership to the country, increasing Federal energy security, reliability, and resilience. FY 2019 funds will support continued assistance on energy projects and energy savings through the provision of technical assistance, energy-related contracting tools and skills training.

- **Building Technologies:** The Budget Request provides $57,000,000 in FY 2019 to support early-stage R&D of innovative building energy technologies such as lighting, space conditioning and refrigeration, windows and envelope and their effective integration into smart, efficient, resilient, grid-connected, and secure building systems. Particular focus will be placed building system interaction with the grid in terms of load management and alternative energy storage technologies. The goal of the program is to overcome the high degree of fragmentation across the heterogeneous buildings industry, spanning construction to appliance and equipment manufacturing. Building Technologies' research also focuses on developing the physics-based algorithms for improved energy modeling and system controls required to better predict and manage energy efficient appliance/equipment, system, and whole-building energy usage. Additionally, Building Technologies' early stage R&D on cyber secure advanced sensors and controls will help strengthen the body of knowledge to enable industry to develop and deploy truly "smart" buildings capable of connecting with the power grid securely, in new and increasingly adaptive manners, to help with overall electric system efficiency, resilience and bringing down energy prices across the grid. Finally, it supports DOE working with industry and stakeholders to meet requirements for statutorily-mandated efficiency standards and building energy codes determinations.

- **Weatherization and Intergovernmental Program:** The Budget Request provides no funding in FY 2019 for both the Weatherization Assistance Program and the State Energy Program due to a departmental shift in focus away from deployment activities and towards early-stage R&D. Activities in FY 2019 will focus on completing work activities associated with existing financial and technical assistance awards and initiatives with states and local governments and stakeholder organizations, closing out awards and agreements as they come to the end of their periods of performance, and providing resources and institutional knowledge to state and local entities as practicable.

EERE supports the following Departmental crosscut:

- **Cybersecurity:** DOE is engaged in two categories of cyber-related activities: protecting the DOE enterprise from a range of cyber threats that can adversely impact mission capabilities and improving cybersecurity and grid resilience. The cybersecurity crosscut supports central coordination of the strategic and operational aspects of cybersecurity and facilitates cooperative efforts such as the Joint Cybersecurity Coordination Center (JC3) for incident response and the implementation of department-wide Identity, Credentials, and Access Management (ICAM).

Energy Efficiency and Renewable Energy
($K)

	FY 2017 Enacted	FY 2018 Annualized CR*	FY 2019 Request	FY 2019 Request vs FY2017 Enacted	
				$	%
Discretionary Summary by Appropriation					
Energy Efficiency and Renewable Energy					
Energy Efficiency and Renewable Energy RDD&D					
Sustainable Transportation					
Vehicle Technologies	306,959	304,874	68,500	-238,459	-77.7%
Bioenergy Technologies	205,000	203,608	37,000	-168,000	-82.0%
Hydrogen and Fuel Cell Technologies	101,000	100,315	58,000	-43,000	-42.6%
Renewable Power					
Solar Energy Technologies	207,600	206,190	67,000	-140,600	-67.7%
Wind Energy Technologies	90,000	89,388	33,000	-57,000	-63.3%
Water Power Technologies	84,000	83,429	45,000	-39,000	-46.4%
Geothermal Technologies	69,500	69,028	30,000	-39,500	-56.8%
Energy Efficiency					
Advanced Manufacturing	257,500	255,751	75,000	-182,500	-70.9%
Federal Energy Management Program	27,000	26,817	10,000	-17,000	-63.0%
Building Technologies	199,141	197,789	57,000	-142,141	-71.4%
Weatherization and Intergovernmental Programs					
Weatherization Assistance Program	225,000	223,472	0	-225,000	-100.0%
Training and Technical Assistance	3,000	2,980	0	-3,000	-100.0%
State Energy Program	50,000	49,660	0	-50,000	-100.0%
Total, Weatherization and Intergovernmental Programs	278,000	276,112	0	-278,000	-100.0%
Corporate Support Programs					
Facilities and Infrastructure (NREL)	92,000	91,375	90,000	-2,000	-2.2%
Program Direction	153,500	152,458	125,110	-28,390	-18.5%
Strategic Programs	19,000	18,871	0	-19,000	-100.0%
Subtotal, EERE	**2,090,200**	**2,076,005**	**695,610**	**-1,394,590**	**-66.7%**
Rescission of Prior Year Balances	-55,618	-35,756	0	+55,618	+100.0%
Total, EERE	**2,034,582**	**2,040,249**	**695,610**	**-1,338,972**	**-65.8%**

*A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution. (These amounts are shown only at the Congressional control level and above; below that level, a dash (—) is shown).

SBIR/STTR:
- FY 2017 Transferred: SBIR $38,920,000; STTR: $6,262,000
- FY 2018 Projected: SBIR $38,656,000; STTR: $6,220,000
- FY 2019 Request: SBIR $14,278,000; STTR $2,010,000

Performance Measures

In accordance with the GPRA Modernization Act of 2010, the Department sets targets for, and tracks progress toward, achieving performance goals for each program.

Vehicle Technologies

	FY 2017	FY 2018	FY 2019
Performance Goal (Measure)	**Batteries - Reduce the cost of batteries for Electric Vehicles (EVs).**		
Target	$ 225 /kWh	$ 200 /kWh	$ 185 /kWh
Result	Exceeded - 219	TBD	TBD
Endpoint Target	$100/kWh by 2028		
Comment	Baseline: $1,000/kWh in 2008 Battery technology that costs $100/KWh useable energy results in an electric vehicle levelized cost of driving (LCD) (i.e., the life cycle cost per mile driven (excluding maintenance and insurance) of $0.28/mile, comparable to the modeled $0.27/mile LCD for a model year 2030 conventional internal combustion engine vehicle. This will enable cost competitive market entry of EVs by reducing the cost of electrical vehicle batteries by approximately 70 percent (roughly $14,000) from FY 2012. Battery cost projections are derived by battery manufacturers using USABC's battery manufacturing cost model for specific battery cell and module designs that meet DOE/USABC system performance targets and are based on a production volume of at least 100,000 batteries per year.		
Performance Goal (Measure)	**Light Duty - Improve Light Duty vehicle fuel economy (mpg) through increased engine efficiency.**		
Target	N/A	41.8 MPG	42.5 MPG
Result	41	TBD	TBD
Endpoint Target	48.6 MPG in 2030 (i.e., a 35% improvement in MPG vs. a 2015 baseline). 35% fuel economy improvement represents 25% from engine efficiency improvement assuming current fuels and an additional 10% from co-optimization with fuels.		
Comment	Fuel economy improvement is compared to a modeled 2015 baseline vehicle with an unadjusted (CAFÉ) fuel economy of 36 MPG. None of the 2019 target will come from co-optimization with fuels, since this effort is still in its early stages. Calculation methodologies for baseline and target costs are found in the presentation Vehicle Energy Consumption Benefits of Low Temperature Combustion (LTC) Engines. Historical trend data is shown in the results field above to provide context, even where no formal GPRA Target was published for that year.		
Performance Goal (Measure)	**Mobility - Complete initial phase of the SMART Mobility National Laboratory Consortium by publishing a results report for each of the five research pillars.**		
Target	N/A	N/A	5 reports
Result	N/A	N/A	TBD
Endpoint Target	Increased productivity in transportation energy from new mobility concepts. A quantitative measure is under development and will be informed by the reports published in 2019.		
Comment	Results Reports will describe the findings from the initial phase of the SMART Mobility Lab Consortium and identify the most promising research paths going forward for the following 5 pillars: Connected and Automated Vehicles, Mobility Decision		

	FY 2017	FY 2018	FY 2019
	Science, Urban Science, Advanced Fueling Infrastructure and Multimodal Transport. Future GPRA targets will show increased energy productivity from specific technologies and systems.		

Bioenergy Technologies

	FY 2017	FY 2018	FY 2019
Performance Goal (Measure)	**Algae - Increase algal biomass productivity.**		
Target	N/A	13.3 g/m2/day	15.9 g/m2/day
Result	10.3	TBD	TBD
Endpoint Target	At least 25 g/m2/day by 2025		
Comment	The FY 2018 baseline of 13.3 g/m2/day is a summer productivity that is often greater than the annual average. Algal biomass productivity targets and their relation to algal biofuel production cost improvements are detailed in the Bioenergy Technologies Office Multi-year Program Plan, at https://www.energy.gov/sites/prod/files/2016/07/f33/mypp_march2016.pdf (pages 2-49 to 2-56). With the establishment of the Algae Testbed Public-Private Partnership and a standardized data collection program, a state-of-technology for algal biomass productivity was conducted for the first time in 2015 for use in establishing and assessing Bioenergy Technologies Office technical targets. The algal biomass productivity calculations and methodologies are detailed in E. Knoshaug, L. M. L. Laurens, C. Kinchin, and R. Davis, Use of Cultivation Data from the Algae Testbed Public Private Partnership as Utilized in NREL's Algae State of Technology Assessments (Golden, CO: National Renewable Energy Laboratory, October 2016), NREL/TP-5100-67289, http://www.nrel.gov/docs/fy17osti/67289.pdf. Historical trend data is shown in the results field above to provide context, even where no formal GPRA Target was published for that year.		
Performance Goal (Measure)	**Pathways - Decrease fuel selling price for the catalytic fast pyrolysis pathway.**		
Target	N/A	$ 4.09 /gge	$ 3.84 /gge
Result	4.34	TBD	TBD
Endpoint Target	Achieve a wholesale minimum fuel selling price (MFSP) of less than $3/gge by 2025.		
Comment	2017 Baseline: $4.34/gge. MFSP assumptions based on 2015 In Situ Ex Situ Catalytic Fast Pyrolysis Design Case (https://www.nrel.gov/docs/fy15osti/62455.pdf) published by NREL and subsequent State of Technology (FY 2017 Q4 milestone report by Abhijit Dutta). Dollar values are in 2014$. MFSP is defined as the fuel selling price (leaving the biorefinery gate) that enables a 10% rate of return over the lifetime of the biorefinery including capital costs, operating costs, and financing. This price does not include fuel marketing or distribution costs, nor does it include any retail markups. Full economic assumptions (e.g. plant lifetime, interest rates, etc.) can be found here: https://www.nrel.gov/docs/fy15osti/62455.pdf Catalytic fast pyrolysis of biomass is recognized as an efficient and feasible process to selectively convert lignocellulose into a liquid fuel—bio-oil. The main challenge of this process is the development of active and stable catalysts that can deal with a large variety of decomposition intermediates from lignocellulose. This cost reduction will be accomplished by optimizing catalyst composition and process conditions for the catalytic fast pyrolysis reactor system to improve carbon efficiency, reduce catalyst cost, and extend catalyst lifetime. Historical trend data is shown in the results field above to provide context, even where no formal GPRA Target was published for that year.		
Performance Goal (Measure)	**Thermochemical - Reduce modeled thermochemical conversion cost of a combined gasoline and diesel production ($/gge)**		
Target	$ 2.47 /gge	N/A	N/A
Result	Met - 2.47	N/A	N/A

	FY 2017	FY 2018	FY 2019
Endpoint Target	$2.47/gge by 2017 ($2011) Measure is being discontinued in FY 2018 as overarching verification goal was met by the end of FY 2017.		
Comment	The 2017 modeled cost target of $2.47/gge (2011 $) was projected through the use of methodology standard to BETO analysis. The details for arriving at this target, definition of nth plant, limitations and validation of figures are documented in the following report: http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-23053.pdf.		

	FY 2017	FY 2018	FY 2019
Performance Goal (Measure)	**Fuel Cell Power - Improve the catalyst specific power of fuel cells (kW/gram of platinum group metal).**		
Target	7.1 kW/g	N/A	N/A
Result	Exceeded - 8	N/A	N/A
Endpoint Target	Measure discontinued in FY 2018 due to the strategic decision to shift towards earlier stage research on non-PGM catalysts. Industry will continue to improve the kW/gram of PGM catalysts without additional government investment.		

	FY 2017	FY 2018	FY 2019
Performance Goal (Measure)	**Fuel Cell Power New - Improve the catalyst activity of Platinum Group Metal (PGM) free catalysts.**		
Target	N/A	25 mA/cm2	29 mA/cm2
Result	21	TBD	TBD
Endpoint Target	44 mA/cm2 by 2025		
Comment	Baseline: https://www.hydrogen.energy.gov/pdfs/review16/fc107_zelenay_2016_o.pdf. The following equation provides the comparison of the catalyst activity target to the previous specific power target. $\frac{mA}{cm^2} * \frac{cm^2}{g_{PGM}} * \frac{V}{10^6} = \frac{kW}{g_{PGM}}$ This new target relates directly the how much catalyst is required to achieve the desired performance, however since it is now PGM-free the previous target of kW per gram PGM no longer applies. Eliminating the PGM catalyst from the stack provides a pathway for the program to meet the fuel cell ultimate cost target of $30/kW to enable a 27₵/mile LCD. Historical trend data is shown in the results field above to provide context, even where no formal GPRA Target was published for that year.		

	FY 2017	FY 2018	FY 2019
Performance Goal (Measure)	**Hydrogen Delivery and Dispensing cost - Reduce the cost of hydrogen delivery and dispensing.**		
Target	N/A	N/A	$ 12 /kg
Result	13	N/A	TBD
Endpoint Target	$5/kg by 2025		
Comment	$5/kg target is aligned with the near-term cost target of $7/kg for hydrogen produced, delivered and dispensed untaxed and assumes $2/kg hydrogen production from natural gas. This is consistent with record: https://www.hydrogen.energy.gov/pdfs/15012_hydrogen_early_market_cost_target_2015_update.pdf. The ultimate (beyond 2030) target for hydrogen to be cost competitive with gasoline on a $/gge basis is $4/kg apportioned to $2/kg for production and $2/kg delivery and would enable a 27₵/mile LCD. Historical trend data is shown in the results field above to provide context, even where no formal GPRA Target was published for that year.		

	FY 2017	FY 2018	FY 2019
Performance Goal (Measure)	**Materials - Identify advanced water splitting materials and associated pathways through leveraging the HydroGEN EMN Consortia.**		
Target	N/A	N/A	5 Materials
Result	N/A	N/A	TBD

	FY 2017	FY 2018	FY 2019
Endpoint Target	11 materials by 2022; accelerated discovery of advanced water splitting materials to meet the hydrogen production cost target		
Comment	Materials identified must have the potential to meet at least two technology-specific targets in efficiency, durability and/or materials cost as defined in the Hydrogen chapter of the FCTO Multi-Year Research Development and Demonstration plan, to reach the ultimate cost goal of <$2/kg. The HydroGEN EMN Consortium is focused on materials discovery and development for four diverse pathways to generate hydrogen via advanced water splitting (AWS): low temperature electrolysis, high temperature electrolysis, photoelectrochemical, and solar thermochemical. The three common parameters chosen for this metric (efficiency, durability, and materials cost) are of the greatest importance to AWS pathways. (The MYRDD is available at: https://energy.gov/sites/prod/files/2015/06/f23/fcto_myrdd_production.pdf)		

Solar Energy

	FY 2017	FY 2018	FY 2019
Performance Goal (Measure)	**Concentrated Solar Power (CSP) - Reduce the levelized cost of Concentrated Solar Power energy**		
Target	N/A	N/A	8 cents/kWh
Result	10	N/A	TBD
Endpoint Target	5 cents/kWh by 2030		
Comment	2017 baseline: 10 cents/kWh. The CSP energy cost target is an unsubsidized cost of energy at utility scale including 14 hours of thermal storage, in the U.S. southwest.		
Performance Goal (Measure)	**Grid - Reduce the modeled system cost of solar + storage to enable nationwide cost effective and safe integration of variable solar energy into our electric grid**		
Target	N/A	N/A	$ 1.65 /WDC
Result	1.96	N/A	TBD
Endpoint Target	$1.45/WDC		
Comment	The solar + energy storage cost target is an unsubsidized cost of energy at utility scale array with 4 hours of battery storage. Model assumptions based on NREL analysis: 2017 NREL PV Benchmark Report, the Annual Technology Baseline and PV plus storage analysis. Historical trend data is shown in the results field above to provide context, even where no formal GPRA Target was published for that year.		
Performance Goal (Measure)	**Photovoltaic (PV) - Reduce the modeled Levelized Cost of Energy (LCOE) Solar PV energy**		
Target	7 cents/kWh	6 cents/kWh	5.5 cents/kWh
Result	Exceeded - 6	TBD	TBD
Endpoint Target	3 cents /kWh by 2030 (without subsidies), cost competitive with traditional electricity sources.		
Comment	The PV solar energy cost target is an unsubsidized cost of energy at utility scale.		

Wind Energy

	FY 2017	FY 2018	FY 2019
Performance Goal (Measure)	**Offshore - Reduce the modeled Levelized Cost of Energy (LCOE) from off-shore wind energy.**		
Target	17.2 cents/kWh	16.2 cents/kWh	15.7 cents/kWh
Result	Met - 17.2	TBD	TBD
Endpoint Target	14.9 cents/kWh by 2020 9.3 cents/kWh by 2030		
Comment	The offshore wind energy cost target is an unsubsidized cost of energy at utility scale. Discount rate is derived from empirical European installations; Capacity weighted average installed CapEx and OpEx values derived from European Installations in 2016; 8.4 m/s Wind speed @ 50m hub height; and 20 year plant life.		

Performance Goal (Measure)	**Onshore - Reduce the modeled Levelized Cost of Energy (LCOE) from land-based wind energy.**		
Target	5.5 cents/kWh	5.4 cents/kWh	5 cents/kWh
Result	Exceeded - 5.2	TBD	TBD
Endpoint Target	5.2 cents/kWh by 2020 3.1 cents/kWh by 2030		
Comment	The onshore wind energy cost target is an unsubsidized cost of energy at utility scale. Real market Weighted Average Cost of Capital (WACC) of 5.6%; national capacity weighted average installed CapEx and OpEx values; 7.25 m/s Wind speed @ 50m hub height; and 25 year plant life.		

Water Power

	FY 2017	FY 2018	FY 2019
Performance Goal (Measure)	**Dams - Reduce the modeled Levelized Cost of Energy (LCOE) from hydropower from non-powered dams.**		
Target	9.7 cents/kWh	9.6 cents/kWh	9.4 cents/kWh
Result	Met - 9.7	TBD	TBD
Endpoint Target	9.2 cents/kWh by 2020 7.5 cents/kWh by 2030		
Comment	The hydropower from non-powered dams energy cost target is an unsubsidized cost of energy at utility scale. All terms and methodologies listed in the Hydropower Vision Report https://energy.gov/eere/water/articles/hydropower-vision-new-chapter-america-s-1st-renewable-electricity-source. Small, low head.		
Performance Goal (Measure)	**Marine & Hydrokinetic (MHK) - Reduce the modeled Levelized Cost of Energy (LCOE) from Marine & Hydrokinetic technologies. 2016: Double energy capture per cost (meters per million dollars) 2015: Increase power-to-weight ratio from a baseline of 0.25 (kW/ton) 2014: Reduce the cost of energy from Marine & Hydrokinetic technologies (cents/kWh) 2013: Test marine and hydrokinetic devices and components to determine baseline cost, performance, and reliability. (Cumulative number of devices tested)**		
Target	66 cents/kWh	64 cents/kWh	60 cents/kWh
Result	Met - 66	TBD	TBD
Endpoint Target	27 cents / kWh by 2030		
Comment	Wave energy cost target is an unsubsidized cost of energy at utility scale, based on Humboldt Bay standardized resource conditions. The goals and trajectories are based on expert opinion as published in the Hydropower Vision Report and reflect cost reductions in Capital Expenditures. https://energy.gov/eere/water/articles/hydropower-vision-new-chapter-america-s-1st-renewable-electricity-source.		
Performance Goal (Measure)	**Streams - Reduce the modeled Levelized Cost of Energy (LCOE) from new stream developments.**		
Target	11.5 cents/kWh	11.4 cents/kWh	11.15 cents/kWh
Result	Met - 11.5	TBD	TBD
Endpoint Target	10.9 cents/kWh by 2020 8.9 cents/kWh by 2030		
Comment	The new stream developments energy cost target is an unsubsidized cost of energy at utility scale. Target is for small, low-head developments. Although the baseline for the hydropower LCOE estimate is derived from empirical data, the sample set of new hydropower builds, on an annual basis, is too small to establish an empirically based national average annually. The goals and trajectories are based on expert opinion as published in the Hydropower Vision Report and reflect cost reductions in Capital Expenditures. https://energy.gov/eere/water/articles/hydropower-vision-new-chapter-america-s-1st-renewable-electricity-source.		

Geothermal Technology

	FY 2017	FY 2018	FY 2019
Performance Goal (Measure)	**Geothermal Systems - Reduce the modeled Levelized Cost of Energy (LCOE) from newly developed geothermal systems. 2013+: includes both hydrothermal and Enhanced Geothermal Systems (EGS).**		
Target	22 cents/kWh	21.8 cents/kWh	21.7 cents/kWh
Result	Met - 22	TBD	TBD
Endpoint Target	6 cents/kWh by 2030		
Comment	The geothermal energy cost target is an unsubsidized cost of energy at utility scale. The Geothermal Electricity Technology Evaluation Model (GETEM) estimates the representative costs of generating electrical power from geothermal energy. The estimated costs are dependent upon a number of factors specific to the scenario being evaluated, with most of these factors defined by inputs provided. Based on the scenario characterization, cost estimates are developed for all aspects of a project needed to provide the specified or calculated power sales. These costs and annual power sales are the basis for determining a levelized cost of electricity (LCOE). The GETEM user manual is published on the Idaho National Lab Website here: https://workingincaes.inl.gov/SiteAssets/CAES%20Files/FORGE/inl_ext-16-38751%20GETEM%20User%20Manual%20Final.pdf.		

Advanced Manufacturing

	FY 2017	FY 2018	FY 2019
Performance Goal (Measure)	**Advanced Materials - Improve manufacturing energy intensity as compared to a 2015 average technology baseline.**		
Target	N/A	7.5 %	10 %
Result	4.9%	TBD	TBD
Endpoint Target	17.5% improvement by 2022 relative to a 2015 average technology specific baseline.		
Comment	This data is derived from 190 Better Plants partner companies with over 2,900 facilities. These represent 11.7% of the total U.S. Manufacturing footprint in diverse industries. Energy intensity is calculated either through Cumulative Energy Savings (TBtu) or Cumulative Cost Savings; baseline is aggregate of partner baselines. The basis for FY 2018 and beyond [no Better Plants] is cumulative from 2015 average technology baseline- derived from bandwidth type studies as compared to new technologies developed within the AMO portfolio: https://www.energy.gov/eere/amo/energy-analysis-data-and-reports. Additional detail on specific technologies and energy productivity improvements is detailed in the Multi-Year Program Plan (MYPP) https://energy.gov/eere/amo/downloads/advanced-manufacturing-office-amo-multi-year-program-plan-fiscal-years-2017 and the PNNL analysis on AMO funded commercialized technologies https://energy.gov/eere/amo/impacts-industrial-energy-use.		

Performance Goal (Measure)	**R&D Consortia - Number of Manufacturing Research and Development Consortia selected for negotiation to demonstrate advanced material and process technologies, leading to commercialization**		
Target	2 Consortia	N/A	N/A
Result	Met - 2	N/A	N/A
Endpoint Target	Measure discontinued in FY18 due to a shift in focus towards early-stage R&D.		

Building Technologies

	FY 2017	FY 2018	FY 2019
Performance Goal (Measure)	**HVAC - Identify technology solutions capable of achieving dehumidification levels with less energy than conventional system.**		
Target	N/A	N/A	1 Technology Solution
Result	N/A	N/A	TBD
Endpoint Target	3 technology solutions by 2021		
Comment	Laboratory prototype tested on the ability to dehumidify air at 33 degrees centigrade with 90% relative humidity to 35% relative humidity isothermally and adiabatically. Note: For gas-fired dehumidification technologies the above numbers need to be divided by the factor of the three to account for the difference between kWh electric vs. kWh thermal. Standards are set according to electric code of federal regulations (as of Dec 28 2017: https://www.ecfr.gov/cgi-bin/text-idx?rgn=div8&node=10:3.0.1.4.18.3.9.2)		
Performance Goal (Measure)	**Lighting - Decrease the manufacturing cost of a warm white LED package. (Lumens/$) 2013: Increase lighting efficacy of "warm white light" solid-state lighting in a lab device.**		
Target	210 lm/$	N/A	N/A
Result	Met - 210	N/A	N/A
Endpoint Target	271 lm/$ by 2020		
Comment	Metric discontinued in FY2018 due to shift towards early-stage R&D.		
Performance Goal (Measure)	**Lighting Energy Efficiency - Increase power conversion efficiency of amber light**		
Target	N/A	13 %	15 %
Result	10 %	TBD	TBD
Endpoint Target	30% power conversion efficiency of amber light by 2025.		
Comment	2017 Baseline: 10% power conversion efficiency of amber light. To achieve the endpoint target of 350 lm/W of mixed monochromatic white light we need to increase the power conversion efficiency of all four wavelengths (green, amber, red and blue). We are focusing on amber in FY 2019 because it has the most significant technical barriers with the greatest early stage R&D opportunity. Increasing the power conversion efficiency of amber light directly contributes towards lm/W, though it is impossible to calculate by exactly how much. FY 2019 target is to achieve, in a laboratory prototype specimen, an increased percent conversion of electric power into amber light (580-595nm) with a 1 mm2 die at current density of 35A/cm2 and junction temperature of 25 C.		
Performance Goal (Measure)	**Standards - Issue energy efficiency standards in line with statutory requirements.**		
Target	N/A	N/A	3 Standards
Result	N/A	N/A	TBD
Endpoint Target	Standards will be issued in line with the statutorily defined standards review schedule.		
Comment	The energy conservation standards performance goal is based on the statutory requirements and associated deadlines.		

Federal Energy Management Program

	FY 2017	FY 2018	FY 2019
Performance Goal (Measure)	**Investments - Total Federal Investment in Facilities Energy Conservation Measures Government-Wide ($Million)**		
Target	$ 750 Million	$ 1,770 Million	$ 1,770 Million
Result	Exceeded - 1,337	TBD	TBD
Endpoint Target	$12.4 Billion in total efficiency investment between 2018 and 2024 required to meet the 25% energy reduction goal for 2025 vs. 2015 baseline. $1,770 million annually through 2024 to be invested by Federal agencies Government-wide through direct obligations and through performance contracting (Energy Savings Performance Contracts (ESPCs) and Utility Energy Service Contracts (UESCs)).		
Comment	Agencies report project investment funded through direct obligations and performance contracting annually in their reports to DOE required under 42 U.S.C § 8258(a), however DOE-FEMP does not receive these investment amounts until mid-way through the following fiscal year. Therefore direct obligations cannot be reported on quarterly basis during current fiscal year, only DOE IDIQ performance contracting awards can be accurately reported on a quarterly basis by FEMP. Government wide performance contracting investment is also tracked by OMB, with FEMP support, and can be reported quarterly during the fiscal year. Investment of $12.4 billion is required to reduce Federal facility energy use by 42.7 trillion Btu to meet the reduction goal of 25% in FY 2025 vs. FY 2015. The 42.7 trillion Btu required reduction assumes a 6.2% reduction in facility footprint (based on Federal Real Property Profile data) and anticipated impact of investment awarded in FY 2015, FY 2016, and FY 2017 (see above). Annual energy saving returned by $1 of investment is based on average return from the $2.2 billion of investment from the DOE FEMP IDIQ ESPCs awarded from FY 2012 through December 2016 (3,449 Btu saved annually per $1). One job-year = $125,000 of infrastructure investment. Cost of energy saved for FY 2015: $25/million Btu escalated 2% each year. The EISA 432 Compliance Tracking System (CTS) developed and managed by FEMP tracks agency performance of energy and water evaluations, project implementation and follow-up measures, and annual building benchmarking requirements. Agencies are required to implement reported energy and water efficiency measures (ECMs), including estimated cost and savings. FEMP also tracks and monitors the follow-up status on implemented measures, including measured savings and persistence of savings.		
Performance Goal (Measure)	**Workforce Development - Increase total hours of workforce development training provided by FEMP**		
Target	N/A	40,000 hours	42,500 hours
Result	37,612	TBD	TBD
Endpoint Target	50,000 training hours developed and offered by FEMP by 2025.		
Comment	FEMP manages all course and training registration/attendance data through the learning management system developed by the National Institute of Building Science's (NIBS) Whole Building Design Guide. All training attendance data is reported monthly to FEMP. The metric, hours of training provided, is calculated using the attendance from each training offering, taking into consideration the type and length of that training format. This metric provides FEMP with a clear and weighted measurement of how FEMP training material is being utilized and identifies which courses are most critical. This also is a more useful metric then just simple registration data, since many attendees take multiple courses throughout the year, thus it is critical to capture their attendance as well.		

Weatherization and Intergovernmental Programs

	FY 2017	FY 2018	FY 2019
Performance Goal (Measure)	**Retrofits - Weatherize homes of low income families**		
Target	33,000 homes weatherized	N/A	N/A
Result	Exceeded - 37,512	N/A	N/A
Endpoint Target	Measure is discontinued as of FY 2018.		
Comment	No targets set past 2017 but results will continue to be reported if appropriations received. Homes weatherized are reported on a quarterly basis. Reports are due 30 days after the close of the applicable reporting period through PAGE (Performance and Accountability for Grants in Energy) -- the online tool for grant performance reporting. Quarterly reports are quality-reviewed by Project Officers and approved before submission as final data.		

Vehicle Technologies

Overview

Vehicles move our national economy. Annually, vehicles transport 11 billion tons of freight[1] – more than $32 billion worth of goods each day[2] – and move people more than 3 trillion vehicle-miles.[3] Growing our economy requires transportation and transportation requires energy. The transportation sector accounts for 70 percent of U.S. petroleum use. With twenty five percent of U.S. petroleum consumption being imported, the U.S. sends more than ten billion dollars per month[4] overseas for crude oil. The average U.S. household spends nearly one-fifth of its total family expenditures on transportation,[5] making it the most expensive spending category after housing. Oil price volatility also affects our national economy, commercial enterprises, and household budgets.

To strengthen national security, enable future economic growth, support energy dominance, and increase transportation energy affordability for Americans, the Vehicle Technologies Program funds early-stage, high-risk research. The research will generate knowledge that industry can advance to deploy innovative energy technologies to support affordable, secure, reliable and efficient transportation systems across America. The Vehicle Technologies Program leverages the unique capabilities and world-class expertise of the National Laboratory system to develop new innovations in electrification, including advanced battery technologies; advanced combustion engines and fuels, including co-optimized systems; advanced materials for lighter-weight vehicle structures and better powertrains; and energy efficient mobility technologies and systems, including connected and automated vehicles as well as innovations in connected infrastructure for significant systems-level energy efficiency improvement. Vehicle Technologies is uniquely positioned to address early-stage challenges due to its strategic research partnerships with industry (e.g., the U.S. DRIVE and 21st Century Truck Partnerships) that leverage relevant technical and market expertise. These partnerships prevent duplication of effort, focus DOE research on the most critical R&D barriers, and accelerate progress. The Vehicle Technologies Program focuses on research that industry either does not have the technical capability to undertake on its own — usually because there is a high degree of scientific or technical uncertainty — or it is too far from market realization to merit sufficient industry emphasis and resources.

To improve transportation energy affordability, strengthen national security, support energy dominance and enable future economic growth, DOE performs early-stage R&D on advanced transportation technology options in the Vehicle Technologies, Bioenergy Technologies and Hydrogen and Fuel Cell Technologies Programs. Common metrics across all three of these programs have been developed to evaluate these advanced options compared to the lifecycle costs and energy consumption of today's technologies. Over a lifecycle basis (vehicle manufacture, fuel production, and fuel use), future (~2030) modeled conventional technology of a gasoline internal combustion engine vehicle (ICEV) is expected to be approximately 27 cents per mile and 4,700 Btu per mile.[6] The Vehicle Technologies Program goals below are necessary for new technology options to be more efficient and at least as affordable compared to this baseline while also accounting for consumer expectations regarding affordability and pay back periods.

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[1] Bureau of Transportation Statistics, DOT, 2016. Table 3-1 Weight and Value of Shipments by Transportation Mode https://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/transportation_statistics_annual_report/2016/tables/ch3/table3_1.

[2] Ibid.

[3] Transportation Energy Data Book 34th Edition, ORNL, 2015. Table 3.7 Shares of Highway Vehicle-Miles Traveled by Vehicle Type, 1970-2014.

[4] Ibid. Table 1.7 Imported Crude Oil by Country of Origin, 1973-2015; Table 10.3 Prices for a Barrel of Crude Oil and a Gallon of Gasoline, 1978-2015. Overseas includes countries and territories outside the 50 States and the District of Columbia.

[5] Bureau of Labor Statistics, Consumer Expenditure Survey, 2015. Average annual expenditures and characteristics of all consumer units, 2013-2015. https://www.bls.gov/cex/2015/standard/multiyr.pdf.

[6] See Record #17008, which can be accessed at https://www.hydrogen.energy.gov/program_records.html#program_related. Both energy and cost per mile are based on a 15-year vehicle lifetime.

Highlights of the FY 2019 Budget Request

The Vehicle Technologies Budget Request supports key efforts that contribute to achieving its high-level goals:

- Advanced Battery R&D: Identify new battery chemistry and cell technologies with the potential to reduce the cost of electric vehicle batteries by more than half, to less than $100/kWh (ultimate goal is $80/kWh), increase range to 300 miles and decrease charge time to 15 minutes or less by 2028.
- Energy Efficient Mobility Systems: By 2020, create cutting-edge modeling, simulations, and high performance computing-enabled data analytics to identify and ultimately enable new technologies, which have the potential to improve energy productivity through new mobility solutions, including connected, shared and automated vehicles.
- Advanced Engines and Fuels: Improve our understanding of, and ability to manipulate combustion processes, fuel properties and catalyst formulations generating knowledge and insight necessary for industry to develop the next generation of engines and fuels capable of improving passenger vehicle fuel economy by 35 percent in 2030 (vs. 2015 baseline of 36 MPG) while cost effectively meeting emission standards.
- Advanced Materials Research: Identify novel approaches to build lightweight, multi-material structures, with the potential to reduce light-duty vehicle glider (i.e. chassis, body structure, and interior) weight 25 percent by 2030 (vs. 2012 baseline of 2,430 lbs.). Focus on the development of high temperature materials for high efficiency engines.
- Technology Integration (formerly Outreach): Fulfill statutory requirements for providing alternative fuel information, publishing the Fuel Economy Guide, and implementing the state and alternative fuel provider fleet program. Support "living labs" to validate data, technologies, and systems in the field, serving as an important feedback loop to inform future Vehicle Technologies research planning. Support national science, technology, engineering, and mathematics education objectives through an advanced vehicle technology competition to provide hands-on training to university students and prepare them for the future workforce.
- Analysis: Using advanced vehicle and transportation data, conduct technical-, economic-, and interdisciplinary analyses that result in insights critical to informing Vehicle Technologies targets and program planning.

Vehicle Technologies Funding
($K)

	FY 2017 Enacted	FY 2018 Annualized CR*	FY 2019 Request	FY 2019 Request vs FY 2017 Enacted
Vehicle Technologies				
Battery and Electrification Technologies	140,530	—	35,500	-105,030
Energy Efficient Mobility Systems Advanced	16,385	—	9,000	-7,385
Engine and Fuel Technologies Materials	83,979	—	13,500	-70,479
Technology	23,565	—	5,000	-18,565
Technology Integration (formerly Outreach)	37,400	—	3,500	-33,900
Analysis	5,100	—	2,000	-3,100
Total, Vehicle Technologies	**306,959**	**304,874**	**68,500**	**-238,459**

SBIR/STTR:

- FY 2017 Transferred: SBIR $8,706,000; STTR $1,224,000
- FY 2018 Projected: SBIR $8,647,000; STTR $1,216,000
- FY 2019 Request: SBIR: $2,128,000; STTR: $299,000

*A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution. (These amounts are shown only at the Congressional control level and above; below that level, a dash (—) is shown).

Budget Structure Crosswalk
($K)

	Proposed FY 2019 Budget Structure						
FY 2017 Enacted Budget Structure	**Battery and Electrification Technologies**	**Energy Efficient Mobility Systems**	**Advanced Engine and Fuel Technologies**	**Materials Technology**	**Technology Integration**	**Analysis**	**Total**
Vehicle Technologies							
Batteries and Electric Drive Technologies	28,500	0	0	0	0	0	**28,500**
Vehicle Systems	7,000	9,000	0	0	0	0	**16,000**
Advanced Combustion Engine R&D	0	0	9,500	0	0	0	**9,500**
Materials Technology	0	0	0	5,000	0	0	**5,000**
Fuel and Lubricant Technologies	0	0	4,000		0	0	**4,000**
Outreach, Deployment, and Analysis	0	0	0	0	3,500	2,000	**5,500**
Total, Vehicle Technologies	**35,500**	**9,000**	**13,500**	**5,000**	**3,500**	**2,000**	**68,500**

Vehicle Technologies
Explanation of Major Changes
($K)

	FY 2019 Request vs FY 2017 Enacted
Vehicle Technologies	
Battery and Electrification Technologies: The reduction in funding level for this subprogram reflects the prioritization of the most critical early-stage activities, within the broader priorities of the Department and the Administration. Battery safety and thermal performance research will be eliminated and performance testing of new battery cell innovations will be minimized. Computer aided design research to couple crash response with electrochemical response will be eliminated. Advanced Battery Materials and Electrochemical Optimization Research will be reduced to support only two multi-lab research teams focused on high capacity cathodes and high capacity anodes, respectively. Support for SuperTruck II will be eliminated.	**-105,030**
Energy Efficient Mobility Systems: The reduction in funding level for this subprogram reflects the prioritization of the most critical early-stage activities, within the broader priorities of the Department and the Administration. Research on multi-modal transportation systems and advanced fueling infrastructure within the SMART Mobility National Laboratory Consortium, which is a multi-disciplinary approach to push the boundaries of understanding the energy efficiency and fuel use reduction impacts from future mobility technologies and transportation systems, will be eliminated, reducing the scope of SMART Mobility from five research pillars to three priority areas. The scope of the three-year high performance computing-enabled data analytics project will be reduced, and work to enhance and update other core transportation energy models, including the Autonomie model, will end.	**-7,385**
Advanced Engine and Fuel Technologies: The reduction in funding level for this subprogram reflects the prioritization of the most critical early-stage activities, within the broader priorities of the Department and the Administration. Research on multi-fueled and spark-ignited engines within the Co-Optimization of Engine and Fuels will be eliminated to focus on multi-mode spark-ignition/advanced compression ignition (SI/ACI) combustion for light duty. Research on light-duty diesel will be eliminated since this technology is facing too many emissions hurdles and industry is unlikely to adopt it in any significant volume. Development of computational fluid dynamics models and modeling of multi-cylinder engines will be eliminated within Predictive Modeling of Engine Combustion and Fuels to focus on high-fidelity submodel development. Research on emission reduction from diesel engines will be reduced within Catalyst R&D for Emission Control/After-Treatment to focus on fundamental catalysis. Consolidate medium- and heavy-duty on- and off-road projects and form a Multi-lab initiative to identify and conduct early stage research. Support for SuperTruck II will be eliminated.	**-70,479**

	FY 2019 Request vs FY 2017 Enacted
Materials Technology: The reduction in funding level for this subprogram reflects the prioritization of the most critical early-stage activities, within the broader priorities of the Department and the Administration. Previous research has focused on reducing the cost of specific lightweight, high-strength materials. In the future, the ability to use multiple lightweight materials on the same vehicle will be the most effective and efficient way to reduce mass. As a result, a multi-lab research effort on joining of dissimilar materials will be the focus of research. Work will be eliminated on reducing the cost or improving the manufacturability of specific lightweight materials in isolation, including aluminum, magnesium and carbon fiber. Research on materials for emissions control and aftertreatment is no longer considered to be within the scope of the Materials Technology program and will be eliminated. Development of high temperature materials for light and heavy-duty vehicles will remain a critical enabler for high efficiency engines and will remain a priority but scope will be reduced. SuperTruck II lightweight materials research will also be eliminated to focus on higher priority research.	**-18,565**
Technology Integration: The reduction in funding level for this subprogram reflects the prioritization of the most critical early-stage activities, within the broader priorities of the Department and the Administration. Outreach is renamed Technology Integration to better reflect program objectives. Minimal support is provided statutory requirements and activities that provide data and lessons-learned to inform future research needs. Minimal support is provided to start a new Advanced Vehicle Competition. The following activities will be terminated: Training, Technical Assistance, and Partnerships and Alternative Fuel Vehicle Community Partner Projects.	**-33,900**
Analysis: The reduction in funding level for this subprogram reflects the prioritization of the most critical early-stage activities, within the broader priorities of the Department and the Administration. Funding is provided for the planning and execution of technology, economic, and interdisciplinary analyses to inform and prioritize Vehicle Technologies technology investments and research portfolio planning, including activities such as research target setting and benefits estimation.	**-3,100**
Total, Vehicle Technologies	**-238,459**

Vehicle Technologies
Battery and Electrification Technologies

Description

The Battery and Electrification Technologies subprogram supports early-stage R&D to identify new battery chemistry and cell technology with the potential to reduce the cost of electric vehicle batteries by more than half to less than $100/kWh and increase the range to 300 miles while decreasing the charge time to less than 15 minutes by 2028. The cost target supports a levelized cost of driving (LCD) of a 300 mile BEV of $0.28/mile, which is comparable to future ICE at $0.27/mile. The ultimate cost goal for a 300-mile BEV battery is $80/kWh, which achieves an LCD of $0.26/mile.

The Battery and Electrification Technologies R&D subprogram funds research programs with partners in academia, National Laboratories, and industry, focusing on generating knowledge of high-energy and high-power battery materials and battery systems that can enable industry to significantly reduce the cost, weight, volume and charge time of plug-in electric vehicle (PEV) batteries. The activity supports the development of innovative materials and cell technologies capable of realizing significant cost reductions in four major R&D areas: Advanced Battery Materials R&D, Advanced Battery Cell R&D, Electrification R&D, and Electric Drive R&D.

Advanced Battery Materials Research ($24.5M) will focus on early-stage R&D of new lithium-ion cathode, anode, and electrolyte materials, which account for 50-70 percent of PEV battery cost of current technologies. Specifically, this work will focus on the development of new materials that offer a significant improvement in either energy or power and have the potential to achieve the DOE battery cost target of $100/kWh and be capable of charging in 15 minutes or less. This work will be carried out through National Laboratory Annual Operating Plans. Research will also focus on the development of innovative battery materials recycling and reuse technologies to assure sustainability and domestic supply. This work will be carried out through competitively-awarded cost-shared projects with industry and/or university partners. In addition, the subprogram will continue the Battery500 research consortium, which includes industry, university and labs and is focused on the development of “Beyond Lithium-Ion” technologies that have the potential to significantly reduce the weight, volume and cost by 3 times ($80/kWh). The Battery500 consortium consists of researchers from National Laboratories and academia focused on multi-disciplined research to overcome performance barriers associated with high energy density battery technology. The activity focus is to design novel electrode and cell architectures that utilize a lithium anode combined with a compatible electrolyte system, and high capacity cathodes that prohibit lithium dendrite growth or polysulfide dissolution and achieve 500 Wh/kg and 1000 cycles at the lab cell level.

The Advanced Battery Cell R&D effort ($3M) will focus on early-stage R&D of new battery cell technology that contains new materials and electrodes that can reduce the overall battery cost, weight, and volume while improving energy, life, safety, and fast charging. This work will be carried out through competitively-awarded, cost-shared awards with industry through funding opportunities supported through the DOE Cooperative Agreement with the U.S. Advanced Battery Consortium (USABC). This activity also supports high fidelity battery performance, life, fast charging, and safety testing of innovative battery technologies at the National Laboratories.

The Electrification R&D effort ($7M) will focus on early-stage research to understand the potential impacts of electric vehicle (EV) charging on the Nation’s electric grid. This work will be carried out through National Laboratory Annual Operating Plans and competitively-awarded, cost-shared projects with industry and university partners. This research will inform the development of communication and cybersecurity protocols; enable industry to enhance the interoperability between charging equipment, the on-board vehicle charger, and charging networks; and foster technology innovations to improve EV refueling through extreme fast charging (including high-power static and dynamic wireless charging), which is beyond 7-10 years from market realization to merit significant industry focus and have not reached critical mass. In FY 2019, this effort will focus on Extreme Fast Charging (XFC) research to understand the charging infrastructure and electricity grid challenges to enabling a 15-minute or less battery charge. Current Direct Current Fast Charge (DCFC) equipment operates at 50-120 kW. The goal for extreme fast charging research is to enable industry to develop and deploy 350+ kW power (over 3-7X improvement) capability that will enable EVs to charge in 15 minutes or less.

Electric Drive Research ($1M) will focus on early stage research of extreme high power density motor and power electronics that have the potential to enable radical new vehicle architectures by dramatic volume/space reductions and increased durability and reliability. Research through National Laboratory Annual Operating Plans will emphasize a ten-fold reduction in the volume of electric traction drive systems using high-density integration technologies, leveraging high performance computing for modeling and optimization, and utilizing new materials for high-density electric motors. Integration of electric traction drive systems based on power electronics and electric motor innovations will also be a priority.

Battery and Electrification Technologies

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Battery and Electrification Technologies $140,530,000	**$35,500,000**	**-$105,030,000**
Advanced Battery Materials Research & Battery500		
• Supported the Battery500 National Laboratory and University Research Consortium (composed of four labs and five universities) focused on beyond lithium-ion research. Three keystone research projects conducted by multi-disciplined teams include (1) investigating solvent in salt electrolytes for lithium metal anodes, (2) research to enable sulfur cathodes, and (3) novel electrode construction coupled with solid state electrolytes. The activity includes five to ten “seedling” projects that explore other beyond lithium-ion technology. • Initiated 15 new competitively awarded seedling projects aimed at innovative battery materials and approaches that complement the Battery500’s Consortium’s research to more than double the specific energy (to 500 watt-hours per kilogram) of lithium battery technologies. These projects enable smaller, safer, lighter weight, and less expensive battery packs that ultimately will make electric vehicles more affordable.	• Continue support for the Battery500 Consortium to significantly increase energy density/reduce cost through “beyond lithium ion” technology. In FY 2019, the three Battery500 Consortium Keystone research projects focused on mitigation of lithium dendrite formation, polysulfide dissolution, and solid-state materials research will continue. Specifically, the 15 seedling projects selected in FY2017 will be down selected to five to eight of the most promising technologies and innovations.	• No new seedling projects will be awarded. The 15 seedling projects selected in FY2017 will be down selected to five to eight of the most promising technologies and innovations.
• Supported 45 National Laboratory, 20 University and four industry R&D Advanced Battery Materials projects in the following focus areas: development and synthesis of high voltage/high capacity cathode materials; high voltage electrolytes; development of new synthesis routes for making lithium rich materials to mitigate voltage fade problem; modeling and first principles calculations of electrode materials, solid-electrolyte interphase	• Funding will support 18 projects at the National Laboratories focused on beyond lithium ion technologies. Specifically, the primary focuses are on: (1) development of a framework or scaffold to host metallic lithium to stabilize the lithium electrode surface and mitigate lithium plating during cycling, and (2) development of novel sulfide based solid electrolytes with improved ionic conductivity and minimal areal surface impedance. Research will continue on	• Current university and industry awards will continue to cost obligated carryover. Laboratory materials research will be down selected from 45 to 18 National Laboratory projects offering the most promising technologies and innovations. New industry and university projects will focus on technologies with potential to achieve significantly higher energy density and the ultimate $80/kWh battery cost target.

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
(SEI) layer and electrode microstructure; and assembly of high density low tortuosity electrodes.	designing novel electrode material structures to increase sulfur mass loading and contain long chain polysulfides on the positive electrode to improve sulfur utilization. Funding will support 3-5 new industry and university projects selected through an open and competitive process. Research will focus on lithium metal, lithium sulfur, and solid-state battery technology.	
• Supported two multi-disciplined, multi-Laboratory research teams to enable next-generation intermetallic anodes for lithium-ion batteries to address a critical problem in getting to higher energy cells. Research is expected to evolve to the following topics: Team 1 will focus on fundamental research to understand and improve the solid-electrolyte-interphase in order to improve calendar and cycle life, and team 2 will explore concentration gradient particles and advanced particle coating technologies, and binder materials to understand and improve power capability and reduce material expansion during lithiation.	• Support one multi-disciplined, multi-Laboratory research team to enable next-generation intermetallic anodes for lithium-ion batteries that address critical barriers in achieving high energy density and long cycle and calendar life. Research is expected to gain a better fundamental understanding of the silicon electrolyte interphase and through this knowledge develop strategies to stabilize this surface. In-house production of silicon particles will begin to develop a stable consistent source of active material that will enable R&D at National Laboratories and Industry. Continue support for research focused on exploring concentration gradient cathodes and advanced particle coating technologies.	• Two multi-Laboratory research teams will be merged into one team in order to focus on higher priority areas of improving the intermetallic anode solid-electrolyte interphase.
• Continued to support R&D at National Laboratories teams to engineer new cathode and electrolyte materials. Developed processes to scale up these materials from lab quantities (grams) to batch quantities (10's of kilograms). This activity enabled expanded laboratory level research on innovative battery materials. Research focused on the engineering and batch scale-up of 2-3 new, innovative cathode materials and 1-2 new electrolyte material.	• Activities in FY 2019 will focus on developing synthetic processing routes to produce a down-selected, high-capacity cathode material and a family (1-3 electrolyte components, up to 4 additives) of high performance electrolyte components. These material components will become the basis for a high voltage, high capacity lithium-ion battery chemistry with potential to achieve program cost and	• The activity will continue to scale, characterize and test promising materials. The engineered materials will be made available to US stakeholders and research institutions for expanded R&D.

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
	performance targets through successful electrochemical optimization research. • Funding will support 2-4 new industry and university projects selected through an open and competitive process. Research will focus on developing new innovations in the recycling and reuse of critical battery materials.	• Fund 2-4 new projects related to recycling and sustainability of lithium ion battery materials to enable long-term availability of critical materials and identify research pathways to further reduce the cost of battery materials.
Advanced Battery Cell R&D		
• Continued to support 12 competitively awarded, cost-shared DOE/ USABC projects to lower battery costs to $100/kWh that focus on research to significantly reduce battery cell and pack cost, increase performance and life, and be capable of extreme fast charging.	• Cost-shared battery cell R&D projects awarded through USABC and funded in FY 2017 will continue. Current funding supports two to four projects expected to complete in FY 2019 and it is expected that another two to three will start in FY 2018 that will require continued support into FY 2019. The new FY2018 projects are expected to focus on lower cost batteries capable of fast charge in less than 15 minutes.	• USABC projects awarded in FY 2017-2018 continue to cost obligated carryover, but no new awards. Research portfolio will be downselected to two to four of the most promising projects in FY 2019.
• Supported 18 high fidelity battery performance, life, thermal response, and safety testing projects at three National Laboratories.	• Consolidate high fidelity performance and life battery testing from three to one National Laboratory and downselect three to four of the most promising projects. The battery thermal testing projects will be eliminated (two to three projects focused on optimizing extreme fast charging cell designs). Battery abuse response and safety projects (three cell designs that incorporate novel active materials and non-flammable electrolytes) will also be eliminated.	• Reduce high fidelity performance and life battery testing to one National Laboratory and downselect from 18 to the three to four most promising projects. Eliminate thermal and safety testing of innovative cells and materials in order to focus on higher priority areas.
• Developed advanced Computer Aided Engineering Battery Design Tools. Activities are limited to up to two multi-National Laboratory projects to couple electrochemical reactions with structural degradation and to improve computational performance.	• No funding requested.	• Current industry awards will continue to cost obligated carryover. Two to three National Laboratory projects focused on coupling crash and safety conditions with electrochemical response models will also continue to cost obligated carryover.
Electrification R&D		

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
• Initiated four research projects focused on the (1) cost, safety & reliability of extreme fast charging (XFC, 300-400 KW) equipment, (2) the impact of XFC to the electric grid, (3) evaluations and testing of existing Combined Charging System (CCS) connectors for XFC applications needed to determine safe, reliable and robust operating limits, and implications to cybersecurity, and (4) standardization to ensure interoperability so that new and legacy vehicles are able to access XFC and existing Direct Current Fast Charge (DCFC) networks. Continued cyber related research.	• Continue research projects focused on enabling extreme fast charging of electric vehicles, grid impacts of EV charging, and cybersecurity. In FY 2019, this activity will focus on the higher power, extreme Fast Charging (300-400 KW) research, and communications, controls and cybersecurity related to vehicle and charging equipment.	• Scope will be reduced to focus on the highest priority research areas.
	• Support 2-4 new awards, selected through an open and competitive process, to develop innovations in dynamic wireless charging technologies.	• New research projects will focus on advanced technologies to support very high power transfer rates with minimized footprint that can allow this autonomous electric vehicle enabling technology to be integrated into roadway and interstate infrastructure projects. Magnetic field shaping and projection control technologies, combined with high speed information sharing and switching controls, will be the focus of the awards made through this initiative.
• Supported Grid Modernization Laboratory Consortium research focused on devices and integrated system testing, sensing and measurement, system operations and power flow, design and planning tools, in order to secure electric vehicle cyber security and grid resilience.	• No funding requested.	• This activity will terminate. Some activities will continue to cost obligated carryover until completion. Some lab projects related to execution of prior year appropriations will continue until completion.
	• Support 2-4 new awards, selected through an open and competitive process, to develop innovative technologies and systems to manage electric vehicle fast charging power and energy needs and assure grid reliability, integrity, resiliency, and efficiency.	• New research projects will focus on enhancing grid reliability, integrity, and resiliency through the development of technologies allowing electric vehicles to be integrated seamlessly into advanced hybrid energy systems. Systems controls developed

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
		will minimize the impact on the electric grid from electric vehicle charging loads while using high power fast chargers, and avoid the need to expand electricity generation.
Electric Drive Technologies R&D		
• Supported projects at the National Laboratories to conduct research of high temperature materials, devices, and components including interfaces and interconnects that enable innovative power electronics designs such as use of wideband gap semiconductors; and advanced motor materials and configurations to eliminate rare earth materials. Efforts emphasized materials and processes for manufacturing to reduce cost with improved performance and reliability to accelerate commercialization.	• Initiate two to four National Laboratory projects on early stage research of extreme high power density motor and power electronics that have the potential to enable radical new vehicle architectures by dramatic volume/space reductions and increased durability and reliability.	• In FY 2019, research efforts will shift focus to emphasize a ten-fold reduction in the volume of electric traction drive systems using high-density integration technologies.
• Initiated a competitive funding opportunity for two to three new projects that will develop plug-in electric vehicle systems that can demonstrate the ability to recharge rapidly at high power levels.	• No funding is requested for this activity.	• This activity will terminate. Some activities will continue to cost obligated carryover until completion.
SuperTruck II		
• Develop energy efficient powertrain technologies that will improve commercial vehicle engine efficiency by 30 percent and freight hauling efficiency of heavy-duty Class 8 long-haul vehicles by 100 percent in 2020, compared to a 2009 baseline vehicle, and demonstrate applicability and cost-effectiveness of these technologies to heavy-duty Class 8 regional-haul vehicles.	• No funding requested.	• This activity will terminate. Some activities will continue to cost obligated carryover until completion.

Description

The Energy Efficient Mobility Systems (EEMS) subprogram supports early-stage research to enable industry innovation that improves the efficiency of the overall transportation mobility system. Initial analysis by DOE indicates that the future energy impact of connected and automated vehicles is highly uncertain and may be quite large, ranging from a potential 60 percent reduction in overall transportation energy use to a 200 percent increase in energy consumption. EEMS will apply complex modeling and simulation expertise, experience with big data, and high-performance computing capabilities unique to DOE National Laboratories to explore the energy impact of emerging disruptive technologies such as connected and automated vehicles, information-based mobility-as-a-service platforms, and advanced powertrain technologies to identify and develop innovative mobility solutions that improve energy efficiency, lower costs for families and business, and enable the use of secure, domestic energy sources. The EEMS subprogram consists of two primary activities, the SMART Mobility National Laboratory Consortium and high performance computing-enabled data analytics, which build upon Vehicle Technologies work in advanced powertrains, controls and electric vehicle charging. The Subprogram's overall goal is to identify pathways and develop innovative technologies and systems that can dramatically improve *mobility energy productivity* when adopted at scale. The EEMS subprogram is currently developing a quantitative metric to measure mobility energy productivity, or the value derived from the mobility system per unit of energy consumed, which will be required to evaluate program success.

The SMART (**S**ystems and **M**odeling for **A**ccelerated **R**esearch in **T**ransportation) Mobility National Laboratory Consortium ($7.5M, Lab AOP) will develop new knowledge and understanding of the energy efficiency and fuel use opportunities from future mobility technologies and applications, and conduct pioneering research and development of mobility solutions that benefit the U.S. economy and improve American competitiveness in the transportation sector. Efforts within the five-lab SMART Mobility Consortium are organized into three coordinated research pillars, representing a multi-disciplinary approach that is beyond the scope or capability of a single company or organization:

- Connected and Automated Vehicles: Research focuses on understanding the energy efficiency opportunity presented by new vehicle connectivity and automation solutions, including simulation and validation of how these technologies will perform in real-world operation.
- Mobility Decision Science: Research evaluates the interaction between new mobility options and human decision-making to develop transportation choices that American consumers want.
- Urban Science: Research considers the unique transportation challenges faced by American cities, including the interactions among travelers, freight movement, infrastructure, and the built environment.

The high performance computing-enabled data analytics effort ($1.5M, Lab AOP) will research how to apply artificial intelligence, machine learning and data science tools to improve vehicle and transportation efficiency. The exponential growth in available transportation-related data presents opportunities to evaluate and improve mobility and energy efficiency at the city and regional transportation network level, but challenges exist in management, analysis, and visualization of these large and complex data sets. DOE and its National Laboratories are highly qualified and well positioned to use their unique expertise in artificial intelligence, machine learning and high-performance computing to develop actionable information from big data to identify the most promising research pathways leading to more energy efficient transportation systems. High performance computing-enabled data analytics represents a targeted multi-lab effort that merges the exploratory findings of the SMART Mobility Consortium, specific data sets from public and private entities, and unparalleled computational and analytical resources to solve specific transportation energy challenges faced by cities, states, and regions of the U.S.

Energy Efficient Mobility Systems

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Energy Efficient Mobility Systems $16,385,000	**$9,000,000**	**-$7,385,000**
• Established the SMART Mobility Lab Consortium, to conduct advanced transportation system modeling and simulation across five research pillars, to vet complex future mobility scenarios and identify areas for early-stage R&D to provide cost-effective mobility choice to consumers. • Provided updates to core vehicle modeling and simulation tools, including the Autonomie vehicle-level modeling platform, and conducted testing and evaluation activities to validate software models. • Initiated three new competitively selected awards to conduct research that leads to energy savings benefits from connected and automated vehicles. These projects will create new software, controls, and technologies that use connectivity and automation to improve vehicle efficiency, establish a novel research vehicle testbed to evaluate connected and automated technologies, and evaluate the system-wide energy opportunities through connectivity, automation, and shared mobility.	• Conduct research in the SMART Mobility Lab Consortium through three priority research pillars: connected and automated vehicles, mobility decision science, and urban science. • Develop the data science and high performance computing framework needed to build next-generation mobility systems models and operational analytics, to address energy-specific transportation system problems at geographic and temporal scale.	• The advanced fueling infrastructure and multi-modal research pillars under the SMART Mobility Consortium will be eliminated, with critical tasks from these pillars consolidated into the three priority pillars. Emphasis will shift from transportation system-level understanding to specific technology solutions. • Core modeling and simulation activities will be incorporated into, and directly support, SMART Mobility. No improvements or updates to core modeling and evaluation tools will be made. • No new industry projects will be awarded. Current industry awards will continue to cost obligated carryover.

Description

The Advanced Engine and Fuel Technologies subprogram supports early-stage R&D to improve our understanding and ability to manipulate combustion processes, fuel properties and catalyst formulations. This generates the knowledge and insight necessary for industry to develop the next generation of engines and fuels for light- and heavy-duty vehicles. As a result, co-optimization of higher-efficiency engines and high performance fuels has the potential to improve light-duty fuel economy by 35 percent (25 percent from advanced engine research and 10 percent from co-optimization with fuels) by 2030 compared to 2015 gasoline vehicles. The subprogram supports cutting-edge research at the National Laboratories, in close collaboration with academia and industry, to strengthen the knowledge base of high-efficiency, advanced combustion engines, fuels, and emission control catalysts. The Advanced Engine and Fuel Technologies subprogram will utilize unique facilities and capabilities at the National Laboratories to create knowledge, new concepts and research tools that industry can use to develop advanced combustion engines and co-optimize with fuels that will provide further efficiency improvements and emission reductions. These unique facilities and capabilities include the Combustion Research Facility at Sandia National Lab, Advanced Photon Source at Argonne National Lab, Institute for Integrated Catalysis at Pacific Northwest National Lab, detailed fuel chemistry expertise at the National Renewable Energy Lab, chemical kinetic modeling and mechanism development at Lawrence Livermore National Lab, and the Spallation Neutron Source at Oak Ridge National Lab, along with their high performance computing resources and initial work to utilize future exascale computing resources. The subprogram will work closely with the DOE Office of Science to utilize their basic research results. The subprogram will form a new Multi-lab initiative focused on early-stage research to optimize efficiency of on- and off-road medium- and heavy-duty vehicles, including high performance computing and hardware in-the-loop resources. The subprogram has four major activities: predictive modelling, experimental combustion including fuels and engines, emissions control and crosscutting medium- and heavy-duty vehicle and engine technologies.

Predictive, high fidelity models will be developed by the National Laboratories ($3.3M, Lab AOP) that will be able to use future exascale computing capabilities, to simulate the fundamental physics of fuel injection sprays, heat transfer, turbulence and combustion phenomena using high performance computing resources to achieve results comparable to the detailed experiments. The subprogram will fund fundamental early-stage research of fuel properties utilizing chemical kinetics modeling of different molecules to determine their impact on combustion efficiency and emissions. Numerical routines and sub-models of complex chemical reactions will be developed that can reduce the computational time and increase the accuracy required for high fidelity engine models making them viable as engine design models for industry.

Experimental combustion projects conducted by the National Laboratories ($4.6M, Lab AOP) will develop data to establish quantitative relationships between fuel properties and efficiency improvement potential for engines operating in advanced compression ignition combustion and multi-mode spark ignition/compression ignition regimes. Advanced laser, high intensity X-Ray and neutron-based optical diagnostics will be conducted to determine how fuel injection, air mixing and combustion take place in the engine and how emissions are formed. In combination, the knowledge from this research will enable companies to develop a new generation of low-temperature combustion engines with higher efficiency and lower emissions.

The subprogram will fund experiments conducted by the National Laboratories ($3.5M, Lab AOP) using high-resolution microscopy for understanding chemical reactions at the atomistic level on catalyst surfaces and within the catalysts that have the potential to reduce emissions at the low exhaust temperatures from high-efficiency engines. New catalyst compounds with higher activity and lower costs will be synthesized, and models to simulate the chemical reactions rates using high performance computing will be developed.

The knowledge and high-fidelity models developed for combustion, fuels and emission control will be available for use by industry (through licensing or development by industry suppliers of commercial tools based on the fundamental models)to design, develop and deploy more efficient and clean engines. Industry does not have the unique facilities and scientific capabilities that are available at the National Laboratories to conduct this early-stage R&D. The subprogram will utilize cost-shared CRADAs and pre-competitive research to address critical industry needs while still leveraging unique National Laboratory resources.

Establishes a new multi-lab initiative ($2.1M, Lab AOP) focused on crosscutting on- and off-road medium- and heavy duty vehicle and engine technologies that will identify new barriers and enabling technologies to achieve significant gains in energy efficiency. Trucks move 11 billion tons of freight in the U.S. and this is expected to grow and shift as more people order goods to be delivered to homes. The goal of this new initiative is to conduct coordinated early-stage research at National Laboratories having unique facilities and capabilities for heavy-duty vehicles research. The funding will be provided through competitive lab calls with proposals reviewed by Vehicle Technologies and independent reviewers. This will include both traditional combustion engine architectures as well as new opportunities to partially electrify truck operations or use systems approaches to reduce energy during operation. This subprogram will coordinate with and utilize expertise from other subprograms as needed.

Advanced Engine and Fuel Technologies

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Advanced Engine and Fuel Technologies $83,979,000	**$13,500,000**	**-$70,479,000**
Predictive Modeling of Engine Combustion and Fuels		
• Conducted development of computer simulations of engine combustion using high performance computing facilities at the National Laboratories. Included: modeling of fuel injection sprays, intake and exhaust flows and heat transfer processes, chemical kinetics mechanisms of combustion and fuels, and air-fuel motion and mixing inside an engine along with movement of internal engine components.	• Develop high fidelity submodels of the physics for fuel sprays, heat transfer and turbulence, including adaption for future Exascale-based high performance computing at the National Laboratories. Develop detailed chemical kinetic models of fuels and combustion processes along with numerical techniques to reduce processing time.	• Eliminate three projects at the National Laboratories for modeling combustion using large eddy simulation (LES), Computational Fluid Dynamics (CFD) model development and modeling of multi-cylinder engines. • Reduce predictive modeling efforts to focus on fuel sprays and chemical kinetic submodel development.
Lean/Next Generation Combustion Engines and Fuels R&D and Heavy-Duty Combustion Engines and Fuels R&D		
• Conducted single-cylinder engine research projects at National Laboratories supporting fundamental advanced combustion and fuels research in optically accessible engines with in-cylinder optical and laser diagnostics, and X-Ray- and neutron-based fuel injection spray visualization providing experimental validation for simulation models. • Supported projects at National Laboratories and universities on the Co-Optimization of Engines and Fuels with emphasis on fuel properties research to remove barriers to higher vehicle efficiency. Research focused on performance tailored blendstocks, including bio-derived, synthetic and petroleum-based blend stocks that will increase vehicle efficiency. Engine research focused on advanced conventional and kinetically controlled engine technologies with advanced fuels that enable maximum engine performance.	• Focus on utilizing new advanced research tools at the National Laboratories (e.g., laser, neutron spallation, X-ray light source) to improve the fundamental understanding of advanced combustion processes and emissions formation inside an operating engine. Utilize experimental results to validate and enhance simulation models. • Co-optima research will focus on multi-mode compression-ignition/spark-ignition engines and their optimal fuels, and ideal fuel properties for full-time advanced compression ignition (ACI) engines. Research will continue to focus on performance tailored blendstocks, including bio-derived, synthetic and petroleum-based blendstocks that will increase vehicle efficiency. Further, refine the efficiency and emissions Merit Function for ACI to include fuel properties with	• Eliminate two projects at the National Laboratories for light-duty optical diesel engine and multi-cylinder high-energy ignition systems. • Eliminate two additional projects at the National Laboratories for multi-cylinder advanced compression ignition and gasoline direct injection engine research. Reduce efforts to generate experimental chemical kinetics data. • Reduce Co-optima research effort on spark-only engines and focus on multi-mode compression ignition engines as well initial determination of fuel properties needed in medium and heavy-duty advance compression ignition engines. • Eliminate 18 projects at the National Laboratories in the following research areas: impact of exhaust gas recirculation on high-load operation; reactivity controlled compression ignition engine research;

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
	the greatest potential to balance needs for efficiency and emissions for various medium- and heavy-duty duty cycles.	octane on demand; small volume fuel tester; and low-speed pre-ignition research. • Eliminate multi-laboratory research projects related to spark ignition combustion within Co-Optima. Increase research on fuel properties for medium- and heavy-duty engines.
Catalyst R&D for Emission Control/After-Treatment		
• Supported cost-shared CRADAs with industry to address advanced emission control technologies. • Continued development of computer models needed to produce the kinetics and mechanistic information for simulating chemical reactions within and on catalyst surfaces for predicting the performance of lean NOx trap (LNT) and selective catalytic reduction (SCR) catalysts, as well as advanced multi-functional emission control systems.	• Support three of four cost-shared CRADAs with industry to address advanced emission control technologies. • Develop kinetic and mechanistic models of catalyst and substrate materials to predict the performance of oxidation, lean NOx trap (LNT), hydrocarbon (HC) trap, and selective catalytic reduction (SCR) catalysts, as well as advanced multi-functional emission control systems.	• Reduce research on diesel engine related selective catalytic reduction research and focus on emission control for lean-gasoline and advanced compression engines. • Reduce efforts to coordinate research between universities, industry and National Laboratories. Increase focus on single atom-catalysis research to reduce platinum group metal content and cost. • Reduce modeling of emissions control systems.
On- and Off-road Medium/Heavy duty Vehicle and Engine Technologies		
• No funding requested.	• Conduct research on engine and vehicle level technologies applicable to both on and off road medium- and heavy-duty vehicles, including waste heat recovery, fundamental combustion, electrified driveline systems and hybridization of the powertrain, and operational systems that can reduce fuel consumption through more efficient operation.	• Utilize a Multi-lab initiative to consolidate some previous work as well as start new work though a comprehensive and strategic view of the total truck and its operation. Technologies to improve freight efficiency through engine/powertrain improvements, electrification, lightweighting, vehicle simulation and modeling, and autonomous driving will be investigated. This will build upon previous individual projects in combustion, electrification and mobility but will bring it together in a coordinated effort.
• Conducted a background study to determine the amount of energy used in the mobile, off-road fluid power sector and evaluated opportunities for efficiency gains. Held a public workshop to assess research needs related to mobile, off-road fluid	• No funding requested.	• This activity will terminate. Some activities will continue to cost obligated carryover until completion.

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
power systems. Initiated up to three new competitively selected awards based on the workshop findings. Solicited concept papers from National Laboratories for potential fluid power research projects.		
Natural Gas Engine Technology R&D		
• Conducted public workshop to evaluate research needs related to natural gas engine technology R&D focused on low-TRL research. Initiated up to three new competitively selected awards based on the workshop findings. Solicited concept papers from the National Laboratories for potential natural gas research projects. Initiated a multi-lab study of research opportunities and potential benefits associated with medium and heavy duty natural gas vehicles.	• No funding requested.	• This activity will terminate. Some activities will continue to cost obligated carryover until completion.
SuperTruck II		
• Develop energy efficient powertrain technologies that will improve commercial vehicle engine efficiency by 30 percent and freight hauling efficiency of heavy-duty Class 8 long-haul vehicles by 100 percent in 2020, compared to a 2009 baseline vehicle, and demonstrate applicability and cost-effectiveness of these technologies to heavy-duty Class 8 regional-haul vehicles.	• No funding requested.	• This activity will terminate. Some activities will continue to cost obligated carryover until completion.

Vehicle Technologies
Materials Technology

Description
The Materials Technology subprogram supports vehicle lightweighting and improved propulsion (powertrain) efficiency through early-stage R&D to discover and further understanding of how to manipulate and use novel materials and enabling technologies for industry to develop and deploy light- and heavy-duty vehicles. The Materials Technology research portfolio supports the Vehicle Technologies goals of affordable transportation and energy security. Reducing the weight of a conventional passenger car by 10% results in a 6-8% improvement in fuel economy and similar benefits are achieved for battery electric and heavy-duty vehicles. To achieve this, research focuses on activities that have a high degree of scientific or technical uncertainty, or that are too far from market realization to merit sufficient industry emphasis and resources. The Materials Technology subprogram accomplishes its technical objectives through research programs with academia, National Laboratories, and industry.

Subprogram activities focus on the following cost and performance targets, which contribute to Vehicle Technologies program level goals:

- Enable a 25 percent weight reduction for light-duty vehicles including body, chassis, and interior as compared to a 2012 baseline at no more than a $5/lb.-saved increase in cost by 2030;
- Validate a 25 percent improvement in high temperature (300° C) component strength relative to components made with 2010 baseline cast aluminum (AL) alloys (A319 or A356) for improved efficiency light-duty engines by 2025.

Lightweight Materials Technology ($3M, AOP including LightMat Consortium) supports research in advanced high-strength steels, aluminum (Al) alloys, magnesium (Mg) alloys, carbon fiber composites, and multi-material systems with potential performance and manufacturability characteristics that greatly exceed today's technologies. This includes projects addressing materials and manufacturing challenges spanning from atomic structure to assembly with an emphasis on establishing and validating predictive modeling tools for materials applicable to light- and heavy-duty vehicles. In FY 2019, the subprogram will fund research conducted by the National Laboratories with a focus on new joining technologies for multi-material structures in vehicles. This includes joint work with industry through the Lightweight Materials (LightMAT) Consortium established under the Energy Materials Network (EMN) to discover and accelerate advanced materials in dissimilar material joining, assembly technologies, and corrosion prevention enabling the use of various lightweight materials as best suited for particular applications. The complex metallurgical, chemical and mechanical behavior associated with the formation of intermetallic compounds, electrochemical reactions and stress-strain states that exist in joining are not well understood and are outside of the core competencies of industry. Vehicle Technologies has the unique ability to create partnerships between academia, National Laboratories, and all aspects of the industrial supply chain in order to find solutions to these technical challenges that any one entity could not achieve on their own.

Propulsion Materials Technology ($2M, AOP) supports research to develop higher performance materials that can withstand increasingly extreme environments and address the future properties of a variety of relevant, high-efficiency powertrain types, sizes, fueling concepts, and combustion modes. The activity will continue to apply advanced characterization and multi-scale computational materials methods, including high performance computing, to accelerate discovery and early-stage development of cutting-edge structural and high temperature materials for more efficient powertrains. In FY 2019, research areas will focus on (1) the development of high temperature materials for high efficiency engines for heavy-duty vehicles, (2) the development of predictive models for powertrain materials, and (3) Integrated Computational Materials Engineering (ICME) tools that use high performance computing (HPC) capabilities, multi-length (atoms to components) material models, and boundary layer resolved thermo-kinetic models. Each of these activities will be funded through AOPs at the National Laboratories with industry cost shared agreements due to the required expertise and use of very high-resolution characterization tools and high performance computing facilities, which are beyond the capabilities available to most industry partners. The Propulsion Materials portfolio is closely aligned with other Vehicle Technologies subprograms to identify critical future materials needs for next generation high-efficiency powertrains for both heavy and light-duty vehicles that are beyond current market drivers.

Materials Technology

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Materials Technology $23,565,000	**$5,000,000**	**-$18,565,000**
Lightweight Materials Technology		
• Supported research on reducing the cost of carbon fiber through two FOA awards, National Laboratory research, and support of the Carbon Fiber Technology Facility (CFTF).	• No funding requested.	• Eliminate all research on reducing the cost of carbon fiber. Some activities will continue to cost obligated carryover until completion.
• Continued support of National Laboratory research to improve the properties and manufacturability of lightweight metals such as advanced high strength steels (AHSS), aluminum (Al), and magnesium (Mg).	• No funding requested.	• Eliminate all research on improved properties and manufacturability of lightweight metals. Some activities will continue to cost obligated carryover until completion.
	• Investigate and develop new innovative joining technologies for Mg-metal and carbon fiber composites-metal joining interfaces, complex joining mechanisms, and corrosion mitigation concepts through the Joining Core Program.	• Address specific early stage technical challenges limiting the incorporation of Mg alloys and carbon fiber reinforced polymers (CFRP) into multi-material structures through National Laboratory research.
• Initiated four new CRADA projects to accelerate the development of lightweight materials by connecting industry to National Laboratory capabilities through the Lightweight Materials (LightMAT) Consortium under the Energy Materials Network (EMN).	• Initiate one to two new CRADA projects utilizing the LightMAT Consortium to engage the automotive industry in accelerating the discovery and development of advanced materials technology.	• Reduce number of CRADA projects utilizing the LightMAT consortium from four to two. Reduce scope of the DataHUB to maintain current functionality without adding new data tools.
Propulsion Materials Technology		
• Supported research projects at the National Labs with industry partners on Materials for Energy Recovery and Exhaust Systems.	• No funding requested.	• Eliminate research on materials for energy recovery and exhaust systems.
• Supported four research projects on High Temperature Materials for High Efficiency Engines at the National Laboratories with industry partners.	• Support one National Laboratory project focused on the development of high temperature materials for high efficiency engines for heavy-duty vehicles.	• Downselect to support one National Laboratory project for high efficiency engine components. Re-focus work exclusively on heavy-duty vehicles.
• Supported three research projects at a National Laboratory in Integrated Computational Materials	• Develop predictive models for lightweight powertrain materials in order to develop a new low-cost super alloy family utilizing the recent	• Downselect to the most promising two Industry/National Laboratory CRADAs.

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Engineering (ICME) tools to accelerate the development of advanced powertrain alloys for next generation high efficiency engines. Performed atomic scale characterization and large super cell density functional theory calculations carried out at high performance computing facilities to identify strengthening mechanisms.	National Laboratory's breakthrough technology for high temperature engine components.	
SuperTruck II		
• Develop energy efficient powertrain technologies that will improve commercial vehicle engine efficiency by 30 percent and freight hauling efficiency of heavy-duty Class 8 long-haul vehicles by 100 percent in 2020, compared to a 2009 baseline vehicle, and demonstrate applicability and cost-effectiveness of these technologies to heavy-duty Class 8 regional-haul vehicles.	• No funding requested.	• This activity will be terminated. Some activities will continue to cost obligated carryover until completion.

Vehicle Technologies
Technology Integration

Description

The Technology Integration subprogram covers a broad technology portfolio that includes alternative fuels (e.g., biofuels, electricity, hydrogen, natural gas, propane) and energy efficient mobility systems. These technologies can strengthen national security through fuel diversity and the use of domestic fuel sources, reduce transportation energy costs for businesses and consumers, and enable energy resiliency with affordable alternatives to conventional fuels that may face unusually high demand in emergency situations. The subprogram provides minimal support to Data and Systems Research activities, including "living lab" projects – i.e. competitively-awarded projects to validate data, technologies, and systems in the field, serving as an important feedback loop to inform future Vehicle Technologies research planning. Technology Integration also supports Vehicle Technologies statutory requirements related to alternative fuels and the annual Fuel Economy Guide and includes the Advanced Vehicle Competitions activity that supports science, technology, engineering, and mathematics (STEM) and workforce development interests. For FY 2019, the subprogram will focus on the following two activities:

- The Data and Systems Research activity ($2M) includes living lab projects that evaluate technology solutions in real world conditions, generating data and lessons learned to inform future research needs. FY 2019 funds also provide minimal support to Vehicle Technologies statutory programs, the Alternative Fuel Data Center and Fuel Economy Guide, for data and information dissemination through online tools and resources.[1] In addition, the Data and Systems Research also supports the state and alternative fuel provider fleet regulatory program, which requires certain state government and alternative fuel provider fleets to acquire alternative fuel vehicles as part of their annual light-duty vehicle acquisitions.[2]
- The Advanced Vehicle Competitions activity ($1.5M) supports a collegiate engineering competition that provides hands-on, real-world experience in advanced vehicle technologies and designs. By engaging university students in advanced technology research and providing specialized training, the Advanced Vehicle Competitions activity helps address workforce development needs for more highly trained engineers and supports national efforts that encourage students to pursue careers in science, technology, engineering, and math. Following the successful EcoCAR 3 competition, FY 2019 funds will support a new competition in alignment with the latest advanced technology trends in the automotive industry.

[1] The AFDC responds to section 405 of the Energy Policy Act of 1992, which requires a public information program about the costs and benefits of alternative fuels for motor vehicles; the Fuel Economy Guide, required by the Energy Policy and Conservation Act of 1975, requires the Department to publish and distribute the annual guide in partnership with the U.S. Environmental Protection Agency.

[2] The State and Alternative Fuel Provider Fleet Program is required by sections 501 and 507 of the Energy Policy Act of 1992.

Technology Integration

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Technology Integration $37,400,000	**$3,500,000**	**-$33,900,000**
Data and Systems Research $34,900,000	**$2,000,000**	**-$32,900,000**
Information and Tools		
• In accordance with "Public Information Program" requirements in section 405 of the Energy Policy Act of 1992, updated alternative fuel, vehicle, and infrastructure information, including station locator and cost calculator tools, incentives database, and fuel-savings strategy information in the Alternative Fuels Data Center.	• Funds supporting the provision of alternative fuel information will be limited to what is necessary for annual updates to alternative fuel, vehicle, and infrastructure information, in accordance with section 405 of the Energy Policy Act of 1992.	• Only basic updates to alternative fuel, vehicle, and infrastructure information, in accordance with section 405 of the Energy Policy Act of 1992, will occur. No updates of other information and no other system or overall improvements will occur. • Minimal support will be provided for the Fuel Economy Guide, in accordance with requirements in the Energy Policy and Conservation Act of 1975, reducing mid-year updates or other fuel economy information to consumers.
• In accordance with requirements in the Energy Policy and Conservation Act of 1975, published and distributed the new model year Fuel Economy Guide, in partnership with the U.S. Environmental Protection Agency, Update data, tools (e.g., Find-a-Car, Fuel Cost & Savings Calculator), and fuel economy information on www.fueleconomy.gov.	• Funds supporting vehicle fuel economy information will be limited to the new model year Fuel Economy Guide, in accordance with requirements in the Energy Policy and Conservation Act of 1975.	
• Funding provided objective data, tools, and insights to local communities and other stakeholders to support their decision-making as it relates to Alternative Fuels, Advanced Technologies, and Energy Efficient Mobility Systems.	• No funding requested	• This activity will terminate. Some activities will continue to cost obligated carryover until completion.

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
State and Fuel Provider Fleet Requirements		
• Tracked covered fleet compliance with annual alternative fuel vehicle acquisition requirements, in accordance with Title V of the Energy Policy Act of 1992.	• Track covered fleet compliance with annual alternative fuel vehicle acquisition requirements, in accordance with Title V of the Energy Policy Act of 1992.	• Minimal support to meet statutory requirements as outlined in Title V of the Energy Policy act of 1992.
Training, Technical Assistance, and Partnerships		
• Expanded technical and problem solving assistance to key stakeholders to help in overcoming specific market and technical barriers. • Enabled direct feedback from industry experts and other key stakeholders to inform research planning. • Continued on-going support of the nationwide network of local Clean Cities coalitions to align activities with national objectives for energy efficiency and cost effective alternative energy at the local community level.	• No funding requested for Training, Technical Assistance, and Partnerships.	• This activity will terminate to focus on early stage R&D. Some activities will continue to cost obligated carryover until completion.
Financial Assistance		
• Initiated Alternative Fuel Vehicle Community Partner projects. These projects will accelerate widespread introduction and adoption of commercially available advanced vehicle technologies to increase local fuel diversification, and catalyze adoption of clean transportation technologies. Up to two projects will be awarded with Federal funding leveraged by a minimum 50 percent cost share from private sector partners. • Initiated three new living lab projects to collect data and provide real-world technology usage feedback to inform Vehicle Technologies research planning efforts.	• No funding requested.	• This activity will terminate to focus on early stage R&D. Some activities will continue to cost obligated carryover until completion.

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Advanced Vehicle Competitions $2,500,000	**$1,500,000**	**-$1,000,000**
	• Support Living Labs one to two small living lab projects to collect data and provide feedback on real-world technology usage to inform future Vehicle Technology research plans cut across all technologies to collect data and provide feedback to the research program for future research needs.	• Support fewer and smaller-scale living lab projects. Support one to two small living lab projects that will collect data and provide feedback to the research program for future research needs.
• Completed year three of collegiate engineering competition, EcoCAR 3. Teams built and refined their advanced technology vehicles to present fully integrated vehicles capable of driving in both electric and conventional modes while sustaining charge.	• Launch a new university student competition that provides science and technology training for the future advanced automotive workforce.	• Launch new university student competition.

Description

The Analysis subprogram provides critical information and analyses to prioritize and inform Vehicle Technologies research portfolio planning through technology-, economic-, and interdisciplinary-based analysis, including target-setting and program benefits estimation. FY 2019 funds will support vehicle data, modeling and simulation, and integrated and applied analysis activities using the unique capabilities, analytical tools, and expertise resident in the National Laboratories. Trusted and public data are critical to Vehicle Technologies efforts and are an integral part of transportation and vehicle modeling and simulation. In addition, the Analysis subprogram supports the creation, maintenance, and utilization of vehicle and system models to explore energy impacts of new technologies relevant to the Vehicle Technologies portfolio. The subprogram also supports integrated and applied analyses that bring together useful findings and analysis of the energy impacts of transportation systems through the integration of multiple models including vehicle simulation, traveler behavior, and energy accounting of the entire system. The result creates holistic views of the transportation system, including the opportunities and benefits that advanced vehicle technologies create by strengthening national security, increasing reliability, and reducing costs for consumers and businesses. Overall, Analysis activities explore energy-specific advancements in vehicles and transportation systems to inform Vehicle Technologies' early-stage research and offer analytical direction for potential and future research investments.

Analysis

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Analysis $5,100,000	**$2,000,000**	**-$3,100,000**
• Using analytical capabilities and tools unique to National Laboratories, funds supported vehicle data, modeling and simulation, and integrated and applied analysis activities to inform and prioritize research portfolio and program planning. Funds supported 15 projects with National Laboratory partners, leveraging DOE-developed analytical models.	• Leveraging analytical capabilities and tools unique to National Laboratories, use vehicle and transportation data and models to conduct technology-, economic-, and interdisciplinary-analyses to inform and prioritize technology investments and research portfolio planning. Funds will support 6 to 8 projects.	• Funding is reduced in order to prioritize critical early-stage research activities in other Vehicle Technologies subprograms. The reduction in funding eliminates maintenance, updates to modeling capabilities at National Laboratories, and reduces the number of projects by approximately 50 percent.

Bioenergy Technologies

Overview

The Bioenergy Technologies Program focuses on early-stage applied research and development (R&D) of transformative, sustainable bioenergy technologies that can support a growing bioeconomy[1] and a more energy secure and prosperous nation. Price-competitive, advanced technologies to convert the Nation's abundant domestic, renewable biomass and waste resources into advanced biofuels and co-products are a key contributor to U.S. energy security, economic productivity, and overall competitiveness. DOE is investing in cutting-edge technologies designed to produce biofuels from non-food sources of biomass[2] such as wastes and agricultural residues, and from energy crops like switchgrass and algae. The program's primary focus is on R&D to produce "drop-in" biofuels that are compatible with existing fueling infrastructure and vehicles across a range of transportation modes, including renewable-gasoline, -diesel, and -jet fuels. The program also supports early-stage R&D on converting biomass into high-value chemicals and products where they can enhance the economics of biofuel production and enable market competitiveness for U.S. biofuel industry.

Increasing domestic production of bioenergy and co-products supplements American petroleum-based fuels and products to strengthen U.S. energy security by increasing energy supply, diversity, affordability, and reliability. Additionally, domestically -produced renewable biomass and its subsequent conversion to bioenergy and bioproducts, offers an opportunity to create American jobs across the supply chain, boost economic growth, and encourage investment across the Nation.

By 2030, the U.S. has the potential to produce 1 billion dry tons of non-food biomass resources without disrupting agricultural markets for food and animal feed.[3] This could potentially produce 50 billion gallons of biofuels (25 percent of U.S. transportation fuels), while also generating: 50 billion pounds of high-value chemicals and products, 75 billion kWh of electricity (enough to power 7 million homes), 1.1 million American jobs, and $260 billion to the U.S. economy.[4] However, realizing this potential requires DOE to conduct early-stage R&D in areas that industry either does not have the technical capability to undertake or is too far from market realization to merit sufficient industry focus and resources.

To improve transportation energy affordability, strengthen national security, support energy dominance and enable future economic growth, DOE performs early-stage R&D on several advanced transportation technology options in the Vehicle Technologies, Bioenergy Technologies and Hydrogen and Fuel Cell Technologies programs. Common metrics across all three of these programs have been developed to evaluate these advanced options compared to the lifecycle costs and energy consumption of today's technologies. Over a lifecycle basis, (vehicle manufacture, fuel production, and fuel use) future (~2030) modeled conventional technology of a gasoline internal combustion engine vehicle (ICEV) is expected to be approximately 27 cents per mile and 4,700 Btu per mile.[5] The Bioenergy Technologies Program goals below are necessary for new technology options to be at least as efficient and affordable compared to this baseline, while also accounting for consumer expectations regarding affordability and pay back periods.

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[1] "Bioeconomy" is defined as "the industrial transition to sustainably utilizing renewable aquatic and terrestrial biomass resources for production of energy, intermediate, and final products with economic, environmental, social, and national security benefits," by the Biomass Research and Development Board within the Federal Activities Report on the Bioeconomy, February 2016 https://www.energy.gov/sites/prod/files/2016/02/f30/farb_2_18_16.pdf.

[2] As recommended in the Quadrennial Energy Review: Energy Transmission, Storage, and Distribution Infrastructure, April 2015.

[3] U.S. Billion Ton Update https://energy.gov/sites/prod/files/2016/12/f34/2016_billion_ton_report_12.2.16_0.pdf.

[4] Rogers, J. N.; Stokes, B.; Dunn, J.; Wu, M.; Haq, Z.; Baumes, H. *An assessment of the potential products and economic and environmental impacts resulting from a billion ton bioeconomy.* Biofuels Bioprod Bioref **11***(1):*110–128 *(*2017*).* *http://onlinelibrary.wiley.com/doi/10.1002/bbb.1728/full.*

[5] See Record #17008 which can be accessed at: https://www.hydrogen.energy.gov/program_records.html#program_related. Both energy and cost per mile are based on a 15-year vehicle lifetime.

In FY 2019, the Bioenergy Technologies Program will work towards the goal of improving affordability of transportation by achieving the following subprogram GPRA Goals:

- The Advanced Algal Systems subprogram will increase algal biomass productivity to 15.9 g/m^2/day, a 20 percent improvement relative to the FY 2016 State of Technology (SOT) summer baseline of ~13.3 g/m^2/day.
- The Conversion Technologies subprogram will use the catalytic fast pyrolysis reactor system to reduce cost and extend lifetime by optimizing catalyst compositions and process conditions to achieve a reduction in the modeled cost to $3.84/gge, a reduction of $0.50/gge compared to the FY 2017 SOT of $4.34/gge.

The Bioenergy Technologies Program employs EERE's technology readiness level metric (TRL) to prioritize work within a subprogram and across the portfolio. Early stage R&D falls within TRL 1-3, defined as Basic Principles observed through Proof of Concept with substantiated technical feasibility at immature or laboratory scale. Aspects of TRL 4-6 are also considered when conducting systems research and gathering necessary performance data that will reduce technology uncertainty to enable industry to scale up the technology.[1] This can mean systems research for first-of-a-kind integration of innovative bioenergy processes at the pilot/engineering-scale. Evaluating the integrated process steps at the pilot-scale will highlight further early-stage (TRL 1-3) research needs. The program will rely on the private sector to fund later stage demonstration and deployment of fully-integrated biorefineries in real-world environments.

Highlights of the FY 2019 Budget Request

- All Bioenergy Technologies Program research funding in the FY 2019 Request will support research and development conducted through lab calls and the annual operating plans (AOPs) with the National Laboratories.
- The Feedstock Supply and Logistics subprogram will support a new Feedstock Conversion Interface Consortium (FCIC) of eight National Laboratories and industry experts. FCIC seeks to improve the operational reliability of integrated biorefineries through increased understanding of the complexity and variability of biomass materials; and the fundamental physical properties that govern feedstock behavior, energy density and conversion performance. This science-oriented, early-stage R&D will help achieve nameplate capacities and system reliability and will provide tools for the entire industry to build upon as markets for feedstocks expand. The challenges that the FCIC seeks to address requires expertise from numerous disciplines which is enabled by an inclusive and thoroughly integrated approach within the consortium.
- The Advanced Algal Systems subprogram will fund early-stage applied research by DOE National Laboratories on new strain development, approaches to culture management, and methods of crop protection to improve algae productivity.
- The Conversion Technologies subprogram will support transformative R&D in synthetic biology of engineered organisms through the Agile BioFoundry and explore the potential of novel catalysts through the Chemical Catalysis for Bioenergy (ChemCatBio) consortium to enable industry to improve yields and selectivity of drop-in biofuels and renewable chemicals. In addition, the subprogram will continue to investigate performance-advantaged bioproducts, including those from lignin, with the potential to improve the economics and efficiency of biomass utilization. The program will also fund exploratory work at the DOE National Labs in the area of CO_2 utilization for production of fuels and chemicals in collaboration with the Office of Fossil Energy, building on a public workshop held in FY 2017.
- The Advanced Development and Optimization (ADO) subprogram will continue collaborative R&D with the Vehicle Technologies Program on the Co-Optimization of Fuels and Engines (Co-Optima) to develop bio-based fuels/additives with the potential to improve light-duty fuel economy by 35 percent (25 percent from advanced engine research and 10 percent from co-optimization of advanced engines with fuels) by 2030 compared to 2015 gasoline vehicles.
- The Strategic Analysis and Cross-cutting Sustainability subprogram will conduct integrative analyses to inform R&D priorities and program goals and complete a multi-dimensional analysis that quantifies and characterizes key economic and environmental benefits of an expanding bioeconomy.

The Bioenergy Technologies Program coordinates its outcome-driven applied R&D activities with the U.S. Department of Agriculture and six other agencies through the Biomass Research and Development Board to leverage resources and avoid duplication across the Federal Government. In order to fully develop a bioeconomy, the program's transformational

[1] OECD (2015), *Frascati Manual 2015: Guidelines for Collecting and Reporting Data on Research and Experimental Development*, OECD Publishing, Paris. http://dx.doi.org/10.1787/9789264239012-en

research and development is fostering partnerships that will enable American industry, including start-up enterprises, to create new jobs in emerging energy and manufacturing fields ultimately benefiting the U.S. economy.

Bioenergy Technologies Funding
($K)

	FY 2017 Enacted	FY 2018 Annualized CR*	FY 2019 Request	FY 2019 Request vs FY 2017 Enacted
Bioenergy Technologies				
Feedstock Supply and Logistics	20,000	—	4,500	-15,500
Advanced Algal Systems	30,000	—	4,000	-26,000
Conversion Technologies	90,230	—	16,500	-73,730
Advanced Development and Optimization (formerly Demonstration and Market Transformation)	54,041	—	7,000	-47,041
Strategic Analysis and Cross-cutting Sustainability	10,729	—	5,000	-5,729
Total, Bioenergy Technologies	**205,000**	**203,608**	**37,000**	**-168,000**

SBIR/STTR:

- FY 2017 Transferred: SBIR $6,560,000; STTR $923,000
- FY 2018 Projected: SBIR $6,515,000; STTR $917,000
- FY 2019 Request: SBIR $1,184,000; STTR $167,000

*A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution. (These amounts are shown only at the Congressional control level and above; below that level, a dash (—) is shown).

Bioenergy Technologies
Explanation of Major Changes
($K)

	FY 2019 Request vs FY 2017 Enacted
Bioenergy Technologies	
Feedstock Supply and Logistics: The reduction in funding level for this subprogram reflects the prioritization of the most critical early-stage activities, within the broader priorities of the Department and the Administration. The subprogram will prioritize research through the Feedstock-Conversion Interface Consortium to improve operational reliability through enhanced scientific understanding of solids flow behavior and mass transfer of multi-phase systems, quantifying the range of variability of biomass feedstocks, and developing plans to mitigate that variability for conversion processes. The subprogram will discontinue activities related to high-moisture feedstocks in favor of research on dry, terrestrial biomass feedstocks which represent the majority of domestic biomass feedstocks. The subprogram will de-emphasize in-field sensors for real-time assessment of biomass quality and supply scenario analysis.	**-15,500**
Advanced Algal Systems: The reduction in funding level for this subprogram reflects the prioritization of the most critical early-stage activities, within the broader priorities of the Department and the Administration. The subprogram will prioritize early-stage research that shows the greatest promise for improving algae productivity, namely strain development and culture management. The subprogram will reduce microalgal resource assessment modeling, and algal and terrestrial feedstock blending strategies. Later-stage downstream algae R&D activities, including harvesting, the conversion interface, and integration studies, such as those previously conducted at the Algae Testbeds will be discontinued.	**-26,000**
Conversion Technologies: The reduction in funding level for this subprogram reflects the prioritization of the most critical early-stage activities, within the broader priorities of the Department and the Administration. The Conversion Technologies subprogram will focus on early-stage applied research through the Agile BioFoundry and the ChemCatBio multi-laboratory consortium. Funding will support early-stage applied conversion research in the areas of lignin valorization, applied bioenergy separations, and identifying and synthesizing performance advantaged co-products that can enable the production of biofuels. No funding is requested to address challenges in the conversion of wet wastes to fuels and co-products. Certain research areas will be eliminated, such as aerobic upgrading and cellulase development.	**-73,730**
Advanced Development and Optimization: The reduction in funding level for this subprogram reflects the prioritization of the most critical early-stage activities, within the broader priorities of the Department and the Administration. Funding is provided for early-stage R&D in conjunction with the Vehicle Technologies Program on the Co-optimization of Fuels and Engines. Support of the integrated testing and pilot-scale work will continue as the program leverages previous investments in integrated process development/pilot-scale/systems research capabilities at the National Laboratories and, potentially, universities and industry. No funding is requested in FY 2019 for new pilot-scale and demonstration scale projects. No funding for biopower is requested in FY 2019.	**-47,041**

Strategic Analysis and Cross-cutting Sustainability: The reduction in funding level for this subprogram reflects the prioritization of the most critical early-stage activities, within the broader priorities of the Department and the Administration. Activities will focus on analysis and strategies to achieve price reductions for biofuel production. The subprogram will prioritize maintenance and updates of high-priority models for lifecycle analysis and estimating potential environmental and economic effects of biofuel production, and defer maintenance on models that have reached a level of maturity and are being used by the program, industry, and other institutions.	**-5,729**
Total, Bioenergy Technologies	**-168,000**

Description

The primary goal of the Feedstock Supply and Logistics (FSL) subprogram is to generate the knowledge upon which industry can develop and improve strategies, technologies, and systems to provide affordable, consistent-quality feedstock that performs reliably in handling and conversion systems on a year-round basis at different types of biorefineries. The subprogram has recently achieved the FY 2017 target of a total average delivered cost of $84/dry ton [1] (from $137/dry ton in FY 2014 in 2014 dollars) and by FY 2019 has goals to expand feedstock volumes and to quantify and improve system operational reliability through fundamental R&D in the Feedstock-Conversion Interface Consortium (FCIC). Specifically, the FSL subprogram will conduct research on particle mechanics to develop a fundamental understanding of the flow characteristics of a range of preprocessed biomass materials, novel engineering approaches to improve the flowability of solid biomass materials in gravity flow and mechanized conveyance machinery, and mass transfer characteristics of multi-phase (solids, liquids, gases) systems found in biomass conversion unit operations. The FSL subprogram will also conduct advanced characterization of the physical, mechanical and chemical characteristics of a variety of preprocessed feedstocks, and develop computational tools to address feedstock variability and how changes in physical, mechanical and chemical properties alter feedstock handling characteristics in scaled-up applications. Additionally FSL will analyze the potential trade-offs between the spectrum of feedstock quality parameters and affordability of feedstock delivery systems to inform the feasibility and utility of feedstock quality specifications.

Industry implements technology improvements to strengthen their position in nascent and current markets. In contrast, the FSL subprogram is focused on early-stage R&D that will expand the market for biomass. For example, this subprogram has made significant investment in understanding fundamental feedstock characteristics, and will continue conducting research to develop quality specifications for feedstock.

Past accomplishments of this subprogram include publishing the 2016 *U.S. Billion-Ton Update Volume 1 and Volume 2*,[2] disseminating yield data for energy crops from the Sun Grant Regional Feedstock Partnership project, [3] and enabling logistics cost reductions through competitively-awarded high-tonnage feedstock logistics projects focused on agricultural and forestry equipment development and demonstration, the results of which are publicly available on the Bioenergy Knowledge Discovery Framework.[4] In FY 2016, the subprogram initiated two new projects from the Advanced Logistics II Funding Opportunity Announcement (FOA) to further reduce the delivered cost of short rotation woody crops and to study how preprocessing feedstocks at industrial scale could reduce biorefinery processing time while increasing the amount of available feedstock within a given delivery radius using newly developed equipment and preprocessing strategies. Recent successes have included reducing delivered cost of biomass to the biorefinery by up to $13/dry ton, as well as reducing biomass bale processing time by 43 percent.

Feedstock-Conversion Interface Consortium ($3M): In FY 2019, the FSL subprogram will prioritize funding for early-stage research to overcome challenges at the feedstock-conversion interface. The FSL subprogram will address challenges related to the behavior and performance of biomass in preprocessing operations, including but not necessarily limited to conveyance, milling, washing, drying, and introduction into the first biomass deconstruction operation of the conversion process. This research will be conducted at DOE National Laboratories through the Feedstock-Conversion Interface Consortium (FCIC).

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[1] Verified in FY 2017. Verification in for a modeled potential of 285 million dry tons accessible at up to $84/dry ton in FY 2022 in a national model.

[2] https://energy.gov/sites/prod/files/2016/12/f34/2016_billion_ton_report_12.2.16_0.pdf; https://energy.gov/eere/bioenergy/downloads/2016-billion-ton-report-volume-2-environmental-sustainability-effects.

[3] The Regional Feedstock Summary Report, July 2016; accessed at https://www.energy.gov/eere/bioenergy/downloads/regional-feedstock-partnership-report.
http://sungrant.tennessee.edu/NR/rdonlyres/8CF2F183-8B72-4E48-9E2F-BCAB4E421C7A/3630/46Halbleib_Mike.pdf

[4] http://www.bioenergykdf.net.

The FCIC is a consortium involving eight National Laboratories and is directed toward solving obstacles encountered by integrated biorefinery projects. The work in FCIC is organized into five families of AOPs with different Labs performing R&D activities in related sets of non-overlapping tasks. A sixth set of AOPs focuses on overall FCIC consortium management and reporting, coordinating interactions with the Industry Advisory Board, and managing industry outreach activities. Each AOP family involves teams of scientists and engineers from any or all of the 8 Consortium Labs, depending on their capabilities and expertise. The Consortium is led by INL and NREL with oversight from BETO and a Leadership Team made up of managers from each of the eight National Laboratories, as well as an eight member Industry Advisory Board. Specifically, the FCIC focuses on five R&D areas:

- Characterizing the range of variability of physical, mechanical, and chemical properties and how they change in the targeted feedstock materials across the value chain during preprocessing operations;
- Modeling the behavior and performance of selected feedstocks in gravity flow and conveyance operations during preprocessing operations and introduction into the conversion process prices, based on an understanding of the fundamental characteristics of those materials (from first bullet above);
- Process integration of feedstock supply, preprocessing, and first stage deconstruction to benchmark and verify performance in integrated operations and to implement mitigation strategies suggested by modeling results (from previous bullet above);
- System-wide throughput analysis to benchmark current integrated system reliability, process economics and environmental impacts, and estimate how system reliability changes (better or worse) with the implementation of mitigation strategies developed in the above bullets; and
- Process controls and optimization to develop sensors and feedback control logic that monitor performance at critical points in integrated systems and adjusts throughput to achieve high levels of system reliability over time.

Analyzing and understanding both the impacts of preprocessing operations on feedstock physical, mechanical, and chemical characteristics and the impacts of those characteristics on conversion performance, system reliability, and process economics is critical to identifying the most cost-effective ways to deliver high-quality, efficiently convertible biomass feedstocks to the biorefinery, and maintain biofuel/bioproducts yield, quality, and minimum fuel selling price (MFSP) targets.[1]

Consortium research will also focus on the molecular deconstruction of cell wall biopolymers in the initial steps of conversion processes to enable the scalability of feedstock handling in different conversion processes, while also maximizing robust yields and minimizing production costs of targeted biofuel products/intermediates. Specifically, models and tools will be developed by the FCIC that use characterization data to inform the proper selection, design, and integration of feedstock and conversion technologies for optimum performance in handling, preprocessing and conversion equipment. The FSL subprogram will not fund scale-up activities but will expand the knowledge base on solids handling as well as develop new bulk solids characterization techniques and monitor the effect of variability in feedstock physical, mechanical, and chemical properties in the initial steps of conversion processes. Additionally, FCIC will continue to develop control logic and systems to improve the robustness and flexibility of integrated preprocessing and feeding systems.

Crosscutting Feedstock Logistics R&D ($1.5M): In addition to FCIC funding, the subprogram will fund logistics R&D that is complementary to the scope of the FCIC, particularly those activities considered upstream of the interface activities, such as biomass densification, real-time sensors, and supply chain risk analysis.

[1] MFSP is defined as the fuel selling price (leaving the biorefinery gate) that enables a 10 percent rate of return over the lifetime of the biorefinery including capital costs, operating costs, and financing. This price does not include fuel marketing or distribution costs, nor does it include any retail markups. Full economic assumptions (e.g. plant lifetime, interest rates, etc.) can be found here: https://www.nrel.gov/docs/fy15osti/62455.pdf.

Feedstock Supply and Logistics

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Feedstock Supply and Logistics $20,000,000	**$4,500,000**	**-$15,500,000**
• Fund five existing projects at $5.6 million to address feedstock handling and preprocessing challenges at the feedstock-conversion interface. • Release a directed funding opportunity for $8.0 million to encourage industry collaborative R&D with the DOE National Laboratories under the FCIC. • Fund eight cross-cutting feedstock logistics R&D projects to address challenges to dry terrestrial and high-moisture feedstocks that are complementary to the goals of FCIC; funded at $6.4 million. • Provide the preprocessed feedstock components for the FY 2017 verification at scale of at least one technology pathway to produce a hydrocarbon biofuel at a mature modeled price of $3/gge with GHG emissions reduction of 50 percent or more compared to petroleum derived fuel. • Complete resource assessments and analyses, to support the publication of *2016 Billion-Ton Report, Volume 2: Environmental Sustainability Effects of Select Scenarios from Volume 1*. • Funding for up to two competitively-selected projects under the Biomass Research and Development Initiative.	• Fund six FCIC groups of projects at $3.0 million to focus on R&D strategies to improve operational reliability of biomass feedstock handling, preprocessing and conversion over the baseline established in FY 2018. • Industry collaborative R&D projects with the FCIC National Laboratory consortium selected through the directed funding opportunity will continue with prior year funds. • Fund two cross-cutting feedstock logistics R&D projects at $1.5 million on biomass densification technologies and supply chain risk analysis. These projects will focus on dry terrestrial biomass feedstocks. • No verification activities will be conducted in FY 2019 due to successful completion of the FY 2017 verification activities. • Competitively-selected projects under BRDI will continue with prior year funds. Funding Opportunity Announcement with USDA under the Biomass Research and Development Initiative.	• Reduced funding level for FCIC due to the completion of the FY 2018 baseline analysis. • No funding is requested to support for FCIC directed funding opportunity for collaborative projects with industry. • No funds for development of field sensors for assessing biomass quality. Emphasis will shift to development of real-time sensors for assessing feedstock quality through FCIC; no funding is requested for cross-cutting feedstock logistics R&D related to high-moisture feedstocks; no funding is requested to conduct annual State of Technology on feedstock handling and preprocessing systems. • FY 2017 verification studies were successfully completed on schedule. • Due to successful completion of the 2016 Billion-Ton Reports, activities related to supply chain scenario analysis will be de-emphasized; no funds are requested for resource assessment activities. • No funding is requested issue a joint competitive funding opportunity with the U.S. Department of Agriculture in support of the Biomass Research and Development Initiative.

Bioenergy Technologies
Advanced Algal Systems

Description

The Advanced Algal Systems subprogram supports early-stage R&D of algal biomass[1] production and logistics systems. Algal biomass has potential as a domestic energy resource due to its ability to grow quickly, use waste resources (including in non-potable water and on non-arable land), and produce fuel and product precursors. Algal biofuels could potentially contribute up to 5 billion gallons of advanced biofuels per year, about 25 percent of the current jet fuel market, which contributes to the U.S. domestic production of liquid transportation fuels by 2030.[2] In recent years, knowledge outputs from research by the subprogram have improved: capabilities to predict, breed, and select the best-performing algal strains; tools to monitor and control system inputs in a dynamic and integrated fashion; methods to harvest algae at high-throughputs; and processes to extract and convert more algal biomass components into fuels.[3]

Through the successful conclusion of the five projects awarded through the Advancements in Algal Biomass Yield competitive funding opportunity, the Advanced Algal Systems subprogram achieved its 2018 milestone to verify biofuel yields of 2,500 gallons of intermediate per acre per year ahead of schedule. These yields were reported in the program's biennial peer review[4,5] and, if modeled in the program's state of technology techno-economic model for the hydrothermal liquefaction of whole algae biomass, would reduce the price of algal biofuel from the FY 2014 unlined pond baseline of $14.78/gge[6] to $5-8/gge[7].

While accomplishing this yield goal was a major achievement, the modeled minimum fuel selling price (MFSP) of algae biofuel remains too high (FY 2016 state of technology (SOT) with fully-lined open ponds: $16-17/gge)[8] to be commercially viable in the near-term. The factors that have the highest impact on algae MFSP continue to be most sensitive to algal productivity, the composition of the harvested algal biomass, and the frequency of crop failures. Therefore, with FY 2019 appropriations, the subprogram will fund early technology readiness level (TRL) work to develop stable algal cultivars that produce high yields, resist predators, and are suitable for cultivation in farming operations. The subprogram will also support work that evaluates improving culture performance between the laboratory and field. In addition, the subprogram will support co-product development from promising cultivation species by continuing quantitative analyses of algal biomass composition, energy content, and productivity.

In FY 2019, as a result of ongoing projects with prior year funding the subprogram expects to reach its milestone to verify an increase of the value of cultivated algal biomass by 30 percent, thereby lowering the modeled cost of algal biofuels from $9.32 in the FY2016 SOT to $6.52 per gallon gasoline equivalent.[9] This milestone will be achieved by a combination of National Laboratory and competitive research projects focused on the production and recovery of valuable co-products

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[1] The term algae refers to microalgae, cyanobacteria (often referred to as "blue-green algae"), and macroalgae (or seaweed).

[2] Ryan Davis, Daniel Fishman, Edward Frank, et al., "Renewable Diesel from Algal Lipids: An Integrated Baseline for Cost, Emissions, and Resource Potential from a Harmonized Model," Argonne National Laboratory, ANL/ESDA/12-4 (2012), http://greet.es.anl.gov/publication-algae-harmonization-2012.

[3] U.S. Department of Energy. 2016. *National Algal Biofuels Technology Review.* Office of Energy Efficiency and Renewable Energy. Bioenergy Technologies Office. Available at: https://www.energy.gov/eere/bioenergy/downloads/2016-national-algal-biofuels-technology-review.

[4] Behnke et al. (2017), "Biomass Productivity Technology Advancement toward a Commercially Viable, Integrated Algal Biomass Production Unit," Presented at the 2017 Advanced Algal Systems Peer Review. Available at: https://energy.gov/sites/prod/files/2017/05/f34/algae_behnke_135220.pdf.

[5] Lundquist et al. (2017), "Scale-Up of Algal Biofuel Production Using Waste Nutrients," Presented at the 2017 Advanced Algal Systems Peer Review. Available at: https://energy.gov/sites/prod/files/2017/05/f34/algae_lundquist_135240.pdf.

[6] Jones, S. B., Zhu, Y., Snowden-Swan, et al. (2014). "Whole Algae Hydrothermal Liquefaction: 2014 State of Technology" (No. PNNL-23867).

[7] BETO MYPP HTL unlined SOT pathway, in preparation.

[8] BETO MYPP HTL and CAP Pathways, in preparation.

[9] FY2016 State of Technology (SOT) for Combined Algae Processing (CAP) Pathway.

that can be produced along with biofuel intermediates, specifically the projects enabled by the Targeted Algal Biofuels and Bioproducts competitive funding opportunity announced in July 2015.

The subprogram will integrate the latest technological advances into robust state of technology techno-economic analyses. This work allows the subprogram to more effectively evaluate the agronomy of algae cultivation and strategically target pre-competitive R&D strategies that have the greatest potential to enable businesses to successfully pursue larger-scale integration and demonstration.

FY 2019 activities focus on the highest impact factors for advancing algal biofuels: productivity, composition, and crop protection. These early stage R&D efforts will be continued through targeted funding to the DOE National Laboratories.

Development of Integrated Screening, Cultivar Optimization, and Validation Research (DISCOVR) Project ($1.3M): The program will prioritize support for DISCOVR — a project consortium of four DOE National Laboratories with unique and complementary capabilities to support core algae R&D. In FY 2019, efforts will continue with the deep characterization of high productivity and resilient microalgae strains with the overall goal of delivering new robust performers for year-round outdoor cultivation. The DISCOVR Team will also continue coordinating and working with other laboratory efforts, as well as collaboration with competitive projects awarded with prior year funds, to provide valuable field and modeled data into the techno-economic analysis. The DISCOVR Consortium will also lead the 2019 State of Technology (SOT) analyses for algal biomass production and combined algae processes.

Targeted Core Algae Research ($2.4M): FY 2019 funds will focus on functional characterization of algal strains, strain composition and co-products, hydrothermal liquefaction (HTL) modeling, and crop protection through targeted research at the DOE National Laboratories. All of which contribute significantly to the goal of increasing productivity on a fundamental level. Key breakthroughs anticipated in these targeted research areas will complement ongoing competitive efforts awarded in FY 2017 from the Productivity Enhanced Algae and ToolKits (PEAK) FOA, under which the program selected seven projects focused specifically on biological strain and toolkit developments to increase productivity and crop protection.

These activities represent pre-commercial, early-stage research and development that will strategically enhance the state of technology beyond current industry areas of focus. The algae industry remains focused on commercial operations for small scale (100 acres or less) farms producing high value-nutraceuticals. The success of these activities will enable industry to increase scale of production and begin accessing energy markets when the technology uncertainty is reduced and market conditions are aligned.

Advanced Algal Systems

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Advanced Algal Systems $30,000,000	**$4,000,000**	**-$26,000,000**
• Funding of $11.0 million for National Laboratory research through the DISCOVR project consortium to identify and investigate algae strains that robustly and reliably outperform the FY 2016 SOT for algae cultivation. Efforts focus on developing an integrated screening platform for the rapid discovery of highly productive and resilient strains — target 30 fully characterized strains by operational parameters; 10 strains characterized by cultivation parameters, composition, stress/predator strategies; 6 strains by intensive biochemical characterization, pond crash studies, and non-GMO improvement strategies; and 4 strains characterized outdoors. Effort also includes SOT activities and TEA coordination. • Targeted R&D along the algal biofuels supply and logistics chain will continue through the National Laboratories. • The Advanced Algal Systems subprogram will provide $16.8 million in competitive R&D projects to achieve programmatic targets for algae productivity and yield (1 project focused on pre-pilot integration of production and pre-processing, together with 7 projects in productivity-enhanced algae and toolkits.	• Funding of $1.3 million to support early stage and precompetitive applied research under the DISCOVR project National Laboratory consortium to increase algal productivity, composition, and crop protection. FY 2019 efforts will focus on characterization of robust, productive strains – target <30 strains fully characterized by operational parameters; <10 strains characterized by cultivation parameters; minimum experimental outdoor testing for SOT and TEA coordination. • $2.7 million to support targeted ongoing National Laboratory research associated with increasing productivity, composition, and crop protection will continue. Activities include functional strain characterization, strain composition and co-products, HTL modeling, and crop protection strategies. • Competitively-selected projects will continue with prior year funds.	• DISCOVR activities prioritized on 'known/previously identified potentially high productivity, robust strains for operational and cultivation parameterization; minimal experimental data collection and analysis and modeling for SOT and TEA coordination (maximum 6 week experiments per quarter). • The subprogram will reduce microalgae resource assessment modeling, and algal and terrestrial feedstock blending strategies. • No funds are requested to support competitive awards for increasing algae productivity or downstream algae R&D activities, such as harvesting, the conversion interface, and integration studies, such as those previously conducted at the Algae Testbeds.

Bioenergy Technologies
Conversion Technologies

Description

The Conversion Technologies subprogram pursues early-stage applied R&D to generate knowledge that enables industry to demonstrate and deploy technologies for converting biomass feedstocks into transportation fuels and related bioproducts that enable biofuels. Conversion research explores concepts in both biological (using biological organisms) and thermochemical (using heat, pressure, and chemical processes) routes to convert biomass into "drop-in" biofuels (gasoline, diesel, jet and marine fuels), fuel components, and chemical intermediates.

Due to the emergent nature of the bio-based fuel and products economy, industry is ordinarily focused on immediate barriers facing their individual technology and is not willing or able to fund foundational, cross-cutting research that benefits the industry at large (e.g., generalized tools and techniques for catalyst or organism development, analytical methods that benefit many processes, etc.). These are the areas on which the Bioenergy Technologies conversion research focuses as a unique and industry-enabling role of government.

Given the diversity of biomass resources and the range of useful end-products, there is no single, superior conversion process or pathway. Therefore, the program conducts prioritized, applied research on a portfolio of technical challenges that support promising feedstock-flexible conversion technologies that can meet the goal of cost competitive fuels (less than $3.0/gge) and coproducts, while allowing industry to build on the knowledge generated by the subprogram to develop and deploy novel technology for their unique market opportunities. This applied research supports multiple possible biorefinery configurations that industry may pursue. For example, improved organism development could improve the viability of direct conversion of cellulosic sugars to fuels or co-products and/or add value to a thermal conversion process by converting a current waste stream to a fuel or co-product.

To address a number of these research challenges, the conversion subprogram has established three key multi-laboratory consortia to leverage and coordinate the unique capabilities within the National Laboratories and to facilitate active collaboration with industry and university partners. The consortia arose from recommendations made in the 2015 external peer review as well as internal efficiency measures. The purpose is to reduce the potential for duplicative efforts and to bring each lab's unique and core capabilities that are relevant to a common challenge or area of research to bear in a collaborative and cooperative effort. These three consortia, the Chemical Catalysis for Bioenergy, the Agile BioFoundry, and Bioprocessing Separations Consortium are described in greater detail below.

Agile BioFoundry (ABF, $2.8M)[1]: The development of an Agile BioFoundry (ABF) continues to be a key activity in FY 2019. The effort leverages recently developed synthetic biology tools (ways to engineer organisms) to improve efficiencies in the conversion of biomass to fuels and products. Currently, the industrial biotechnology sector scales up processes on a case-by-case basis, without tools that can be extrapolated to multiple host organisms, pathways, and applications.

The ABF will produce a set of tools and organism development packages that would be readily transferred to the biotechnology industry, enabling the scaling of multiple, high-impact chemicals in multiple, industrially-relevant host organisms at half the time and cost while significantly improving conversion efficiency. To accomplish this, the BioFoundry connects distributed capabilities across eight National Laboratories to develop processes for engineering biology to enable predictable-design by establishing a robust biomanufacturing set of principles, which use standardized DNA elements and commercially relevant and optimized host organisms. The ABF is organized into six different tasks, with each laboratory contributing to or leading a subset of those tasks. An executive committee comprised of laboratory management and task leads is responsible for overall consortium management along with a program manager at the lead institution (Lawrence Berkeley National Laboratory). An external Industry advisory board also meets quarterly with the executive committee and the BETO Technology Manager.

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[1] https://agilebiofoundry.org/

The ABF specifically focuses on the following tasks:

- Host Onboarding. Host Onboarding takes promising organisms with limited genetic tool development but high industrial relevance and transforms them into highly efficient and engineerable hosts though the application of genetic tools to those organisms.
- Design-Build-Test-Learn (DBTL): In a typical DBTL cycle, the Design team uses computationally-aided design tools to generate DNA construct designs which are passed to a highly automated Build team which assembles plasmids and transforms them into an engineered organism. The Test team then assays these new organisms for outputs like growth, robustness, and product production at various scales producing large quantities of data that are fed to the Learn team. Machine learning and data visualization tools are then used to inform the next round of Design.
- Integrated Analysis: The Integrated Analysis team examines the technoeconomic viability of each proposed target molecule and host. This allows for the research team to focus on the areas of engineering most relevant to reducing production costs.
- Process R&D: Organisms can behave differently at very small scale than they do in production-scale fermentations. The Process R&D team tests engineered strains in bioreactors and seeks to create transfer functions that allow for a predictive understanding of organism productivity and growth.
- Industry Outreach: The Industry Outreach team conducts one-on-one interviews and hosts listening days to get feedback from industry on Agile BioFoundry activities to ensure the consortium's relevance to industry stakeholders.
- Management: A management team oversees the project progress, makes personnel decisions, and maintains the Agile BioFoundry website and vision materials.

In FY 2018 three new host organisms were on-boarded into the ABF, greatly expanding the available fermentation platforms and range of potential target molecules. In addition, product titers of 500 mg/L were developed in an on-boarded host after successful completion of a second round of Design-Build-Test-Learn (DBTL). To directly show the power of the tools developed by the BioFoundry, several competitive, laboratory-selected, and cost-shared projects were also initiated from a large pool of applicants to leverage laboratory capabilities in FY 2018.

In FY 2019, funds will be used to continue to develop these unique, publically accessible R&D tools, data and robust organisms, enabling the pursuit of additional R&D in support of the bioeconomy. Specifically in FY 2019, this will include completion of ≥ 3 cycles of DBTL on ≥ 3 target host pairs with at least 100 percent improvement in baseline titer, rate, and yield. In addition, DBTL throughput will be increased by ≥ 20 percent, allowing more constructs to be designed, built, tested, and analyzed resulting in faster strain improvements.

Chemical Catalysis for Bioenergy (ChemCatBio or CCB, $2.2M)[1] is a consortium involving six National Laboratories and is dedicated to identifying and overcoming catalysis challenges for biomass conversion processes. The goal of the consortium is to reduce the time and cost required to develop novel catalytic materials by targeting both pathway-specific and overarching catalysis challenges such as increasing the catalyst lifetime, conversion efficiency and selectivity. Established as part of the Energy Materials Network[2] in FY 2017, ChemCatBio showcases National Laboratory capabilities and establishes a single point of contact to simplify industry access to National Laboratory catalysis expertise and other essential infrastructure.

The work in CCB has been organized into six technical tasks (three catalytic tasks and three enabling tasks) and is managed by a leadership team that works together to coordinate reporting, articulate strategic direction, establish CCB-led CRADA partnerships with industry, and manage interactions with stakeholders, including an industry advisory board, quarterly public webinar, and outreach days at national conferences. One enabling task, the Catalyst Cost Model was completed and made available to the public in FY 2018. In FY 2019, CCB will focus on the following five tasks (three catalytic technologies and two enabling technologies):

- Catalytic Upgrading of Indirect Liquefaction Intermediates. Gasification of biomass generates a diversity of small gaseous molecules that need to be catalytically upgraded into useful fuels.

[1] http://www.chemcatbio.org

[2] https://energy.gov/eere/energy-materials-network/energy-materials-network

- Catalytic Upgrading of Biochemical Intermediates. Biomass hydrolysis and fermentation generates discrete intermediates such as mixed organic acids, furans, and diols. This task explores catalytic processes for upgrading those intermediates into fuels.
- Catalytic Fast Pyrolysis: Fast pyrolysis is a method for deconstructing biomass at high temperatures to generate a bio-oil. This task is developing catalysts for introduction insidue (in situ) or outside (ex situ) of the pyrolysis reactor to result in a bio-oil with improved specifications that can be upgraded with known chemistry.
- Advanced Catalyst Synthesis and Characterization. The goal of this task is to deliver high performing, cost-effective catalytic materials that meet the needs of the other CCB projects by leveraging unique synthesis and characterization capabilities at various National Laboratories.
- Consortium for Computational Physics and Chemistry (CCPC).[1] This task is the computational modeling arm of CCB and provides predictive simulation tools to enable CCB teams to optimize yield and fuel properties.

These tasks work in concert to accelerate the development of catalysts and related technologies for biomass to biofuels pathways. The CCB team is composed of over 100 researchers and has published 84 peer-reviewed manuscripts since its inception in FY 2017 and is managed by a leadership team that works together to coordinate reporting, articulate strategic direction, establish CCB-led CRADA partnerships with industry, and manage interactions with stakeholders, including an industry advisory board, quarterly public webinar, and outreach days at national conferences.

In FY 2018, the consortium showed accelerated materials design cycle through integration of experiments, computation and theory as shown by the identification of key catalyst structure-function relationships for conversion of ethanol to hydrocarbon fuel and chemical precursors. A catalyst cost model identified in the 2017 Bioenergy Technologies Program peer review was completed and made available for public use in FY 2018.

In FY 2019, ChemCatBio will pursue technology advances across several conversion pathways. For Catalytic Fast Pyrolysis, ChemCatBio will show an increase in carbon efficiency (from 33 percent to 40 percent) resulting in a $0.5/gge reduction in MFSP to a projected $3.84/gge (from a starting point of $6.61 in 2014) on a path to $3.0/gge or less by 2022. For the Catalytic Upgrading of Biological Intermediates, ChemCatBio will convert biomass-derived intermediates at bench scale to demonstrate that the catalyst technical performance resulting in a MFSP less than $3.0/gge (or $2.0/gge with diversion of a portion of sugars/biological intermediates to co-products) with greater than 25 percent (gge basis) of the fuel in the jet or diesel ranges.

Bioprocessing Separations Consortium (BioSep, $1.2M)[2]: The BioSep consortium involves seven National Laboratories and is dedicated to advancing efficient and cost-effective separation technologies that make optimal biogenic carbon. BioSep is managed by a leadership team that coordinates reporting, articulates strategic direction, and manages interactions with stakeholders, including an industry advisory board, and outreach days at national conferences. BioSep will coordinate with separations activities funded by the Advance Manufacturing Program to leverage common resources and approaches; however, BioSep will focus on separation problems unique to biofuel and bioproducts processes. A limited amount of resources will be directed toward lignin valorization. In FY 2019, there will be three technical tasks:
- Separations for Biochemical Streams: This task will focus on three approaches for improving lignin quality generated from homogenous and heterogeneous catalytic depolymerization, including ultrasonic fines removal, tangential flow filtration for molecular weight fractionation, and sodium hydroxide recovery.
- Separations for Thermochemical Streams: This task will focus on catalytic hot gas filtration of catalytic fast pyrolysis streams.
- Separations Technologies Analysis: This team will provided techno-economic and lifecycle analysis for all technologies under investigation and will guide design of technology parameters to ensure economic and lifecycle improvements over incumbent technologies.

[1] CCPC is an element of the larger ChemCatBio consortium, which brings together catalyst scientists and biologists across the DOE National Laboratories to understand the fundamental mechanisms underlying catalyst and enzyme behavior. Specifically the new knowledge developed with CCPC and incorporated into models will accelerate R&D, help target new research, and aid in design of advanced catalysts, enzyme systems, and reactors.

[2] http://www.bioesep.org/

In FY 2018, the consortium is organized into six technical tasks (two tasks focused on separations technologies for biochemical conversion, three tasks focused on thermochemical conversion, and one separations technologies analysis task that provides technoeconomic and life cycle analysis for all proposed technologies).

In addition to the consortia, applied research is being conducted in other areas that add value to a number of biorefinery configurations or approaches:

Lignin Deconstruction and Valorization ($2.4M): Lignin makes up almost a third of biomass by weight but due to its chemical complexity, it is generally burned for heat and power rather than being converted into valuable fuels or products. Applied research on producing higher-value products or "valorizing" (creating higher value from) lignin is essential to improve the economics of biofuel production. In FY 2018, an initial target process/methodology was identified and will be pursued through targeted AOP research at DOE National Laboratories in the coming year with the ultimate goal of developing conversion pathways that can yield value-added co-products from lignin that can reduce fuel costs by more than $2.0/gge. In FY 2019, the subprogram will research catalytic methods with the potential for greater than 50 percent conversion of lignin to upgradable intermediates that can subsequently valorized as fuels or co-products. Subsequent upgrading to high value co-products will be proven at purity levels (>99.8 percent) that meet property criteria relative to petroleum derived equivalents.

Co-Products R&D ($0.8M): In the context of a biorefinery, value-added co-products can enable biofuel production by improving the overall financial viability of the bio-refinery much the same as occurs in petroleum refineries. In addition, much of the bioproduct research investigating conversion of streams that are currently waste from a biofuel process or are put to low-value use. Lastly, lignocellulosic-based biofuel and bioproduct processes share half or more of "upstream" processes in common (feedstock supply, feeding, deconstruction to sugar or syngas intermediates, cleanup, separation, etc.). High-value bioproducts present the industry with very economically attractive early targets that will result in the shake-down and de-risking of the upstream processes thus reducing biofuel production uncertainty. Performance advantaged bioproducts research, in particular, is targeted at products that are more efficiently made from biomass due to biomass' structurally complex nature and which products may offer superior performance compared to conventional materials or chemicals. Research will develop and test computational models for predicting product properties from molecular structures of bio-derived polymers which will help target promising bio-derived co-products that can be manufactured domestically with similar or improved performance and affordability compared to their petroleum-derived equivalent. In FY 2018, performance requirements were identified for performance-advantaged molecules which will also be used to help identify promising molecules for targeted research.

In addition, a focused number of pathways for biological deconstruction and upgrading of biomass to competitive fuels and higher value co-products will continue to be explored through project plans and research facilities at the DOE National Laboratories.

Biochemical Conversion Pathways ($2.6M): In FY 2018, R&D on biochemical conversion pathways focused on the development of two high priority anaerobic pathways for the conversion of lignocellulosic biomass to hydrocarbon biofuels. Through the combination of improved genetic engineering strategies, progress was made in FY 2018 on the production of an important biochemical intermediate, butanediol, with fermentation concentrations increasing by more than 50 percent to 75 g/L at high yields (>80 percent) over prior baselines. In FY 2018, the subprogram also achieved yield improvements for mixed organic acid (acetic and butyric acid) fermentations by reducing byproduct formation by more than 50 percent.

In FY 2019, the subprogram will prioritize further organism improvements and fermentation research, to achieve target butanediol concentrations of >100 g/L which are concentrations that can readily be converted to hydrocarbon fuels and bioproducts via work ongoing in the ChemCatBio Consortium

Analytical Method Development and Process Control ($1.1M): In FY 2018, protocols for more precise characterization and quantification of lignin, hydrolysates, and other biochemical species were developed under the analytical methods work. These characterization methods are utilized by many portions of the Conversion R&D portfolio as well as external entities to standardize key performance parameters related to product yields. National Laboratory work also developed real-time process control strategies by using numerous spectroscopic methods: near-infrared, Dielectric, and Raman. In FY 2019, the most impactful control scheme will be implemented and tested on a number of fermentation systems to allow for real-time monitoring of key performance parameters with the aim of improving fuel and co-product production rates.

Thermochemical characterization work in FY 2018 included National Laboratory work on protocols for bio-oil samples to link functional groups to physical properties including corrosive potential for different reactive surfaces commonly used in bio-oil refining. This work examines samples from facilities across the country derived from multiple feedstocks at a scale that would be out of the scope of any single private entity. In FY 2019 work will shift towards characterization of samples from high-priority upgrading pathways, and de-emphasize characterization of samples derived from fast pyrolysis.

In FY 2019, applied research will address hurdles for the integration of bio-oils and other intermediates into existing petroleum refineries and petrochemical plants such as characterization methods for bio-based oils and analysis of the fate of such oils in the refinery. By conducting this work at the National Laboratories, the program can ensure the data and findings of the research will be made publically-available to all researchers and refinery operators, thus advancing R&D across industry and academia. This effort will enable biofuels to leverage the existing petroleum infrastructure by inserting biofuel intermediates directly into existing refineries, rather than creating separate production and distribution channels for biofuels. Prior work between National Laboratories and industry has indicated that there are economic and overall fuel yield benefits to pursing this approach, in addition to potential energy security benefits of enhancing fuel production from domestic feedstocks. In FY 2018, DOE collaborated with an industry led larger scale and duration demonstration with a bio-oil producer and a petroleum refiner through fundamental modeling and analysis to support industrial acceptance.

Conversion Technologies

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Conversion Technologies $90,230,000	**$16,500,000**	**-$73,730,000**
• Fund the successful launch of 8-Lab Agile BioFoundry consortium at $15.0 million for direct National Laboratory research to leverage the tools of synthetic biology (ways to engineer organisms) to enable the biotechnology industry to ultimately bring new of biologically-derived molecules to market at half the current time and cost. Additionally support up to $5.0 million for competitively-selected projects with industry and university partners to collaborate with the BioFoundry through a directed funding opportunity.[1] • Fund the successful launch of 6-Lab Chemical Catalysis for Bioenergy (ChemCatBio) consortium at $13.7 million for direct National Laboratory R&D across 6 tasks, including development of the Catalyst Cost Model (CCM) for estimating pre-commercial catalyst manufacture costs. Additionally support up to $4.5 million for competitively-selected projects with industry and university partners to collaborate with ChemCatBio through a directed funding opportunity.[1] • Bioproducts: Fund one additional project at $1.8 million from the FY 2016 MEGA-BIO FOA to develop additional co-product strategies and technologies for converting biomass to fuels and chemicals. • Fund National Laboratory projects to develop analytical methods for the characterization of	• Fund the Agile BioFoundry consortium at $2.8 million to accelerate the R&D of new biologically-derived molecules through the completion of ≥ 3 cycles of DBTL on ≥ 3 target host pairs with at least 100 percent improvement in baseline titer, rate, and yield. • Fund the ChemCatBio at $2.2 million across five tasks to an increase in carbon efficiency (from 33 percent to 44 percent) resulting in a $1.8/gge reduction in MFSP. The project will also achieve projected $3.0/gge technical performance for an additional pathway. • Fund Bioproducts R&D with National laboratories at $0.8 million to synthesize, characterize and test at least 25 new bio-derived performance-advantaged materials that will enable biofuels across a range of polymer applications that verify the predictive model developed in FY 2018. • Fund analytical method development and applied materials issues to the extent needed to support ongoing projects. Fund development of a single process control scheme. • The lignin valorization research at $2.4 million will focus on a single potential pathway (downselected from 3 pathways in FY 2017) to convert at least 50 percent lignin stream to upgradeable intermediates. • No funding is requested in the area of gaseous or wet feedstocks conversion (conversion of biosolids) and advanced anaerobic digestion.	• The Agile BioFoundry will reduce host on-boarding from 3 new organisms in FY 2017 to 1 new organism in FY 2019. This will be accompanied by a downselect of organisms on-boarded in FY 2017 and FY 2018 to the most promising 2 with the addition of 1 new FY 2019 organism. No funding is requested to support cost-shared R&D partnerships between the BioFoundry and industry and academic partners. • ChemCatBio research will prioritize 3 catalytic processes (down from 5 processes in FY 2017). This down-select is based on the relative maturity of the conversion pathways and the potential for those processes to produce cost-competitive biofuels. CCPC modeling of deconstruction and catalyst systems will be reduced from ≥3 pathways at atomic-, meso-, and reactor scale in FY 2017 to ≥1 pathway(s) at atomic-, and/or meso-scale in FY 2019 in response to more targeted thrust research within ChemCatBio. No funds are requested for the Catalyst Cost Model (CCM) due to expected completion and public release in FY 2018. • Bioproducts: Research on bioproducts that enable biofuels will shift to National Laboratory investigators reflects the need to develop a general-use roadmap and explore early stage R&D. No funds are requested for additional competitive awards.

[1] Includes use of Cooperative Research and Development Agreements (CRADAs) or similar agreements in calls for innovative concepts and a channel for the National Laboratories to work with industry and/or universities to amplify these applied research consortia.

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
lignin, sugars, and other process parameters using three process control schemes. Methods developed will be shared for industry-wide use and broader adoption. • Fund National Laboratory early stage applied research on lignin valorization which can reduce effective biofuel cost by nearly $2.0/gge. In FY 2017, three pathways will be pursued as well as broadly enabling research. • Fund innovative technology seed projects at National Laboratories in the areas of wet wastes use, performance advantaged bioproducts, and to develop carbon advanced research fuels to increase conversion efficiencies. • Contribute the conversion components of FY 2017 verification at scale of at least one technology pathway for hydrocarbon biofuel at a mature modeled price of $3/gge with GHG emissions reduction of 50 percent or more compared to petroleum derived fuel. • Fund biochemical pathway development to break down feedstock using pretreatment and cellulases followed by biological and chemical upgrading to fuels. Four pathways from cellulosic sugars to hydrocarbon fuels are being investigated. • Fund existing projects at $5.7 million to address feedstock handling and preprocessing challenges at the feedstock-conversion interface. • Fund the successful launch of the Bioprocessing Separations (BioSep) consortium including 9 technical tasks (4 biochemical, 3 thermochemical, 1 ionic liquid, and 1 separations technologies analysis) to develop energy- and carbon-efficient bioprocess separations technologies.	• No funding is requested for verification at scale for hydrocarbon biofuels pathways. • Biochemical fermentation development will continue for 1-2 biochemical processes for the conversion of lignocellulosic biomass to hydrocarbon biofuels. No funding is requested to support research in aerobic upgrading strategies and cellulase development to produce cost-competitive bio-based hydrocarbon fuels and products. • Separations: Down-select tasks within the Bioprocessing Separations consortium from 9 technical tasks to 3 (one biochemical, one thermochemical, and one separations technologies analysis). • Competitively selected projects under BRDI will continue with prior year funds. Funding Opportunity Announcement with USDA under the Biomass Research and Development Initiative.	• Activities to develop analytical methods, process measurement and control, computational modeling and technical analysis will prioritize dielectric spectroscopy process control schemes; no additional funds are requested to advance analytical methods developed in prior years. • Lignin research efforts will focus on one pathway, downselecting from three pathways in FY 2017. No broadly enabling research will be pursued to reach a critical mass of funding on a single pathway. • No funding is requested in the area of wet feedstocks conversion (conversion of biosolids) and advanced anaerobic digestion. Conversion R&D will only focus on the feedstocks available in the largest quantities, namely dry terrestrial feedstocks based on Billion Ton Study results. • FY 2017 verification studies were successfully completed on schedule. • No funds for FCIC are requested in Conversion in FY 2019. • 4 biochemical pathways in 2017 have been downselected to 1 or 2 based on more promising fermentation results and associated results from techno-economic analysis. Work on anaerobic fermentations is prioritized due to fewer technical challenges and existing cellulose technologies will be employed. • Separations: Reduced funding requested for the BioSep consortium to focus on priority separations strategies. • No funding is requested issue a joint competitive funding opportunity with the U.S. Department of Agriculture in support of the Biomass Research and Development Initiative.

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
• Funding for up to two competitively-selected projects under the Biomass Research and Development Initiative.		

Bioenergy Technologies
Advanced Development and Optimization

Description

The Advanced Development and Optimization (ADO) subprogram will continue collaboration with the Vehicle Technologies Program on the Co-Optimization of Fuels and Engines (Co-Optima) effort in FY 2019 to strengthen the knowledge-base upon which industry can demonstrate and deploy the next generation of fuels and engines for light- and heavy-duty vehicles that are co-optimized to enable higher efficiency and performance. Co-Optimization of higher-efficiency engines and high performance fuels has the potential to improve light-duty fuel economy by 35 percent (25 percent from advanced engine research and 10 percent from co-optimization of advanced engines with fuels) by 2030 compared to 2015 gasoline vehicles. Through a collaborative R&D effort at nine National Laboratories that includes industry stakeholders, the project explores phenomena related to fuel chemistry – fuel property – engine performance relationships and investigates preferential fuel options that have potential to maximize domestic fuel sourcing. The effort leverages unique properties available from domestic biofuels, such as high octane and sensitivity that enable higher engine efficiency.

Accomplishments in FY 2016 and FY 2017 include the development and application of a rigorous fuel property selection process to identify eight high-potential fuel candidates, from an initial list of 470, that have the properties to maximize the efficiency and performance of advanced spark ignition engines and could be produced from domestic biomass resources. In addition, eight university Funding Opportunity Announcement (FOA) selections supporting the project goals were initiated in FY 2017. Activities in FY 2019 will focus on the evaluation of novel bio-based fuel molecules and mixtures that provide properties that maximize the efficiency and performance of advanced compression ignition (ACI) engines. In FY 2019, the R&D focus will shift towards evaluating fuels for medium and heavy-duty vehicles and will result in a list of high-potential fuel candidates for ACI engines that provide desirable fuel properties.

The ADO portfolio also includes pilot, demonstration, and pioneer integrated biorefinery projects fully funded by prior appropriations. The subprogram will continue to manage these existing projects through to completion. Reflecting the shift in focus to early-stage R&D, no new projects will be solicited or awarded in FY 2019.

The ADO portfolio includes development of first of a kind engineering-scale system testing in relevant environments. The funded projects are typically integrated technology verifications, where a system or component is being tested at engineering-scale for the first time in an experimental prototype, and it is realistic to expect additional applied research refinements will be needed which will feed back into the Advanced Algal Systems, Feedstock Supply & Logistics, Conversion, Strategic Analysis and Sustainability subprograms following the successful development phase. Verifying these technologies at smaller partially integrated scales is essential for reducing risk and technology uncertainty, when tied with the feedback loop to applied R&D continuing to reduce cost and improve performance of the feedstock and conversion processes. Verification is vital to establish baselines, so that R&D progress can be measured at the end of the project and the successful accomplishment of the project goal is verified. Additionally techno-economic analysis and lifecycle assessments are of significantly higher quality when derived from engineering scale data and these analyses are both used to measure progress and to drive the most impactful applied research.

Support of the integrated testing and pilot-scale work will continue in FY 2019 through the ADO subprogram, as BETO will leverage our previous investments in integrated process development/pilot-scale/systems research capabilities potentially at universities, as well as at the DOE National Laboratories including at the: National Renewable Energy Laboratory (NREL) – Integrated Biorefinery Research Facility (IBRF), NREL – Thermochemical Users Facility (TCUF); Idaho National Laboratory (INL) — Biomass Feedstock National User facility (BFNUF); Lawrence Berkeley National Laboratory (LBNL) – Advanced Biofuels Process Development Unit (ABPDU) and Pacific Northwest National Laboratory (PNNL) – HydroThermal Liquefaction (HTL) skid. Two National Laboratory projects will evaluate alternate routes to produce JP-10 from biomass, and investigate bio-derived fuels (including bio-intermediates and bio-blends) for marine engine uses.

In FY 2017 BETO began investments in several pilot- and demonstration-scale projects which will complete phase one activities in FY 2019. These projects may proceed into phase two, based on the availability of prior year funds and the successful completion of a down-select process. BETO will continue its best practice of using an independent engineer to help with oversight and verification of engineering-scale system testing. No funding is requested in FY 2019 to support additional pilot or demonstration-scale projects.

In FY 2017 BETO competitively awarded eight projects which will continue in FY 2019 focused on R&D challenges within existing integrated biorefineries (IBRs) that need to be addressed to enable reliable and continuous operation. The eight projects are addressing critical R&D barriers in three different sub-system areas: 1) Robust, continuous handling of solid materials (dry and wet feedstocks, biosolids, and/or residual solids remaining in the process) and feeding systems to reactors under various operating conditions; 2) High value products from waste and/or other under-valued streams in an IBR; and 3) Analytical modeling of solid materials (dry and wet feedstocks, and/or residual solids remaining in the process) and reactor feeding systems.

Advanced Development and Optimization

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Advanced Development and Optimization $54,041,000	**$7,000,000**	**-$47,041,000**
• Fund the Co-Optimization of Fuels and Engines (Co-Optima) consortium of nine National Laboratories ($12M) to conduct early-stage R&D and related analysis to identify and evaluate the most promising biofuel candidates to enable fuel economy and efficiency targets for advanced diesel and multi-mode spark ignition engines in collaboration with the Vehicle Technologies Program. • Continue Co-Optima early-stage R&D at four universities focused on fuel characterization and performance prediction, which were fully funded through prior year appropriations. • Fund competitive projects ($8M) to solve critical research and developmental challenges encountered for the successful scale-up and reliable operations of integrated biorefineries, decrease capital and operating expenses, and focus on the manufacture of advanced or cellulosic biofuels and higher-value bioproducts. • Provide $10 million for National Laboratory led R&D on innovative technologies to advance biopower from biomass, biosolids and sorted Municipal Solid Waste with industrial partners. • Funds early-stage, system-level research, leveraging world-class capabilities from prior investments at the National Laboratories ($7.5M) • Funds to support one phase-two award at $15 million, contingent upon completing a successful down-selection. Currently, six existing projects are in phase one of the competitive award.	• Collaborate with the Vehicle Technologies Program on the Co-Optimization of Fuels and Engines initiative. Fund the consortium of nine National Laboratories to conduct early stage R&D and related analysis to evaluate the most promising biofuel candidates to enable fuel economy and efficiency targets for advanced compression ignition (ACI) engines at a level of $5.5 million. • Support of the integrated testing and pilot-scale work will continue in FY 2019 through the ADO subprogram, as the program will leverage previous investments in integrated process development/pilot-scale/systems research capabilities potentially at universities, as well as at the National Laboratories. Additionally, two National Laboratory projects will evaluate alternate production routes for JP-10 from biomass, and investigate bio-derived fuels (including bio-intermediates and bio-blends) for marine engine uses. The total funding level for these activities is $1.5 million. • Validation and downselect from existing phase one competitive projects will be competed by the end of FY 2019 with prior year funds.	• Co-Optimization of Fuels and Engines activities on boosted spark ignition (SI) engines will be completed in FY 2018 and emphasis will shift towards fuels to enable multi-mode ACI/SI engines for light duty vehicles and ACI engines for medium and heavy duty vehicles. • National Laboratory-led work with industry partners to develop and refine industry safety and sustainability codes and standards will conclude in FY 2018. This supports the shift of the program's work to earlier R&D. • No funding is requested to support biopower R&D reflecting the prioritization of higher-value biofuels and co-products. • No new integrated biorefinery pilot, demonstration, or pioneer projects will be solicited or awarded. Management of existing projects will continue to completion. This supports the shift of the program's work to early-stage R&D.

Bioenergy Technologies
Strategic Analysis and Cross-cutting Sustainability

Description

Strategic Analysis activities provide quantitative analysis to inform the Bioenergy Technologies Program's decisions regarding the future direction and scope of its early-stage research and development (R&D) portfolio. Activities include techno-economic, resource, impact, and risk assessments that provide the analytical basis for planning and assessing progress against program goals and cost targets. System-level analyses identify the key gaps in existing knowledge and where additional research could have the greatest impact. Decision support, data management, and analytical tools allow the program to identify and verify performance goals, and measure progress toward these goals.

Cross-cutting Sustainability activities are conducted by National Laboratories, industry, and academic partners to improve understanding of and focus the research portfolio on potential win-win solutions that maximize both economic and environmental value. This includes research targeting underproductive aspects of agricultural and forestry systems and leveraging the ability of biomass to improve degraded soil and water resources. Cross-cutting Sustainability research also fills critical knowledge gaps about how to increase bioenergy production without detriment to food security, air, land, and water resources. This research involves close collaboration with other agencies to ensure that the results and outcomes provide maximum value.

Key accomplishments of the Strategic Analysis and Cross-cutting Sustainability subprogram include the creation of state-of-the art tools and analyses to answer critical questions about the potential economic and environmental benefits of bioenergy. For example, the Water Analysis Tool for Energy Resources (WATER) evaluates water use and water quality effects in the production of biofuels and could ultimately help improve efforts to use water more efficiently if utilized by industry. The Jobs and Economic Development Impact (JEDI) models estimate the economic impacts of constructing and operating biofuel plants at the local and state levels. Additional models developed through the subprogram include the Greenhouse Gas, Regulated Emissions, and Energy Use in Transportation Model (GREET), the Biomass Scenario Model (BSM), the Landscape Environmental Assessment Framework (LEAF), and the Feedstock Production Emissions to Air Model (FPEAM).

In FY 2019, funding from Cross-cutting Sustainability and Strategic Analysis will support activities at the National Laboratories. Activities will result in peer-reviewed publications that answer critical research questions about the potential effects and benefits of emerging advanced bioenergy pathways, helping researchers and industry to capitalize on these opportunities while mitigating potential challenges.

Model and Tools ($3M): The subprogram will focus on making necessary updates to high-priority models and tools for use by the program, industry and academia. The Program will apply these tools to conduct high-priority analyses focused on understanding the potential economic and environmental effects of novel bioenergy technologies and processes.

Analysis and Strategies for Biofuel Cost Reductions ($2M): In FY 2019, the subprogram conduct analysis identify innovative strategies for cost reductions toward $2.0/gge, including integrated landscape management strategies, as well as completing a multi-dimensional analysis that quantifies and characterizes key economic and environmental benefits, such as job creation, of an expanding bioeconomy.

Strategic Analysis and Cross-cutting Sustainability

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Strategic Analysis and Cross-cutting Sustainability $10,729,000	**$5,000,000**	**-$5,729,000**
• Make necessary improvements to models and tools (including GREET, BSM, WATER, JEDI and LEAF) and apply models to conduct high-priority analyses—expected to result in at least 10 peer reviewed publications and technical reports—focused on understanding the potential economic and environmental effects of novel bioenergy technologies and processes (funding at a level of $4 million). • Analyze pathways and R&D strategies capable of enabling industry to achieve an ultimate cost target of $2.0/gge (funding at a level of $1 million). • Conduct sustainability research to identify and fill knowledge gaps related to increasing bioenergy production without detriment to food security, air, land, and water resources. This includes two field research projects on the sustainability effects of energy crop production (funding at a level of $4 million). • Conduct lifecyle analysis in support of the 2017 verification at scale of at least one technology pathway for hydrocarbon biofuel production will meet GHG emissions reduction of 50 percent or more compared to petroleum derived fuel and a mature	• Update tools (including GREET, WATER, JEDI and LEAF) and apply models to conduct high-priority analyses—expected to result in at least 10 peer reviewed publications and technical reports. (funding at a level of $3 million) • FY 2017 analysis of pathways to achieve $2.0/gge will be incorporated into R&D strategies across BETO portfolio, and additional analysis will be conducted on integrated landscape management strategies to reduce the cost of biofuels. (funding at a level of $1 million) • Complete a multi-dimensional analysis that quantifies and characterizes key economic and environmental benefits, including job creation, of an expanding bioeconomy. (funding at a level of $0.5 million). • Conduct sustainability research to identify and fill knowledge gaps related to increasing bioenergy production without detriment to food security, air, land, and water resources. (funding at a level of $0.5 million). • No verification activities will be conducted in FY 2019 due to successful completion of the FY 2017 verification activities.	• The subprogram will prioritize maintenance and updates of GREET, JEDI, WATER and LEAF models, and defer maintenance to BSM and FPEAM) that have reached a level of maturity and are being used by the program, industry, and other institutions to analyze market, economic, and environmental aspects of bioenergy scenarios. • Crosscutting analysis of pathways to achieve $2.0/gge is completed in FY 2018 and used to inform R&D priorities across the program. • Analyses of potential environmental effects of biomass production will be de-emphasized following the successful completion of the 2016 Billion-Ton Reports. • Field research conducted by the National Labs on the sustainability effects of energy crop production will be reduced, as two field research projects have concluded and their findings have been published.

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
modeled price of $3/gge. (funding at a level of $0.2 million). • Completion of analyses, development, and publication of 2016 Billion-Ton Report, Volume 2: Environmental Sustainability Effects of Select Scenarios from Volume 1 (funding at a level of $1.5 million).		

Hydrogen and Fuel Cell Technologies

Overview

Hydrogen can be produced from diverse domestic resources, such as natural gas, oil, coal, and biomass, as well as from renewables using methods such as direct or indirect water splitting. Fuel cell electric vehicles using hydrogen can achieve significantly higher efficiencies than combustion engines resulting in overall less energy use. Domestically-produced low cost hydrogen enables energy independence. In addition to transportation applications, hydrogen and fuel cell technologies can also serve stationary applications improving energy security and reliability by providing responsive back-up power and other electric and fuel distribution services. Thus, fuel cell and hydrogen technologies are an option that enables American energy dominance through safely and efficiently harnessing domestic resources. However, the highly specialized hydrogen and fuel cell industry is still nascent, and lacks the capabilities and critical mass resources necessary for the early-stage research and development (R&D) that can ultimately enable successful market impact. Therefore, DOE's role under the Hydrogen and Fuel Cell Technologies Program is to focus on early-stage R&D that enables industry to develop and deploy hydrogen and fuel cell technologies which are cost competitive with conventional technologies.

To improve transportation energy affordability, strengthen national security, support energy dominance and enable future economic growth, DOE performs early-stage R&D on several advanced transportation technology options in the Hydrogen and Fuel Cell Technologies, Vehicle Technologies, and Bioenergy Technologies Programs. Common metrics across all three of these programs have been developed to evaluate these advanced options compared to the lifecycle costs and energy consumption of today's technologies. Over a lifecycle basis, (vehicle manufacture, fuel production, and fuel use), future (~2030) modeled conventional technology of a gasoline internal combustion engine vehicle (ICEV) is expected to be approximately 27 cents per mile and 4,700 Btu per mile.[1] The Hydrogen and Fuel Cell Technologies Program goals below are necessary for these new technology options to be more efficient and at least as affordable compared to this baseline while also accounting for consumer expectations regarding affordability and pay back periods.

To be cost competitive with gasoline on a cents-per-mile driven basis, the cost of hydrogen produced, delivered and dispensed from domestic resources needs to be less than $4/gge and the cost of a durable fuel cell system needs to be $30/kW. While the focus is on transportation, the research concurrently benefits stationary fuel cells – such as backup power, reversible fuel cells, or small-scale tri-generation of fuel, heat and power that provide resiliency and flexibility across multiple sectors. In all cases, the key issue is the need for significant reductions in cost and improvements in performance and durability. The scope is technology-neutral and feedstock-flexible, emphasizing low- and medium-temperature fuel cells applicable to transportation, as well as enabling electricity and fuel distribution reliability and flexibility through cost-competitive hydrogen production, delivery and storage technologies.

Highlights of the FY 2019 Budget Request

The Fuel Cell R&D subprogram will focus on early-stage fuel cell component R&D with potential for transportation and cross-cutting applications. Early-stage research areas will include catalysts, membranes, and fuel cell performance and durability (including R&D to address electrode, mass transport and degradation issues). In addition, the program will conduct proof-of-concept testing, technical analysis and high-throughput combinatorial R&D, coupled with high-performance modeling to enable the development of platinum group metal (PGM) free catalysts and electrodes. Funding will focus on research that industry either does not have the technical capability to undertake or is too far from market realization to merit sufficient industry focus and critical mass.

The Hydrogen Fuel R&D subprogram's efforts will emphasize applied materials research and early-stage component and process development to enable industry to develop and deploy novel hydrogen production and onboard storage technologies capable of utilizing a diversity of domestic energy resources. The subprogram's hydrogen production efforts will emphasize longer-term renewable options that can completely revolutionize the energy sector, such as advanced water splitting. The subprograms onboard hydrogen storage efforts will continue to focus on early-stage applied R&D for advanced storage technologies offering high-energy density at lower pressures compared to today's systems.

[1] See Record #17008 which can be accessed at https://www.hydrogen.energy.gov/program_records.html#program_related. Both energy and cost per mile are based on a 15-year vehicle lifetime.

The highlights of these two subprograms in FY 2019 are National Laboratory-led efforts, offering state-of-the-art multi-lab core capabilities that leverage university and industry partners to dramatically accelerate materials breakthroughs and innovations in early-stage R&D. Focus areas through 'virtual' lab-led consortia, are:

- ElectroCat for PGM-free catalysts;
- HydroGEN for advanced water-splitting; and
- HyMARC for hydrogen storage materials research.

In addition, the Hydrogen Infrastructure R&D subprogram will include early-stage R&D activities to support the H2@Scale concept, which enables innovations to generate H_2 as an energy carrier and the Beyond Batteries initiative. By producing hydrogen when power generation exceeds load, electrolyzers can prevent curtailment of renewables and enable grid stability and resiliency, while also producing a feedstock for end users across a variety of sectors. For example, hydrogen produced from existing baseload and variable generation assets can be stored, distributed and used as a fuel for process or building heat or as a chemical feedstock for transportation, stationary power, and industrial sectors creating an additional revenue stream for those assets. The Program will focus on modular, scalable concepts for dispatchable H_2 production, delivery and storage, liquefaction, materials development, and integration with diverse generation sources. In FY 2019, the subprogram will continue using the consortium approach and will invest in fundamental and transformational materials R&D to enable industry to develop and deploy viable and safe technologies, including advanced liquefaction and hydrogen detection technologies. The H2@Scale activity includes exploratory R&D to identify and develop early-stage concepts with potential to enable significant cost reductions in the storage, use, and transport of hydrogen, with two focus areas: the Hydrogen Materials (H-Mat) Consortium and Hydrogen Carriers. The H-Mat Consortium will comprise a comprehensive R&D framework covering both metallic and non-metallic materials for use in hydrogen service, with a focus on scientific tools to predict and enhance materials compatibility, durability, and performance. The second focus area will be on foundational research to identify and develop hydrogen carriers with the potential to store and transport hydrogen at ambient temperatures and low pressures, and with significantly greater energy densities compared with current high-pressure gaseous tube trailer or liquid tanker options.

As a part of the DOE Grid Modernization Initiative (GMI), Beyond Batteries focuses on advances in controllable loads, hybrid systems incorporating generation from all sources, and new approaches to energy storage, which are essential to increasing the reliability and resiliency of our energy systems. Advances in these areas will allow for loads to be combined with generation from all sources to optimize use of existing assets to provide grid services, and increase grid reliability. The program's R&D under the Beyond Batteries effort will focus on innovative concepts for reversible fuel cells to provide easily dispatchable power to address resiliency and grid and microgrid needs.

Hydrogen and Fuel Cell Technologies
($K)

	FY 2017 Enacted	FY 2018 Annualized CR*	FY 2019 Request	FY 2019 Request vs FY 2017 Enacted
Hydrogen and Fuel Cell Technologies				
Fuel Cell R&D	32,000	—	19,000	-13,000
Hydrogen Fuel R&D	41,000	—	19,000	-22,000
Hydrogen Infrastructure R&D	0	—	19,000	+19,000
Systems Analysis	3,000	—	1,000	-2,000
Safety, Codes and Standards	7,000	—	0	-7,000
Technology Acceleration	18,000	—	0	-18,000
Total, Hydrogen and Fuel Cell Technologies	**101,000**	**100,315**	58,000	-43,000

SBIR/STTR:

- FY 2017 Transferred: SBIR $2,528,000; STTR $356,000
- FY 2018 Projected: SBIR $2,511,000; STTR $354,000
- FY 2019 Request: SBIR $1,856,000; STTR $261,000

Budget Structure Crosswalk ($K)

	Proposed FY 2019 Budget Structure				
FY 2017 Enacted Budget Structure	Fuel Cell R&D	Hydrogen Fuel R&D	Systems Analysis	Hydrogen Infrastructure R&D	Total
Fuel Cell R&D	19,000	0	0	0	19,000
Hydrogen Fuel R&D	0	19,000	0	19,000	38,000
Systems Analysis	0	0	1,000	0	1,000
Safety, Codes and Standards	0	0	0	0	0
Technology Acceleration	0	0	0	0	0
Total, Hydrogen and Fuel Cell Technologies	**19,000**	**19,000**	**1,000**	**19,000**	**58,000**

*A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution. (These amounts are shown only at the Congressional control level and above; below that level, a dash (—) is shown).

Hydrogen and Fuel Cell Technologies
Explanation of Major Changes ($K)

	FY 2019 Request vs FY 2017 Enacted
Hydrogen and Fuel Cell Technologies	
Fuel Cell R&D: In FY 2019, the program will focus on early stage innovations such as PGM-free catalysts and reduce work on low PGM catalysts, balance of plant R&D, and system related operation and performance validation. The subprogram will also reduce funding for the Fuel Cell Performance and Durability (FC-PAD) consortium and will transition this durability work to industry by encouraging industry to partner with the National Laboratories to make use of their unique resources and capabilities. The sub-program will initiate early-stage R&D on components such as membranes, catalysts and electrodes to optimize them for unitized reversible fuel cells that store energy and generate power as required in support of Beyond Batteries.	**-13,000**
Hydrogen Fuel R&D: In FY 2019, the subprogram will focus on early-stage applied materials R&D for hydrogen production and on-board storage. The program will discontinue development of low cost 700 bar composite tanks, storage balance of plant components, and cryocompressed hydrogen storage work in order to focus subprogram resources on the most critical early stage R&D. Work on near-term technology development for production and delivery of hydrogen is also discontinued to enable a greater focus on early stage applied R&D. Efforts on station infrastructure and H2@Scale activities will be moved to the Hydrogen Infrastructure R&D subprogram.	**-22,000**
Hydrogen Infrastructure R&D: In FY 2019, the new subprogram will build on work previously conducted under Hydrogen Fuel R&D to focus on applied materials research and early-stage component and process development to enable industry to develop and deploy novel hydrogen infrastructure and bulk storage technologies including advanced concepts to support H2@Scale and hydrogen station infrastructure**.** The subprogram will also conduct early-stage R&D to increase the security and resilience of the Nation's critical infrastructure under H2@scale including opportunities for H_2 energy storage, materials compatibility R&D, and innovative H_2 carriers contributing to a strong domestic economy and energy independence, security & resilience.	**+19,000**
Systems Analysis: In FY 2019, the program will discontinue work more appropriately conducted by industry to measure return on investment, infrastructure financing analysis, and state partnership support. The subprogram will focus on providing analysis to identify key areas in which to strategically prioritize R&D efforts.	**-2,000**
Safety, Codes and Standards: No funding requested in FY 2019.	**-7,000**
Technology Acceleration: No funding requested in FY 2019.	**-18,000**
Total, Hydrogen and Fuel Cell Technologies	**-43,000**

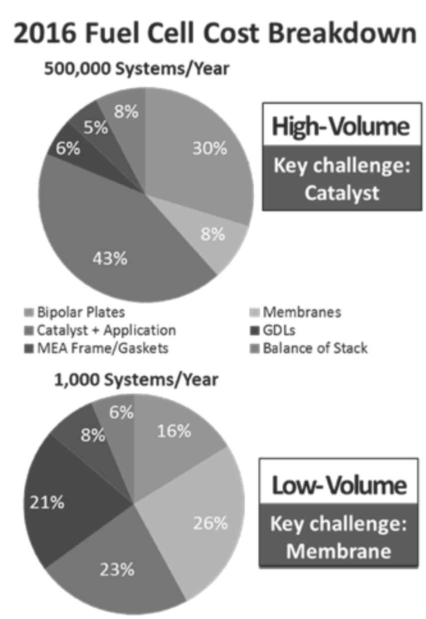
Description

The Fuel Cell R&D subprogram supports early-stage R&D to expand the body of knowledge upon which industry can develop and deploy technologies that improve durability, reduce costs, and enhance performance (e.g., power, efficiency, start-up time, transient response, etc.) of fuel cells. Key goals include validating concepts that reduce the modeled high-volume cost of automotive fuel cells to $40/kW and improve fuel cell durability to 5,000 hours (approximately 150,000 miles of driving) for automotive systems by 2025 as an interim step towards the ultimate goal of enabling direct cost competitiveness with internal combustion engine light duty vehicles at $30/kW and 8,000 hours beyond 2030. Innovations resulting from subprogram activities have facilitated a more than 50 percent cost reduction in fuel cells developed and deployed by industry over the last decade. Nevertheless, modeled automotive fuel cell costs for high manufacturing volumes (100,000 units/year) is roughly $60/kW (the low-volume cost, associated with current production levels, is estimated at roughly $230/kW based on input from OEMs). Similarly, the subprogram has enabled a four-fold increase in durability, now at over 4,000 hours, but an additional doubling is necessary to be comparable to incumbent technologies. These differences represent the potential for knowledge generated through early-stage R&D to foster substantial technology advances by industry. Funding is focused on longer-term, high risk research areas with commercial application expected beyond the near-term (~5 year) investment focus of industry. Industry is encouraged to utilize the specialized tools and characterization facilities at the National Laboratories through CRADAs to advance nearer-term commercialization.

The planned early-stage R&D, conducted with projects competitively selected through lab calls, will focus on automotive applications with high potential for knowledge spillover benefits relevant to other uses such as distributed power (primary and backup), Auxiliary Power Units (APUs), and specialty vehicles. The program will ensure continued industry engagement through the US DRIVE partnership which will provide feedback on the programs early-stage precompetitive R&D and will encourage industry partnership with the National Laboratories through CRADAs. While the focus is on polymer exchange membrane (PEM) fuel cells, the portfolio is technology neutral and projects may include exploration of alkaline membrane fuel cells, medium-temperature fuel cells such as phosphoric acid fuel cells, and higher-temperature fuel cells like molten carbonate fuel cells, as long as they are expected to contribute to the Program goals.

In FY 2019, the Fuel Cell R&D subprogram will focus R&D in the key areas of fuel cell components and materials, as well as fuel cell performance and durability. Figure 1 shows the primary contributors to cost based on state-of-the-art technology both at high volume and low volume, emphasizing the importance of catalysts, as well as other components such as membranes, bipolar plates, and gas diffusion layers (GDLs).[1] Today, the fuel cell industry relies entirely on platinum based catalysts and automakers have focused on commercializing vehicles rather than on game-changing early-stage research to displace platinum. Discovery and development of PGM-free catalysts and electrodes, with equivalent activity and performance, could reduce fuel cell stack cost by approximately 40 percent. The removal of PGMs will also mitigate US dependence on South Africa, Russia, China and other countries for precious metal imports. Therefore, the subprogram will place particular emphasis on expediting the development of PGM-free catalysts and electrodes. This will be achieved by streamlining private industry and university access to National Laboratory capabilities through the lab-led consortium, ElectroCat ($6M). Through Lab AOP funding of ElectroCAT projects the subprogram will further develop advanced high-performance computing, unique synthesis and characterization tools, and high-throughput combinatorial approaches focused on the development,

Figure 1 R&D Focuses on High Cost Areas



[1] Program Record, https://www.hydrogen.energy.gov/pdfs/16020_fuel_cell_system_cost_2016.pdf

processing, component integration, qualification and end-use of PGM-free catalysts and electrodes into membrane electrode assemblies (MEAs). These modeling and experimental approaches will capture the effects of materials processing and end-use performance and will accelerate advanced materials R&D.

The Beyond Batteries fuel cell effort ($7M) will focus on early-stage applied R&D to enable energy storage and resilience including liquid and reversible fuel cells such as unitized Reversible Fuel Cell (RFC) technologies. RFCs are versatile and fuel-flexible, offering unique benefits in energy-production, energy storage, and grid services including improvement of grid and microgrid reliability and resiliency. High-temperature RFCs operated in the 'forward' fuel cell power generation mode can run on a wide range of fuels, including fossil fuels (such as natural gas), liquid fuels (e.g. methanol, biofuels and other carriers), and hydrogen. Further, they can generate combined heat, hydrogen and power (i.e., 'tri-gen') with flexibility on how much of each is produced. In the 'reverse' electrolysis mode, RFCs can use excess electricity when the grid demand is low to convert water or other feedstocks into high-value hydrogen fuel for transportation, energy storage, and other end uses. With bi-directional functionality, a compact footprint, and rapid dynamic response (particularly in lower-temperature implementations) RFCs can play an important role in increasing the reliability and resiliency of our energy systems. The viability and cost-competitiveness of these technologies requires continued foundational R&D in materials compatibility, enhanced durability, and optimized bi-directionality to improve roundtrip efficiency and meet long-term targets less than $1,250/kW capital cost and a cycle life of 5,000 cycles.[1] Maintaining performance during repeated cycling between fuel cell and electrolysis modes as well as maximizing performance and efficiency in both modes are key challenges. Specific research priorities include bifunctional catalysts, advanced membrane separators (such as polymer-based and solid-oxide based membranes), electrodes with optimized mass-, electronic-, and ionic-transport properties including effective water management under both operating modes, and corrosion protection schemes.

In addition, the subprogram will fund low-technology readiness level (TRL)[2] component R&D conducted by industry, academia and the National Laboratories through competitively selected projects such as alkaline and non-water dependent membranes, electrodes and component innovations (such as gas diffusion layers, bipolar plates, etc.) and MEA fabrication research innovations ($4M). The remaining funds, directed at unique capabilities existing at the National Laboratories, will focus on fuel cell modeling, proof of concept testing, safety research, and cost analysis to guide R&D prioritization and performance and durability. This includes the lab-led consortium FC-PAD (Fuel Cell Performance and Durability) which brings together National Laboratory capabilities with university and industry partners to develop a better foundational mechanistic understanding, and risk mitigation strategies to improve fuel cell mass transport and prevent degradation ($2M).

To maximize the impact of government funding and avoid duplication, R&D efforts will leverage outside activities, through coordination with other offices and agencies, including the Office of Science, the Office of Nuclear Energy, the Office of Fossil Energy, the National Science Foundation (NSF), the National Aeronautics and Space Administration (NASA), and the Department of Defense (DoD).The subprogram will also continue to support peer reviews and relevant activities under the Energy Policy Act of 2005 (EPACT) and relevant legislation, including analyses supporting the Federal advisory committee (the Hydrogen and Fuel Cell Technical Advisory Committee) and the interagency working group. Consistent with rigorous peer review processes, competitive selection of projects in topic areas will be determined based on the relative merit, applicability, and potential for R&D progress, including lab calls and calls for Cooperative Research and Development Agreements (CRADAs) with industry and academia.

[1] https://energy.gov/sites/prod/files/2017/03/f34/quadrennial-technology-review-2015_1.pdf, Chapter 3, Table 3.C.2
[2] https://www.directives.doe.gov/directives-documents/400-series/0413.3-EGuide-04/@@images/file, p. 9.

Fuel Cell R&D

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Fuel Cell R&D $32,000,000	**$19,000,000**	**-$13,000,000**
• Develop innovative catalyst and electrode technologies and integrate state-of-the-art components in advanced MEAs through 10 projects competitively selected via FOAs and 8 projects competitively selected via lab-calls to achieve 7.2kW/g PGM.	• No funding requested in FY 2019.	• No solicitations for new projects on low-PGM catalysts and electrode R&D. Terminate 3 lab-call selected low-PGM catalyst projects to increase catalyst activity per gram PGM in order to focus on early stage research at the National Laboratories (ElectroCAT) for PGM-free catalysts.
• Select 4 FOA projects and support 4 National Laboratory projects to accelerate PGM-free catalyst, electrode and MEA development through the application of high-performance computing, high-throughput combinatorial based approaches and advanced modeling, capturing the effects of processing and end-use performance, to facilitate meeting the ultimate fuel cell cost target $30/kW.	• Down select to the 4 most promising early-stage R&D on cutting edge PGM-free catalysts to achieve a catalyst activity of at least 29 mA/cm^2, a 50 percent improvement to the 2016 value (16 mA/cm^2).	• Shift efforts to focus on the most promising PGM-free catalyst research to enable breakthroughs in catalyst activity without the need for platinum.
• Continue development of higher temperature fuel cell stack components, as well as system and subsystem components and system integration through 3 competitively selected industry FOA projects to extend fuel cell operational life beyond 50,000 hours.	• Support up to 6 of the most promising early-stage membrane and reversible fuel cell component R&D AOP projects that are too far from market realization to merit sufficient industry focus.	• Balance of plant (BOP) R&D will not be pursued in order to focus on fuel cell stack innovations and rely on industry for BOP work. Stack component R&D at higher TRLs, including bipolar plate R&D which can be pursued by industry will not be conducted No industry/university funding solicitations on BOP components and bipolar plate R&D will be issued.
• Issue Fuel Cell R&D solicitation and select 3 to 6 projects that will help achieve the fuel cell system cost ($40/kW by 2025) and durability (5,000 hours by 2025) metrics.	• Conduct preliminary testing of early-stage R&D concepts with potential to achieve fuel cell cost target of $40/kW and determine cost projection for at least two manufacturing volumes through National Laboratory AOP projects.	• Focus will shift to long-term lab-led early stage R&D. No industry funding solicitations will be issued. Industry and academia may partner with labs through the consortia mechanism or CRADA calls.
	• Issue a Funding Opportunity Announcement and select 3 to 5 projects focused on components such as membranes, catalysts and electrodes optimized for liquid and unitized reversible fuel cells.	• This is a new activity in FY 2019

Hydrogen and Fuel Cell Technologies
Hydrogen Fuel R&D

Description

The Hydrogen Fuel R&D subprogram supports foundational and applied materials research as well as technology development to enable industry to develop and deploy novel hydrogen production and onboard storage technologies capable of utilizing a diversity of domestic energy resources. The overarching goal of the Hydrogen Fuel R&D subprogram is to enable viable options for hydrogen production and on-board storage which could ultimately lead to industry development and commercialization, thereby enabling energy security, economic growth and environmental benefits. A key subprogram goal is to focus early-stage R&D on the production of hydrogen from diverse domestic resources at a production cost of less than $2/gge (untaxed, at high volumes, target is <$4/gge with delivery). This target represents the threshold at which hydrogen for FCEVs will be competitive on a cent-per-mile basis with conventional vehicles due to the inherently higher fuel efficiency of fuel cell electric vehicles. High-level techno-economic and life-cycle analyses will continue to provide important guidance on subprogram priorities in foundational and applied research needs for maximizing the energy security, economic growth and environmental benefits offered by hydrogen fuel.

The hydrogen production component of the Hydrogen Fuel R&D subprogram will address early-stage research and development in the following key areas: (1) high temperature thermochemical hydrogen production, (2) direct photoelectrochemical (PEC) hydrogen production, and (3) low and high temperature electrolysis. By leveraging the DOE Energy Materials Network (EMN), the subprogram will continue to emphasize R&D associated with the HydroGEN EMN consortium, including advanced high throughput/combinatorial approaches to enable rapid identification and development of promising materials essential for dramatic advances in water-splitting pathways. Specific research areas include new catalysts, membranes, electrode structures, energy conversion materials, and materials compatible with hydrogen at a broad range of temperatures and pressures. The HydroGEN EMN includes six core National Laboratories, competitive solicitations and CRADA calls to encourage partnerships with industry and academia ($10M). The FY 2019 activities will include a competitive solicitation, and at least six direct funded National Laboratory projects focused on advanced electrolysis, photoelectrochemical (PEC) water splitting, and solar thermochemical (STCH) water splitting and leverage the HydroGEN EMN Consortium and that are selected based on scientific results and down-selections of prior research projects.

Additional subprogram focus areas ($5M) will include early-stage foundational research in technologies for widespread domestic hydrogen production outside the water-splitting pathways covered in HydroGEN. Topics include: (1) innovative biological approaches such as dark- and photo- fermentation as well as microbial electrolysis for producing hydrogen from bio- and industrial waste streams; (2) novel catalytic and thermochemical technologies for efficient large scale processing of fossil an biomass feedstocks; and (3) hybrid systems efficiently leveraging fossil, nuclear and renewable resources. FY 2019 activities in these areas will include competitive solicitations as well as Lab and CRADA calls to select at least four high-impact research projects that best leverage National Laboratory resources in conjunction with stakeholder investments.

The Hydrogen Fuel R&D subprogram is also developing advanced technologies to enable efficient and cost-effective hydrogen storage systems, such as materials-based storage, with potential for significantly improved energy density and performance through the HyMARC EMN Consortium ($3M) and technoeconomic analysis and modeling at the national laboratories to guide early stage R&D activities ($1M). The overarching goal of the program's hydrogen storage efforts is to enable a driving range of more than 300 miles (~500 km), while meeting the cost and performance requirements of current and future vehicle markets. Automakers have recently started to lease and sell vehicles that can achieve a driving range of more than 300 miles with 700 bar compressed H_2. However, at 700 bar, the energy density of hydrogen is only about 15% the energy density of gasoline. So even with the higher efficiency of hydrogen fuel cell vehicles, the hydrogen storage system is about four times larger than today's conventional gasoline tanks. Industry will need to develop and deploy advanced storage approaches to achieve a driving range of 300 miles across all platforms without compromising passenger and cargo space or performance, and at a cost that will be commercially viable. Through collaboration with industry, the subprogram has established onboard automotive storage density goals (for gravimetric and volumetric density) along with a long-term system cost target of $8/kWh. While some promising hydrogen-rich materials have been identified, no single material has been identified that meets all storage requirements simultaneously, reinforcing the long-term nature of this materials R&D challenge. In FY 2019, the Program will focus on unique National Lab capabilities to advance hydrogen storage materials R&D, maintain U.S. scientific leadership, and enable industry to double the energy density compared to today's 700 bar systems.

To maximize the impact of government funding the subprogram will increasingly leverage world-class capabilities at the National Laboratories (e.g. using National Laboratory Consortium models) which are supported by DOE and which will be made available to facilitate collaborative stakeholder activities and investments in early stage R&D for hydrogen production and storage through competitive solicitations and laboratory calls as well as funds-in CRADA calls. To further maximize government funding impact and avoid duplication, R&D efforts will leverage outside activities, through coordination with other offices and agencies, such as the Office of Science, National Science Foundation, National Aeronautics and Space Administration, and Department of Defense. The subprogram will also continue to support peer reviews, safety R&D relevant to hydrogen production and storage, prize competitions, and relevant activities under EPACT and relevant legislation, including analyses supporting the Federal advisory committee (the Hydrogen and Fuel Cell Technical Advisory Committee) and the interagency working group. Consistent with rigorous peer review processes, competitive selection of projects in key topic areas will be determined based on the relative merit, applicability, and potential for R&D progress, including lab calls and calls for CRADAs with industry and academia.

Hydrogen Fuel R&D

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Hydrogen Fuel R&D $41,000,000	**$19,000,000**	**-$22,000,000**
• Complete establishment of HydroGEN, the renewable hydrogen production consortium on advanced water-splitting technologies established under the Energy Materials Network, including enhancement of core capabilities in accelerated materials-level discovery and development for advancing innovative water-splitting technologies based on electrochemical, photoelectrochemical and solar-thermochemical approaches. Competitively 18 new consortium-associated seedling projects in advanced water-splitting including industry, academia, and/or laboratory participants.	• Evaluate early-stage computational and experimental R&D within the HydroGEN Consortium to down-select from 18 seedling projects to at least 6 of the most promising projects addressing the three core water-splitting pathways based on electrolytic, photoelectrochemical and thermochemical approaches; through this process identify 5 promising new materials-based approaches that meet at least 2 criteria related to energy conversion efficiency and durability for enabling hydrogen production at $2/gge.	• Efforts will focus on exploratory early stage materials R&D to identify and emphasize the most promising water splitting approaches with the potential to meet the hydrogen production apportionment of the cost target, while de-emphasizing less promising approaches through a down selection process.
• Through outcomes of 2 hydrogen production projects analyzing systems for electrochemical water splitting and for reduced-emission natural gas reforming, demonstrate sustainable low cost hydrogen production technologies with potential to achieve 10 percent reduction in GHG emissions compared to the 2016 baseline.	• Initiate at least 4 new early-stage foundational research projects in high-impact hydrogen production topics supplemental to the HydroGEN water splitting topics that leverage National Laboratory resources as well as external stakeholder investments.	• R&D efforts in the highest impact hydrogen production topics supplemental and complementary to water splitting activities in HydroGEN will be identified with guidance from stakeholder feedback, and research in these topics will increasingly focus on leveraging foundational National Laboratory capabilities in collaborative projects with industry and university partners.
• Through outcomes of a hydrogen production project to develop a novel reformer/purifier technology that is compatible with natural gas as well as gaseous bio-feedstocks, demonstrate that this technology can meet its target to produce hydrogen at 100 kg/day with CO_2 emissions that are 40 percent lower than steam methane reforming of natural gas.	• No funding requested for this activity in FY 2019	• In FY 2019, efforts will shift away from higher TRL demonstrations to focus on early-stage R&D that can enable subprogram hydrogen production goals in cost and performance.
• Through at least 3 hydrogen delivery project outcomes, demonstrate technologies in innovative hydrogen compression (e.g., utilizing compression consolidation schemes), in dispenser	• No funding requested for this activity in the Hydrogen Fuel R&D subprogram.	• In FY 2019 this effort will be moved under the Hydrogen Infrastructure R&D subprogram

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
materials/components (e.g., hoses, nozzles, seals, etc.) and stationary storage (e.g., steel wire-wrapped cylinders) that enable early-market costs of 80 percent of the 2016 baseline for hydrogen dispensed at forecourt refueling stations.		
• Through outcomes of 2 hydrogen delivery projects focused on innovative intelligent networks for hydrogen dispensing and through outcomes of the H2ReFuel H-Prize competition to develop a home/community-based refueler, demonstrate optimized hydrogen forecourt dispensing technologies that enable refueling with less than 4 percent error.	• No funding requested for this activity in the Hydrogen Fuel R&D subprogram.	• In FY 2019 this effort will be moved under the Hydrogen Infrastructure R&D subprogram
• Through outcomes from 2 National Laboratory-led hydrogen delivery project investigating the potential of hydrogen liquefaction using magnetocaloric materials, demonstrate that this technology has the potential to be at least 20 percent more efficient than conventional liquefaction, while comparable in capital cost.	• No funding requested for this activity in the Hydrogen Fuel R&D subprogram.	• In FY 2019 this effort will be moved under the Hydrogen Infrastructure R&D subprogram.
• Complete projects on the evaluation of high-strength glass fiber composites as an alternative to carbon fiber composites in 700 bar compressed hydrogen storage systems, with identification of the potential impacts on reducing system costs towards $9/kWh by 2025, and toward the ultimate subprogram goal of $8/kWh.	• Focus critical mass efforts on HyMARC using computational materials design to prioritize research strategies that will identify materials with suitable hydrogen absorption and desorption kinetics at temperatures relevant for use in PEM applications.	• Efforts will focus on foundational early stage materials research for advanced low pressure onboard storage and discontinue higher TRL efforts on carbon fiber tank systems.

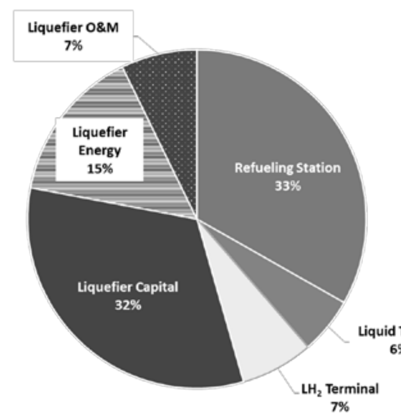
Hydrogen Infrastructure R&D

The Hydrogen Infrastructure R&D subprogram supports the program's mission through applied early-stage research and technology development to enable industry to develop novel hydrogen Infrastructure, and bulk storage technologies capable of utilizing a diversity of domestic energy resources. Subprogram includes R&D for H2@Scale to increase the security and resilience of the Nation's critical infrastructure including opportunities for H_2 energy storage, materials compatibility R&D, and innovative H_2 carriers contributing to a strong domestic economy and energy independence, security & resilience.

There are technical challenges associated with compression, storage, and dispensing (CSD) at the station that affect the final cost of hydrogen produced at both central and local point-of-use hydrogen production sites. The subprogram is pursuing advances in innovative and safe technologies for hydrogen delivery and station CSD that can enable industry to reduce costs, with the ultimate goal of reducing the delivery portion of the total hydrogen cost to less than $2/gge (at high volumes) to enable FCEVs to be cost competitive with ICEVs on a cents per mile basis. The program has an interim delivery cost target of $5/gge by 2025. High-level techno-economic and life-cycle analyses will continue to provide important guidance on subprogram priorities in foundational and applied research needs for maximizing the energy security, economic growth and environmental benefits offered by hydrogen fuel. The FY 2019 hydrogen fuels research scope will also include R&D to help address gaps in the body of knowledge identified in the H2@Scale initiative related to hydrogen production and storage.

By focusing on R&D of innovative materials for emerging technologies in hydrogen compression, liquefaction, transport, storage & dispensing the subprogram is investing in early-stage, innovative technologies that enable America to harness its energy resources safely and efficiently. Figure 2 shows the major cost contributors to liquid hydrogen delivery and key focus areas guiding R&D. In support of the H2@Scale initiative ($7M), the subprogram will leverage National Laboratory capabilities and industry through competitive funding opportunities and lab calls to continue R&D of innovative materials systems for viable, highly efficient hydrogen liquefaction; and initiate R&D on hydrogen diffusion characteristics and detection to enable station footprint reduction.

Figure 2 Liquid Hydrogen Cost Contribution to the $/kg Dispensed Cost



The H2@Scale activity will also focus on exploratory R&D to identify and develop early-stage concepts with potential to enable significant cost reductions in the storage, use, and transport of hydrogen, with two focus areas: the Hydrogen Materials (H-Mat) Consortium ($6M) and Hydrogen Carriers ($4M). The H-Mat Consortium will be based on a comprehensive R&D framework covering both metallic and non-metallic materials for use in hydrogen service, with a focus on scientific tools to predict and enhance materials compatibility, durability, and performance. Computational materials science will be used to better understand the physics of hydrogen-induced degradation and to assess the relevant microstructural properties such as fracture and fatigue. This information will enable a structural assessment of materials in relevant design spaces, and will also promote development of new materials, selection criteria, test methods, and failure mitigation strategies. The H-Mat Consortium will be comprised of National Laboratories with world-class expertise and facilities in the area of hydrogen materials compatibility and will engage with industry through a funding opportunity announcement.

The second area of research, Hydrogen-Rich Materials as Hydrogen Carriers, will include foundational research to identify and develop hydrogen carriers with the potential to store and transport hydrogen at ambient temperatures, low pressures, and with significantly greater energy densities compared with current high-pressure gaseous tube trailer or liquid tanker options. Due to these attributes, chemical carriers such as methyl-cyclohexane, formic acid, methanol and others could offer game-changing value in large-scale hydrogen transport/export applications. These carrier concepts are still far from commercial realization due to challenges with: chemical durability under repeated hydrogenation/dehydrogenation cycling; energy efficiency of hydrogenation and/or dehydrogenation processes; catalyst reliability; and costs of chemical synthesis and regeneration. Fundamental materials discovery and development of high-performance, low-cost carriers and catalysts will be the emphasis.

To maximize the impact of government funding and avoid duplication, R&D efforts will leverage outside activities, through coordination with other offices and agencies, such as the Office of Science, National Science Foundation, National Aeronautics and Space Administration, and Department of Defense. The subprogram will also continue to support peer reviews, safety R&D relevant to hydrogen production, delivery and storage, prize competitions and relevant activities under EPACT and relevant legislation, including analyses supporting the Federal advisory committee (the Hydrogen and Fuel Cell Technical Advisory Committee) and the interagency working group. Consistent with rigorous peer review processes, competitive selection of projects in key topic areas will be determined based on the relative merit, applicability, and potential for R&D progress, including lab calls and calls for CRADAs with industry and academia.

Hydrogen Infrastructure R&D

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Hydrogen Infrastructure R&D $0	**$19,000,000**	**+$19,000,000**
• No funding requested within this subprogram for FY 2017.	• Develop advanced concepts to enable a 2X increase in liquefaction efficiency versus the baseline of 10 kW/kg to enable cost-competitive, scalable delivery of hydrogen through two AOP projects at the National Laboratories, in support of H2@Scale	• In FY 2019 this effort is moved from Hydrogen Fuel R&D and refocused under the Hydrogen Infrastructure subprogram
	• Address early-stage R&D needs identified in H2@Scale Roadmap through the solicitation and selection of at least 5 projects which engage industry and academia with lab capabilities in H2@Scale consortium	• In FY 2019 this effort is moved from Hydrogen Fuel R&D and refocused under the Hydrogen Infrastructure subprogram
	• In support of H2@Scale, expand research portfolio to explore chemical carriers to achieve a 2X increase in storage capacity versus high pressure tanks by 2022	• In FY 2019 H2@Scale is expanded to include research on hydrogen carriers through a funding opportunity announcement
	• Conduct early-stage R&D to increase materials service life 2X by 2022 a mechanistic understanding of materials.	• In FY 2019 the H-Mat consortium will be launched at the national laboratories with a FOA to add industry partners

Hydrogen and Fuel Cell Technologies
Systems Analysis

Description

The Systems Analysis subprogram performs the analytical research that provides a technical basis for informed decision making for the program's R&D direction and prioritization. Analyses include identifying synergies and interactions with other energy sectors such as natural gas as well as assessing R&D gaps, planning, and budgeting. The subprogram gauges the requirements of potential end-users to determine metrics for processes, components, and subsystems. Results also support annual updates to key planning documents that provide direction and milestones for the program, including peer reviews.

The Systems Analysis subprogram ($1M) will continue to develop, refine, and use analytical models and tools, as well as develop program milestones and technology readiness goals. The subprogram will perform techno-economic analysis of hydrogen production and infrastructure to identify research and technology gaps, as well as risks, to guide targeted applied early-stage R&D that will enable the sustainability and domestic competitiveness of hydrogen and fuel cell technologies. Underlying technical analysis is included for technology-related go/no-go decisions. Identifying and understanding potential opportunities/system trade-offs can be determined through modeling and analyzing the synergies between hydrogen and fuel cells with other emerging technologies and fuels such as natural gas/biogas, and nuclear energy (e.g. related to H2@Scale), medium and heavy duty vehicles, and energy systems. The subprogram will support approximately three direct funded National Laboratory projects for these activities.

Analysis efforts will leverage outside activities, through coordination with other offices and agencies and will support peer reviews and relevant activities under EPACT and relevant legislation, including analyses supporting the Federal advisory committee (the Hydrogen and Fuel Cell Technical Advisory Committee) and the interagency working group.

Systems Analysis

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Systems Analysis $3,000,000	**$1,000,000**	**-$2,000,000**
• Continue to determine the market impacts of DOE R&D funding in advancing fuel cell and hydrogen technologies to determine the program's progress and technology advances.	• No funding is requested for this activity in FY 2019.	• Market impacts and return on investment will not be assessed in FY 2019 as industry is capable of conducting this type of analysis.
• Assess sensitivity of components on fuel cell performance and life cycle cost for FCEVs in support of continued fuel cell R&D.	• Assess impact of fuel cell performance, including on the life cycle cost for hydrogen and fuel cell technologies that will identify potential R&D priorities for hydrogen or fuel cell breakthroughs.	• The program will continue annual analysis to identify R&D needs.
• Assess life cycle GHG, petroleum use, costs, and sustainability for future hydrogen/FCEV pathways with renewable hydrogen production to identify areas requiring continued R&D.	• Perform analysis to identify early R&D that can maximize energy independence and increase fuel diversity, including regional impacts.	• The program will focus on analysis to prioritize R&D.
• Conduct regional life cycle analysis of water use based on at least two hydrogen production pathways, with emphasis on future renewable approaches.	• No funding is requested for this activity in FY 2019.	• Regional work on life cycle water use for hydrogen production pathways is not a priority area for FY 2019 and will be discontinued.
• Assess business cases for hydrogen infrastructure financing and investment strategies and employment impact, particularly with respect to the U.S. veteran community for growing hydrogen and fuel cell industries.	• Assess program milestones and technology readiness goals, including risk analysis to identify opportunities that prioritize R&D.	• The program will continue to assess readiness goals and risk analysis but will not include financial evaluations.
• Continue to support approximately six direct-funded National Laboratory projects to achieve these outcomes.	• Continue to support approximately three direct-funded National Laboratory projects to achieve these outcomes.	• Down select to three direct funded laboratory projects

Hydrogen and Fuel Cell Technologies
Safety, Codes and Standards

Description

The Safety, Codes and Standards subprogram conducts critical early-stage applied research and development to enable the safe rollout of hydrogen and fuel cell technologies. Examples include the development of models for quantitative risk assessment and research related to hydrogen releases that can apply across the industry, and materials compatibility studies. The subprogram has also conducted extensive collaborative efforts among government, industry, standards development organizations, universities, and National Laboratories in an effort to harmonize regulations, codes, and standards (RCSs) both domestically and internationally to enable domestic competitiveness and mass market penetration of safe hydrogen and fuel cell technologies. Efforts have involved valuable stakeholder input from automobile manufacturers and the energy, insurance, and aerospace sectors, as well as the fire protection community and academia, to enhance and create safety knowledge tools for emergency responders and relevant authorities. The subprogram has also supported the development and implementation of best practices and procedures to ensure safety in the operation, handling, and use of hydrogen and fuel cell technologies in program-funded projects. Continual availability of safety knowledge tools, distributed via an array of media outlets to reach the largest number of safety personnel possible, will be transitioned to industry so that critical mass activities can focus on safety research.

Reflecting the shift in focus to early-stage research and development in hydrogen fuel and fuel cells, no funding is requested for the Safety, Codes and Standards subprogram in FY 2018 and FY 2019. Some management activities related to the execution of prior year appropriations will continue until completion. Safety considerations will continue to be an important parameter integrated into early-stage R&D projects and activities funded through the Hydrogen Fuel and Fuel Cell subprograms. Some management activities related to the execution of prior year appropriations will continue until completion.

Safety, Codes and Standards
Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Safety, Codes and Standards $7,000,000	**$0**	**-$7,000,000**
• Continue to support approximately six direct funded National Laboratory projects and competitively select via a FOA and/or lab solicitation 1 to 2 projects to achieve these outcomes. • Evaluate metallic materials that could potentially be used in hydrogen service to reduce cost by at least 10 percent without sacrificing safety. • Develop better understanding of hydrogen effects in non-metallic materials for hydrogen infrastructure, on-board vehicle storage, and balance of plant. • Initiate the development of a publicly available technical reference for non-metallic material behavior in the presence of hydrogen and testing of high priority materials from the coupon to system level. • Continue R&D and initiate support for the development of a domestic supply chain of safety, codes and standards-related hydrogen and fuel cell components, including a testing and standard committee providing input for critical components (e.g. nozzles, metering, and sensors). • Expand existing outreach, education, and training activities and train at least 1,000 first responders and code officials to support the public acceptance of hydrogen and fuel cell technologies through H2USA, state and industry initiatives.	• No funding is requested for this activity in FY 2019. Safety considerations will continue to be an important parameter integrated into early-stage R&D projects and activities funded through the Hydrogen Fuel and Fuel Cell subprograms.	• The Hydrogen and Fuel Cell Technologies Program is refocusing efforts on early stage R&D and no funding is requested for Safety Codes and Standards activities.

Hydrogen and Fuel Cell Technologies
Technology Acceleration

Description

The primary goal of the Technology Acceleration subprogram is to accelerate the transition from R&D to commercial viability and market acceptance. Specific objectives of the program have been to develop advanced fabrication technologies and processes to meet the cost targets of hydrogen and fuel cell technologies; test and evaluate advanced hydrogen and fuel cell technologies under real-world conditions — providing valuable feedback to R&D efforts while validating the performance of pre-commercial technologies; and operate near-commercial technologies evaluating various fuel cell applications in user environments. These efforts have enabled informed decisions for public and private investment in continued R&D and/or commercial deployment. Another key goal has been to increase penetration of hydrogen and fuel cell technologies in key early markets by demonstrating both technical viability and business cases in emerging commercial applications. In FY 2019, the subprogram plans to complete on-going projects to demonstrate fuel cell and hydrogen technology in new applications, develop diagnostics for defect detection on roll-to-roll manufacturing of membrane electrode assembly (MEA) materials (e.g. MEA, membranes, etc.) and provide critical data to predict whether FCEVs and hydrogen refueling stations can meet program targets through use of prior year funding.

Reflecting the shift in focus to early-stage research and development, no funding is requested for the Technology Acceleration subprogram in FY 2019. Some management activities related to the execution of prior year appropriations will continue until completion.

Technology Acceleration
Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Technology Acceleration $18,000,000	**$0**	**-$18,000,000**
• Develop real-time quality control devices that are readily implementable in a roll-to-roll production line for the manufacture of MEA component materials that can detect anode and cathode defects as small as 0.5 cm2. • Collating input from industry and National Laboratory projects, determine the cost of materials and manufacturing infrastructure components (e.g., dispensers, nozzles, hoses, etc.); identify opportunities for U.S. manufacturing, cost reduction, and standardization. • Through a combination of a competitive FOA and National Lab call, conduct the world's first-of-its-kind in situ demonstration to verify the goal of reducing hydrogen distribution pipeline cost by 20 percent from conventional welded steel pipelines. • Using data from field demonstrations, validate doubling of the driving range of electric parcel delivery truck, the performance, and fuel cost for mobile refueler trucks and hydrogen refueling stations in novel demand response programs to support the grid. • Using data from field demonstrations, validate targets e.g. 5kg H_2 in <3 min performance, maintenance and operations, at multiple stations as well as early market technologies such as buses. • Initiate field testing and gather and analyzed data to validate lower fuel cost with respect to advanced hydrogen compression, storage, or dispensing equipment. • Demonstrate novel refueling infrastructure systems such as home/workplace refueling and gather data	• No funding is requested for this activity in FY 2019.	• The Hydrogen and Fuel Cell Technologies Program is refocusing efforts on early stage R&D and no funding is requested for Technology Acceleration activities

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
from these systems to validate a lower cost relative to the current, low volume status of around $14/gge. • Complete field testing and analyze data gathered during the demonstration to validate diesel fuel savings using auxiliary power units for refrigerated trucks. • Continue collaboration with other Federal agencies and state fleets on the pilot program by collecting preliminary data and conducting technical – economic analyses. • Collect and analyze technical and economic data from a fuel cell hybrid utility van field demonstration to validate a 2X increase in battery electric vehicle range. • Evaluate education needs of key stakeholders and develop education/outreach materials and implementation strategies.		

Solar Energy

Overview

EERE's Solar Energy Program funds early-stage research and development (R&D) of solar technologies while supporting the reliability, resilience and security of the U.S. electric grid. Reflecting the recent and projected future growth in PV deployment, the program is increasing its emphasis on addressing the challenges related to integrating high penetrations of solar onto the electric grid, including storing solar energy so it is available on demand. The program will also continue its efforts to build the knowledge base upon which industry can achieve further reductions in the cost of solar electricity, promoting greater energy affordability. Taken together, these objectives will invigorate American technological leadership in solar energy, diversify the Nation's electricity supply, enhance grid resilience and reliability, catalyze domestic economic growth including job creation, and reduce the air and water impacts of electricity generation.

The program works to achieve the SunShot 2030 targets of $0.03/kWh without subsidies for utility-scale photovoltaic (PV) systems, which use semiconductors to convert solar photons directly to electricity, and $0.05/kWh for baseload concentrating solar power (CSP) systems, which convert photons to thermal energy that can be stored before it is used to generate electricity. Achieving these 2030 goals, which would make solar electricity one of the most affordable forms of electricity in the U.S., requires cost reductions of 50-75 percent from 2017 benchmarks for utility-scale, commercial and residential PV as well as CSP.[1] The program has a history of success in enabling solar energy cost reduction: the original SunShot goal for unsubsidized, utility-scale solar PV electricity of $0.06/kWh by 2020 was achieved in 2017, three years ahead of schedule.

Deployment of PV across the U.S. has been growing at a rapid rate, with a record 14.8 GW installed in 2016 — a nearly 20-fold increase from the 2010 level.[2] Today there is over 47 GW of solar power across the U.S., and solar is supplying about two percent of U.S. electricity[3], and several times more during peak hours. The solar industry has also shown significant job growth. Rapid declines in solar costs have made these market increases possible. Nevertheless, significant work remains before solar realizes its full potential. With continued innovation to drive down solar electricity costs and overcome grid integration barriers, solar energy has the potential to provide a significant amount of the Nation's electricity demand in the coming decades.

Highlights of the FY 2019 Budget Request

The Solar Energy Program will support focused activities in FY 2019:

- With solar contributing four percent of the Nation's peak electricity generating capacity—and as high as 15 percent in some regions of the U.S. — the challenges of even higher levels of solar generation on the grid need to be researched to enable industry to develop and deploy cost-effective solutions in the future that improve the resilience, security and reliability of the grid. As part of DOE's grid modernization efforts, the program will focus on the tools and technologies to measure, analyze, predict, protect and manage the impacts of solar generation on the grid of the future. It supports early-stage research and development activities at the National Laboratories in solar integration studies, power system planning and operation, power electronics, sensing and communication integrity, data analytics, and cybersecurity. In addition, the program supports integration of solar with energy storage and other distributed energy resources (DERs). National Laboratory research also supports industry's development of test and evaluation standards.
- FY 2019 work in CSP will be aimed at seeding long-range, transformative ideas in high temperature thermal engineering and optical design to develop new concepts for low-cost solar thermal applications. FY 2019 will also investigate CSP-relevant power cycles and solar collector technologies that will be able to utilize and provide the 700^{o}C heat for third generation CSP thermal transport and storage systems.
- Research on emerging photovoltaic technologies at the National Laboratories and universities will focus on improving the efficiency and reliability of PV devices with the potential to achieve the 2030 SunShot targets. FY 2019 work focuses on understanding reliability physics and materials science to better predict performance, improve energy output, and

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[1] R. Fu et al., "U.S. Solar Photovoltaic System Cost Benchmark: Q1 2017," NREL Technical Report, September 2017. 2017 benchmarks for utility-scale, commercial and residential PV are 6, 11 and 16 cents/kWh, respectively. The 2015 CSP benchmark was 12 cents/kWh.

[2] "Q3 2017 U.S. Solar Market Insight Report," GTM Research and SEIA, September 2017.

[3] Measured in the first nine months of 2017. EIA, Electric Power Monthly, Table 1.17.b .

increase durability. These topics will continue to support U.S. leadership in PV innovation, which has led to more than 50 percent of the world records in solar power conversion efficiency over the past 35 years.

- To spur the commercialization of the Solar Energy Program's early stage R&D focused portfolio, the American-Made Challenges: Solar Prize will be continued in FY 2019. The FY 2019 work on the Solar Prize will focus on building off of the initial prize competition run in FY 2018. The Prize incentivizes the rapid research and development of new products for solar energy with an eye toward catalyzing domestic manufacturing.

The program closely coordinates activities with the Office of Science and other DOE offices to ensure the most efficient use of taxpayer dollars, while maximizing the department-wide impact on solar energy.

Solar Energy Funding

($K)

	FY 2017 Enacted	FY 2018 Annualized CR*	FY 2019 Request	FY 2019 Request vs FY 2017 Enacted
Solar Energy				
Concentrating Solar Power	55,000	—	11,000	-44,000
Photovoltaic R&D	64,000	—	18,000	-46,000
Systems Integration	57,000	—	37,000	-20,000
Balance of Systems Soft Cost Reduction	15,000	—	0	-15,000
Innovations in Manufacturing Competitiveness	16,600	—	1,000	-15,600
Total, Solar Energy	**207,600**	**206,190**	**67,000**	**-140,600**

SBIR/STTR:

- FY 2017 Transferred: SBIR $6,243,000; STTR $878,000
- FY 2018 Projected: SBIR $6,201,000; STTR $872,000
- FY 2019 Request: SBIR $2,144,000; STTR $302,000

*A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution. (These amounts are shown only at the Congressional control level and above; below that level, a dash (—) is shown).

Solar Energy
Explanation of Major Changes
($K)

	FY 2019 Request vs FY 2017 Enacted
Concentrating Solar Power: Funding focuses efforts at the National Laboratories on developing high temperature components for next generation CSP systems with thermal energy storage. Relative to FY 2017, CSP efforts in the FY 2019 request will not support Funding Opportunities for non-National Laboratory researchers. Funding includes new thermochemical processes and materials that leverage CSP technology to produce advanced storage solutions.	**-44,000**
Photovoltaic R&D: Funding focuses on targeted efforts at the National Laboratories to improve PV reliability, efficiency and performance prediction. In FY 2017, the PV subprogram fully-funded 27 competitive Funding Opportunity Announcement awards to academia and industry; non-National Laboratory competitive programs will not be supported in FY 2019. Additionally, maintaining the research efforts by the DuraMat consortium is not supported at the request level. Finally, the combined efforts in the core PV R&D programs at Sandia and NREL would be reduced by approximately 50 percent in FY 2019 relative to the FY 2017 Enacted Budget.	**-46,000**
Systems Integration: Funding focuses on maintaining core efforts at the National Laboratories to advance grid integration models and technologies as well as a $21 million funding opportunity to improve grid reliability, flexibility, and resilience through the integration of advanced inverter capabilities and storage technologies with building loads. In FY 2017, greater emphasis was placed on competitive funding opportunities accessible to not just National Laboratories. Funding addresses approaches to improved grid reliability, flexibility, and resilience through the integration of advanced inverter capabilities using power electronics at scale and storage technologies, materials and manufacturing concepts that may be combined with building loads, including microgrid applications focused on improving security. The goal being directed toward dispatchable solar, making solar available when needed.	**-20,000**
Balance of Systems Soft Cost Reduction: No funding is requested for this subprogram due to shift in focus to early stage R&D.	**-15,000**
Innovations in Manufacturing Competitiveness: Funding focuses on the continuation of the Solar Prize, began in FY 2018, to incentivize the research and development of U.S. manufacturable solar products. In FY 2017, the core funding programs supported were the signature Incubator and SolarMat programs. Support of existing awards will continue in FY 2018, however, funding to support additional rounds of awards is not requested.	**-15,600**
Total, Solar Energy	**-140,600**

Solar Energy
Concentrating Solar Power

Description

The Concentrating Solar Power (CSP) subprogram supports early-stage R&D of CSP with thermal energy storage as a unique path to supply low cost solar power on demand, supporting the Secretary's emphasis on grid reliability and energy affordability.

The goal of the CSP subprogram is to generate the scientific and technological knowledge necessary to reduce the cost of CSP electricity at utility scale to $0.05/kWh by 2030, from a baseline of $0.21/kWh in FY 2010 (in FY 2017, the cost of CSP with 14 hours of storage, in the US Southwest was benchmarked at $0.10/kWh). Government funding for early-stage R&D provides an innovation pipeline that enables industry to drive down costs toward this goal, which could make CSP electricity cost competitive with electricity from other sources. An additional benefit is that because CSP, as well as PV, technologies utilize sunlight to generate electricity, they are not subject to fuel-price uncertainties over the lifetime of the plants.

Funding in FY 2016 and FY 2017 leveraged promising component-level CSP research developed in prior fiscal years to integrate best-in-class components at the megawatt scale. That effort is informing further component level research in the major CSP focus areas (i.e., solar collection, receivers and heat transfer fluids, power conversion, and thermal energy storage). Moreover, significant challenges exist in understanding the integration of the subcomponent technologies of the solar field, thermal receivers, thermal storage, and power block.

The CSP subprogram funds the DOE National Laboratories, in partnership with academia, non-profit research institutes and industry, in advanced R&D topics including solar field design, high-temperature receiver development, and thermal energy storage allowing turbine operation beyond the daytime hours, advanced power cycles, and systems integration. This funding will be distributed by soliciting research proposals for both multi-year and single-year projects in topics relevant CSP components and sub-systems from all of DOE's National Laboratories. By soliciting competitive proposals and subjecting them to external merit review, the Solar Energy Program will ensure that CSP R&D will be high quality and relevant. Following selection, project performance milestones are negotiated and the program is regularly updated on progress towards these benchmarks during project performance. To ensure appropriate stewardship of Federal funds, projects are comprehensively reviewed and subjected to a Go/No-Go decision for performance and relevance on at least an annual basis. The full FY 2019 Request for CSP ($8M) continues the efforts at the National Laboratories with a focus on seeding long-range, transformative ideas in high temperature thermal engineering and optical design to develop new concepts for low-cost solar thermal applications, as well as investigate CSP-relevant power cycles and solar collector technologies that will be able to utilize and provide the heat for advanced CSP thermal transport and storage systems. Included in the National Laboratory funding is approximately $750 thousand to support the National Solar Thermal Test Facility (NSTTF) at Sandia National Laboratories (SNL). Funding will emphasize early-stage research with a periodic feedback loop of early subsystem integration and testing to verify theory and potential while establishing benchmarks for prioritizing further R&D. In addition, early-stage R&D will include investigation of thermochemical cycles for thermochemical energy storage for CSP and the use of solar energy to drive the production of economically important chemical products (including solar-produced fuels).

The Solar Energy fellowship program funds ($200K) emerging leaders in the field that will pursue breakthrough solar energy technologies at universities, National Laboratories, and other research facilities as well as at DOE. In addition, funds may be used to support efforts such as merit/peer reviews, data collection and dissemination, technology assistance, and technology to market activities.

Concentrating Solar Power

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Concentrating Solar Power $55,000,000	**$11,000,000**	**-$44,000,000**
• Continue approximately ten R&D projects at the National Laboratories, in partnership with academia and industry, to build upon the state of knowledge in the areas of solar field design, high temperature receiver development, thermal energy storage, advanced power cycles, and systems integration.	• Initiate approximately ten merit-reviewed R&D projects at the National Laboratories, in partnership with academia and industry, targeting early-stage concepts in high temperature thermal engineering and optical design, as well as advancing CSP-relevant power cycles and solar collector technologies.	• New cycle of three-year projects begin in FY 2019.
• Support the operations and maintenance of the National Solar Thermal Test Facility (NSTTF) and Sandia National Laboratories to enable testing of CSP collectors and high-temperature CSP components and systems.	• Support the operations and maintenance of the National Solar Thermal Test Facility (NSTTF) and Sandia National Laboratories to enable testing of CSP collectors and high-temperature CSP components and systems.	• No significant change.
• Carry forward funding for 6-12 awards to develop cost effective collection, storage, and thermal desalination technologies, under the Solar Desalination FOA.	• No new funding requested.	• Funding shifted to support greater emphasis on the importance of grid reliability and resilience, specifically to integrate solar energy with other technologies to better match energy supply and demand.
• Carry forward funding for 6-12 awards to develop integrated high-temperature thermal transport systems, including an integrated receiver, heat transfer media, thermal energy storage, and primary heat exchanger, for coupling CSP systems to advanced high-efficiency power cycles, under the CSP Gen 3 FOA.	• No new funding requested.	• Funding shifted to support greater emphasis on the importance of grid reliability and resilience, specifically to integrate solar energy with other technologies to better match energy supply and demand.
• No FY 2017 funds provided for solar energy fellowships; work continued on projects awarded in FY 2016.	• Fund 1-2 emerging leaders that will pursue breakthrough solar energy technologies at universities, National Laboratories, and other research facilities as well as at DOE.	• Funding is needed to support the ongoing solar energy fellowships.
	• Initiate 1-3 projects investigating thermochemical cycles for energy storage for CSP as well as driving the production of economically important chemical products (including solar-produced fuels).	• New research focus on grid reliability and resilience as part of the Beyond Batteries initiative, with a specific focus on adaptable, solar-based, energy storage alternatives.

Solar Energy
Photovoltaic R&D

Description

The Photovoltaic Research and Development (PV R&D) subprogram funds early-stage R&D in support of the Secretary's emphasis on affordable energy. The subprogram focuses on generating the scientific and technological knowledge necessary to achieve the SunShot target of $0.03/kWh by 2030 for unsubsidized, utility-scale systems, which would make PV one of the lowest cost sources of electricity in the U.S. While the PV industry has had great success in the reduction of upfront hardware costs, government-funded research is critical to advance the foundational knowledge of PV technology performance and reliability, enabling industry to develop and deploy new PV innovations needed to reach the 2030 goal and promote energy affordability.

The PV R&D subprogram advances state-of-the-art PV technologies with National Laboratory, industry, and academic partners. Specifically, the subprogram funds early-stage research and development to enable improved PV performance (including improved efficiency and durability), reduced cost, and better understanding of long-term reliability. FY 2019 projects will, as an example, build upon the state of knowledge in the areas of fundamental solar cell performance limits, advanced materials science models for polycrystalline devices, and the impacts of outdoor soiling, temperature cycling, ultra-violet light and humidity on PV performance and reliability.

In FY 2019, the PV R&D subprogram will initiate a new cycle of merit-reviewed research activities at the National Laboratories, performed in partnership with academia and industry. This work covers foundational analytical research addressing potential cost and value of PV technologies to inform research directions, advancement of existing and emerging technologies, understanding of reliability physics to improve module durability and performance prediction, and development of new measurement and characterization techniques. National Laboratory research also supports the industry's development of test and evaluation methods by providing objective data and modeling that can be trusted by all involved parties to inform best practices. Lab projects are structured with input from industry participants and reviewers to ensure relevance and impact to PV technologies that have the potential to be commercialized. The PV subprogram also funds the Regional Test Centers (RTCs), which are located in Denver, Colorado; Albuquerque, New Mexico; Orlando, Florida; Las Vegas, Nevada, and Williston, Vermont. The RTCs provide facilities to study and validate the performance of PV technologies, including semiconductor materials, packaging and power electronics. These data elements deliver essential feedback to early-stage R&D. During FY 2019, the Nevada, Vermont and Florida sites will continue the transition begun in FY 2018 to a self-sustainable business model that is not reliant on Federal funding; the National Lab capabilities at the NREL and SNL RTCs will continue to receive federal support.

The Solar Energy fellowship program funds ($200K) emerging leaders in the field that will pursue breakthrough solar energy technologies or analysis at universities, National Laboratories, and other research facilities as well as at DOE. In addition, funds may be used to support efforts such as merit/peer reviews, data collection and dissemination, technology assistance, and technology to market activities. The remainder of the funds will support year 9 of a 10-year university PV R&D center (Quantum Energy and Sustainable Solar Technologies Engineering Research Center) in collaboration with the Nation Science Foundation.

Photovoltaic R&D

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Photovoltaic R&D $64,000,000	**$18,000,000**	**-$46,000,000**
• Continue approximately 30 merit-reviewed research projects at the National Laboratories (NREL, SNL, and LBNL). This work advances the performance of emerging and existing photovoltaic technologies, develops new measurement and characterization techniques, and employs materials science and reliability physics to improve module durability. Most projects have industry and/or academic partners. LBNL tracks worldwide developments to provide feedback to the early-stage technology efforts at NREL and SNL.	• Initiate approximately 15 merit-reviewed R&D projects at the National Laboratories, in partnership with academia and industry, to improve the performance and reliability of PV technologies and perform foundational analytical research.	• Funding level reduced in order to place greater emphasis on grid reliability and resilience in the Systems Integration subprogram.
• Continue the collaboration (year 7 of 10) with the National Science Foundation to support the Quantum Energy and Sustainable Solar Technologies Engineering Research Center at Arizona State University.	• Continue the collaboration (year 9 of 10) with the National Science Foundation to support the Quantum Energy and Sustainable Solar Technologies Engineering Research Center at Arizona State University. This program is managed and reviewed by the NSF. DOE supports the activities via an interagency agreement (IAA) and participates in the annual review. Funding is requested for year 9 of 10 of the obligations in the existing agreement with NSF that is an effective method for the Solar Energy Program to leverage fundamental research.	• No significant change.
• Continue the DuraMat National Laboratory Consortium, part of the Energy Materials Network, initiated in FY 2016 under the Innovations in Manufacturing subprogram, which is dedicated to modeling, discovering, and measuring durable coatings and packaging materials for photovoltaic modules including advanced anti-reflective coatings, anti-soiling solutions, encapsulants, flexible packaging, and glass or polymer alternatives.	• At the request level, the DuraMat National Laboratory Consortium research dedicated to modeling and measuring durable coatings and packaging materials for PV modules including advanced encapsulants and flexible packaging concepts would cease and the efforts would focus solely on convening activities and maintaining a shared data hub.	• Funding level reduced to partially maintain core research capabilities at the National Labs. The reduction reflects the discontinuation of DuraMat consortium research activities on durable coatings and packaging materials for PV modules including advanced encapsulants and flexible packaging concepts.

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
• Fully funded 27 PVRD 2 FOA awards for approximately $21 million, focusing on improvements in module assembly and reductions in installation time, representing important development avenues for reducing the levelized cost of PV electricity and energizing the future growth of the US PV industry.	• No new funding requested.	• No new FOA will be issued. Existing work will continue to be managed.
• No FY 2017 funds provided for solar energy fellowships; work continued on projects awarded in FY 2016.	• Fund 1-2 emerging leaders that will pursue breakthrough solar energy technologies at universities, National Laboratories, and other research facilities as well as at DOE.	• Funding is needed to support the ongoing solar energy fellowships.

Solar Energy
Systems Integration

Description

The Systems Integration (SI) subprogram, in coordination with the DOE Grid Modernization Initiative (GMI), funds early-stage research and development in support of the Secretary's emphasis on grid reliability, resilience and security. The FY 2019 SI request includes supporting the Beyond Batteries initiative. As a part of GMI, Beyond Batteries focuses on advances in controllable loads, hybrid systems incorporating generation from all sources, and new approaches to energy storage, which are essential to increasing the reliability and resiliency of our energy systems. The SI subprogram focuses on generating the scientific and technological knowledge necessary to enable the seamless integration of hundreds of gigawatts of solar power into the electricity grid in a secure, reliable, safe and cost-effective manner and to enable solar energy to increase grid resilience. As the deployment of solar generation systems in electric distribution systems has rapidly accelerated over the past few years, utilities, regulatory agencies, and developers face a significant and growing set of new challenges for which early-stage research can provide fundamental understanding to accelerate innovation. Key technical challenges related to the grid integration of solar power include power variability, voltage regulation, frequency control, unintentional islanding, protection coordination (planning for fault currents), and two-way power flow. Further, the expansion of solar power at centralized and distributed scales underscores the growing need to strengthen the body of knowledge to enable industry and regulatory agencies to develop technologies and best practices for timely and cost-effective interconnection procedures, accurate prediction of sunlight and solar power generation, as well as monitoring and control of solar power. The SI subprogram will address these challenges by supporting early-stage research and development of solar integration models and technologies that have the potential to improve system performance, reliability, resiliency and security. Early-stage research will focus on long-term solutions that are beyond the timeframe that industry is addressing, to create a pipeline of ideas and technologies.

As part of the DOE's grid modernization efforts, the SI subprogram will focus on the tools and technologies to measure, analyze, protect, and control the integration of variable solar energy sources with variable energy uses as they interact on the electrical grid. It will continue supporting research and development outlined in the Grid Modernization Multi-Year Program Plan which focuses on devices and integrated system and component validation, sensing and measurement, system operations and power flow, design and planning tools, security and resilience, and institutional support.

GMI coordinates efforts across the Department to develop the concepts, tools, and technologies needed to measure, analyze, predict, protect, and control the grid of the future. Guided by the Grid Modernization Multiyear Program Plan, foundational projects which have equities across several DOE offices can be coordinated through leadership from the GMI. Projects are executed by or in close coordination with Grid Modernization Lab Consortium (GMLC), a collection of National Laboratories that bring together the leading experts, technologies, and resources to modernize the nation's grid. By requiring close collaboration on projects between the GMLC, industry, academia, and other important stakeholders, the GMI accelerates technology development, promotes innovation, and encourages broader investment in the grid.

Funding in FY 2019 will support early-stage R&D activities at the National Laboratories through the GMLC foundational lab call and Solar Program-specific lab call, in partnership with academia and industry, in foundational analysis and evaluation of solar integration challenges, solar impact to power system planning and operation, power electronics and intelligent control, sensing and communication integrity, data analytics, and cybersecurity. In addition, the program supports integration of solar with energy storage and other distributed energy resources. This early-stage research is beyond the scope of utilities and regulatory agencies and provides a critical knowledge base for industry to use in addressing grid integration challenges. National Laboratory research also supports industry's development of test and evaluation standards by providing objective data and modeling that can be trusted by all involved parties.

FY 2019 funding will also support a $21 million competitive funding opportunity announcement to fund projects that will develop, test and validate innovative technologies for integrating distributed solar systems with building loads and energy storage to improve grid reliability, resilience and cybersecurity, while increasing consumer power supply choices and affordability. The solicitation will focus on early-stage research and development of system models and hardware and software prototypes, which include the methods for securing and hardening solar generation devices to address vulnerability to cybersecurity attacks and enhance resilience after disruptive events.

The Solar Energy fellowship program ($200K) funds emerging leaders in the field that will pursue breakthrough solar energy technologies or analysis at universities, National Laboratories, and other research facilities as well as at DOE. In addition, funds may be used to support efforts such as merit/peer reviews, data collection and dissemination, technology assistance, and technology to market activities.

Systems Integration

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Systems Integration $57,000,000	**$37,000,000**	**-$20,000,000**
• Continue approximately 20 merit-reviewed R&D projects with the National Laboratories, including through the GMLC, to address foundational analysis and evaluation of solar integration challenges, solar power forecasting, power system planning and operation, power electronics, sensing and communication integrity, and data analytics. National Laboratory research also supports industry's development of test and evaluation standards by providing objective data and modeling to inform standard processes.	• Initiate approximately 8-12 merit-reviewed R&D projects with the National Laboratories, through the GMLC, to address foundational analysis and evaluation of solar integration challenges, power system planning and operation, power electronics, sensing and communication integrity, data analytics, and cybersecurity. National Laboratory research also supports industry's development of test and evaluation standards by providing objective data and modeling to inform standard processes.	• No significant change.
• Issue a competitive solicitation to fund 10 to 20 projects developing innovative microgrid concepts that improve resiliency and cybersecurity while increasing consumer power supply choices.	• Fund 10-20 competitively selected projects to develop, test and validate innovative technologies for integrating distributed solar systems with building loads and energy storage, as well as development of new storage technologies specifically designed for integration with solar energy systems, to improve grid reliability, resilience and cybersecurity.	• Funding supports greater emphasis on the importance of grid reliability and resilience through the Beyond Batteries initiative, specifically to integrate solar energy with other technologies to better match energy supply and demand. Efforts leverage FY 2017 funding for advanced power electronics capabilities to enhance cybersecurity and resilience. Overall no significant changes.
• Fund 7 competitive awards under GMLC Resilience Distribution Systems lab call to support early stage research and development of next-generation tools and technologies that will further improve the resilience of the Nation's electric grid.	• No new funding requested.	• Work will continue to be managed until complete, however, additional funding to support this effort is not requested.
• Fully fund 8 Solar Forecasting II FOA awards to advance predictive modeling capabilities for solar generation.	• No new funding requested.	• FOAs will continue to be managed until complete, however, additional funding to support this FOA is not requested.
• Fund National Laboratories - for the administration of Solar Energy Innovation Network projects.	• No new funding requested.	• This projects has completed.

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
• Carry forward funding for approx. 10-15 Advanced Power Electronics Design for Solar Applications FOA awards.	• No new funding requested.	• FOAs will continue to be managed until complete, however, additional funding to support this FOA is not requested.
• No FY 2017 funds provided for solar energy fellowships; work continued on projects awarded in FY 2016.	• Fund 1-2 emerging leaders that will pursue breakthrough solar energy technologies at universities, National Laboratories, and other research facilities as well as at DOE.	• Funding is needed to support the ongoing solar energy fellowships.

Solar Energy
Balance of Systems Soft Cost Reduction

Description

The Balance of Systems Soft Cost Reduction (BOS) subprogram supports the development of innovative and scalable solar energy solutions, enabling economic growth, creating economically sustainable market conditions, and establishing clean energy initiatives to meet evolving needs. Soft costs include financing, customer acquisition, permitting, installation, labor, inspection, and other non-hardware costs. Taken together, soft costs constitute over half the cost of total system prices for residential, commercial and community PV systems.

The BOS subprogram works with a broad range of stakeholders, typically through later-stage development and deployment activities, to quantify cost reduction opportunities, highlight best practices and expand access to solar energy to every home, business, and community. The subprogram funds workforce training for veterans, the next generation of power systems engineers, real estate professionals, first responders, code officials and others, to address workforce gaps. It also develops a new generation of powerful data and information technology tools to increase market transparency, improve consumer protection, and improve access to low-cost financing for a growing number of consumers.

As overall solar prices have dropped, the U.S. has enjoyed unprecedented growth in both solar installations and jobs through the development of successful business and deployment models across the country. Between 2008 and 2016, the U.S. saw a rapid increase in renewable energy generation from solar. The solar sector of the economy now employs over 260,000 people and continues to add more than 1,000 high paying jobs per week. As the industry continues to mature, there is no longer a strong role for the Federal Government to fund balance of systems cost reduction activities. Instead, industry is better positioned to fund these later-stage development and deployment activities.

Reflecting the shift in focus to early-stage research and development, no funding is requested for the BOS subprogram in FY 2019. Some management activities related to the execution of prior year appropriations will continue until completion.

Balance of Systems Soft Cost Reduction

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Balance of Systems Soft Cost Reduction $15,000,000	**$0**	**-$15,000,000**
• Funding continued to support work at the National Laboratories, veteran training initiatives, and other training programs.	• No funding requested in FY 2019.	• Reflects shift in focus to early stage R&D. Existing projects will continue.

Solar Energy
Innovation in Manufacturing Competitiveness

Description

The Innovations in Manufacturing Competitiveness (IM) subprogram was established to increase U.S. competitiveness in clean energy manufacturing while advancing progress toward the Nation's energy goals. The focus for the IM subprogram has been to increase America's market share for added-value manufacturing by helping companies with promising solar technology survive the funding gaps that often emerge in the development cycle of new technologies.

Focused research in the Technology to Market portfolio has supported innovation at the earliest stages of commercial research and development. The flagship program in the Technology to Market portfolio is the DOE SunShot Initiative Incubator program, currently in its twelfth round. The DOE SunShot Initiative Incubator Program has supported businesses seeking to develop innovations in hardware installation, grid conversion technologies, and novel business models as well as software platforms for reducing soft costs. Past recipients have attracted more than $22 in follow-on funding for every $1 in Federal investment. The Solar Manufacturing Technologies (SolarMAT) Program has funded the development and demonstration of innovative, but commercially and technically viable, manufacturing technology that can achieve a significant market or manufacturing impact within several years of project completion. As the industry continues to mature, there is no longer a strong role for the Federal government to fund commercialization and manufacturing development and demonstration activities. Instead, industry is better positioned to fund these later-stage activities.

Reflecting the shift in focus to early-stage research and development, no further funding is requested for the IM activities listed above in FY 2019. Some management activities related to execution of prior year appropriations will continue until close.

Funding requested for FY 2019 ($1M) will be used to run additional rounds of the American-Made Challenges: Solar Prize, which began in FY 2018, to spur the commercialization of the Solar Energy Program's early stage R&D focused portfolio. The FY 2019 work on the Solar Prize will focus on building off of the initial prize competition run in FY 2018. The Prize incentivizes the rapid research and development of new products for solar energy with an eye toward spurring domestic manufacturing. The Prize leverages National Laboratory research and development capacity in the generation and prototyping of new technologies. Finally, and most importantly, the Prize will continue to emphasize the integration of the private sector in the competition to ensure it is the private sector which ultimately selects and brings the highest impact products to market.

Innovations in Manufacturing Competitiveness

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Innovations in Manufacturing Competitiveness $16,600,000	**$1,000,000**	**-$15,600,000**
• Funding requested in the PV R&D subprogram to continue the DuraMat Consortium established in FY 2016.	• No funding requested in FY 2019.	• Reflects shift in focus to early stage R&D. Existing projects will continue through outlay of previously obligated prior appropriations.
• Implement Incubator round 12 to provide early stage assistance to help 10 to 20 small businesses commercialize innovative solar technologies.	• No funding requested in FY 2019.	• Reflects shift in focus to early stage R&D. Existing projects will continue through outlay of previously obligated prior appropriations.
• Issue SolarMAT V solicitation and competitively select 5 to 10 projects focused on developing solar manufacturing technologies with the greatest potential to reduce cost in manufacturing and supply chain to reduce the trade imbalance in the solar industry.	• No funding requested in FY 2019.	• Reflects shift in focus to early stage R&D. Existing projects will continue through outlay of previously obligated prior appropriations.
	• Funding to support next rounds of the Solar Prize which was started in FY 2018. The Solar Prize incentivizes the research and development of new solar energy technologies that can be manufactured domestically.	• This second year of funding reflects the desire to catalyze domestic energy manufacturing using the successful Prize model.

Wind Energy

Overview

The U.S. has abundant land-based and offshore wind resources across the nation, and wind power has confirmed its credibility as a scalable, reliable, and environmentally sound domestic energy technology. Wind power is affordable, safe, secure, and clean, making it a valuable component in the national portfolio of domestic power generation solutions. Wind has rapidly become a mainstream power source in the U.S. electricity portfolio, with 85 gigawatts (GW) of installed capacity across 41 States as of September 2017,[1] supplying 6.1 percent of the Nation's electricity end-use demand in 2016,[2] and representing 30 percent of all newly installed U.S. generation capacity from 2012-2016.[3] Strong market demand, coupled with the increasing size of wind turbine components, has spurred the growth of a robust domestic manufacturing sector. The U.S. wind industry supports over 100,000 U.S. jobs in installation, manufacturing, and operations,[4] with more than 500 U.S. wind-manufacturing facilities in 41 states.[5] DOE's Wind Energy Program funds early-stage research and development (R&D), and related testing, to build the knowledge base upon which industry can develop and deploy technologies that enable continued growth of the U.S. wind industry, enhance U.S. competitiveness, increase U.S. energy security and independence, strengthen domestic manufacturing, and provide local economic opportunity across the entire U.S. As the industry continues to mature, these early-stage technology innovations are critical to strengthening the body of knowledge upon which industry can develop and deploy new technologies that significantly reduce costs and increase competitiveness.

The Wind Energy Program has unique roles in conducting high risk, transformational R&D that are typically not being undertaken by individual U.S. wind industry participants due to real or perceived cost, risk, the need to focus on near-term investment returns, or the proprietary and competitive nature of their business. Federally-funded activities can also address different time-scales and/or engage comprehensive competencies that industry alone cannot tackle, such as the application of DOE's high-performance computing capabilities to high-fidelity tools for wind plant design and optimization, and provision of facilities such as the National Wind Technology Center at the National Renewable Energy Laboratory (NREL) for physical testing of new innovations. The R&D funded by the program also informs regulatory and interagency processes to address issues related to wind energy deployment.

DOE's Wind Energy Program activities target innovations applicable to land, offshore, and distributed wind opportunities to enable industry to achieve wind power that is cost-competitive on an unsubsidized basis across the country, and thereby further an affordable, reliable, secure and diverse energy portfolio nationwide. Program activities focus on science and early-stage innovations to optimize the design and operation of future wind plants, and aim to strengthen the body of knowledge which industry can utilize to develop the taller towers, larger rotors, lower weight components, plant-level control strategies, and technologies to reduce environmental and community impacts that will be required to achieve necessary cost reductions, improve grid reliability, and reduce regulatory burdens.

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[1] U.S. DOE Energy Information Administration. Preliminary Monthly Electric Generator Inventory. https://www.eia.gov/electricity/data/eia860m/.

[2] U.S. DOE Energy Information Administration. Electricity Data, Form EIA-861M. https://www.eia.gov/electricity/data/eia861m/.

[3] U.S. Federal Energy Regulatory Commission. Energy Infrastructure Update. https://www.ferc.gov/legal/staff-reports.asp

[4] U.S. DOE. 2017 U.S. Energy and Employment Report. January 2017. https://energy.gov/downloads/2017-us-energy-and-employment-report.

[5] American Wind Energy Association. "Wind Brings Jobs And Economic Development To All 50 States." March 9, 2017. http://awea.files.cms-plus.com/AWEA%20Economic%20Development%20Impacts%20of%20Wind%20Energy%20FINAL.pdf.

Highlights of the FY 2019 Budget Request

The FY 2019 budget request will support the Wind Program's portfolio of early-stage R&D Annual Operating Plans (AOPs) at the National Laboratories. In accordance with The Office of Energy Efficiency and Renewable Energy's AOP development and implementation policy, the program will use a transparent and uniform merit review and selection process to identify and inform high-quality science and technology projects from the National Laboratories that have the maximum potential to accomplish mission objectives.

In FY 2019, through its Atmosphere to electrons (A2e) initiative — a collaboration among DOE, industry, academia, and other stakeholders — the program will fund fundamental, early-stage R&D to improve the performance and reliability of next-generation wind plants by investigating systems-level interactions influenced by atmospheric conditions, variable terrain, and machine-to-machine wake interactions. This enhanced understanding will enable innovations that have the potential to reduce unsubsidized wind energy cost of energy by up to 50 percent by 2030, compared to a $46/MWh national average in 2015.[1] The program will conduct field experiments to validate high-fidelity computational models, leveraging DOE's high-performance computing (HPC) capabilities, and establish the performance improvements from innovative wake controls in realistic atmospheric operating conditions. DOE investment in the national wind energy test facilities maintains unique, state-of-the-art capabilities to provide U.S. industry and academia a resource for research, development, testing and validation of their innovations. For example, research-quality data collected in field experiments at both the National Wind Technology Center at NREL and the Scaled Wind Farm Technology (SWiFT) facility at SNL is used to validate high-fidelity models.

In FY 2019, the program will characterize the potential cost, grid, and deployment impacts of innovations related to A2e wind plant technologies such as wake steering and predictive wind plant control strategies, and will expand A2e atmospheric science research to offshore applications. The program will also leverage its systems engineering optimization tools to evaluate potential innovations in offshore floating systems to determine the most promising pathways for achieving deep cost reductions, and fund R&D on early-stage technologies such as instrumentation and control algorithms to enhance wind farm operations and asset management.

In FY 2019, the program will continue an R&D effort, began in FY 2018, focused on the scientific challenges associated with the design and manufacturing of low-specific power rotors (larger swept area) for tall wind applications. This effort will strengthen the body of knowledge necessary for industry to mitigate aerodynamic loads, deploy new materials and approaches to structural design, and apply novel methods of fabrication and transportation, including evaluation of the potential for onsite manufacturing. These activities will help overcome barriers to achieving a 10 percent improvement in wind plant capacity factor.[2]

In FY 2019, the program will fund R&D on wind energy grid integration and grid infrastructure modernization challenges in collaboration with electric grid operators, utilities, regulators, and industry to enable incorporation of increasing amounts of wind energy into the power system, while maintaining economic and reliable operation of the national transmission grid. As part of the DOE's Grid Modernization Initiative (GMI) efforts, the program will focus on the tools and technologies to measure, analyze, predict, protect, and control the impacts of wind generation on the grid as it evolves with increasing amounts of wind power, and will continue to develop and refine the ability of wind turbines to provide Essential Reliability Services (ERS). The program will continue supporting the early-stage R&D activities outlined in the GMI Multi-Year Program Plan.

In FY 2019, the program will continue to develop technical solutions to reduce regulatory restrictions associated with radar interference and wildlife impacts from domestic wind energy development. The program will work with the Departments of Defense (DOD), Homeland Security (DHS), Transportation (DOT), Interior (DOI), and Commerce (DOC), and other agencies to address the impacts of wind development on critical radar missions, including support for projects to evaluate proof-of-concept mitigation measures in operational settings and ready them for broad deployment.

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[1] Enabling the SMART Wind Power Plant of the Future through Science-Based Innovation. U.S. Department of Energy. NREL/TP-5000-68123. August 2017. https://www.nrel.gov/docs/fy17osti/68123.pdf.

[2] Enabling the SMART Wind Power Plant of the Future through Science-Based Innovation. U.S. Department of Energy. NREL/TP-5000-68123. August 2017. https://www.nrel.gov/docs/fy17osti/68123.pdf.

The Grid Modernization Initiative (GMI) coordinates efforts across the Department to develop the concepts, tools, and technologies needed to measure, analyze, predict, protect, and control the grid of the future. Projects are executed by or in close coordination with Grid Modernization Lab Consortium (GMLC), a collection of National Laboratories that bring together the leading experts, technologies, and resources to modernize the nation's grid. In FY 2019, the program will fund research through a laboratory call coordinated through GMI to further evaluate and refine essential reliability services (such as voltage control, frequency response, and ramp rate control) provided by wind power plants. Additionally, the program will utilize renewable integration studies to evaluate various power system scenarios with ever increasing amounts of wind energy to better understand impacts to issues such as low short circuit current, weak grid issues, and other system reliability issues.

Additionally, in FY 2019, the program will support the new initiative entitled Beyond Batteries, by issuing a funding opportunity announcement ($5M) and by funding laboratory-based R&D on adaptable, wind-based, energy storage alternatives. As a part of GMI, Beyond Batteries focuses on advances in controllable loads, hybrid systems incorporating generation from all sources, and new approaches to energy storage, which are essential to increasing the reliability and resiliency of our energy systems. Advances in these areas will allow for loads to be combined with generation from all sources to optimize use of existing assets to provide grid services, and increase grid reliability.

Wind Energy Funding
($K)

	FY 2017 Enacted	FY 2018 Annualized CR*	FY 2019 Request	FY 2019 Request vs FY 2017 Enacted
Wind Energy				
Technology Research, Development & Testing and Resource Characterization (Land, Offshore, Distributed)	28,346	—	19,993	-8,353
Technology Validation and Market Transformation	40,000	—	0	-40,000
Mitigate Market Barriers	12,863	—	11,822	-1,041
Modeling and Analysis	8,791	—	1,185	-7,606
Total, Wind Energy	**90,000**	**89,388**	**33,000**	**-57,000**

SBIR/STTR:

- FY 2017 Transferred: SBIR $824,000; STTR $116,000
- FY 2018 Projected: SBIR $818,000; STTR $115,000
- FY 2019 Request: SBIR $1,056,000; STTR $149,000

*A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution. (These amounts are shown only at the Congressional control level and above; below that level, a dash (—) is shown).

Wind Energy
Explanation of Major Changes
($K)

	FY 2019 Request vs FY 2017 Enacted
Wind Energy	
Technology Research, Development & Testing and Resource Characterization (Land, Offshore, Distributed): Decrease reflects the completion of the Wind Forecasting Improvement Project Phase 2 (WFIP II) field campaign, the completion of a design, fabrication, and testing R&D activity on wind-specific optimized carbon fiber composites, the completion of the Gearbox Reliability Collaborative 1.5 (GRC 1.5) field test, and the completion of design, fabrication, and structural validation of the National Rotor Testbed (NRT) blades.	**-8,353**
Technology Validation and Market Transformation: No funding is requested for this subprogram as all funding for offshore demonstrations has been appropriated and obligated to awardees.	**-40,000**
Mitigate Market Barriers: Decrease reflects the shift in focus to early-stage transformative science and technology research. The funding reflects discontinuation of later-stage research activities. The subprogram will continue to strengthen the body of knowledge necessary to improve wind energy grid integration. Additionally, the subprogram will develop and evaluate technology solutions to inform regulatory and interagency processes, and address issues related to wind energy deployment such as wind turbine radar interference, and environmental performance.	**-1,041**
Modeling and Analysis: Decrease reflects a reduced emphasis on analysis related to the National Offshore Wind Strategy, reduction in development and maintenance of analytical capabilities, and refocusing the modeling and analysis program on the evaluation of potential early-stage transformative science and technology R&D opportunities in wind technology.	**-7,606**
Total, Wind Energy	**-57,000**

Wind Energy
Technology Research, Development & Testing (RD&T) and Resource Characterization (Land, Offshore, Distributed)

Description

The primary objective of the Technology Research, Development and Testing (RD&T) and Resource Characterization (Land, Offshore, Distributed) subprogram is to conduct early stage R&D to generate scientific and engineering knowledge that enables industry to reduce the cost and improve the performance of U.S. land, offshore, and distributed wind systems. The subprogram's strategy is to explore concepts and improve modeling and simulation capabilities that enable wind plant optimization as an integrated system, rather than focusing solely on individual wind turbines and components. To enable industry to address key cost drivers — capital costs, O&M costs, annual energy production (AEP), and financing rates — and improve the performance and reliability of the wind plant overall, the subprogram invests in a range of parallel and complementary basic and applied R&D activities. These activities inform wind turbine technology innovations — including those that enable higher hub heights, larger rotors, and improved wind plant energy capture.

The program's research portfolio ($19.9M), informed through collaborative activities with industry and reinforced by independent peer review, takes an integrated approach to improving wind plant performance through early-stage R&D focused on complex aerodynamics, advanced component manufacturing, wind plant reliability, resource characterization, controls, sensors, and modeling. The subprogram manages wind-specific test facilities that enable validation of R&D results that can ultimately inform industry development and deployment of novel technologies to reduced wind plant costs for land and offshore applications. The Atmosphere to Electrons (A2e) initiative is a major component of the subprogram, examining the performance of an entire wind plant comprised of an array of turbines. This complete system approach enables the design of low-cost wind power plants by improving current predictive capability of wind plant flow and performance. A2e is a laboratory-based consortium, working collaboratively with industry, academia and other government agencies across the U.S. and internationally. An external merit review board consisting of senior representatives from industry, National Laboratories, academia, government agencies, and international stakeholders provides feedback on current projects and suggestions for future work to an internal DOE management committee. Most of the projects under the A2e initiative are collaborative efforts, engaging multiple National Laboratories, academia and other government agencies to execute the work packages. A2e is conducting R&D for next-generation wind plants to reduce wind plant underperformance due to turbine-turbine wake interaction (20-30 percent observed in current operational wind plants). Ultimately, the goal is to develop the modeling, simulation, sensors, and control capabilities that enable industry to improve wind plant reliability over a 30 year design lifetime and demonstrate a wind plant through real-time plant-flow control strategies capable of increased energy capture and mitigating stress loading in both existing and next-generation wind plants, and to lower land-based wind plant unsubsidized cost by over 50 percent from a 2015 baseline.[1]

In FY 2019, $11.5 million will support the A2e initiative to conduct research to improve the wind forecasting high fidelity models and transition them to the industry. The initiative will build upon data gathered from comprehensive field experiments to develop and validate high-fidelity wind inflow and wake models, and to develop and test innovative wind-plant flow control strategies for land and offshore wind applications. A2e will leverage DOE high-performance computing (HPC) capabilities at the National Laboratories to develop wind application-focused, high-fidelity, and computational simulations to model the physical processes critical to predicting wind plant performance and turbine loads.

As part of A2e, the budget will continue to support the A2e High Fidelity Model (HFM) development effort in collaboration with the Office of Science and NNSA's Exascale Computing Project (ECP). Through the Exascale Predictive Wind Plant Flow Physics Modeling project, the program will continue to examine the most appropriate methods for incorporating future exascale computing capability for a coupled atmosphere to turbine integrated analysis capability that resolves the atmosphere/wind plant coupled interactions. This effort will provide an integrated analysis method to assess new wind-plant technology options and predict actual installation cost and performance with a high degree of certainty, using a virtual digital environment.

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[1] Enabling the SMART Wind Power Plant of the Future through Science-Based Innovation. U.S. Department of Energy. NREL/TP-5000-68123. August 2017. https://www.nrel.gov/docs/fy17osti/68123.pdf.

The budget provides $1.2 million to continue to support early-stage R&D challenges associated with low-specific power rotors for tall wind applications. Low-specific power rotors sweep a larger area of the available wind, improving the capacity factor of a wind turbine. The Big Adaptive Rotor (BAR) initiative is an integrated program across four National Laboratories that aims to achieve an improvement in energy capture of up to 15 percent as a result of changing the specific power from current technology of greater than 200 watts per meter squared (W/m2) to the 150 W/m2 rotor systems envisioned for tall wind applications. Several technical challenges, including addressing adaptive load control via passive and active aerodynamic devices, innovative blade materials, new design concepts, and overcoming transportation constraints in delivering large blades and towers, require development of fundamentally different architectures. The investment required to develop these architectures is high risk and will require a new multidisciplinary approach to modeling and validation and will incorporate the advanced flow control knowledge being developed under the A2e initiative. These advanced turbine and rotors technologies will rely on adaptive features and characteristics to increase energy production while improving reliability, and reducing sound emissions and enhancing grid services. These technology innovations, once adopted by industry, will open up a significant number of low wind speed sites.

Funding in FY 2019 will continue to support R&D, performed in collaboration with the DOE Advanced Manufacturing Office and industry through the Manufacturing Demonstration Facility Technical Collaborations Program at Oak Ridge National Laboratory, aimed at increasing U.S. manufacturing competitiveness in wind energy, leveraging previous success in a project that produced a prototype blade mold using additive manufacturing. Strengthening the body of knowledge necessary for reliable and cost-effective materials, including carbon fiber, for use in additive, or 3-D, manufacturing that could remove limitations on tooling, configuration, component design and variations, or production time, lowering costs and transforming the wind manufacturing industry. Prototype additive manufacturing technology, developed through industry-laboratory collaboration, and engaging up to two National Laboratories, will enable completely new ways of fabricating components. This technology is still in early-stage development, and the investment required to develop this technology is high risk and explores new manufacturing methods which could be transferred to industry.

Funding in FY 2019 ($4.5M) will continue to support operation and enhancement of DOE's world-class testing infrastructure, including NREL's National Wind Technology Center (NWTC) in Colorado, and Sandia's Scaled Wind Farm Technology (SWiFT) facility in Texas. DOE investment in test facilities provides unique, state-of-the-art capabilities to U.S. industry and academia as a resource for research, development, testing and validation of their innovations. National Laboratories actively engage industry and academia to encourage use of government facilities in support of later stage R&D. For example, in FY 2018, out of a planned 45 projects utilizing the facilities at the National Wind Technology Center, 39 include external users that are either wholly or partially funding the projects. The testing infrastructure provides a wide breadth of testing and research capabilities critical for supporting basic laboratory research and inform future research priorities, which will lead to U.S. wind energy innovation and cost of energy reductions for all market segments, including development of improved test methods which better reflect field conditions wind turbines are likely to experience.

Technology RD&T and Resource Characterization (Land, Offshore, Distributed)

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Technology RD&T and Resource Characterization $28,346,000	**$19,993,000**	**-$8,353,000**
• The Wind Forecasting Improvement Project (WFIP) Phase 2.0 was a three-year project targeted at better understanding atmospheric phenomenon in complex terrain. WFIP II gathered field data over an 18-month period starting in Q4 of FY 2015. In FY 2017, the field data was used to improve forecasting models.	• FY 2019 resource characterization efforts will analyze previously collected WFIP II data and incorporating new understanding of physical phenomena into high fidelity meteorological models to improve forecasting of wind energy production and higher resolution wind plant inflow and turbulence.	• Complex terrain resource characterization field data campaigns finished in FY 2017 and the Wind Forecasting Improvement Project phase 2 (WFIP II) completed in FY 2018. Work will extend retrospective improved-model runs to a full year, fully incorporating Planetary Boundary Layer 3-D schemes, improved finite-differencing, and Immersed Boundary Method. Three National Laboratories and the National Oceanic and Atmospheric Administration will work on this project.
• The program seeks to overcome issues associated with moving from large-scale weather forecasting to smaller wind plant time and space scales, and to quantify remaining forecast uncertainties for land and offshore wind applications. Conducted joint computational-experimental campaigns, including the following core activity: High fidelity simulations coupling the large-scale physics of the atmosphere to the smaller-scale physics of wind plant and wind turbine inflow in conjunction with validation data collected in field experiments.	• The program will address issues associated with moving from large-scale weather forecasting models to the smaller domain size of wind plant time and space scales, and to quantify remaining forecast uncertainties for land and offshore wind applications.	• New improved physics models will be incorporated into HPC simulations of wind plant Aerodynamics. Verification and validation of results will be accomplished using previously acquired Wind Forecasting Improvement Project phase 2 (WFIP II) field data. Funding will support work at three National Laboratories and the University Corporation for Atmospheric Research.

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
• The program continued to execute the joint computational-experimental program for new research rotors at the Sandia Scaled Wind Farm Technology (SWiFT) facility and leveraging previous activities will focus on high-quality measurements to understand the development of wind turbine wake and its impact on the power production and loads of a downstream turbine under realistic atmospheric inflow conditions.	• The program will execute integrated computational simulations and experimental field campaigns to collect high-fidelity data sets of wind plant complex flow interactions. Data acquired is used to validate high-fidelity simulation tools developed under the Atmosphere to Electrons (A2e) initiative.	• The A2e experimental campaigns will obtain unique datasets that will be used for verification and validation of high fidelity models (HFM) developed to advance understanding of rotor wakes and innovative control paradigms that can be used to minimize the adverse impacts that the wakes have on rotor performance and turbine loads. New research rotors at the SWiFT facility will focus on high-quality measurements to understand the development of wind turbine wake and its impact on the power production and loads of a downstream turbine under realistic atmospheric inflow conditions. Funding will support work at two National Laboratories.
	• Using the Weather Research and Forecast model as a starting point, the program will initiate a new activity to create the Energy Research and Forecasting (ERF) simulation framework to provide high-fidelity weather and environment-dependent energy inflow and boundary condition information to the microscale wind plant simulator within DOE's advanced HPC environments.	• The ERF will provide wind plant specific, high fidelity forecasting for energy relevant time and spatial scales that will optimize grid integration. FY 2019 efforts will utilize WFIP II data for analysis and incorporate new understanding of physical phenomena into high fidelity meteorological models to improve forecasting of wind energy production and higher resolution wind plant inflow and turbulence. Funding will support work at three National Laboratories in coordination with the National Oceanic and Atmospheric Administration.
• Designed, built, and structurally validated the new National Rotor Testbed (NRT) blades, which are specifically designed to replicate the wake characteristics of full-scale turbines.	• Conduct wake steering experiments using the new National Rotor Testbed (NRT) blades specifically designed to replicate the wake characteristics of full-scale turbines.	• The design validation of the NRT blades was completed in FY 2017, allowing the start of the formal verification and validation experimental and simulation campaign for A2e. In FY 2019, the HFM code simulations will continue comparisons to wake data acquired at the SWiFT facility. Funding will support work at one National Laboratory.

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
• Developed turbine component and wind plant system design tools that integrate cost models with system dynamics models for land-based and offshore applications.	• FY 2019 activities tie the high-fidelity modeling and experimental efforts under A2e to a completely new systems approach to the design and analysis of wind plants for both land-based and offshore applications. The effort is focused on three inter-related tasks: systems engineering and optimization of wind plants; multi-physics model validation and uncertainty quantification for both wind turbines and wind plants; and informing design procedures and methodologies.	• In FY 2019, through A2e the subprogram will verify floating offshore foundation and mooring, engineering physics-based simulation tools modeling the coupled dynamic response of turbine and substructures under a full-range of operating conditions. Improved design processes for offshore wind coupled-systems—allowing the turbine and support structure to be simultaneously designed—will enable the identification of the highest potential cost-reduction pathways. One National Laboratory will work on three projects under this program.
• Began a preliminary benchmarking effort to help quantify the risk and uncertainties associated with pre-production estimates to correlate the uncertainty and underperformance of wind plants and associated financial risk to identify technology improvement opportunities.	• FY 2019 A2e Performance, Risk Uncertainty and Finance (PRUF) wind plant performance benchmarking and improvement activities include 3 major projects: expanded benchmark to leverage international experience, initiating planning to benchmark offshore wind plant performance, and evaluating machine learning and other advanced statistical approaches to improving plant performance prediction.	• A preliminary benchmarking effort to help quantify the risk and uncertainties associated with pre-production estimates will be completed in FY 2018 using FY 2017 funds. Focus in FY 2019 shifts to expand benchmark to offshore plants and identifying potential advancements in plant performance prediction based on benchmark results.
• Analyzed and continued to collect meteorological and oceanographic data using offshore buoys and investigated the impacts of hurricane wind and wave conditions on offshore wind turbines.	• FY 2019 offshore wind resource assessment activities will include developing partnerships to deploy wind and met-ocean science buoys in areas identified for offshore wind development. Analysis of prior year meteorological and oceanographic data from offshore buoys will be performed.	• The program will work to redeploy the offshore wind buoys to new locations in order to obtain offshore wind hub-height data on a different set of unique offshore wind and wave conditions critical to first of kind validation for offshore met-ocean computational models. The funding supports the placement of two buoys in separate locations.
• The objectives of this task are to improve turbine availability, reliability and reduce O&M cost. Specific objectives include evaluation of oil sampling systems ability to indicate gear and bearing damage; evaluation of novel diagnostic and prognostic methods based on turbine SCADA data; and continuing to populate and analyze the gearbox failure database.	• FY 2019 reliability activities include assessment of failure mitigation strategies for main bearing and high-speed shaft bearing through material and lubrication innovations.	• The Gearbox Reliability Collaborative (GRC) 1.5 field experiment to collect main and high-speed shaft failures completed in FY 2018. Reliability analysis and mitigation strategies developed will be assessed in FY 2019. The funding supports one National Laboratory to work in collaboration with an industry partner on this project.

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
• Purchased equipment, instrumentation and materials to upgrade and support key personnel for state-of-the-art facilities to include best practices in maintenance, and safety support for facilities at the National Wind Technology Center (NWTC), and the Scaled Wind Farm Technology (SWiFT) facility. NWTC facilities include the blade structural test facility, 225kW, 2.5MW and 5.0MW dynamometers, 7.0MVA Controllable Grid Interface (CGI), Controls Advanced Research Turbines and the DOE 1.5MW wind turbine. The SWiFT facility includes an array of test turbines, meteorological towers, wake measuring systems, and instrumentation.	• Purchase equipment, instrumentation and materials to upgrade and support key personnel for state-of-the-art facilities to include best practices in maintenance, and safety support for facilities at the NWTC and SWiFT. NWTC facilities include the blade structural test facility, 225kW, 2.5MW and 5.0MW dynamometers, 7.0MVA Controllable Grid Interface (CGI), Controls Advanced Research Turbines and the DOE 1.5MW wind turbine. The SWiFT facility includes an array of test turbines, meteorological towers, wake measuring systems, and instrumentation.	• Support for the improvement of capabilities, equipment, operations and maintenance of wind turbine test facilities will reflect increased industry use of the facilities, which provides the U.S. with a world-class suite of test capabilities for R&D of innovative designs.
• Supported distributed wind LCOE reduction to be competitive with other distributed generation technologies and retail electricity rates, and increase the number of certified turbine models.	• The distributed wind Competitiveness Improvement Program (CIP) addresses research, development and manufacturing improvements that directly reduce LCOE and facilitate turbine certification goals. No FY 2019 funding is requested for CIP.	• Through NREL, DOE currently has several active awards under the Competitiveness Improvement Program (CIP) for distributed wind funded with previous year funding that will be managed throughout FY 2019.
• Produced an annual Distributed Wind Market Report covering U.S. wind power in distributed applications — including small, mid-size, and utility-scale installations.	• FY 2019 funding for distributed wind will focus on efforts to collect and analyze distributed wind technology data to identify key trends, R&D opportunities, and document through the annual market report.	• Emphasis in FY 2019 will be placed on identifying specific cost targets for various distributed wind system size and establishing a process for evaluating progress against those targets. Funding will support projects at two or more National Laboratories.
	• Funding in FY 2019 will support the Big Adaptive Rotor (BAR) initiative, which is focused on the design and manufacturing challenges associated with low-specific power rotors. This integrated program will address the fundamental science challenges in adaptive load control via passive and active aerodynamic devices, innovative blade materials and new design concepts that will achieve an improvement in energy capture of up to 15 percent while improving reliability, and	• Research in FY 2019 will be driven by the most promising concepts identified in the R&D opportunity screening that was completed in FY 2018. One to three laboratory R&D projects will be supported that will entail optimization and detailed design, fundamental understanding of subcomponent and full rotor performance. Additional projects will result from a multi laboratory study on transportation constraints for large blades, research identified for large

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
	reducing sound emissions and enhancing grid services. • Funding in FY 2019 will support research on technologies to optimize wind farm operations and accelerate wind farm development, such as improvements in instrumentation and control algorithms to address industry needs for improvement of environmental performance at lowered costs at existing and future wind plants. With increased wind energy deployment nationally and the increasing useful life of wind plants, there is a growing need for early-stage R&D aimed at minimizing operational costs and issues that may hamper future cost reductions or deployment. Addressing these operational concerns will help enable continuing U.S. wind industry growth.	component manufacturing and transportation, including potentially for onsite manufacturing. • Work in FY 2019 will leverage FY 2018 efforts to support early-stage research to advance instrumentation and algorithms aimed at lowering cost and increasing environmental performance of wind turbines.
• This activity supports R&D on wind-specific optimized carbon fiber composites. Carbon fiber offers significantly enhanced mechanical properties compared to fiberglass, however, the high cost of carbon fiber limits its use in wind turbine blades. Two National Laboratories and one university are engaged in an initiative to design, fabricate and test new carbon fiber material systems designed specifically to meet strength and cost targets for wind turbine application to low-specific power rotors.	• The program will evaluate the potential to support additional R&D on wind-specific optimized carbon fiber composites. • Funding in FY 2019 will support R&D, performed in collaboration with the DOE Advanced Manufacturing Office and industry, aimed at increasing U.S. manufacturing competitiveness in wind energy, leveraging previous success in a project that produced a prototype blade mold using additive manufacturing.	• Continued efforts in wind-specific optimized carbon fiber composites will be guided by the results of the design, fabrication, and testing activity that was completed in FY 2018. • Work in FY 2019 will leverage FY 2018 efforts supporting early stage research in additive manufacturing technologies including the reliability and cost effectiveness of materials including carbon fiber for use in additive or 3-D manufacturing. Up to four projects are expected to be conducted.

Description

The primary objective of the Technology Validation and Market Transformation subprogram is to conduct high-risk validation and verification of new technologies at relevant scale. In addition to validating and verifying through testing, the subprogram collects performance and environmental data from these projects and produces public datasets that researchers and private industry may use. Working in tandem to validate the performance, stability and security of early-stage, novel wind technological advancements, the Government and the private sector can promote the nation's economic growth through innovation, and create new products and services for the American people.

In FY 2019, no funding is requested for this subprogram.

Technology Validation and Market Transformation

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Technology Validation and Market Transformation $40,000,000	**$0**	**-$40,000,000**
• Continued support for the Offshore Wind Technology Demonstration projects. The projects continued to be evaluated and monitored by an independent third party for validation and verification of cost, schedule, and milestones. Funded two alternate Offshore Wind Technology Demonstration projects to further substantiate the design and economic value proposition of alternate project designs for offshore wind power. These include concrete semi-submersible foundations as well as monopile foundations designed to reduce ice loading.	• No funding requested for this activity as all funding for offshore demonstrations has been appropriated and obligated to awardees.	• This activity is intended to fund technology validation and verification at large scale. The current Offshore Wind Technology Demonstration projects have been fully funded to completion through past appropriations. The two projects will continue to be evaluated and monitored by DOE and an independent third party for validation and verification of cost, schedule, and milestones. Subject to go/no-go reviews and no-cost extensions, projects are planned for commissioning in 2020.

Wind Energy
Mitigate Market Barriers

Description

The Mitigate Market Barriers subprogram funds R&D activities to strengthen the body of knowledge necessary to inform key grid integration and regulatory decisions associated with the deployment of wind energy. The subprogram determines technology needs and evaluates technology solutions to reduce regulatory restrictions associated with radar interference, wildlife impacts, and human use conflicts associated with domestic energy development, and funds R&D on wind energy grid integration and grid infrastructure modernization challenges as part of coordinated grid modernization efforts across the Department through the National Laboratories and GMI.

This subprogram conducts wind energy grid integration R&D with the purpose of generating knowledge relevant for electric grid operators, utilities, regulators, and industry to develop and deploy novel technologies that enable reliable incorporation of wind energy into the power system. Four states have wind electrical generating capacity greater than 25 percent of their total installed capacity, and some utilities seeing instantaneous wind generation production of up to 60 percent. The Western Wind and Solar Integration Study (Phase 1-3) and the Eastern Renewable Generation Integration Study have framed the groundwork for utilities to understand how to effectively operate the power grid under high penetrations of wind energy and identify technical innovations, such as forecasting and dynamic line rating, that are critical for further successful grid integration.

In FY 2019, the subprogram will fund research ($3M) through a laboratory call coordinated through the Grid Modernization Initiative to further evaluate and refine essential reliability services (such as voltage control, frequency response, and ramp rate control) provided by wind power plants. Additionally, the subprogram will utilize renewable integration studies to evaluate various power system scenarios with ever increasing amounts of wind energy to better understand impacts to issues such as low short circuit current, weak grid issues, and other system reliability issues. Furthermore, this subprogram will continue to analyze various conceptual transmission system development scenarios, in coordination with power system planners, to understand and support the development of infrastructure needed to deliver wind energy from production site to load centers; as well as, continued evaluation of increased utilization of existing transmission infrastructure through a wind based dynamic line rating system by incorporating dynamic line rating forecasting.

Additionally, in FY 2019, the program will issue a funding opportunity announcement ($5M), and fund laboratory-based R&D ($3M), on adaptable, wind-based, energy storage alternatives. As a part of GMI, Beyond Batteries focus on advances in controllable loads, hybrid systems incorporating generation from all sources, and new approaches to energy storage, which are essential to increasing the reliability and resiliency of our energy systems. Advances in these areas will allow for loads to be combined with generation from all sources to optimize use of existing assets to provide grid services, and increase grid reliability.

In FY 2019, collaboration will continue ($500K) with DOD, DHS, DOT, DOI and DOC, and other agencies through the interagency Wind Turbine Radar Interference Mitigation MOU to address the impacts of wind development on critical radar missions. The objectives include completion of a suite of wind-turbine radar-interference mitigation techniques for DOD, FAA, and DHS long-range and terminal radar systems, and deployment of those and other mitigation measures in operational environments to ensure their availability to radar operators.

In FY 2019, the subprogram will allocate $300 thousand to evaluate the environmental performance of wind plants, including avian and bat species interactions with wind turbines, and advance next-generation turbine concepts to inform the development of technical mitigation solutions involving detection, deterrence, and impact avoidance.

Mitigate Market Barriers

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Mitigate Market Barriers $12,863,000	**$11,822,000**	**-$1,041,000**
• With interagency partners, continue to develop measures to mitigate wind turbine-radar interactions. Continue laboratory efforts to address the effects of wind development on sensitive bird and bat species.	• Support research to address regulatory restrictions associated with radar interference and environmental performance. Continue co-funded interagency R&D collaboration with DOD, DHS, DOT, DOI, DOC and other agencies under the MOU. Complete work on at-the-radar software mitigation measures, increase focus on command-and-control system and radar tracker improvements, and facilitate multiple demonstrations of these and other mitigation technologies at existing National Airspace System radars. Evaluate environmental performance, including avian and bat species interactions with wind farms and advance next-generation turbine concepts to inform the development of technical mitigation solutions involving detection, deterrence, and impact avoidance.	• In FY 2019 the program will complete research to identify radar command-and-control and tracking system improvements. It will also complete the first project, with DOD, FAA and other partners, to integrate an infill radar in an operational setting, and establish requirements for deployment of infill radar systems at other sites with radar interference issues. Research and development through the National Laboratories to assess and improve the environmental performance of wind facilities, including avian and bat species interactions with wind turbines, will result in the completion of an analysis of the effectiveness of various bat impact minimization technologies.
• Conduct next generation integration studies using newly developed 10-year wind data sets, including a North American Renewable Integration Study (NARIS).	• No funds requested for this activity. Program will evaluate the need for follow-on work in this area.	• Prior year appropriations will be used to complete the NARIS during FY 2019.
• Further develop the wind-based transmission line planning tool architecture and improve integration of wind forecast information into grid operational tools.	• Wind-based transmission line routing tool development, with increased focus on dynamic line rating forecasting capability development to allow generator dispatch to use the new line capacity.	• Transition focus from dynamic line rating methodology development, and increase focus on dynamic line rating forecasting capability development through one project conducted by one National Laboratory.
• Continue the development of integrated Energy/Distribution/Building Management Systems (EMS/DMS/BMS) to allow control across each operational area and continue the evaluation of the analysis impacts of geographic and temporal decomposition for use in production cost modeling.	• No funds requested for this activity.	• The development of the integrated Energy/Distribution/Building Management tools is scheduled for completion in FY 2018.

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
	• Within the new Beyond Batteries initiative, the secure and reliable hybrid systems baseload energy grid service capabilities activity will issue a funding opportunity announcement (FOA) to develop hybrid wind systems that provide predictable blocks of energy coupled with hydrogen production and capable of providing Essential Reliability Services (ERS) including inertia, frequency response, and voltage control.	• In FY 2019, the program will issue a FOA to support 1-3 projects focused on enhancing grid reliability and resiliency by targeting advances in secure and reliable hybrid system concepts.
• Funded Eagle Impact Mitigation Technologies research solicitation and competitively selected 6 research projects to support the development and validation of technologies that reduce potential impacts of wind energy facilities on Bald and Golden Eagles. A field-testing and validation component will independently test the performance of high-technology readiness level (TRL) measures such as eagle detection and deterrence devices, while an R&D focus component will be aimed at the development of lower-TRL concepts to improve the efficacy and reduce the cost of and need for detect-and-deter or other mitigation technologies.	• No funding requested for this activity.	• DOE issued a FY 2016 FOA and issued 6 awards to address these research needs. Projects are currently on-going and funded through prior appropriations. Two of these projects will be completed in FY 2019.
• Completed a National Public Acceptance Baseline Study to provide the first quantitative assessment of the factors associated with public acceptance of wind energy development across the country.	• No funding requested for this activity. Program will evaluate the need for follow-on work in this area.	• The program completed this study, conducted by one National Laboratory, in FY 2018.
• Continue support to WINDExchange and Wind Energy Regional Resource Centers to ensure decision-makers are using the best available science to support wind energy decisions.	• No funding requested for this activity. Program will evaluate the need for follow-on work in this area.	• Support for this activity is deferred.
• Continue support of the Wind for Schools and Collegiate Wind Competition for development of a robust domestic wind energy workforce.	• No funding requested for this activity. Program will evaluate the need for follow-on work in this area.	• Support for this activity is deferred.

Wind Energy
Modeling and Analysis

Description

The Modeling and Analysis subprogram provides objective analysis to evaluate and prioritize wind energy technology innovation opportunities for land, offshore, and distributed applications, based on a solid understanding of current technology and market conditions as well as state-of-the art systems engineering, cost and deployment models and tools. The subprogram also provides regular reporting and analysis of costs and market trends to ensure transparency in its analytical basis and methods; performs fundamental analysis of wind's impacts on economic factors such as land use and jobs; and provides the analytical basis for program development of annual and multi-year plans and technology roadmaps and investments. Using state of the art modeling tools such as ReEDS (energy capacity expansion model) and WISDEM (systems engineering model), and accessing the most detailed wind data available, the subprogram will continue improving the knowledge base surrounding techno-economic factors associated with wind energy in electric sector and wholesale energy modeling, as well as providing detailed analytical data in the form of annual technology market reports to facilitate informed policy and investment decisions across the wind industry.

In FY 2019, the subprogram will provide $1.18 million to support specific new techno-economic and life-cycle assessments that assist the program and industry in prioritizing highest impact technology research and development priorities. Analysis activities will support wind plant technology development undertaken within the Technology Research, Development & Testing (RD&T) and Resource Characterization (Land, Offshore, Distributed) subprogram, including the Atmosphere to Electrons (A2e) initiative. Investments will focus on elaborating the potential impact of innovations such as coupled offshore wind turbines and substructures, plant operations strategies, and A2e wind plant control and monitoring technologies that enhance annual energy production. One example of innovation-focused analysis is the floating offshore wind technology characterization initiative which will, concurrently assess a broad range of floating foundation concepts to identify, characterize, and compare the key advantages and drawbacks of each design type.

Modeling and Analysis

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Modeling and Analysis $8,791,000	**$1,185,000**	**-$7,606,000**
• Conducted technology characterization data gathering, and system cost analyses using laboratory generated analysis tools, evaluated the impact of new and emerging technologies on system cost (sensitivity analyses), and provided unbiased information to stakeholders on the status of the domestic wind market in the U.S.	• In FY 2019, the subprogram will focus on data collection in partnership with two National Laboratories, and a variety of industry participants to feed systems engineering and other analysis necessary to determine remaining cost reduction opportunities in land-based and offshore wind and identify opportunities where DOE investment has a unique role in driving innovation.	• Data collection will feed analysis of the impact of A2e plant technologies for offshore wind and particularly for floating offshore systems, to be completed by the end of FY 2019.
• Utilized systems engineering and levelized cost of energy (LCOE) analysis modes to support evaluation of transformative "SMART" wind plant technologies developed under the A2e initiative and offshore wind-specific substructure and operational innovations.	• In FY 2019, the subprogram will complete the second phase of a multi-year analysis effort through one National Laboratory project on high-fidelity systems engineering evaluation of floating offshore wind systems to identify the turbine, substructure and balance-of-plant R&D pathways necessary for system optimization and deep cost reductions.	• The subprogram will complete development of at least three systems engineering tools necessary for full system optimization studies for floating offshore wind turbines, and complete a detailed analysis highlighting the greatest potential areas of cost reduction and related research and development needs in floating offshore wind systems.
• Applied and improved core-capacity expansion models — including ReEDS, Plexos and NEMS — to identify and leverage opportunities for accelerated wind deployment and understand variable wind generation's actual costs and benefits with the five Power Markets within the U.S.	• FY 2019 activities will support two laboratory projects to characterize the electricity system costs and benefits associated with wind on the grid to utilities and ratepayers, and identifying the potential effects of improvements in wind technology to provide ancillary services and integration with other technologies such as battery storage.	• No significant change in focus for this activity.
• Continued to implement processes to gather, evaluate, verify, and analyze data and information regarding technical and project management performance and progress relative to the Program's cost and performance goals.	• In FY 2019, the subprogram will conduct program-wide external/industry project reviews and continue improvement of detailed program impact analysis and wind technology roadmap updates, engaging eight National Laboratories and dozens of industry partners and other stakeholders.	• Program project reviews and wind technology roadmap updates help ascertain the status and progress of all of the critical actions identified to support transformative wind technology development. These inform the long-term strategy and multi-year program plans of the program as a whole.

Water Power

Overview

Hydropower and marine and hydrokinetic (MHK) energy generate renewable electricity that supports domestic economic prosperity and energy security while enhancing the reliability and resiliency of the U.S. power grid. The Department of Energy's (DOE) Water Power Program conducts early-stage research and development (R&D) to strengthen the body of scientific and engineering knowledge enabling industry to develop new technologies that increase U.S. hydropower and MHK generation.

Hydropower has provided the U.S. with sustainable, reliable, and affordable power for over 100 years. In 2016, hydropower supplied 6.5 percent[1] of the Nation's electricity end-use demand — more electricity generation than any other renewable energy source. Currently, there is over 100 GW[2] of installed hydropower and pumped storage hydropower (PSH) capacity supporting 87,000 U.S. jobs[3] and powering the equivalent of 21 million homes.[4] In addition to the economic benefits of providing cost-competitive and low-carbon electricity, the flexible nature of hydropower makes it among the most valuable forms of generation, providing the full range of flexibility and essential reliability services required by the electrical bulk-power system. In addition, PSH can also be used to store excess variable generation, further contributing to grid reliability, reducing the curtailment of other generation sources, and supporting the integration of a larger share of variable renewables like wind and solar into the power grid.

Even though many technologies used in hydropower today are well-established and commercially available, there is still opportunity for innovation and growth. In 2016, DOE's Hydropower Vision found that an additional 50-65 GW of new hydropower and PSH could be added to the U.S. generation mix by 2050 through a combination of upgrades to existing plants, new hydropower at existing unpowered dams and in new stream-reaches, and new PSH capacity. DOE developed these future hydropower growth scenarios in coordination with both the hydropower industry and environmental organizations alike. However, in order to realize this potential, difficult scientific challenges facing the existing hydropower fleet must be addressed and new technologies developed to reduce the costs and environmental impacts of new projects.

The Water Power Program supports partnerships among the National Laboratories, universities, and industry to conduct early-stage R&D activities that address fundamental science and technology gaps to achieve necessary cost reductions and environmental performance improvements for new modular hydropower designs. This includes research on the interactions between design elements and site characteristics that occur far before commercialization of any given system, providing a basis of understanding for the viability and tradeoffs of different design choices and enabling future industry-led R&D. The program's early-stage R&D enables industry to develop novel technologies and operational strategies that can increase hydropower's capability to provide baseload generation, essential grid services, and environmental performance at existing facilities while meeting multiple use demands of energy generation, irrigation, and recreation.

The program also invests in research of new technologies that enable hydropower to provide increased flexibility and grid-reliability services. This will include supporting efforts to model the value and long-term costs of different reliability services that hydropower and PSH projects provide to the grid; a computationally-intensive and interdisciplinary research challenge that is beyond the capability of any single hydropower developer, operator, or regulator. These investments in new hydropower technologies, efforts to model hydropower and PSH's contributions to increased grid flexibility and services, and investments in transformative designs of PSH technology, also support the Department's Beyond Batteries initiative.

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[1] U.S. Energy Information Administration. Table 7.2A Electricity Net Generation: Total (All Sectors). Accessed January 30th, 2018. https://www.eia.gov/totalenergy/data/browser/?tbl=T07.02A#/?f=A&start=200001.

[2] "Hydropower Vision Executive Summary," U.S. Department of Energy. Page 1. July 26, 2016. Accessed January 30th, 2018. https://energy.gov/sites/prod/files/2016/10/f33/Hydropower-Vision-Executive-Summary-10212016.pdf.

[3] "U.S. Energy and Employment Report," U.S. Department of Energy. Table 1. Generation and Fuels Employment by Sub-Technology and Figure 26. Employment by Transmission, Distribution, and Storage Sub-Technologies (Q1 2016). January, 2017. Accessed January 30th, 2018.
https://energy.gov/sites/prod/files/2017/01/f34/2017%20US%20Energy%20and%20Jobs%20Report_0.pdf

[4] "2014 Hydropower Market Report Highlights," U.S. Department of Energy. Page 2. April, 2015. Accessed January 30th, 2018. https://energy.gov/sites/prod/files/2015/04/f22/Hydropower-Market-Report-Highlights.pdf.

As a part of the DOE Grid Modernization Initiative (GMI), Beyond Batteries focuses on advances in controllable loads, hybrid systems incorporating generation from all sources, and new approaches to energy storage, which are essential to increasing the reliability and resiliency of our energy systems. Advances in these areas will allow for loads to be combined with generation from all sources to optimize use of existing assets to provide grid services, and increase grid reliability. GMI coordinates efforts across the Department to develop the concepts, tools, and technologies needed to measure, analyze, predict, protect, and control the grid of the future.

Guided by the Grid Modernization Multiyear Program Plan, foundational projects which have equities across several DOE offices can be coordinated through leadership from the GMI, while projects sponsored by individual programs, such as the Water Program's hydropower valuation and PSH projects, continue to address their specific requirements for grid modernization. Projects are executed by or in close coordination with Grid Modernization Lab Consortium (GMLC), a collection of national laboratories that bring together the leading experts, technologies, and resources to modernize the nation's grid. By requiring close collaboration on projects between the GMLC, industry, academia, and other important stakeholders, the GMI accelerates technology development, promotes innovation, and encourages broader investment in the grid.

The Water Power Program also supports fundamental research to better understand the relationships between energy generation, water flow and important indicators of environmental health, enabling industry to develop technologies and operational models that can increase both power generation and environmental performance at existing facilities. Whereas existing industry tools are designed to optimize for fluid flow and structural loading, the program's early-stage R&D combines experience across biological sciences, hydrology, engineering, and the computing resources at the National Laboratories, to quantitatively describe interactions between hydropower components and site-specific environmental conditions. The resulting design codes and models articulate the trade-offs between environmental and operational considerations to enable industry innovation in turbine design and inform scheduling and dispatch models so they can be more effective at optimizing across multiple mandates. This research is designed in close collaboration with industry and Federal hydropower operating agencies, with the program research focusing on knowledge generation that feeds future industry innovation and commercialization.

Marine and hydrokinetic (MHK) technologies convert the energy of waves, tides, and river and ocean currents into electricity and have the potential to provide millions of Americans with locally sourced, clean, and reliable energy. MHK is also a predictable, forecastable resource with a generation profile complimentary to the seasonal or temporal variations of other resources such as onshore wind and solar, which can enhance its contributions to grid resilience and reliability. MHK technologies also have the potential to provide cost-effective energy for numerous existing distributed and alternate applications. In non-grid connected or remote, coastal areas — including forward operating military bases and smaller communities — where electricity costs are high, MHK devices may contribute to least-cost power (either as part of a portfolio of balanced local resources or as the dominant technology) while avoiding the expense and risk of relying on imported fuels. MHK is also uniquely situated to satisfy the energy needs of a number of distributed ocean applications, including ocean-based sensors, monitoring equipment (for civilian, scientific, industrial, and national security functions), and autonomous vehicle recharging at sea, as well as reducing desalination costs by avoiding the step of generating electricity.

MHK technologies are at an early stage of development due to the fundamental scientific and engineering challenges of generating power from dynamic, low-velocity and high-density waves and current while surviving in corrosive ocean environments. These challenges are intensified by high costs and lengthy permitting processes associated with in-water testing. To address these challenges, the program invests in early-stage R&D specific to MHK applications to generate knowledge relevant for industry to develop innovative components, structures, materials, systems, and approaches to manufacturing. Key to this process, the program develops, improves, and validates computer modeling tools and methodologies needed to optimize device and array performance and reliability across operational and extreme conditions. It also supports testing infrastructure to enable systematic technology development testing by industry at multiple scales. The program works to aggregate, analyze and disseminate data enabling industry-led development of cheaper and more effective monitoring instrumentation, ultimately increasing permitting and regulatory process efficiencies.

The program's early R&D work in MHK focuses on addressing scientific and engineering challenges that enable breakthroughs that have broad, industry-wide benefits. It has developed strategic partnerships across the industry and into other scientific, engineering and industrial disciplines to leverage and focus resources on long-term MHK goals. Through support of device design and testing, the program has demonstrated cost and performance baselines and improved device-specific efficiency and reliability. The program has also provided critical, third-party validated data to inform continued early-stage research into new designs, materials, and systems.

Highlights of the FY 2019 Budget Request

The Water Power Program will pursue the following major activities in FY 2019:

- Increasing energy affordability for water power technologies: The program will invest in early-stage research and development to enable improvements in controls, structures, materials and power take-offs for early-stage wave, tidal and ocean current technologies, ultimately leading to reduced costs and increased competitiveness of marine energy devices. Investments in hydropower technology R&D for innovative standardized and modular approaches to hydropower development can lower overall project costs versus traditional projects at Greenfield sites and non-powered dams.
- Improving grid resiliency and reliability: The program will continue its focus on hydropower and PSH's roles in grid reliability and resiliency by continuing to support innovative PSH technologies and conducting new research to evaluate the specific grid resiliency services provided by hydropower and/or PSH. Through its partnerships with the Navy and with university-National Laboratory collaborations, the program will validate reliability of marine energy technologies and the value of integrating energy from prototype devices into the electric grid.
- Reducing regulatory burdens: The program will support the development of innovative environmental mitigation technologies and new research to inform licensing studies and requirements in order to reduce the time, cost and uncertainty of hydropower licensing. In marine energy, monitoring of open water tests and continuing to analyze and disseminate the results of new research will reduce perceived environmental risk and the time associated with device permitting.

Water Power Funding
($K)

	FY 2017 Enacted	FY 2018 Annualized CR*	FY 2019 Request	FY 2019 Request vs FY 2017 Enacted
Water Power				
Hydropower Technologies	25,000	—	35,000	+10,000
Marine and Hydrokinetic Technologies	59,000	—	10,000	-49,000
Total, Water Power	**84,000**	**83,429**	**45,000**	**-39,000**

SBIR/STTR:

- FY 2017 Transferred: SBIR $1,427,000; STTR $200,000
- FY 2018 Projected: SBIR $1,417,000; STTR $199,000
- FY 2019 Request: SBIR $1,430,000; STTR $201,000

*A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution. (These amounts are shown only at the Congressional control level and above; below that level, a dash (—) is shown).

Water Power
Explanation of Major Changes
($K)

	FY 2019 Request vs FY 2017 Enacted
Water Power	
Hydropower Technologies: In FY 2019, the subprogram provides increased funding for development of new standard, modular hydropower technologies through competitive solicitations for industry-led projects, such as turbines and civil works structures for powering non-powered dams. Funding is increased for PSH research and research into hydropower's contributions to grid resiliency, with efforts focused on low-impact pumped storage designs and grid services capabilities. The subprogram invests in industry-led R&D to develop new technologies for increasing dissolved oxygen levels at hydro facilities – a significant environmental and regulatory issue for hydropower in the eastern U.S. The subprogram is not funding the design and testing of acoustic fish tags for American Eel and Pacific Lamprey, which was completed in FY 2018. No funding is provided for implementation of Section 242 of the Energy Policy Act of 2005.	**+10,000**
Marine and Hydrokinetic Technologies: In FY 2019, no funding is provided for the construction of the open water test facility, which was fully-funded in FY 2017. Because the open water test facility is not planned to be fully operational until after FY 2020, funding is not provided for new competitive solicitations focused on development and testing of specific marine energy systems and components, such as power take-off, controls, or structural designs. The FY 2018 Request included funds to scope a 2nd wave energy prize competition, replicating the success of the 2016 Wave Energy Prize, but focused on low-power applications like marine sensors or underwater vehicle charging applications. In FY 2019, the subprogram will complete design of a prize competition to support running the competition in FY 2020.	**-49,000**
Total, Water Power	**-39,000**

Water Power
Hydropower Technologies

Description
Hydropower is the oldest and largest renewable energy generation resource in the U.S. While hydroelectricity has been in use for over a century, there is still opportunity for additional generating capacity and grid reliability services realized through novel design and operations innovations. The 2016 DOE Hydropower Vision report, which represented views regarding hydropower development across industry, environmental organizations, and all levels of government, verified this potential. The Vision identified a number of credible scenarios where industry could realize up to 50 GW of new hydropower capacity from upgrading and modernizing the existing fleet, installing generation on non-powered dams, and developing new small hydropower and pumped storage technologies.

The program's hydropower strategy is aligned to the roadmap in the Hydropower Vision, which set forth priority pathways identified by industry, environmental groups, and other hydropower stakeholders as the necessary steps to realize the full potential benefits of hydropower in the U.S. These pathways involve strengthening the body of knowledge that enables industry to develop and deploy new technologies, quantify the value of grid reliability services, address regulatory requirements, and maintain and improve the sustainability of U.S. hydropower assets. While DOE is not engaged in every activity suggested in the Vision roadmap, it leads in areas where government R&D is appropriate and most effective.

The Water Power Program targets both critical information and technology development challenges currently limiting hydropower generation, as well as research and analysis to improve understanding of any long-term costs–and potential technology solutions – associated with operating hydropower so as to maximize its long-term contributions to the grid. Examples of important technology challenges include reducing the site-specific costs of construction, powerhouse design/installation, and environmental mitigation with new standardized, modular approaches to hydropower project design at non-powered dams and new stream-reaches; turbine designs that simultaneously optimize both generation and environmental performance; evaluating technologies that allow multiple run-of-river hydropower facilities and energy storage systems to operate as a single, dispatchable system; and PSH technology configurations that reduce siting limitations and environmental impacts.

R&D efforts focus on areas where hydropower turbine manufacturers and hydropower-owning utilities are unlikely or unable to spend private capital. This typically includes the initial conceptual design, and numerical modeling and validation of technologies that can subsequently be adopted by industry for further development and commercialization. For entirely new and unproven approaches to hydropower development, such as modular hydropower or innovative PSH designs, the program partners with competitively-selected technology developers to perform early-stage research focused on innovative approaches to hydropower design and configurations, improving DOE's ability to propagate cost-reductions and environmental performance improvements across the industry. Hydropower R&D efforts are closely coordinated with the Federal agencies that own and operate half of the hydropower capacity in the U.S. to inform operations & maintenance decision-making processes across the U.S. hydropower fleet, ensuring that hydropower can continue to maintain its value to the U.S. electric grid. While a small portion of these agencies' budgets also go toward R&D, such efforts are targeted more to solve specific pressing O&M challenges associated with their own fleets as opposed to generating knowledge benefits relevant to the hydropower industry at-large.

Traditionally, hydropower was designed to provide optimal performance and value when operating at a constant output level. Both hydropower and PSH, however, are capable of adjusting their output quickly and on demand, providing a highly flexible generation source with critical services that help maintain the reliability and resiliency of the nation's power grid. Services include quick response dispatchable power that can be used to meet peak demand and balance variable renewables like wind and solar, as well as a discrete set of technical capabilities ranging from sub-second frequency response to black-start capabilities that can help the grid quickly recover from an outage. Pumped storage provides many of these same services, in addition to the ability to absorb excess generation during the pumping mode and store power for when it is needed most. The importance of these capabilities and flexibility will increase as the nation's electric grid evolves, however the specific design and operational attributes that will prove most valuable are not well understood and remunerated, which leads to potential inefficiencies in how existing power and ancillary services are procured and compensated. The program continues research to quantify and understand the economic value of the services provided by hydropower and PSH, and the additional costs or technical requirements of operating hydropower systems in a changing grid. In addition, the program continues to drive innovation in the design of PSH, as traditional designs are capital intensive, limited in where they can be sited, and difficult to finance. New transformative designs could reduce capital investment requirements, expand siting possibilities, and shorten development timeframes for new facilities, thus creating incentive for private investment.

Efforts to improve sustainability and environmental performance of the nation’s hydropower systems are inherently linked to the development of new hydropower technologies and modernization of the existing fleet. Scientific advances that allow developers and operators to more effectively identify and mitigate potential impacts ultimately allows for more new hydropower development, more effective utilization of existing hydropower, and reduced regulatory costs. The program continues to develop turbine design and evaluation tools based on new biological research that enable manufacturers to design new turbines (both for new projects and replacements of existing turbines) that simultaneously optimize generation and environmental performance. The program-funded research informs regulatory study requirements for hydropower permitting and the program also engages with stakeholders and partner agencies to provide unbiased scientific data to facilitate targeted improvements to regulatory processes. For example, the 2016 Memorandum of Understanding (MOU) between the U.S. Army Corps of Engineers (USACE) and Federal Energy Regulatory Commission (FERC) has helped align licensing activities for the development of private hydropower facilities on Corps non-powered dams.

In FY 2019 ($3.5M), the Hydropower subprogram will build on the past three years of research into new standardized, modular approaches to hydropower project design, and develop new engineering tools (e.g., hydrodynamic modeling) and scientific information that the hydropower industry can use for project development at non-powered dams or new stream-reaches. The subprogram will partner with small hydropower companies through competitive funding opportunities to implement and validate these design models by designing and testing small scale physical modules.

In FY 2019 ($2.5M), the subprogram will issue a competitive solicitation to continue early-stage research to design and evaluate new PSH technology configurations that dramatically reduce geographic siting limitations and environmental impacts. Additionally, the subprogram will work with the national laboratories to continue technology and analytical research to evaluate and improve the contribution of PSH and traditional hydropower to grid resiliency and stability, including technologies that would allow multiple small run-of-river hydropower facilities to be paired with an energy storage system (e.g., batteries) and operated together as a single, dispatchable system.

In FY 2019 ($4.5M), the subprogram will continue to develop and finalize design tools based on laboratory-based biological research and field data analysis to enable manufacturers to improve turbine designs that simultaneously optimize both generation and environmental performance. Competitively-selected industry projects will develop new technologies that increase dissolved oxygen levels at hydro facilities, identified by industry as one of the most significant environmental and regulatory issues facing hydropower in much of the eastern U.S. The subprogram will also continue to provide one-of-a-kind unit, plant and integrated river-basin level data and analysis across the hydropower fleet, essential to inform the critical R&D needed for future hydropower growth, the optimization of operations of the existing projects, and priority areas of regulatory process improvements.

In FY 2019 ($20M), the subprogram will support efforts to further develop and validate innovative PSH turbine-motor-generator configurations and integrated system designs with application limited to closed-loop designs. The subprogram will also support hydropower energy grid service capabilities through research to optimize hydropower’s ability to provide quick response and be operated flexibly over long periods of time. As a part of GMI, Beyond Batteries focuses on advances in controllable loads, hybrid systems incorporating generation from all sources, and new approaches to energy storage, which are essential to increasing the reliability and resiliency of our energy systems. Advances in these areas will allow for loads to be combined with generation from all sources to optimize use of existing assets to provide grid services, and increase grid reliability.

Hydropower Technologies

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Hydropower Technologies $25,000,000	**$35,000,000**	**+$10,000,000**
• The program continued National Laboratory efforts to develop design specifications and computational modeling tools for standardized, modular hydropower technologies	• Building on the past three years of research into new standardized, modular approaches to hydropower project design, the subprogram will issue a competitive solicitation for up to five awards to develop new engineering tools (e.g., hydrodynamic modeling) and scientific information that the hydropower industry can use for project development at non-powered dams or new stream-reaches; and will continue national laboratory efforts to develop design specifications and computer modeling tools for standardized, modular hydropower technologies.	• FY 2017 efforts were focused on developing design principles that ultimately require validation by hydropower industry developers to further refine and improve designs for wider application. In FY 2019, the program will select projects under a competitive solicitation to carry out this validation.
• This element was not funded in FY 2017	• Competitively-selected industry projects (up to three awards) to develop new technologies that increase dissolved oxygen levels at hydro facilities.	• Based on feedback provided by industry stakeholders at the 2017 Hydropower Industry Summit, depletion of dissolved oxygen levels are the most significant environmental and regulatory issue facing hydropower in much of the eastern U.S, and is an area where early-stage R&D can lead to innovative solutions that will simultaneously improve environmental performance and reduce the costs of regulatory compliance.
• Continue with the third year of a 4-year partnership with the US Army Corps of Engineers on the design and testing of acoustic fish tags for American Eel and Pacific Lamprey.	• This element is not funded in the FY 2019 Request.	• In FY 2018, the subprogram is finalizing the 4-year project by completing prototype development and initial testing of advanced micro-scale fish tags and anticipates no further funding requirements for FY 2019.
• Techno-economic analysis of the value of pumped storage hydropower at two sites with high levels of intermittent renewable energy generation in the U.S., including economic analysis of the full range of market-based revenue streams, regional cost savings and environmental benefits.	• This element is not funded in the FY 2019 Request.	• FY 2017 efforts were directed by Congress and fully funded. No FY 2019 funds are requested.

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
• This element was not funded in FY 2017.	• The subprogram will support technology and analytical research investments at the National Labs to evaluate technologies that would allow multiple small run-of-river hydropower facilities to be operated together as a single, dispatchable system; and issue a competitive solicitation for up to five awards to design and evaluate new PSH technology configurations.	• In the FY 2019 Request, the subprogram funds critical technology research challenges currently limiting further PSH development by evaluating technology configurations that reduce siting limitations and environmental impacts as well as building on and expanding previous national lab work that evaluates the flexibility and technical capabilities that hydropower and PSH provide to grid reliability and resiliency.
• Implementation of section 242 of the Energy Policy Act of 2005 (P.L. 109-58).	• This element is not funded in the FY 2019 Request.	• No funds are provided in the FY 2019 Request for implementing incentive payments for deployment of hydropower projects as instead the sub-program focuses FY 2019 efforts on early stage research and development.
• This element was not funded in the FY 2017 Request.	• Combination of competitive funding solicitations and National Laboratory funding to further develop and critically validate novel, innovative turbine-motor-generator configurations and integrated system designs, provide test data on new design concepts (including modular configurations).	• This is a new activity in FY 2019.
• This element was not funded in the FY 2017 Request.	• National Laboratory supported R&D focusing on researching, validating, and improving the ability of hydropower to operate flexibly and provide essential grid services.	• This is a new activity in FY 2019.

Water Power
Marine and Hydrokinetic Technologies

Description

Marine and hydrokinetic (MHK) energy technologies convert the energy of waves, tides, river currents and ocean currents into electricity. Resource assessments show the U.S. has 1250–1850 terawatt-hours per year[1] (TWh/yr) of untapped, technically extractable MHK resource potential, equivalent to nearly 30 percent of total electricity generation in the U.S. Developing just one-sixth of the available wave energy in the five Pacific states could power more than five million homes. MHK is a predictable, forecastable resource with generation patterns typically complimentary to other renewables such as onshore wind and solar, enhancing its potential to augment grid stability. Industry deployment of MHK technologies for bulk power generation is nascent, and significant research and development is required to realize cost-competitiveness at the utility scale for MHK technologies. Other applications, including power for remote coastal communities with high electricity costs, charging for ocean-based sensors and underwater vehicles, and non-electric uses like desalination provide industry with opportunities to develop and deploy MHK technologies in the near-term.

The Water Power Program's strategy to help catalyze MHK development focuses primarily on technology research and design tools to enable industry to reduce cost and improve performance of MHK technology concepts. This research involves testing proof-of-concept systems in laboratory and ocean settings to understand performance characteristics, identify and mitigate reliability risks, and provide data to inform future R&D to improve early-stage designs across the industry. The MHK subprogram is committed to investment in early-stage R&D that enables the domestic MHK industry to advance toward achieving cost competitiveness with local hurdle rates in early adopter markets, while working toward long-term cost-competitiveness at the utility scale. This will be accomplished by focusing on design concepts that have the potential to increase energy capture and annual energy production of devices, improve reliability and availability, and reduce capital and operating and maintenance costs if further developed and deployed by industry.

Advanced controls research remains a major programmatic focus, as studies have shown that advanced controls improvements can provide significant increases in energy capture, and recent work has achieved advances doubling the energy capture of previous methods. Controls strategies and technologies are also being leveraged from other industries (e.g. aerospace, defense) that can maximize power production over a range of ocean conditions. Funding will continue DOE's commitment to a joint DOE-Navy project targeting advanced controls, and continues National Laboratory support through technical assistance and partnerships for accessing lab capabilities for competitively selected industry awards to develop new marine energy control systems. Other priorities include improving and validating modeling tools and methodologies needed to optimize device and array performance and reliability across operational and extreme conditions, R&D of advanced materials capable of operating reliably and cost effectively in a marine environment, and investigating new approaches for safe and cost-effective installation, grid integration, operations, maintenance, and decommissioning of MHK projects. These are prioritized research areas where targeted government support at early-stages in the research and development process can generate knowledge benefits applicable to MHK technology development and deployment by industry, as well as broader knowledge spillover benefits from innovations in materials, sensors, and modeling capabilities.

For industry to move MHK technologies beyond small-scale prototypes requires in-water validation of performance and efficiency, as well as reliability, especially in extreme weather. Due to complexity in the wave physics of high-energy sea states and the fluid dynamics of sub-sea currents, even simple MHK prototypes must be validated in the ocean to acquire data that accurately reflects system performance. This validation is expensive and time consuming due to the unique challenges of the marine environment, and it is generally beyond the capacity of pioneering technology companies that comprise the industry. The subprogram partners with industry members to support the development and testing of early-

[1] This range was derived from a sum of ranges related to tidal, wave, and current potential. These ranges can be found within the reports "Mapping and Assessment of the United States Ocean Wave Energy Resource" (https://energy.gov/sites/prod/files/2013/12/f5/mappingandassessment.pdf), "Assessment of Energy Production Potential from Tidal Streams in the United States" (https://energy.gov/sites/prod/files/2013/12/f5/1023527.pdf), and "Assessment of Energy Production Potential from Ocean Currents along the United States Coastline" (https://energy.gov/sites/prod/files/2013/12/f5/energy_production_ocean_currents_us_0.pdf).

stage prototypes, as well as to make available dedicated testing infrastructure to reduce the inefficiency associated with each developer investing in its own separate testing cables and permits. The results of in-water tests are collected and aggregated by DOE and made broadly available to ensure knowledge generated through public funding is widely available.

The subprogram also supports efforts to model and predict the environmental effects of marine energy devices, through research that simulates device-ecosystem interactions and enables industry to develop new technologies that more accurately monitor devices in the water. Subprogram research generates new data and synthesizes and disseminates existing data that would not otherwise be available to resource agencies and regulators. The subprogram is also moving forward with research continuing the development of first-ever national wave classification metrics and site-specific wave energy characterization. This work is similar to much of what DOE has provided historically for the wind and solar industries including national level maps and dynamic resource predictions. This type of national level, unbiased information is essential both to help industry make informed project siting decisions and also to informing device design and DOE’s own R&D priorities.

The aforementioned priorities are areas where targeted government support can broadly benefit the entire research and technology development community. To ensure funds are focused on impactful research efforts, the subprogram activities will align with the comprehensive marine energy strategy finalized in FY 2018, incorporating feedback and input on the draft strategy published in FY 2017. The strategy will highlight and prioritize pathways through strategic investments in early-stage R&D that enable industry to effectively drive down the cost of energy and overcome market barriers.

In FY 2019 ($5.5M), the subprogram will continue ongoing research to develop and evaluate next-generation wave and tidal system designs, supporting and assessing promising components and early-stage integrated systems through National Laboratory and university research, as well as industry partnerships for prototype development and validation. Funding would continue DOE's commitment to a joint DOE/Navy project targeting advanced controls, the highest early-stage R&D priority for marine energy as well as critical R&D in advanced materials capable of operating reliably and cost effectively over long periods of time in marine environments, which is critical for the industry to reach cost competitiveness. This research, together with DOE-funded efforts from the National Laboratories, academia, and private industry, advances integrated wave system design — which evaluates next-generation wave and tidal system designs at low technology readiness levels, with the goal of assessing promising, early-stage innovations.

FY 2019 ($2M) represents the final year of laboratory support for performance validation of industry-developed monitoring instrumentation systems. Another research effort will examine fish interactions with tidal turbines in a natural environment; this builds upon other studies over several years and has the potential to dramatically reduce regulatory concerns over this high-profile issue. Aggregating and analyzing existing information on environmental impacts of MHK deployment and sharing the results with regulatory, development, and research communities can also reduce permitting and regulatory delays.

In FY 2019 ($0.6M), the subprogram supports research to develop national wave classification metrics and site-specific wave energy characterization.

Marine and Hydrokinetic Technologies

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Marine and Hydrokinetic Technologies $59,000,000	**$10,000,000**	**-$49,000,000**
• Design, procurement, and construction for the recently-awarded open-water wave energy test facility.	• No funding is requested as full funding was appropriated in FY 2017.	• Funds provided in FY 2017 were used to complete the award of the facility's construction which is anticipated to be completed by 2021.
• Competitive solicitations for a balanced portfolio of industry-led RD&D of ocean, river, and tidal energy conversion components and systems.	• No funding is requested for this activity.	• Four projects under the FY 2017 competitive solicitation were selected and awarded. As the open water wave energy test facility is not planned to be fully operational until after FY 2020, the FY 2019 Request provides no funding for new competitive solicitations focused on development and testing of specific marine energy systems and components.
• Deliver Wave Energy Converter (WEC) advanced control strategies complete with associated validation data from testing control strategies in a wave tank (Navy collaboration). A second testing campaign was conducted at the Carderock wave tank and six different control strategies were tested and compared. The WEC operated in 1-degree of freedom.	• The subprogram will continue DOE's commitment to a joint DOE/Navy project targeting advanced controls in the FY 2019 Request. The same control strategies and WEC used in FY 2017 will be tested operating in 3-degrees of freedom.	• No change from FY 2017.
• Materials development and structural health monitoring. Material property characterization was completed at the coupon level.	• The subprogram will continue research and development of advanced materials and health monitoring to improve operational reliability and cost effectiveness of marine energy devices. Materials testing will be scaled up to the sub-component level for composite property characterization.	• No change from FY 2017.

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
• Preliminary research to identify specific design requirements for future systems targeted toward a range of applications including high-cost electric or remote and/or off-grid communities as well as non-grid applications such as underwater sensors.	• The subprogram will structure a research, design and test competition for prototype testing of MHK devices designed for promising early-market opportunities. Based on scoping efforts, including a public FORUM held in FY 2018, 1-3 markets will be targeted for competition.	• Numerous potential unique and alternative market applications for MHK technologies could more rapidly allow industry to develop and reduce technology costs. These early market opportunities include power for remote coastal communities and DOD installations with high electricity costs, charging for ocean-based sensors and underwater vehicles, and non-electric uses like desalination. Development and testing for these applications will provide critical data and experience that will accelerate design improvements and cost reductions for grid-connected power generation.
• Environmental monitoring performance, cost evaluation, and instrumentation testing campaign. Workshop was held to identify gaps in instrumentation capabilities for the MHK industry.	• Laboratory support for performance validation of industry-developed monitoring instrumentation systems. Develop instrumentation capabilitie(s) identified as a gap during the 2017 workshop.	• No change – FY 2019 represents the final year of funding.
• Initiate large-scale field study to evaluate strike-risk to fish from tidal turbines.	• Research by the national laboratories examining fish interactions with tidal turbines in a natural environment	• No change from FY 2017 — Builds upon other studies over several years and has the potential to dramatically reduce regulatory concerns over this high-profile issue.
• Continue to support high-fidelity resource characterization to further understand how to design for and harness the resource potential.	• Research by the national laboratories to develop national wave classification metrics and site-specific wave energy characterization.	• No change from FY 2017.

Geothermal Technologies

Overview

Geothermal energy is a domestic energy resource from the heat of the earth, which represents a reliable, secure, clean, and nearly inexhaustible baseload energy source. The current domestic installed capacity is over 3.8 gigawatts (GW).[1] Current estimates of technically-recoverable resource potential include an estimated 30 GW of new undiscovered hydrothermal resources and 100+ GW of new geothermal energy accessible through Enhanced Geothermal Systems (EGS).[2] However, technological innovation is required for industry to convert these resources into useful energy services. The mission of the Geothermal Technologies Program (GTO) is to support early-stage research and development (R&D) to strengthen the body of knowledge upon which industry can accelerate the development and deployment of innovative geothermal energy technologies.

The program's technology portfolio prioritizes early-stage R&D in two closely related geothermal categories: hydrothermal and EGS.[3] This research addresses the high risk in early-stage R&D that industry does not have the technical capabilities or institutional knowledge to conduct. The geothermal industry operates in a harsh subsurface environment with unique technical and operational challenges. Foremost among those challenges is that the resource is "out of sight" at a depth of approximately two to five kilometers, in hard, abrasive rock formations at elevated temperatures and pressures well beyond those typically encountered in oil, gas, or other subsurface operations. Consequently, DOE involvement in early-stage research and development enables the geothermal sector to develop innovative technologies that will help harness American energy resources safely and efficiently.

Highlights of the FY 2019 Budget Request

The Geothermal Technologies Program will pursue the following major activities in FY 2019:

- Frontier Observatory for Research in Geothermal Energy (FORGE): The FY 2019 request will support the stimulation of two or more full-sized wellbores at the Frontier Observatory for Research in Geothermal Energy (FORGE), drilling of monitoring bores, long-term geophysical monitoring and further characterization of the subsurface. The FORGE team will also issue an R&D solicitation focusing on reservoir creation and sustainability technologies.
- EGS Collab: FY 2019 will focus on the design of the stimulation tests based on the detailed site characterization, thermal-hydrological-mechanical-chemical (THMC) modeling of desired tests to optimize preliminary test design, and the design and installation of novel geophysical, hydrological, and geomechanical monitoring networks to track and image the fracturing experiments in situ for the first time ever.
- Hydrothermal: In FY 2019, the program will release a Subsurface R&D funding opportunity announcement focusing on Subsurface Stress Measurement and Simulation to enable the collection of stress data at reservoir scale to better understand fracture propagation, permeability distribution, reservoir management, fluid production, and wellbore integrity.
- Beyond Batteries: As a part of DOE's Grid Modernization Initiative, Beyond Batteries focuses on advances in controllable loads, hybrid systems incorporating generation from all sources, and new approaches to energy storage, which are essential to increasing the reliability and resiliency of our energy systems. FY 2019 GTO funds will support analysis in areas such as subsurface thermal energy storage and thermal management of reservoirs and evaluation of geothermal's potential to respond to electrical demand fluctuations, addressing activities that can operate during times of curtailment and hybrid technologies that integrate baseload geothermal with intermittent generation. Work will support improved grid reliability and resilience through analyses focused on improving the ability for geothermal power to be operated flexibly and provide essential grid reliability services.

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[1] Net Generation by State by Type of Producer by Energy Source (EIA-906, EIA-920, and EIA-923) - 2015, https://www.eia.gov/electricity/data/state/, released Oct. 12, 2016 and EIA Electric Power Monthly March 2017.
[2] Williams et al., 2008a; USGS Fact Sheet 2008-3082; http://pubs.usgs.gov/fs/2008/3082.
[3] Hydrothermal resources exist where there is sufficient temperature, permeability, and fluid in the subsurface such that fluids can flow naturally at economic rates for power generation. EGS reservoirs require rock stimulation for permeability enhancement and fluid injection to allow commercial-scale fluid flow.

Geothermal Technologies Funding ($K)

	FY 2017 Enacted	FY 2018 Annualized CR*	FY 2019 Request	FY 2019 Request vs FY 2017 Enacted
Geothermal Technologies				
Enhanced Geothermal Systems	42,696	—	19,715	-22,981
Hydrothermal	14,152	—	4,200	-9,952
Systems Analysis	3,680	—	6,085	+2,405
Low Temperature and Coproduced Resources	8,972	—	0	-8,972
Total, Geothermal Technologies	**69,500**	**69,028**	**30,000**	**-39,500**

SBIR/STTR:

- FY 2017 Transferred: SBIR $1,615,000; STTR $227,000
- FY 2018 Projected: SBIR $1,604,000; STTR $225,000
- FY 2019 Request: SBIR $960,000; STTR $135,000

*A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution. (These amounts are shown only at the Congressional control level and above; below that level, a dash (—) is shown).

Geothermal Technologies
Explanation of Major Changes
($K)

	FY 2019 Request vs FY 2017 Enacted
Geothermal Technologies	
Enhanced Geothermal Systems: The reduction in funding is attributed to a decreased request for out-year FORGE mortgage (a difference of $25.0 million between the FY 2017 Enacted and the FY 2019 Request). FORGE is fully funded through Year 2 of Phase 3 (FY 2020) through a combination of the request and prior year balances. An increase of $1.9 million for the EGS Collab is requested in FY 2019 to fund experiments focused on mixed-mode fracturing.	**-22,981**
Hydrothermal: No funds are requested for three national lab projects targeting innovative approaches to reducing the cost of geothermal exploration. These projects are slated to end in FY 2018. In addition, FY 2017 marked the last year of funds for the completion of the Play Fairway Analysis effort. The Subsurface R&D national laboratory projects in wellbore integrity will enter into their final year (year three). In FY 2019, the program will release a Subsurface R&D funding opportunity announcement focusing on Subsurface Stress Measurement and Simulation to enable the collection of stress data at reservoir scale.	**-9,952**
Systems Analysis: The change in the Systems Analysis subprogram is attributed to the completion of the GeoVision study in FY 2018 and work under the start of the EERE Beyond Batteries initiative in FY 2019. Up to $5.0 million will be awarded through a Funding Opportunity Announcement (FOA) for the EERE Beyond Batteries initiative, which will include research on improved grid reliability and resilience through enhancing the ability of geothermal power to be operated flexibly and provide essential grid reliability services.	**+2,405**
Low Temperature and Coproduced Resources: No funding requested in FY 2019.	**-8,972**
Total, Geothermal Technologies	**-39,500**

Geothermal Technologies
Enhanced Geothermal Systems

Description

Enhanced Geothermal Systems (EGS) are engineered reservoirs, created where there is hot rock but little to no natural permeability or fluid saturation present in the subsurface. Underpinning the EGS subprogram's major technical thrusts are fundamental geoscience challenges whose resolution hinge on collaborative, early-stage R&D. The focus of the EGS subprogram is to gain an evidence-based understanding of these basic science challenges surrounding long-term subsurface heat flow, permeability enhancement, and stress evolution to enable development of sustainable, man-made heat exchangers. In the long term, strengthening the body of EGS knowledge through early-stage R&D will enable industry to develop a baseload energy resource estimated at over 100 GW[1].

To develop an EGS, fluid is injected into the subsurface at low-to-moderate pressures under a safe, controlled, environmentally responsible stimulation process that will cause pre-existing fractures or weaknesses in the rock fabric to open. The pressure increase causes displacements along the fracture planes and zones of rock heterogeneity, which results in increased permeability and allows fluid to circulate throughout the rock, heating up during circulation. Via a production well, this heated fluid then transports the heat to the surface, where electricity generation and distribution occurs.

EGS research is in a relatively early stage, yet it shares common challenges with other subsurface industries. Operational data and research experience to date indicate that overcoming the challenges in EGS technology development requires a broad-based, multidisciplinary approach. Critical to advancing EGS are technologies that facilitate characterization of local stress, chemical constituents, and evolution of fluid and thermal pathways through space and over time. A final overarching hurdle is sustainable operation, which requires sufficient productivity for power generation without excessive flow localization or reduced flow rates. Inherent in this valuable multi-disciplinary approach is collaboration across the government, academic and private sectors, which adds significant value to the research that is underway in the EGS subprogram's two major initiatives, the Frontier Observatory for Research in Geothermal Energy (FORGE) and EGS Collab, discussed below.

In FY 2019, the Budget provides $10 million for continued Phase 3 work at FORGE. FORGE is a full-scale field laboratory with a focus on developing, testing, and validating technologies to improve EGS reservoir access, creation, and sustainability. By enabling transformative and high-risk science and engineering, FORGE is an essential step toward establishing the capability to improve our understanding of EGS concepts. It is a collaborative and inclusive effort involving a diverse group of geothermal and subsurface stakeholders; participation and contribution from industry, DOE National Laboratories, and academia are integral to its success.

Requested funding for FORGE will enable GTO to complete site preparation activities and issue a Funding Opportunity Announcement in FY 2019, with funding expected to be costed in year two (FY 2020) and three (FY 2021) of Phase 3. These funds will support the completion of the second full-sized wellbore, stimulation of at least two full-sized wells, drilling of monitoring bores, long-term geophysical monitoring and further characterization of the subsurface. The final FORGE team will also issue an R&D solicitation focusing on reservoir creation and sustainability technologies; researchers will use the subsurface characterization data collected since the inception of the project to develop methodologies, tools, and techniques for isolating fracture zones, enhancing permeability, and sustaining that permeability to facilitate long-term power generation. The EGS Subprogram in collaboration with the FORGE team will select ten to twenty proposals submitted by the broader scientific and technical community, potentially including collaborations on crosscutting R&D with other DOE offices engaged in complementary subsurface energy research.

In addition, the subprogram will maintain investment in R&D that feeds into the FORGE operations, such that basic geoscience and computational challenges are resolved and can inform the design of FORGE wells and stimulations. Advanced knowledge of permeability creation, enhancement, and sustainability gained from work at the EGS Collab will be directly applied at FORGE. Collab brings together a National Laboratory-led team comprised of eight national labs, academia, and industry to develop a first-of-its-kind intermediate-scale, in-situ experimental site in a readily accessible

[1] Williams et al., 2008a; USGS Fact Sheet 2008-3082; http://pubs.usgs.gov/fs/2008/3082.

underground facility at intermediate (on the order of 10 m) scale. Accessibility is limited in deep hot reservoirs because environmental conditions at 10,000 feet reduce our ability to physically observe fundamental processes critical to EGS development. The EGS Collab project provides researchers the ability to meet the fundamental challenges of understanding and predicting permeability enhancement and evolution in crystalline rocks by observing the creation of fractures in-situ for the first time. A team of the world's most skilled and experienced scientists and engineers in the areas of subsurface process modeling, monitoring, and experimentation will model, test, and validate how to create sustained and distributed permeability for heat extraction from the reservoir by generating new fractures that will be imaged via high-resolution geological and geophysical characterization of the rock before, during, and after stimulation.

In FY 2019, the Budget provides $7.9 million to support experiments focused on mixed-mode fracturing (where both shearing and tensile fracturing contribute to reservoir growth) will take place within the Sanford Underground Research Facility (SURF) Mine in South Dakota. The success of FORGE will be accelerated by near-term research and development activities and testing at these intermediate scales that can refine our understanding of rock mass response to stimulation and provide a test bed for the validation of thermal-hydrological-mechanical-chemical (THMC) modeling approaches.

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Enhanced Geothermal Systems $42,696,000	**$19,715,000**	**-$22,981,000**
• Frontier Observatory for Research in Geothermal Energy (FORGE): The program will use FY 2017 funds to support full implementation of the selected FORGE site in years one and two (five years total) of Phase 3 (FY 2018 and FY 2019). The first competitive FORGE R&D solicitation will be issued in FY 2019 with FY 2017 funds.	• FORGE: The FY 2019 request will support the completion of the second full-sized wellbore, drilling of monitoring bores, long-term geophysical monitoring and further characterization of the subsurface. The FORGE team will also issue an R&D solicitation focusing on reservoir creation and sustainability technologies.	• Phase 3 FORGE field operations will continue throughout FY 2018 and into 2019 with prior year appropriations. Program will use FY 2017 funding to drill the first full-sized well. FY 2017 and FY 2019 funds will support drilling the second FORGE well. FY 2019 funding will also support stimulation and monitoring activities as well as an additional solicitation open to the public. All baseline geophysical and geochemical characterization, data sharing, as well as robust communications will continue throughout the entirety of Phase 3.
• EGS Collab: The EGS Collab was awarded in FY 2017 to eight National Laboratories and six university partners, led by Lawrence Berkeley National Laboratory. FY 2017 work focused on site selection within the mine, obtaining the appropriate permits and site clearances, experimental design for the first fracture experiment, and drilling of eight wells. The experimentation conducted in 2017 will validate THMC models developed prior to stimulation testing, leading to more complex and focused experiments in FY 2018.	• EGS Collab: FY 2019 will focus on the design of the stimulation tests based on the detailed site characterization, THMC modeling of desired tests to optimize preliminary test design, and the design and installation of novel geophysical, hydrological, and geomechanical monitoring networks to track and image the fracturing experiments in situ for the first time ever.	• EGS Collab: The simple experimentation conducted in FY 2017 and FY 2018 (on hydraulic fracturing) will validate modeling assumptions, leading to more complex and focused experiments in FY 2019 that involve mixed mode fracturing experiments, which represent most realistic scenarios for reservoir creation in geothermal environments.

Geothermal Technologies
Hydrothermal

Description

Hydrothermal resources have three key elements associated with geologically active areas: heat, fluid, and permeability (the ability for fluid to flow through rock). The origin of permeability pathways must be thoroughly understood in order to better characterize how fluid will carry heat to the surface for its intended use. In order to control and predict fracture creation and propagation, and to determine if a region is appropriate for geothermal development, in situ stress magnitudes and directions must be understood. Currently, we can only infer stress magnitude and direction from deep wellbore data. If geophysical data sets collected at the surface can approximate stresses in the reservoir, this aspect of reservoir characterization could be performed upfront prior to drilling, at significantly lower cost, enabling more appropriate site selection for both hydrothermal and EGS development, thus enabling better well targeting. Pursuing enhanced resolution of subsurface stress as early-stage R&D will result in the development of transformative subsurface applications.

The Hydrothermal Subprogram seeks to develop new methodologies for inferring the state of stress on a reservoir / regional scale using field data sets comprised of indirect observations rather than direct wellbore data. GTO will issue a funding opportunity announcement encouraging partnerships among industry, academia, and National Laboratories to collaborate on early-stage R&D into meso-scale (0.1-10km) subsurface stress detection with improved resolution. The increased understanding of stress in the subsurface resulting from these simulation and inversion methodologies will enable the geothermal community to improve reservoir management, fluid production, and wellbore integrity, key components of geothermal resources.

Understanding subsurface stress attributes provides gateways into numerous correlative areas of subsurface research and is relevant to a variety of agencies that focus on subsurface research such as USGS, DOE Offices of Fossil Energy and Environmental Management, the National Science Foundation (NSF), and the Intelligence Community. GTO seeks to share information on and results from this early-stage research and development for the benefit of the larger subsurface community.

Hydrothermal early-stage research investments and collaboration can enable industry to reduce the upfront cost of exploration and resource evaluation to enable the production of cost effective clean, renewable baseload energy. Geothermal power production derives from a reliable, secure fuel source that supports domestic energy security. Understanding reservoir stress will lead to more efficient resource extraction by increasing the understanding of permeability formation and sustainability that will address the goal of meeting $0.09/kWh by 2022 from currently undiscovered hydrothermal resources.

Geothermal Technologies
Hydrothermal

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Hydrothermal $14,152,000	**$4,200,000**	**-$9,952,000**
• Play Fairway Analysis (PFA): Phase III of PFA will focus on drilling and validation of selected PFA methodologies from Phase II.	• PFA: No funding requested.	• PFA: All projects under the PFA effort will be been completed at the end of FY 2018. No additional solicitations or awards planned.
• Hydrothermal Lab R&D: Lab projects in year two of three: ▪ Microhole drilling: a comparison of the efficiency of various microhole drilling technologies will be completed. ▪ Subsurface imaging: testing new imaging processing using a real-world data set. ▪ Cements: evaluate multiple cement recipes for durability and self-healing characteristics.	• Hydrothermal Lab R&D: No funding requested.	• Hydrothermal Lab R&D: With the completion of the Hydrothermal lab R&D projects, resources are shifted to the Subsurface R&D FOA in FY 2019.
• Subsurface R&D: Three Subsurface R&D laboratory projects awarded in FY 2017 investigating wellbore integrity.	• Subsurface R&D: Funding opportunity announcement (FOA) to support 2 to 5 fully-funded, two-year projects focused on Subsurface Stress Measurement and Simulation to enable the collection of stress data at reservoir scale to understand fracture propagation, permeability distribution, reservoir management, fluid production, and wellbore integrity.	• The three Subsurface R&D laboratory projects awarded in FY 2017 investigating wellbore integrity will continue through FY 2019. The FY 2018 projects on waterless stimulation proposed in the FY 2018 Budget Request will broaden subsurface fracture propagation knowledge. Subsurface Stress Measurement and Simulation will be a new FY 2019 FOA.

Geothermal Technologies
Systems Analysis

Description

The goal of the Systems Analysis subprogram is to identify and address barriers to geothermal adoption in the U.S. and validate and assess technical progress across the geothermal sector primarily to inform the direction and prioritization of early-stage R&D. The Systems Analysis subprogram takes a holistic analytical approach across the program's technology portfolio to evaluate trends, conduct impact analyses, identify best practices, and identify key investments needed to refine the Geothermal R&D portfolio aimed at increasing knowledge and understanding of complex geothermal systems and technologies to convert geothermal resources into useful energy. The Systems Analysis subprogram primarily conducts analyses in the following areas: the environmental impacts of geothermal, the policy and regulatory barriers to development and deployment, economic modeling and validation of geothermal technologies, and collecting and disseminating data for stakeholder use to spur geothermal development. Lessons learned resulting from these analyses are subsequently incorporated into the program's strategic planning and either validate or refine the program's overall direction of early-stage R&D. The Systems Analysis subprogram conducts these activities in partnership with the DOE National Labs, Federal agencies, academic institutions, and industry stakeholders to maximize interagency coordination to provide greater impact than that of individual agency activities.

In FY 2019, the program will continue support ($0.9M) for data collection and dissemination across all Geothermal Technologies subprograms. This includes continuing input into the Geothermal Electricity Technology Evaluation Model (GETEM) that is an open source techno-economic analysis tool used by industry to evaluate geothermal prospects, and assisting FORGE teams in deploying a node on the National Geothermal Data System (NGDS) tailored to researcher data requirements, which will expedite EGS research results by leveraging data collection efforts-to-date. The National Geothermal Data System (NGDS) is an open-source, non-membership data repository used by industry to leverage existing data to evaluate a geothermal prospect reducing the need to capture duplicate and costly data. The Systems Analysis subprogram will deploy integrated datasets from Hydrothermal efforts into the NGDS to maximize the number of mapping tools that industry and academia can utilize, thereby reducing the time and cost of determining geothermal potential for a given area.

Additionally, the Geothermal Technologies Program will support improved grid reliability and resilience through the Beyond Batteries initiative. This work will focus on improving the ability for geothermal power to operate flexibly over long periods of time (dispatchability) and to provide essential grid reliability services since it is "always on." Key areas of emphasis include:

- Reservoir Thermal Management: Focus on predicting the impact of reservoir thermal drawdown in flexible generating configurations or with a hybrid power production system as well as evaluating the storage of heat in a reservoir for later use (Borehole or Aquifer thermal energy storage (TES)).
- Electrical Demand Fluctuation and Grid Disturbance Response: Focus on evaluating the ancillary services geothermal energy can provide and an estimate of their value.
- Hybrid Operations: Focus on evaluating primarily solar hybrid systems with TES (but also fossil and other hybrids) operating in a dispatchable mode along with Compressed Air Energy Storage (CAES) that incorporates geothermal power production into storage applications.
- Thermal Demand: Focus on evaluating the on-site thermal demand applications (e.g. desalination).

Systems Analysis

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Systems Analysis $3,680,000	**$6,085,000**	**+$2,405,000**
• GeoVision Study: The Program conducted a robust Geothermal Vision Study to illustrate the geothermal potential and impacts based on scenarios within a geothermal continuum addressing the valuation of a full spectrum of geothermal technologies, including both power generation and direct use.	• GeoVision Study: No funding requested.	• GeoVision Study: Effort concluded in FY 2018.
• FY 2017 funds supported the Geothermal Electricity Technology Evaluation Model (GETEM) and assisting the FORGE teams in deploying a node on the National Geothermal Data System (NGDS). In addition, Technical Monitoring Teams provided independent expert consultation to DOE on major GTO projects.	• FY 2019 work will continue to support the development and maintenance of Geothermal Electricity Technology Evaluation Model (GETEM) and assisting the FORGE teams in deploying a node on the National Geothermal Data System (NGDS). In addition, Technical Monitoring Teams will continue to provide independent expert consultation to DOE on major GTO projects.	• Technical Monitoring Team will provide a more limited level of consultation support on GTO projects in FY 2019 as the number of GTO projects is reduced.
	• Beyond Batteries: Issue a Funding Opportunity Announcement (FOA) to support improved grid reliability and resilience by focusing on improving the ability for geothermal power to operate flexibly and provide essential grid reliability services.	• This will be a new FOA for FY 2019.

Geothermal Technologies
Low Temperature and Coproduced Resources

Description

The Low Temperature and Coproduced Resources subprogram supported targeted RD&D on technologies applicable to geothermal resources below a temperature of 300°F (150°C) as well as geothermal resources, including thermal desalination processes and hybrid power designs that can be co-developed with existing well-field infrastructure and other clean energy technologies. Although these low-temperature resources have a lower power conversion efficiency than other geothermal resources — due to the lower temperature fluids — these resources are abundant; highly accessible across the U.S.; and as in the case of co-produced fluids, have much of the necessary infrastructure in place — attractive attributes that lower the effective LCOE. Improving the efficiency of lower temperature geothermal systems, and expanding their utility through value-added commercial opportunities (i.e., combined mineral recovery, desalination) can enable near-term development of innovative geothermal technologies in more geographically diverse areas of the U.S. However, much of the research and development opportunity in the low temperature and coproduced resources space is later-stage. Thus, industry has a greater incentive and capacity to fund commercialization of novel technologies.

The Low Temperature and Coproduced Resources subprogram also supports R&D of the direct use of thermal resources for process and space heating applications. Direct use geothermal applications have the potential to provide cost-effective, renewable thermal energy in large portions of the U.S. A recently completed USGS assessment estimates 46,500 MW thermal (MWth) of total beneficial heat that is available from geothermal resources below 90°C in the U.S.[1] Preliminary calculations by NREL suggest that full utilization of this resource would equate to supplying nearly one quarter (23 percent), of the total U.S. residential heating demand for the next 30 years.

Reflecting the shift in focus to early-stage research and development, no funding is requested for the Low Temperature and Coproduced Resources subprogram in FY 2019. Some management activities related to the execution of prior year appropriations will continue until completion.

[1] Williams, et al., Revisiting the Assessment of Geothermal Resources <90°C in the U.S. April 10, 2015.

Low Temperature and Coproduced Resources

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Low Temperature and Coproduced Resources $8,972,000	**$0**	**-$8,972,000**
• Deep Direct-Use (DDU) Funding Opportunity Announcement – Projects selected in FY 2017 to determine the feasibility of developing and deploying low-temperature, deep-well geothermal systems for direct heating and cooling applications throughout the U.S.	• No funding is requested.	• No funding is requested. DDU projects awarded in FY 2017 will continue to completion.
• Final year of competitively selected, three-year DOE National Laboratory R&D projects in value-added hybrid systems and geothermal desalination technologies including at least one pilot-scale demonstration of geothermal water purification processes.	• No funding is requested.	• Reflects shift in focus to early-stage R&D.

Advanced Manufacturing

Overview

The Budget for Advanced Manufacturing Office (AMO) continues to reassert the proper role of the Federal Government by reflecting an increased reliance on the private sector to fund later-stage research, development, and commercialization of energy technologies and focusing funding toward early-stage research and development (R&D). Through strategic investments in early-stage R&D activities, AMO works with universities, laboratories, companies (for-profit and not-for profit), state/local governments, or consortia. All of AMO activities depend on merit-based selection and peer-reviewed results. Through various program structures, AMO supports research of manufacturing process, information, and materials technologies essential to the efficient and competitive domestic manufacturing of energy products and to support energy productivity across the entire U.S. manufacturing sector.

Manufacturing generates 12 percent of U.S. gross domestic product (GDP)[1] and employs more than 12 million Americans. The U.S. manufacturing sector also has an annual energy bill of about $200 billion and consumes roughly one-third of primary energy in the U.S.[2] DOE's work researching new technologies with the potential to subsequently improve the energy efficiency and productivity of U.S. manufacturers when commercialized by industry, can enable manufacturers of all kinds to be more competitive in the global marketplace. The program accomplishes this by focusing on early-stage R&D in cross-cutting, platform technologies to both reduce energy intensity within existing manufacturing processes, and promote the development and growth of manufacturing in multiple emerging energy fields. In addition, AMO actively partners with industry to lower scientific uncertainty that would otherwise limit the subsequent demonstration, adoption and use of the new knowledge gained through R&D, to ensure that existing manufacturers and new energy technologies invented in the U.S. ultimately result in the manufacture of products in the U.S.

AMO subprograms are implemented through partnerships with National Laboratories, companies (for-profit and not-for profit), research institutions, and universities through competitive, merit reviewed funding opportunities designed to investigate novel manufacturing technologies. The program supports early-stage research on manufacturing technologies through three different modes: individual R&D projects, collaborative R&D consortia, and technology partnerships that inform subsequent research activities as well as provide a vehicle for field verification research, knowledge dissemination, and transfer of novel manufacturing technologies.

AMO's early-stage applied R&D technology areas are organized around high potential impact areas developed through extensive engagement with private sector firms, non-profits, universities, and National Laboratory partners, as well as consultation with other Federal agencies and departments. These AMO technical focus areas are targeted toward early-stage research needs that, if adopted by industry for further development, can support manufacturing process, information, and materials technologies. The focus of work is knowledge creation from early-stage research that enables industry to develop and deploy novel technologies that address challenges in these high-priority technical focus areas.

AMO technology areas have scientific knowledge gaps applicable to manufacturing and energy. With the crosscutting (i.e., applicable to multiple industries) and platform (i.e., provide a foundation for successive iterations of technological innovation) nature of this research, the new knowledge discovered in this work will be applicable to two or more sectors in energy and manufacturing. The early-stage research supported by AMO is targeted at processes and technological challenges that present a significant degree of scientific or technical uncertainty, require long time frame solution sets, and offer limited commercial appropriability of results. In contrast, industry R&D is typically focused on near-term cost reduction and process improvements, which provide a competitive advantage. Examples of AMO focus areas include:

- Advanced Materials: Advanced materials broadly applicable to energy products, including energy conversion materials, materials for extreme or harsh conditions, and nanomaterials needing innovative approaches to processing;
- Critical Materials: Critical materials (ex: rare-earth materials) essential to energy for which there is potential for supply chain disruption;

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[1] "GDP by Industry / VA, GO, II, EMP," 2013, Bureau of Economic Analysis; available from: http://www.bea.gov/industry/xls/GDPbyInd_VA_NAICS_1997-2013.xlsx.

[2] Annual Energy Outlook 2014: Reference Case Data, U.S. Energy Information Administration, available from: http://www.eia.gov/forecasts/aeo/data.cfm.

- Composites and Lightweight Materials: New composite and lightweight materials processes generating high-strength and low-weight materials for energy;
- Additive Manufacturing Processing: Additive (3D) processes capable of direct net-shape formation of metals, polymers, and ceramic materials for application in energy;
- Roll-to-Roll Processing: Roll-to-roll processes with potential to form complex two-dimensional multi-material assemblies, and functional structures, including batteries, membranes and fuel cells;
- Wide Bandgap Power Electronics: Wide bandgap electronics based on semiconductors that potentially reduce energy losses and improve reliability in electric power systems;
- Novel Sensors and Process Controls: Technologies that leverage advanced sensors, controls, platforms, and models to enable real-time, operational energy efficiency improvements in processes; this also includes the new application of High Performance Computing to improve materials and manufacturing process technologies;
- Chemical and Thermal Process Intensification: Chemical and thermal process intensification to reduce the size and energy intensity of manufacturing processes through higher reaction efficiency, novel mixing and separations, and low thermal budget heating and cooling;
- Grid and Resource Integration in Manufacturing: Grid and resource integration, including new technologies for high efficiency Combined Heat and Power (CHP), waste heat to power, distributed generation, and real-time manufacturing demand response; and
- Sustainable Manufacturing: Sustainable manufacturing, including technologies for the efficient use of raw materials and water in manufacturing.

Highlights of the FY 2019 Budget Request

FY 2019 activities support Administration, Department and Programmatic goals. Highlights include:

- Orientation of program on early-stage applied R&D. The program is organized around three mechanisms of support including: 1) individual research projects; 2) research consortia; and 3) technology partnerships with National Laboratories. The focus of this early-stage R&D is the discovery of new technical knowledge and investigation of new technical ideas.
- R&D projects ($31.5M): Focus on early-stage research in materials and process knowledge relevant to manufacturing, including application of high performance computers for modelling and simulation relevant to energy in manufacturing. Executed through competitive merit reviewed individual projects researching a technical solution to a manufacturing challenge.
- R&D consortia ($32.5M): Focus on coordinated early-stage R&D in high-priority areas essential to energy in manufacturing, including the discovery of foundational knowledge in rare-earth materials, additive processes, power semiconductors, innovative process controls, new materials and processes; and innovative approaches to clean water. Executed through competitive merit reviewed consortia lead by national laboratories and universities including small and medium manufacturing companies that research multiple solutions to a manufacturing challenge. These consortia create an innovation ecosystem that accelerates the transition of innovative advanced manufacturing technologies to industry.
- Technology partnerships ($11M): Focus on research and validation of early-stage research through partnerships with National Laboratories that provides support for the adoption of advanced energy efficiency technologies.

EERE's role in the initial establishment of the Oak Ridge Manufacturing Demonstration Facility (MDF) and Carbon Fiber Test Facility (CFTF) ended in FY 2016. In FY 2019, EERE will fund only early-stage R&D projects that utilize the MDF and CFTF facilities for validation and feedback to further research.

Advanced Manufacturing Funding ($K)

	FY 2017 Enacted	FY 2018 Annualized CR*	FY 2019 Request	FY 2019 Request vs FY 2017 Enacted
Advanced Manufacturing				
Advanced Manufacturing R&D Projects	80,500	—	31,500	-49,000
Advanced Manufacturing R&D Consortia	150,500	—	32,500	-118,000
Advanced Manufacturing Technical Partnerships	26,500	—	11,000	-15,500
Total, Advanced Manufacturing	257,500	255,751	75,000	-182,500

SBIR/STTR:

- FY 2017 Transferred: SBIR $8,000,000; STTR $1,914,000
- FY 2018 Projected: SBIR $7,946,000; STTR $1,901,000
- FY 2019 Request: SBIR $2,400,000; STTR $338,000

*A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution. (These amounts are shown only at the Congressional control level and above; below that level, a dash (—) is shown).

Advanced Manufacturing
Explanation of Major Changes
($K)

	FY 2019 Request vs FY 2017 Enacted
Advanced Manufacturing R&D Projects: Activities will be refocused to support only early-stage advanced materials manufacturing R&D for energy applications in high-impact foundational technology areas. Funding allows for an increase in support of R&D at National Laboratories for early-stage advanced manufacturing technology R&D, focusing on emergent technology challenges, as well as activities affecting secure and reliable hybrid power systems through flexible combined heat and power research and new storage technologies. Funding for high-performance computing for manufacturing (HPC4MFG) will be prioritized and listed as a separate element within the R&D project's budget.	-49,000
Advanced Manufacturing R&D Consortia (previously R&D Facilities): No funds are requested for the Critical Materials Hub, the Clean Water Hub, or the five existing and one previously proposed institutes in the Manufacturing USA network. Balances from prior year appropriations will be used to conduct an orderly wind-down and termination of the existing institutes. These institutes have provided valuable innovative contributions, but their focus is not aligned with AMO's shift in emphasis to early-stage research. Funding for the MDF and CFTF will be focused on the highest priority projects focused on early-stage R&D. Additional activities will focus on early stage applied research in National Laboratory and university based consortia to more efficiently address the underlying scientific challenges in key advanced manufacturing technical areas. In addition, enhanced focus will be placed on technologies for wide-bandgap power electronics that incorporate storage controls, improve system reliability, lower manufacturing costs, and enable scalable domestic manufacturing.	-118,000
Advanced Manufacturing Technical Partnerships (previously Industrial Technical Assistance): Reflecting the shift in focus to early-stage R&D, no funds are requested for the Industrial Assessment Centers (IACs), which primarily provided technical assistance support for small and medium manufacturers. Some existing partnership programs designed to inform the direction of applied R&D and clearly support new knowledge creation and validation of research results with the private sector will be continued. Additional activities include competitively merit reviewed support from National Laboratory and university-led projects that focus on early-stage R&D of novel manufacturing technologies.	-15,500
Total, Advanced Manufacturing	**-182,500**

Advanced Manufacturing
Advanced Manufacturing R&D Projects

Description

Through renewed focus on competitively selected, early-stage applied R&D projects in foundational, energy-related advanced manufacturing technologies, the program will increase the impact of its work in areas relevant to energy-intensive and energy-dependent manufacturing processes, as well as platform technologies widely applicable across multiple energy related manufacturing industries. The Advanced Manufacturing R&D Projects subprogram will support early-stage proof of concept projects, cost-shared with companies and research organizations that focus on generating knowledge relevant to specific manufacturing technology challenges. Through a combination of merit based competitive FOA solicitations and peer-reviewed National Laboratory based projects (in partnership with industry), the results of these foundational research projects will enable industry development of next-generation manufacturing technologies. The program will identify the specific research challenges based on stakeholder input, alignment with the program's technology thrust areas, and potential energy, environmental, and economic impacts.

In FY 2019, the subprogram will support R&D projects totaling $31.5 million. There will be $6.5 million in competitive solicitations for Advanced Manufacturing R&D projects and STEM education, including at least one FOA solicitation for laboratories and universities with emphasis on emerging scientific and technical approaches to address knowledge and workforce gaps for the priority thrust areas identified in the AMO MYPP for Fiscal Years 2017 through 2021. The program will only fund early-stage research focused on technology challenges, which present a significant degree of scientific or technical uncertainty across a relatively lengthy time span, making it unlikely that industry will invest significant R&D on their own. Specifically, projects will be screened to ensure that either industry does not have the technical capability to undertake the research effort or the innovation is too far from market realization to merit sufficient industry focus and critical mass. Of the $6.5 million in competitive solicitations, $1.5 million will support STEM education traineeships where there is a demonstrated gap in scientific workforce of individuals of U.S. origin in technical areas where the lack of a knowledge-based workforce would limit the ability for U.S. manufacturers to produce competitively in the U.S. technologies based on early-stage-research supported by the U.S.

AMO will support $19.5 million in early-stage manufacturing research at National Laboratories in partnership with businesses, including $6.5 million, which will be dedicated to supporting new projects led by new early-career post-doctoral researchers, enabling fresh ideas and innovative approaches to address fundamental manufacturing challenges identified by industry where the need for new scientific and technical knowledge can be identified.

To enable research that leverages the unique High-Performance Computing resources of the National Laboratories on manufacturing relevant, first of kind early-stage R&D projects, $5.2 million will support the High-Performance Computing for Manufacturing (HPC4MFG) program, funding new competitively solicited projects to advance new knowledge in this research impacting both computer science and manufacturing science. In addition, a total of $5.5 million will support competitively selected projects relating to secure and reliable hybrid power systems through flexible combined heat and power research and new storage technologies. Finally, $1.25 million is applied to quantitative analysis research that provides knowledge for identifying research gaps and potential new research activities.

Advanced Manufacturing R&D Projects

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Advanced Manufacturing R&D Projects $80,500,000	**$31,500,000**	**-$49,000,000**
• AMO will support 25 to 50 competitively selected, merit-based, R&D projects to address core technical issues for foundational technologies that will enable U.S. manufacturers to realize significant gains in energy productivity, product yield, and economic growth at National Laboratories, universities, and companies. Specifically support will be for R&D addressing issues with scientific gaps and innovative new technical approaches that if explored would advance the state of technical knowledge for manufacturing, such as materials for harsh conditions, energy conversion materials, materials for energy systems, roll-to-roll materials and processes, innovative computational process modelling in manufacturing, and energy intensive manufacturing processes.	• During FY 2019, AMO will support 15 to 30 competitively selected, merit-based, early-stage applied R&D projects at National Laboratories, universities, and companies. ▪ $5.2 million will to support the HPC4MFG program ▪ $19.5 million total in early-stage manufacturing research at National Laboratories in partnership with businesses, of which $6.5 million will be dedicated to supporting new projects led by new early-career post-doctoral researchers in competitive solicitations, including $1.5 million for STEM education ▪ $5.5 million in funding also will support Beyond Batteries R&D through competitively selected cooperative agreements between industry and National Laboratories focused on secure and reliable hybrid power systems, as well as new storage technologies.	• Decrease attributable to support of fewer projects with the program re-focused on only early-stage applied R&D where there are gaps in knowledge or there are potential innovative new approaches to the materials and processes in manufacturing.

Advanced Manufacturing
Advanced Manufacturing R&D Consortia

Description

The Advanced Manufacturing R&D Consortia subprogram supports collaborative, early-stage research and development between industry, academia, non-profit institutions, and National Laboratories that can help enable the development and deployment of novel technologies by U.S. manufacturers. These collaborative efforts are effective mechanisms for supporting early-stage R&D and transferring innovative technologies to the private sector. These advanced manufacturing R&D consortia are designed to generate knowledge spillover benefits from adjacent energy sectors into multiple industries and improve U.S. competitive advantage, especially for small- and medium-sized enterprises.

Research consortia are an effective means of conducting this early-stage applied R&D as they can focus the technology investigations on the creation of relevant new knowledge, while lowering the barriers to transferring that knowledge from laboratories to the private sector for subsequent advancement. The FY 2019 funding of $27.5 million will support six to ten advanced manufacturing consortia to conduct collaborative early-stage R&D in the priority areas listed below:

- Scientific research into the foundational knowledge related to rare-earth materials;
- New approaches to sensors, modeling, communications, security and controls in manufacturing;
- Next generation materials, structures and processes for chemical processes;
- Discovery of new composite materials and structures;
- Semiconductor (power and nanoscale) manufacturing materials and processes; and
- Clean water in manufacturing and new materials approaches to cost-effective use of materials resources in manufacturing.

In FY 2019, $16.5 million is requested for support of merit-based, early-stage R&D consortia at National Laboratories and universities to address these important scientific and technical issues relevant to U.S. manufacturing. Consortia create an innovation ecosystem that research multiple solutions to a manufacturing challenge accelerating the transition of innovative advanced manufacturing technologies to industry. The program will ensure awarded consortia focus only on early-stage research to address technology challenges that present a significant degree of scientific or technical uncertainty across a relatively lengthy time span, making it unlikely that industry would invest significant R&D on their own. Specifically, projects will be screened to ensure that individual industry actors do not have the technical capability to undertake the research effort absent collaboration. In addition, $5 million will support a funding opportunity announcement focused on technologies for wide-bandgap power electronics that incorporate storage controls, improve reliability, lower costs and enable scalable domestic manufacturing.

No funds are requested for the previously supported institutes in the Manufacturing USA network. Using prior year appropriation balances, termination of the Manufacturing USA institutes will include assessment of closeout costs and dual-use manufacturing base impacts. Similarly, no funds are requested for the Critical Materials Institute and Energy Innovation Hub. Instead, the program will pursue its mission through a more concentrated focus on early-stage research targeting discovery of new scientific knowledge in National Laboratory and university based consortia.

Additionally, in FY 2019, $11 million is requested for early-stage R&D activities at National Laboratory based MDF and CFTF, a model for public-private consortia on cost-shared early-stage applied R&D at the National Laboratories, particularly in areas of additive manufacturing and carbon fiber materials research related to energy. Consortia activities will be selected through competitive merit reviewed processes that research multiple solutions to a manufacturing challenge. These consortia activities create an innovation ecosystem that accelerates the transition of innovative advanced manufacturing technologies to industry.

Advanced Manufacturing R&D Consortia

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Advanced Manufacturing R&D Consortia $150,500,000	**$32,500,000**	**-$118,000,000**
• Support the incremental funding ($14M) of one new Institute. Also, provide support ($70 million) for five existing Institutes, ($25M) of investment in the Critical Materials Hub and the Water Desalination Hub ($20M). • The program will support R&D projects at the MDF and CFTF to enable the facilities to accommodate increased demand for projects funded by industry.	• Support the highest priority early-stage R&D projects at the MDF, CFTF and six to ten public-private partnership consortia. For the MDF 3 of 7 technology areas funded in FY 17 will be downselected. • $5 million for a funding opportunity announcement to select 2 to 4 projects focused on in funding also will support activities associated with Beyond Batteries R&D, specifically technologies for wide-bandgap power electronics that incorporate storage controls, improve system reliability, lower manufacturing costs, and enable scalable domestic manufacturing.	• The decrease is primarily attributable to the elimination of the Critical Materials Hub and Manufacturing USA institutes. The shift to early-stage R&D consortia better leverages existing laboratory and university capabilities, with an added focus on Beyond-Batteries R&D.

Advanced Manufacturing
Advanced Manufacturing Technical Partnerships

Description

The advanced manufacturing technical partnerships subprogram provides engagement with the private sector to ensure that the results from the early-stage R&D related to advanced manufacturing and energy can be transferred to the private sector for further development or commercialization. These partnerships focus on knowledge transfer, of both the relevant results from scientific research as well as feedback from the private sector on the science and technology challenges that might be addressed through early-stage applied R&D.

In FY 2019, the Advanced Manufacturing technical Partnerships sub-program will request $11 million. Reflecting the shift in focus to early-stage R&D, no funding is requested for the IACs, which primarily supported technical assistance for small and medium manufacturers. Closeout costs for the IAC program will include collection and public dissemination of scientific and technical data from prior IAC field verification studies to inform new research.

Within the available resources, $3 million is requested for early-stage R&D into new information tools and technologies that facilitate the exchange of technical knowledge and validate research results with the private sector in areas of advanced manufacturing and energy productivity, including tools for field validation of new technologies to inform future research direction. The request includes $2 million for student-led research projects at National Laboratories in areas relevant to advanced manufacturing and energy, advanced materials manufacturing and advanced chemical processes technologies. Student led projects provide a mechanism for partnership between universities and National Labs in early stage research where the results would subsequently have positive impact in industry.

Advanced Manufacturing Technical Partnerships

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Advanced Manufacturing Technical Partnerships $26,500,000	**$11,000,000**	**-$15,500,000**
• The program continues support for both the IACs and the CHP Technical Assistance Partnerships. • Also includes enhanced support for the Better Buildings Better Plants program partners and expansion of the SEP ISO/ANSI certified facility program.	• Funding will support 2 to 4 partnerships between national labs and universities facilitating exchange to the private sector of new technical knowledge resulting from research. These partnerships will include tools for gathering information from technology validation as well as the feedback of information to inform new research opportunities. • New funding for student-led projects at National Labs will enable National Laboratories to house 4 to 16 students and provide the necessary access to R&D equipment, facilities, and expertise to complete their projects.	• The decrease is primarily due to the completion of closeout activities for the IAC program, as well as a refocus of resources on tools for field validation.

Federal Energy Management Program

Overview

As the U.S. Federal Government is America's largest single energy consumer with more than 350,000 buildings and 600,000 vehicles, it has an opportunity and responsibility to take the lead in cutting energy waste and advancing America's progress toward energy independence, resiliency, and security. The Federal Energy Management Program (FEMP) enables all Federal agencies to reduce their $16. 1 billion annual energy bill, meet energy-related goals, identify affordable solutions, and provide energy leadership to the country. FEMP achieves its mission by supporting Federal agencies in meeting Executive Order and statutory energy and water management-related goals by identifying government best practices, providing technical assistance, tracking progress, and helping train the Federal workforce and additional stakeholders.

In FY 2019, FEMP will help agencies leverage federal investment in support of other DOE mission areas and collaborate, cooperate, and coordinate with other EERE programs to enhance federal investments to include resilience, system cybersecurity for facility related control systems, reliability, and facility optimization.

FEMP supports the Administration's goal of energy dominance by providing opportunities for more efficient, cost effective and secure energy usage and management in government facilities. FEMP's leadership to assist agencies in facility management reduces costs, increases energy and water security, maintains and modernizes infrastructure, and improves the health and safety of federal employees.

Federal energy use is significant and FEMP tracks and assesses it annually. In 2016, the Federal Government used 1.3 quads of primary energy at a cost of $16.1 billion.[1] Energy used in buildings and facilities represents about 57 percent of the total energy use of the Federal Government, with vehicles and equipment energy use accounting for 43 percent.[2] However, substantial opportunities still exist for further energy cost reduction and energy conservation. Agencies estimated and report that between $9 billion[3] and $15 billion of potential cost effective investment energy savings exist in Federal buildings.[4] FEMP works with all federal agencies to improve the U.S. Federal Government's energy management and energy and water security by providing guidance, training, technical assistance, data coordination and review, and best practices to improve and monitor overall Federal energy management.

Highlights of the FY 2019 Budget Request

The FEMP FY 2019 Budget Request of $10 million supports Federal agencies in achieving energy and water resilience and meeting statutory energy and water management related goals and requirements[5]. With FEMP provided assistance, initiatives, training and partnerships, the Federal Government reduced its facility energy intensity by 49 percent since 1975 and 25 percent since 2003. To provide context with commercial facilities, General Services Administration facilities, which are mainly office buildings, have an energy intensity of 51,273 Btu per gross square foot[6] while the energy intensity of all U.S. office buildings is 77,800 Btu per gross square foot[7] (or approximately 52 percent higher). Similarly, Veterans Affairs facilities, which are mainly hospitals, have an energy intensity of 145,142 Btu per gross square foot while the average

[1] Table A-4 and Table A-2 http://ctsedwweb.ee.doe.gov/Annual/Report/Report.aspx.
[2] In terms of primary (source) energy use.
[3] Almost $9 billion identified by agencies in their evaluations of facilities comprising 75 percent of Federal facility square footage;
https://ctsedwweb.ee.doe.gov/CTSDataAnalysis/Reports/PublicAgencyReport_ComprehensiveEvaluationFindings.aspx.
[4] *Updated Estimates of the Remaining Market Potential of the U.S. ESCO Industry,* April 2017, Lawrence Berkeley National Laboratory; https://emp.lbl.gov/sites/default/files/revised_market_potential_final_25apr2017_0.pdf.
[5] Energy management requirements of the National Energy Conservation Policy Act, as amended (42 U.S.C. 8253-8258); the Energy Policy Act of 2005 (42 U.S.C. 15852); and Executive Order 13693. For full list of requirement refer to https://www4.eere.energy.gov/femp/requirements/.
[6] FY 2016 Energy Intensity of GSA goal subject buildings adjusted for source savings http://ctsedwweb.ee.doe.gov/Annual/Report/GoalSubjectBuildingSiteDeliveredEnergyUseperGrossSquareFoot.aspx.
[7] 2012 Energy Intensity of all U.S. office buildings https://www.eia.gov/consumption/commercial/data/2012/.

hospital in the U.S. has an energy intensity of 172,700 Btu per gross square foot (or approximately 19 percent higher).[1] Through cost effective building optimization strategies, agencies have and can continue to lower costs and reduce stress on the grid enhancing grid reliability. While the Federal Government has made progress in energy and water management, opportunity remains to share replicable solutions for energy intensive facilities, including laboratories and data centers; to increase force readiness for the Department of Defense (DoD); and to improve water management in water use intensive facilities such those in the Department of Justice.

FEMP is the primary Federal entity that provides energy management technical assistance for agencies. In 2019, FEMP will develop performance contracting models and business case methodology that optimizes facilities, increases energy efficiency which leads to enhanced energy and water resilience and security in addition to reducing the operating cost of Federal facilities. FEMP will provide technical project development assistance for energy savings performance contracts (ESPC), utility energy savings contracts (UESC), and power purchase agreements in pursuit of energy and water efficiency improvements, renewable energy projects, and demand reduction services. FEMP will also coordinate with the agencies that have broad performance contracting vehicles including, but not limited to, the U.S. Army Corps of Engineers, Veteran's Affairs, and General Services Administration to provide a consistent and standardized process for Federal agencies and Department of Defense to design and execute all performance contracts related to energy.

In conjunction with technical assistance, FEMP will provide portfolio planning and facility optimization guidance that includes the strategic integration of advanced technologies into power supply and master facility planning, helping DOE as a whole strengthen national energy security, increase resilience, and improve reliability through strategic energy management and implementing a diversity of energy sources. FEMP will also foster Federal facility and fleet optimization by providing guidance and tools focused on metering, auditing, operations and maintenance, and water use.

To increase the agility and skills of the Federal workforce, FEMP will lead the Energy Exchange training workshop, provide internationally accredited training, and enhance opportunities for veterans. Energy Exchange will strengthen coordination with commercial, state, city, and local government stakeholders and provide technical training and successful replicable models. The Better Buildings Summit will be consolidated with the Energy Exchange training workshop.

FEMP will continue to fulfill its statutory requirements to monitor and provide Federal accountability for energy facility managers' performance through proactive engagement and enhanced workforce development services and opportunities.

[1] Commercial Buildings Energy Consumption Survey (CBECS), U.S. Energy Information Administration. Table C4. Sum of major fuel consumption and expenditure gross energy intensities, 2012; https://www.eia.gov/consumption/commercial/data/2012/c&e/cfm/c4.php.

Federal Energy Management
Program Funding
($K)

	FY 2017 Enacted	FY 2018 Annualized CR*	FY 2019 Request	FY 2019 Request vs FY 2017 Enacted
Federal Energy Management Program				
Federal Energy Management Program	27,000	—	10,000	-17,000
Total, Federal Energy Management Program	**27,000**	**26,817**	**10,000**	**-17,000**

*A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution. (These amounts are shown only at the Congressional control level and above; below that level, a dash (—) is shown).

Federal Energy Management Program
Explanation of Major Changes
($K)

	FY 2019 Request vs FY 2017 Enacted
Federal Energy Management Program: In FY 2019, FEMP will provide assistance, monitor and track agencies' energy management performance and identification, design, and completion of energy and water efficient projects through energy savings performance contracts (ESPCs), utility energy savings contracts (UESCs), and power purchase agreements (PPAs). As part of the technical assistance available to agencies, FEMP will provide system standardization, tools to foster building optimization, consistent best practices, guidance and process quality assurance. FEMP programming will also focus specifically on developing and disseminating training resources that enhance the skills and agility of the existing Federal workforce.	**-17,000**
Total, Federal Energy Management Program	**-17,000**

Federal Energy Management Program

Description
The Federal Energy Management Program (FEMP) assists all Federal agencies in achieving applicable statutory and executive order goals and objectives.

The Federal Government is the largest U.S. energy consumer. As such, the Federal Government carries significant responsibility to demonstrate leadership in improving energy efficiency and reducing energy costs. The authority provided by National Energy Conservation Policy Act, as amended,[1] mandates DOE, through FEMP, to promote the conservation and the efficient use of energy and water, and the use of renewable energy sources, by the Federal Government. The original passage of this law and subsequent amendments, mandated that DOE lead the coordination, implementation, guidance development, training, technology evaluation, and compliance tracking for Federal Agencies related to all elements of goals and requirements mandated in this section of the law.

To provide this leadership, the FEMP subprogram engages with public and private sector partners to demonstrate effective practices for reducing energy and water management costs through optimized facility management that also enhances energy and water security. FEMP works with Federal agencies and National Laboratories to develop and disseminate training resources that enhance the skills and agility of the existing Federal energy management workforce, as well as private sector and educational institutions. FEMP maximizes interagency coordination through a variety of forums, including the Interagency Energy Management Task Force, to identify top agency needs and barriers and inform technical assistance focus areas. FEMP also engages with the broader Federal energy management community, which encompasses a broad range of stakeholders including Federal energy managers, private sector contractors, energy service companies, and utilities.

FEMP provides technical assistance that leverages performance contracting and power purchase agreements to leverage investments in efficient, resilient, and secure Federal facilities that support broader DOE and Administration goals. FEMP assists Federal agencies in completing energy and water savings projects that leverage private-sector financing and appropriations while also enhancing grid reliability, facilitating resilience, and addressing cybersecurity concerns. FEMP's leadership in facility management reduces costs, increases energy and water security, maintains and modernizes infrastructure, and improves health. In addition to reducing energy costs, facility optimization can enhance grid reliability and facility resilience by providing a two-way grid interface and reducing the load on the grid.

In 2019, FEMP will work with agencies to provide necessary technical assistance to overcome barriers to design affordable, replicable, energy and water savings projects that optimize facilities and enhance energy and water resilience. Technical assistance will address specific facility, site, mission, and agency needs and utilize all available technologies to demonstrate best practices, facilitate identification of barriers, and capture lessons learned with a focus on continuous improvement. FEMP develops and assists agencies as they apply business case methodology for affordable energy reliability at the facility level providing edge of grid benefits that are behind the meter at the installation grid interface and leveraging performance contracting for replicable, affordable solutions. FEMP will develop, implement, and test performance contracting solutions (helping to develop and improve contract language, performance metrics, and projects) that include specific cybersecurity and resilience portfolio components and incorporate renewables, microgrids, and advanced storage options (building energy storage and building energy storage technologies).

As part of the authorized responsibility of the program to respond to and support Federal agencies' requests for assistance, in FY 2019, FEMP will develop technical assistance services and guidance for implementing energy management projects and documenting results. As part of this support requested by Federal agencies, FEMP, working directly through experts at the DOE National Laboratories, will:

- Provide portfolio planning best practices for facilities including, but not limited to, energy sources, integration factors, energy storage, and pathways for resilience and reliability;

[1] National Energy Conservation Policy Act (As Amended) (42 U.S.C. 8252 and 8253) (Pub. L. 95–619, title V, § 542, Nov. 9, 1978, 92 Stat. 3277; Pub. L. 100–615, § 2 (a), Nov. 5, 1988, 102 Stat. 3185; Pub. L. 102–486, title I, § 152 (a), Oct. 24, 1992, 106 Stat. 2844.) http://uscode.house.gov/view.xhtml?path=/prelim@title42/chapter91&edition=prelim.

- Improve facility energy and water resilience through developing and implementing the business case for enhanced energy management technologies and tools focused on facility optimization and cost reduction;
- Offer portfolio planning guidance to strategically integrate advanced energy technologies (such as renewable energy, micro-grids and advanced battery storage) into agency and facility power supply and master site planning to develop secure, resilient facilities;
- Share replicable, affordable best practices for implementing resilient energy management strategies in Federal facilities;
- Develop best practice approaches to address the challenges and risks organizations face from cyber threats to the energy management platform;
- Standardize steps agencies can take to secure their energy-related hardware and data while integrating effective energy management; and
- Integrate building optimization tools and portfolio planning models that can be adopted as enterprise-wide approaches.

In 2019, FEMP will build on globally recognized leadership in performance contracting that facilitated agencies' record investment of $1.1 billion in FY 2016 and will result in a guaranteed energy reduction of 2.8 billion BTU. As a result of progress made to date, agencies are primed to continue leveraging performance contracting and FEMP will continue to provide publically accessible training and educational resources to develop a resilient and self-reliant Federal workforce and leverage lessons learned. FEMP will develop performance contracting models for energy and water savings while strengthening resilience and security and explore opportunities in energy storage.

Since 1992, Congress authorized Federal agency use of performance contracts to help Federal agencies achieve energy and water conservation goals through energy efficiency, renewable energy, and water efficiency improvements in Federal facilities. By using performance contracts such as ESPCs and UESCs, the Federal Government is able to engage a private sector energy service company to invest in needed energy projects and pay for the investment through the energy, water, and operations and maintenance (O&M) savings achieved over the life of the contract. Aging Federal buildings can be improved/updated and obsolete equipment still in operation from the 1940s, 50s, or 60s, can be replaced. The backlog of deferred maintenance and repairs is also increasing, with approximately $165 billion required to bring Government owned property, plant and equipment to an acceptable condition.[1] Performance contracting can address a portion of this larger need.

Performance contracting, with FEMP support for quality assurance and life of contract support, is a valuable tool to implement planned efficient infrastructure investments rather than costly emergency repairs. FEMP support helped agencies achieve $1.1 billion of investment in FY 2016 and more than $4.5 billion since CY 2012. The 356 performance contracts awarded over the last five years will generate 14 trillion Btu in annual energy savings, an amount equivalent to the annual energy usage of 158,000 average U.S. households, 4 percent of the government's annual facility use, and a cost savings of approximately $8 billion in the Federal Government's utility and facility maintenance expenditures over the next 18 years. Over the life of the contract, the approximately $8 billion in savings are used to pay for the facility infrastructure investments, including the installation of new energy and water related equipment and savings verification. Additional savings that occur during the contract or after the contract term accrue to the agency. FEMP leverages performance contracting to assist agencies with statutory compliance and energy management portfolio planning for mission assurance and resilience preparedness.

FEMP's performance contracting assistance also includes critical data collection tools such as eProject Builder (ePB) National ESPC & UESC database system – a secure, online tool developed and managed on behalf of FEMP by the University of California/Lawrence Berkeley National Laboratory (LBNL) for Federal and non-Federal entities to standardize the collection, calculation, and reporting of performance data for all performance contracts (including state and local contracts) and to provide government access to anonymized/arrogated project data across government and the private sector to improve analysis of performance contracting. DOE's ESPC indefinite delivery, indefinite quantity (IDIQ) contract awarded April 2017 requires the use of ePB. The continued support of the ePB system and Federal access to the data will provide

[1] https://www.fiscal.treasury.gov/fsreports/rpt/finrep/finrep16/supp_info/fr_supplement_info_defer_maint.htm.

valuable benchmarking information to improve the performance and cost of all Federal contracts.

FEMP also addresses statutory requirements to hold agencies accountable for energy management performance, provides proactive engagement and collaboration with stakeholders, and enhance a future workforce through training and development. FEMP tracks the government's progress and status in energy and related goal achievement for trend analysis and ensures the program's capabilities are a known resource for the Federal energy management community. The National Energy Conservation Policy Act (NECPA), as amended by EISA 2007 (42 U.S.C. § 8258(a)) requires that DOE collect, verify, and report on Federal agencies' progress toward their goals to address energy efficiency in facilities. In FY 2019, the program will continue to collect and publish data for the Annual Report to Congress and on agency compliance with Section 432 of EISA, Management of Energy and Water Efficiency in Federal Buildings (42 U.S.C. § 8258(f)). In addition, through its awards program, FEMP recognizes energy champions at Federal agencies and showcases best practice efforts; and through the Veterans Intern program, provides opportunities for veterans to learn energy management, while helping agencies meet their goals.

FEMP will strive to increase the agility and skills of the Federal workforce through training including enhancing opportunities for veterans. FEMP will continue to enhance workforce competencies and strengthen performance through innovative, internationally accredited training programs while leveraging public-private partnerships, such as the Energy Exchange conference and accredited e-Training series and through support for the Federal Building Personnel Training Act. In FY 2017, FEMP offered 142 courses, workshops, and webinars sessions; plus, 135 Energy Exchange sessions, for a total of 277 training sessions. This translates to FEMP having provided over 30,525 training hours, including having awarded 5,795 International Association of Continuing Education and Training Continuing Education Unit (CEU) Certificates. FEMP's online training is available, at no cost to the participant, to Federal workforce, private sector and educational institutions. FEMP will continue to develop and host the flagship Energy Exchange event, which brings together subject matter experts from a wide range of technical disciplines to share their knowledge; drive an efficient Federal Government; and provide best practices and lessons learned while showcasing emerging technologies developed by DOE and its National Laboratories. FEMP provided over 37,612 hours of training in FY 2017 alone, through number of mechanisms which include the Energy Exchange training event, on-demand training courses, regional interactive workshops and live webinars. Of those attending the on-demand, regional workshops, and live webinars, just over 51 percent were U.S. Federal government employees, the rest came from private sector, including commercial, education, and industry sectors. At Energy Exchange 2017, of the 2,616 attendees, 1,236 were Federal sector attendees, 922 were private sector and 458 were exhibitors. Over 3,200 attendees from Government and industry are expected to attend Energy Exchange 2019 for accredited training, networking and to discuss cost-effective best practices and lessons learned. The increased attendance is due to consolidation with the Better Building Summit and integration of commercial, state and local stakeholders.

FEMP is statutorily required to carry out the following functions specifically related to tracking and implementing effective energy and water management throughout the Federal Government:

- Hold agencies accountable and develop analytical reports to OMB and Congress annually which track Federal progress towards goals on energy efficiency (42 U.S.C. § 8258(a)), renewable energy use (42 U.S.C. § 15852(d)), and vehicles (42 U.S.C. § 6374e(a));
- Track agency compliance with the requirements of Section 432 of EISA, Management of Energy and Water Efficiency in Federal Buildings (42 U.S.C. § 8258(f)), including the completion of comprehensive evaluations of designated covered facilities, reporting potential and initiated efficiency measures, and annually benchmarking metered buildings;
- Require each Executive agency is to establish and maintain a program to ensure that facility energy managers are trained energy managers. Every agency is to report to DOE-FEMP on their progress in meeting this requirement. DOE-FEMP is authorized to develop training and resources to assist with this requirement (42 U.S.C. § 8262c(a));
- Develop energy efficiency design requirements for new Federal buildings and buildings undergoing major renovations through updates to rules 10 CFR 433 and 10 CFR 435, develop guidance, and track performance of agencies with regards to meeting 10 CFR 433 & 10 CFR 435 (42 U.S.C. § 6834(a)(3)(A));
- Consultation with the Secretary of Defense and the Administrator of General Services, shall develop, and issue a report on, best practices for the use of advanced metering of energy use in Federal facilities, buildings, and equipment by Federal agencies. (42 U.S.C. § 8253(e));
- The term "FEMP designated product" means a product that is designated under the Federal Energy Management Program of the Department of Energy as being among the highest 25 percent of equivalent products for energy

efficiency. FEMP's requirement is to establish the technical performance requirements for the applicable technologies (42 U.S.C. § 8259b(b)); and

- Establish appropriate procedures, methods, and clarifications and guidance for use by federal agencies with regard to the administration and award of energy savings performance contracts (ESPCs 42 U.S.C. § 8287 et seq.).

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Federal Energy Management Program $27,000,000	**$10,000,000**	**-$17,000,000**
• Support 25 scorecard agencies in identification, design, and completion of energy-savings projects through the use of performance contracting and power purchase agreements. • Enhance workforce development through the Energy Exchange technical training event. Launch 13 new on-demand training courses, offer 10 onsite regional training workshops, 10 pre-Energy Exchange training workshops, and held 22 live webinars. • Leverage performance contracting to assist agencies implement prioritized resilient portfolio and master planning for mission assurance and provide detailed technical assistance to support projects including, but not limited to, combined heat and power and renewable energy projects. Implement enhancements, to eProject Builder (ePB) on measurement and verification and changes for the new IDIQ contract to enhance the quality of data collected to quantify the impact of performance contracts. • Provide detailed support for UESC projects including support for the development of procurement documents and the statement of work from project pre-development to contract award. • Work with Interagency Energy Management Task Force to gather feedback from agencies, including DoD, to identify top barriers and advance energy management best practices	• Engage in strategic partnerships with 1 to 2 agencies to work intensely together for a specific period of performance resulting in specific tools and solution sets that will yield application benefits across the country to enhance resiliency and physical facility security. • Consolidate Energy Exchange and Better Building Summit event to increase collaboration between commercial, federal, state, and local stakeholders. Develop 3-5 on-demand training courses. Continue to hold at least 7 pre Energy Exchange workshops, at least 2 regional training workshops, and 10-15 live webinars. • Change the focus of leveraging performance contracting technical assistance to concentrate on maintaining current tools and offerings. Focus on maintenance of ePB as a critical data collection tool for performance contracts. • Provide focused support for development of UESC acquisition strategy. • In collaboration with agency partners, implement a systems approach and framework, with integrated tools, metrics and measurements, to facilitate prioritized mission driven energy management at the agency and installation level utilizing best practices and available optimization technologies. • Develop up to 3 new tools but focus on maintaining existing tools for evaluation, optimization, and strategic management of water resources.	• FEMP will concentrate activities to focus on technical assistance leveraging performance contracting and power purchase agreements for limited agencies, assisting 1 to 2 selected agencies with energy and water resilience and security, helping agencies meet their statutory requirements, and enhancing workforce development and free training opportunities in the field of effective energy management for the civil service. • Consolidate Energy Exchange and Better Buildings Summit to increase collaboration with commercial, federal, state, and local stakeholders.

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
• Continue to track the Government’s progress in energy goal achievement; ensuring the program’s capabilities are a known resource for energy management; coordinating the program's strategic planning, budgeting, and evaluation; and supporting public access to Federal energy data. Develop 8 tools to assist with evaluation, optimization, and strategic management of water resources. • Share best practices for effective energy management tailored to energy-intensive facilities including, but not limited to, federal data centers and laboratories.	• Provide statutorily-required reporting and technical guidance.	

Building Technologies

Overview

Residential and commercial buildings are the single largest energy-consuming sector in the U.S. economy, representing approximately 75 percent of the Nation's electricity use and 40 percent of its total energy demand.[1] As a result, Americans spend nearly $400 billion each year to power their homes, offices, schools, hospitals, and other commercial and residential buildings.[2] The Building Technologies Office's (BTO) long-term goal is to reduce the energy intensity of homes and commercial buildings by 50 percent or more through the application of cost-effective efficiency technologies. Reducing building energy use per square foot, or energy use intensity, helps conserve valuable natural resources and strengthens the U.S. economy by creating jobs, improving the productivity of businesses, and helping families save money. Government investment in early-stage research and development (R&D) to enable the building sector to develop and deploy technologies that can improve the efficiency and reduce the Nation's energy costs is essential because some industries within the building sector under-invests in R&D compared to the U.S. industry average. For example R&D funding in the building construction industry is roughly 0.3 percent, about one tenth of the U.S. industry average of 3 percent.[3]

This underinvestment is largely due to the building industry's highly fragmented nature and long-standing market barriers/failures, which make it difficult for any given firm to fully capture the returns of building energy efficiency R&D (and thus recover their R&D costs). The building sector is fragmented in multiple (and overlapping) ways: residential and commercial sectors, new construction and retrofit, building use, ownership, and climate zones. Within any given building, there are numerous building sub-systems or technologies (lighting, heating, building envelope, controls, etc.) many with their own technological and market complexities. In order for a building to operate efficiently and meet the needs of the occupants, each building sub-system must be integrated into a full building system in a unique manner. The market actors that sell, install, use, and pay the bills for each technology and subsystem are generally distinct from one another. This also makes it difficult for any single firm to be able to aggregate sufficient information to address the complexity of the integration challenges necessary to improve efficiency at the scale of the whole building levels. As an example, the construction, homebuilding, design, and engineering sectors are generally split among many small firms[4], which have difficulty capturing the returns on R&D investment. The overarching consequence of these many layers of fragmentation in the building sector is that the large potential social returns from R&D investment in building efficiency technologies and systems will not be realized without government support. Through pre-competitive, early-stage R&D supported by EERE's Building Technologies (BTO), a fundamental understanding of physical properties and phenomena relevant to buildings, building materials, and building equipment enables the various buildings technology industries to innovate novel technologies that ultimately improve the efficiency of energy services such as lighting and heating to consumers.

BTO-sponsored research focuses on opportunities to transform the energy efficient technologies that impact the largest energy system users within buildings: lighting, space conditioning and refrigeration, water heating, appliances and miscellaneous electric loads (MELs), as well as the building envelopes themselves. BTO's research also focuses on developing the physics-based algorithms for improved energy modeling and system controls required to better predict and manage energy efficient appliance/equipment, system, and whole-building energy usage. Additionally, BTO's early-stage R&D on advanced and transactive controls will help strengthen the body of knowledge to enable industry to develop and deploy truly "smart" buildings capable of connecting with the power grid in new and increasingly adaptive manners to help with overall energy system efficiency, resiliency and reducing energy prices. As a result, BTO not only acts as a catalyst for

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[1] U.S. Energy Information Administration. *Annual Energy Outlook 2017 with projections to 2040*. DOE/EIA- 0383(2017). Washington, DC: U.S. Department of Energy, January 2017. https://www.eia.gov/outlooks/aeo/pdf/0383(2017).pdf.

[2] Spending derived from the U.S. Energy Information 2012 Commercial Building Energy Consumption Survey (CBECS) and 2009 Residential Energy Consumption Survey (RECS) from "Total Building Site Energy Expenditures".

[3] Wolfe, Raymond M. (2013). Business Research and Development and Innovation: 2008-10 Detailed Statistical Tables. NSF 13-332. Arlington, VA: National Center for Science and Engineering Statistics. Accessed September 24, 2014: https://www.nsf.gov/statistics/nsf13332/pdf/nsf13332.pdf .

[4] U.S. Department of Energy, Building Technologies Program (January 2017). "Saving Energy and Money with Appliance and Equipment Standards in the U.S." Accessed April 24, 2017: https://energy.gov/sites/.../equipment_standards_factsheet_updated_Feb_11_2015.pdf.

innovation, but spurs U.S. economic competiveness through scientific and engineering leadership. Additionally, BTO activities support development of researchers and others in STEM fields.

BTO also conducts building systems research to gain knowledge and understand physical phenomena that occur not only at a component level but at the system and whole building levels. In addition, BTO collaborates with industry, academia and other leaders across the building sector to conduct research and validation to integrate connected, energy-efficient building components and sub-systems into efficient, resilient and secure building systems and advanced building construction and retrofit design principals and solutions that help building owners and homeowners reduce energy waste. These collaborative efforts also support STEM and workforce development. These design and decision tools help Americans apply efficient building operational practices and technologies through improved understanding of their costs and benefits, resulting in more cost-effective, productive and healthy buildings.

Lastly, BTO works with industry and stakeholders to test and implement statutorily-mandated energy and water conservation standards and test procedures, which are expected to save U.S. business and residential consumers more than $1 trillion in energy costs by 2020.[1] Similarly, as required by statute, BTO participates in industry efforts to develop new building energy codes, which inform state and local building code processes, and includes making a formal determination as to whether new versions make buildings more efficient than preceding versions.

Highlights of the FY 2019 Budget Request

FY 2019 activities support Administration, departmental, and programmatic goals. Highlights include:

- Buildings-to-Grid R&D ($8M): Focus early-stage R&D on cyber physical systems for buildings to include advanced communication platforms and data management systems; advanced sensing, monitoring, and control capabilities; and data analytics to ensure assets are secure and resilient. These advanced technologies will allow for much greater control of building energy management as well as improvements in building operation and maintenance, which are key strategies to meeting BTO's overall goals for reducing energy use in buildings.
- Building Equipment and Envelope R&D ($5M): Early-stage research on solid state cooling and non-vapor compression technologies for building equipment applications and investigations into mechanisms affecting thermal conductivity reduction and greater heat transfer manipulation for building envelope and window materials.
- Solid State Lighting R&D ($5M): Lighting research focus on critical early-stage R&D challenges for advancing understanding of semiconductor physics behind LED and Organic LED (OLED) technologies as well as cross-cutting scientific investigations into the physiological impacts of light and light utilization research.
- Beyond Batteries R&D ($15M): Early stage research will focus on advancing understanding of behind-the-meter assets and opportunities in distributed resource integration and new non-traditional energy storage technologies to enhance grid reliability and resiliency while making building energy efficiency more dynamic and dispatchable, and meeting the needs of the building occupants.
- Equipment and Building Standards ($22M): Meet statutory obligations for test procedures, energy and water conservation standards, and building codes.

BTO subprograms are implemented through partnerships with National Laboratories (direct lab funding through merit reviewed Lab Calls) and with companies, research institutions, and universities through competitive merit reviewed funding opportunity announcements (FOA). In FY 2019, it is expected that about $13-16M will be available for competitive FOAs and the remaining early-stage R&D efforts will be conducted through BTO's lab Annual Operating Plan. Equipment and Building Standards activities will be carried out with technical assistance from established contracts and National Laboratories.

In addition, FY 2019 funds may be used to support efforts such as peer reviews; data collection and dissemination; and technical, market, and economic research studies and other analyses across the BTO portfolio.

[1] U.S. Department of Energy, Building Technologies Program (January 2017). "Saving Energy and Money with Appliance and Equipment Standards in the U.S." Accessed April 24, 2017: https://energy.gov/sites/.../equipment_standards_factsheet_updated_Feb_11_2015.pdf.

Building Technologies Funding ($K)

	FY 2017 Enacted	FY 2018 Annualized CR*	FY 2019 Request	FY 2019 Request vs FY 2017 Enacted
Building Technologies				
Building Energy Research & Development				
Lighting R&D	25,000	—	5,000	-20,000
HVAC and Refrigeration R&D	23,051	—	4,000	-19,051
Buildings-to-Grid R&D[1]	0	—	8,000	+8,000
Sensors and Controls	9,722		0	-9,722
Transactive Controls	23,500		0	-23,500
Building Envelope R&D	7,791	—	1,000	-6,791
Building Energy Modeling R&D	9,336	—	2,000	-7,336
Beyond Batteries	0	0	15,000	+15,000
Total, Building Energy Research & Development	**98,400**	**—**	**35,000**	**-63,400**
Commercial Buildings Integration	**25,662**	**—**	**0**	**-25,662**
Residential Buildings Integration	**21,079**	**—**	**0**	**-21,079**
Equipment and Buildings Standards	**54,000**	**—**	**22,000**	**-32,000**
Total, Building Technologies	**199,141**	**197,789**	**57,000**	**-142,141**

SBIR/STTR:

- FY 2017 Transferred: $3,017,000; STTR $424,000
- FY 2018 Projected: SBIR $2,997,000; STTR $421,000
- FY 2019 Request: SBIR $1,120,000; STTR $158,000

*A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution. (These amounts are shown only at the Congressional control level and above; below that level, a dash (—) is shown).

[1] Sensors & Controls and Transactive Controls are combined into a single, integrated Buildings-to-Grid R&D activity.

Building Technologies
Explanation of Major Changes
($K)

	FY 2019 Request vs FY 2017 Enacted
Building Energy Research and Development: Decrease reflects elimination of late-stage R&D efforts in all technology areas. The most significant eliminations include technology application R&D for solid-state lighting, CRADAs with industry for heating, ventilation, air conditioning, and refrigeration equipment (HVAC&R), demonstration and deployment of transactive controls at the campus- and neighborhood-level, as well as over an 80 percent reduction in the annual BENEFIT FOA. The SSL FOA will only include topics on core technologies development for LEDs and OLEDs, not product development or manufacturing topics. The remaining funds support pre-competitive R&D that allow for world-class energy discoveries, particularly at the DOE National Laboratories. These innovations can be leveraged broadly across industry to facilitate secure, connected, energy-efficient buildings that will benefit American consumers, both household and business. Specifically, the Budget initiates new research on non-traditional energy storage technologies to enhance grid reliability and resiliency.	**-63,400**
Commercial Buildings Integration: The reduction in funding level for this sub-program reflects prioritization of the most critical early-stage activities, within the broader priorities of the Department and the Administration. Consideration and modeling of building technology integration will be emphasized in early-stage R&D projects.	**-25,662**
Residential Buildings Integration: The reduction in funding level for this sub-program reflects prioritization of the most critical early-stage activities, within the broader priorities of the Department and the Administration. Consideration and modeling of building technology integration will be emphasized in early-stage R&D projects.	**-21,079**
Equipment and Buildings Standards: Decrease reflects shift in the funding mechanism for ENERGY STAR test procedure development and performance verification efforts. The Environmental Protection Agency will fund ENERGY STAR through fee collections and use reimbursable authority to cover the cost of related test procedures conducted by DOE. Energy conservation standard compliance activities will maintain compliance with statute. Technical assistance to state and local governments on state and local building codes will be limited to maintaining and updating DOE's REScheck and COMcheck software and the energycodes.gov website.	**-32,000**
Total, Building Technologies	**-142,141**

Description

The Building Energy Research and Development (BERD) Program sponsors early-stage R&D in energy-efficient building technologies, enabling innovation in a range of U.S. industries from building construction and renovation to building equipment and component manufacturing. BERD's conducts research at the component, systems, and whole building levels in the following technology areas: Buildings-to-Grid; Building Equipment and Envelope; Solid State Lighting; and Building Energy Modeling (BEM). In addition, BTO collaborates with industry, academia and other leaders across the building sector to conduct research and validation to integrate connected, energy-efficient building components and sub-systems into efficient, resilient and secure building systems and advanced building construction and retrofit design principals and solutions that help building owners and homeowners reduce energy waste. This early-stage research portfolio leverages the National Laboratories' researchers, laboratory high performance computing capabilities as well as unique National Laboratory facilities that are critical for BTO to enable industry to achieve the goal of reducing the average energy use per square foot of all U.S. buildings by 50 percent from 2010 levels (153.6 kBtu/sqft), thus saving consumers money while enhancing productivity and comfort.

The innovations supported through BTO's early-stage R&D portfolio define new research opportunities in the private and public sector. The focus is on fundamental technical questions that have the potential for high return on investment because of their broad relevance. However, a significant degree of uncertainty and long-time spans are inherent to early-stage research, making it unlikely that industry will invest significant R&D on their own. In many cases, private companies working in the building sector do not have the technical capabilities to undertake these types of early-stage research activities. The building sector can be divided in numerous ways and within any given building, there are numerous building sub-systems or technologies (lighting, heating, building envelope, controls etc.), many with their own market complexities. In order for a building to operate efficiently and securely while still meet the needs of the occupants, all of the technologies must be integrated into a full building system. As a result, it is difficult, if not impossible, for a given firm to fully capture the benefits of investments in energy efficiency R&D. The pre-competitive, early-stage R&D supported by BTO leads to an improved fundamental understanding of physical properties and phenomena relevant to buildings, building materials, and building equipment. This enables many industries to innovate and develop novel technologies that ultimately improve the efficiency of energy services to consumers. While this early-stage R&D is focused on building sector applications, it generates knowledge spillover benefits for other industries, such as defense, computing, manufacturing.

Two competitive funding opportunity announcements (FOA) are envisioned in FY 2019: one for the Solid-State Lighting (SSL) activities and the annual BENEFIT (Building Energy Efficiency Frontiers & Innovation Technologies) FOA.

The FY 2019 SSL FOA ($3-4M) will target early-stage R&D projects for both LEDs and Organic LEDs (OLEDs) that seek to address the key scientific challenges to the industry such as advancing the understanding of semiconductor physics critical to improving efficacy in LEDs & OLEDs. This research will assist industry on the path to a 2030 LED package efficacy goal of 255 lumens/Watt and a 2030 OLED panel efficacy goal of 190 lm/W. The priority research areas for the FY 2019 LED FOA include:

- LEDs: Emitter materials, down-conversion materials, encapsulation and advanced LED prototypes and platforms; and
- OLEDs: Novel materials for stable, efficient white devices and designs for efficient light extraction and utilization.

The FY 2019 BENEFIT FOA ($1-2M) will address R&D challenges at the intersection of building-energy modeling and advanced building controls as they relate to transactions between buildings, building systems and the electricity grid. This FOA leverages a topic in the FY 2018 BENEFIT FOA and builds upon buildings to grid R&D. In addition, the FOA will include early-stage R&D on Controllable Loads and Building Energy Storage activities as they relate to the Beyond Batteries initiative.

Research areas of interest for the FY 2019 BENEFIT FOA include:

- Miscellaneous electric loads research such as incorporating wide bandgap materials advancements into small AC/DC converters;
- Thermal storage integration with building equipment; and

- Research to incorporate time-of-use energy consumption into core building energy modeling tools.

In addition to FOAs, BTO direct funds DOE National Laboratory R&D that leverages their unique facilities and expertise and fosters laboratory collaboration and accessibility. While this work is pre-competitive and early-stage, it will include private sector and university engagement through Cooperative Research and Development Agreements (CRADAs) for early-stage R&D efforts.

The direct laboratory funding is divided into the four technology categories with a focus on basic principles, communications and physical phenomena for next-generation technologies to enable secure, energy efficient, grid-connected buildings.

Buildings-to-Grid (B2G)
R&D will consist of foundational cyber-physical systems research needed to identify, measure and prevent vulnerabilities associated with the interaction between the electricity grid and energy efficient buildings that are enabled by an increasing number of internet-connected devices. This work is outside of the scope of electric utilities' grid modernization activities, as utility companies are not in a position (due to engineering, legal, business model, and/or regulatory constraints) to operate "across the meter", i.e., on end-user assets, equipment and/or buildings. Furthermore, building assets today are not sufficiently monitored and controlled at the whole-building level to enable effective two-way communication across the meter and do not benefit from the kind of R&D that is focused on securing assets on the utility side of the meter (e.g. generation, transmission, distribution). This is the core issue that defines the scientific questions addressed by BTO's R&D within buildings and at the building-to-grid edge. A major research thrust area will be the investigation into building energy management systems capable of self-training and recognizing the complex patterns in digital representations of buildings connected to the electricity grid and/or distributed energy sources. This research enables data-driven, automatic vulnerability assessments of connected buildings by both building owners and utilities so that the electric grid remains secure and resilient. This early-stage research is also a critical strategy in meeting BTO's overall goals for reducing the average energy use in buildings because today building efficiency is significantly degraded due to poor operation and maintenance practices. It is estimated that 20-30 percent of the energy savings opportunity in buildings can be achieved through improvements in operating efficiency through advanced sensors & controls technologies. These advanced technologies will also allow for much greater control of building energy management and will provide additional information about energy consumption in buildings.

The following FY 2019 activities will be a continuation of the B2G R&D supported in FY 2018:
- Solid-state device physics such as studying energy transfer mechanisms and antenna-diode interfaces;
- Multi-variate optimization across generating and consuming devices using predictive analytics and high-fidelity physics-based and data-driven models;
- Autonomous control and pattern matching capable of changing or alternating operation to reduce system distortion at the building-level and to facilitate building-to-grid integration; and
- Integration of detection and diagnostics for whole-building level faults (both software and hardware) impacting building performance with analytics for other complementary distributed energy resources at the grid edge.

New research areas in FY 2019 include:
- Buildings as "virtual storage" (in which the buildings and equipment inherent thermal and other properties can perform stand-alone storage) through advances in controllable building loads, distributed resource integration and building energy storage technologies to improve grid reliability, resilience and affordability;
- Sensitivity analysis of the building envelope contribution to a building's virtual storage capacity;
- Transactive & smart transformers R&D; and
- Data models and analytics to intelligently shut down devices or place devices in sleep mode.

BTO's B2G strategy has been developed in coordination with partners like the National Institute of Science and Technology and DOE's other DOE program offices through the Grid Modernization Initiative (GMI) to fully address cyber physical security and resilience and to avoid duplication. BTO has also played a strong role in DOE's grid modernization efforts which focus on the tools and technologies to measure, analyze, predict, protect, and control the grid of the future. In FY 2019, BTO will continue supporting the early-stage R&D that enables the Grid Modernization Multi-Year Program Plan which focuses on devices and integrated system testing, sensing and measurement, system operations and power flow, design and planning tools, and security and resilience.

The Grid Modernization Initiative (GMI) coordinates efforts across the Department to develop the concepts, tools, and technologies needed to measure, analyze, predict, protect, and control the grid of the future. Guided by the Grid Modernization Multiyear Program Plan, foundational projects which have equities across several DOE offices can be coordinated through leadership from the GMI, while projects sponsored by individual programs continue to address their specific requirements for grid modernization. Projects are executed by or in close coordination with Grid Modernization Lab Consortium (GMLC), a collection of national laboratories that bring together the leading experts, technologies, and resources to modernize the nation's grid. By requiring close collaboration on projects between the GMLC, industry, academia, and other important stakeholders, the GMI accelerates technology development, promotes innovation, and encourages broader investment in the grid.

Solid State Lighting

R&D direct National Laboratory funding supports cross-cutting research topics that are relevant across the solid state lighting industry. This work is done with close collaboration with key players in the industry in order to inform new R&D opportunities. Research areas of interest include investigations into the physiological response to light, such as studies of color perception and spectral optimization and lighting utilization and energy management research.

Building Equipment (HVAC&R) & Envelope

R&D targets fundamental research that enables performance advances in HVAC&R and envelope technologies. This work includes the characterization of new materials properties, specifically around state-of-the-art approaches to managing and controlling heat through innovative materials (solid-state cooling or advanced window applications) and novel device design (e.g. next-generation heat exchangers or thermal diode for walls and foundation). The R&D portfolio supports early-stage, pre-commercial investigations that have multiple practical applications, and therefore, are less likely to be researched by industry due to difficulties in capturing knowledge spillover benefits. For example, investigations into methods for manipulating the phonon transport properties of non-electrically conductive materials or mixed electrical conductivity composites would be informative to a range of building envelope applications, but could also benefit material design for cutting-edge heat exchangers and other equipment components. This research will contribute to BTO’s goal to enable industry to achieve a 24 percent reduction in HVAC energy consumption and 37 percent savings in water heating energy consumption by 2030 relative to a 2010 baseline.

The following FY 2019 activities will be a continuation of the R&D supported in FY 2018:

- Thermally-driven compressors used in fuel-fired applications, including natural gas or propane;
- Exploring methods for enhancing the heat transfer rate, including across solid/liquid interfaces;
- Electrochemical compression for water heating and thermotunneling processes for space conditioning applications;
- Thermal modeling to develop an understanding of stress/strain at material interfaces under extreme temperature changes;
- Self-healing and multi-property materials for non-linear thermal transport in order to reclaim and dissipate heat; and
- Materials that can independently modulate near infrared and visible light.

New research activities of interest in FY 2019 include:

- Building equipment needed to enable building-to-grid integration, such as use of multi-physics tools key for research into high part-load efficiency technology; and
- Materials discovery and characterization to improve and enhance thermal storage in buildings.

Building Energy Modeling (BEM)

R&D seeks to characterize and implement models of the physical phenomena for building components and systems that enable increased use of BEM tools for the design and operation of secure, resilient and energy efficient buildings in the U.S. This includes scientific validation to improve basic algorithms with an increased emphasis on new, innovative model development combining numerical analysis, symbolic algebra, and high performance computing.

BTO's BEM research portfolio has been developed to enable and support the building energy modeling field, but does not compete with companies and other market actors. BTO's software is the most sophisticated and advanced BEM tool available; it directly leverages the researchers and facilities at the DOE National Laboratories. The software accounts for thermal loads based on a wide-range of internal and external variables, energy consumption of all major building subsystems, including distributed generation and storage while accounting for control schemes, complex interactions among building systems, thermal and visual comfort and indoor air quality. This requires unique experimental and theoretical physics characterization as well as numerical analysis and computer science expertise. BTO maintains the scientific expertise in building physics as well as measurement and validation facilities that are unique National Laboratory assets. BTO ensures that the software has a commercial-friendly open-source license so that it can be embedded and utilized broadly by researchers in academia and industry. BEM does not support end-users and end-use applications and leaves that for market actors.

The following FY 2019 activities will be a continuation of the R&D supported in FY 2018:

- Developing new BEM models from measured experimental data, equation derivation and testing analytical/quasi-analytical solutions;
- Treatment of uncertain and stochastic inputs, such as occupancy and infiltration, via hybrid models and uncertainty frameworks;
- Numerical stability and time-step issues, specifically for incorporating building controls and grid-integration; and
- Differentiability, composability and multi-resolution issues to maintain flexibility, execution speed, long-term maintenance and integration with other models.

As a part of GMI, Beyond Batteries focuses on advances in controllable loads, hybrid systems incorporating generation from all sources, and new approaches to energy storage, which are essential to increasing the reliability and resiliency of our energy systems. Advances in these areas will allow for loads to be combined with generation from all sources to, optimize use of existing assets to provide grid services, and increase grid reliability.

BTO's Beyond Batteries research will focus on utilizing behind-the-meter assets to enhance grid reliability, resiliency and security while improving building energy efficiency and meeting the needs of the building occupants. Energy storage, on both side of the meter, is viewed as a key solution to seamlessly and reliably integrating end-use loads in buildings and distributed/variable generation into the electric grid. For example, in the case of buildings, there is a unique and very large opportunity to leverage the thermal storage capacity of existing building equipment (water heaters and HVAC) or thermal mass of building envelope in combination with advanced, transactive controls. In FY2019, BTO will support the GMI through new FOAs totaling $10 million and a Lab Call totaling $5 million. Specifically, BTO will fund research on: secure and reliable hybrid systems ($5M), specifically distributed energy resource integration such as building loads, and new energy storage technologies such as building energy storage ($10M) for resilience and security needs at the building and campus/district scales.

- New Energy Storage Technologies: Building Energy Storage ($10M): Energy storage for buildings has largely been overlooked relative to storage technologies at the grid or transportation scale. With the increasing penetration of distributed energy resources, however, energy storage at the building and/or district scale becomes more compelling. Building energy storage and related technologies have the capability to contribute to the resiliency and security of energy systems. This activity focuses on technologies and approaches to using buildings and building components to store energy as part of solution sets for resiliency-security portfolio planning. Through support for projects selected through a funding opportunity announcement, BTO will focus on developing building energy modeling and controls strategies for whole buildings, systems and components to store thermal energy from building equipment, components and sub-systems. Research areas of interest include:
    - Enhancing the thermal storage capabilities of existing building components – water heaters, HVAC, building enclosure; and
    - Fully automated control of component technologies that allow buildings to time-shift and store energy to optimize use of existing assets to provide grid services, and increase grid reliability.

- Secure and Reliable Hybrid Systems: Distributed Resource Integration ($5M): As new energy technologies are installed, energy systems consist of an increasingly diverse mix of loads, generation sources, and storage devices, installed at all scales (individual homes, commercial buildings, and utility installations) across the country. These component technologies must be coordinated in a sophisticated manner to provide needed energy resources and ensure a reliable and resilient electricity grid. Buildings can function as a hub for integration across energy technologies. Through a funding opportunity announcement, BTO will support projects that focus on the development of flexible and secure behind-the-meter technologies and approaches for the integration of these technologies with electric vehicles, combined heat and power systems, hydrogen fuel cells, and other building loads. Research areas of interest include:
    - Research into predictive analytics and data-driven models specific for the incorporation of advanced CHP, fuel cells, and EVs into buildings operating through innovative control methodologies.
    - Coupling of generation and storage with heating, air conditioning, and water heating equipment so that waste heat can be harvested to reduce heating costs and offset the upfront cost of distributed generation.

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Building Energy Research and Development $98,400,000	**$20,000,000**	**-$63,400,000**
Lighting R&D $25,000,000	$5,000,000	-$20,000,000
• Continue support to improve performance and cost for LEDs and OLEDs. The roadmap-driven LED cost target for FY 2017 is 210 lumens/$, leading to the 2020 goal of 271 lumens/$. Awarded nine FOA projects supporting innovations in LED and OLED core technologies (i.e., down converters, stable white OLEDs), product development (i.e., LED package development, low-cost OLED electrodes), and manufacturing (i.e., LED test equipment, OLED materials manufacturing).	• Continue to support early-stage R&D into the core scientific challenges for the solid-state-lighting (SSL) community for both LED and OLED technologies. FY 2019 funds includes direct National Laboratory support and a targeted competitive FOA. • Award two LEDs FOA projects focused on emitter materials, down-conversion materials, and encapsulation. Award two OLED FOA projects focused on novel materials for stable, efficient white devices and designs for efficient light extraction and utilization. • One direct funded lab AOP project that focuses on crosscutting early-stage research topics of interest including investigations into the physiological response of light and light utilization.	• In FY 2019, the SSL FOA will not include product development (i.e., LED package development, low-cost OLED electrodes) or manufacturing (i.e., LED test equipment, OLED materials manufacturing) resulting in a reduction in FOA awards from nine to four. • The technology application R&D work including field and laboratory evaluations, technical support for industry standards and technology competitions will not be funded in FY 2019.
HVAC & Refrigeration R&D $23,050,487	$4,000,000	-$19,051,487
• Continue to support direct laboratory funding for research in HVAC, water heating, and appliances with an increased emphasis on heat transfer science and materials and system science and research for novel materials as well as foundational, pre-competitive research lessons learned that are a broadly applicable for making U.S. businesses more globally competitive. This included one-two mid-size projects as well as four-five scoping studies to inform future research directions.	• Direct laboratory funding for three research projects in HVAC, water heating, and appliances with an increased emphasis on heat transfer science and materials and system science and research for novel materials as well as foundational, pre-competitive research lessons learned that are a broadly applicable for making U.S. businesses more globally competitive. • One to two new scoping studies on building equipment needed to enable building-to-grid integration and materials characterization to inform thermal storage.	• Topic not included in BENEFIT FOA resulting in all FY 2019 funding through lab AOP as well as, and seven - nine CRADAs with industry partners.
Buildings-to-Grid (B2G) R&D $0	$8,000,000	+$8,000,000
• This work was not included in the FY 2017 appropriation, instead Sensor & Controls and Transactive Controls were written as separate activities.	• Support of the foundational B2G activities that support one to two projects in solid-state physics research for advanced sensor development as well as three to five projects focused on autonomous control and pattern	• Explanation of reductions are included under Sensors & Controls and Transactive Controls.

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
	matching and integrated multi-scale data analytics. • Exploratory investigation into the building envelope contribution to a building's virtual storage capacity, transactive & smart transformers R&D and analytics needed to intelligently shut down devices or place devices in sleep mode. This include three to five scoping studies.	
Sensors & Controls R&D $9,722,238	$0	-$9,722,238
• Lab-directed R&D continued to develop foundational cyberphysical systems R&D to enable building equipment and energy management systems to operate properly within the building to ensure energy efficiency performance. There were also one topic in the FY 2017 BENEFIT FOA one controls for miscellaneous electric loads.	• In FY 2019, funding requested under Buildings-to-Grid activity level.	• Sensors & Controls and Transactive Controls are combined into a single, integrated B2G R&D activity in FY 2019 • This represents a reduction of two FOA projects and two lab directed projects. The remaining projects are described under the B2G R&D activity.
Transactive Controls R&D $23,500,000	$0	-23,500,000
• In coordination with DOE Grid Modernization Initiative, funding supported R&D in the development of Transactive Energy Applications to better integrate Distributed Energy Resources directly within buildings and the electric power system. Through this work, the subprogram developed a characterization methodology to quantify the capacity/availability of resources in buildings to deliver grid and other services; designed, developed, and fielded a multi-purpose controller and algorithms to ensure real time optimal operation.	• In FY 2019, funding requested under Buildings-to-Grid activity level.	• Sensors & Controls and Transactive Controls are combined into a single, integrated B2G R&D activity in FY 2019. • Terminated projects include campus- and neighborhood-level demonstrations of transactive energy, activities to advance transactive control for grid services – especially tools and applications needed for direct building/campus participation, building and campus scale microgrids and smart cities deployments that provide grid resources utilizing open communication standards, protocols, platforms.
Building Envelope R&D $7,791,067	$1,000,000	-$6,791,067
• Three FOA awards focusing on novel hygrothermal and thermal insulation materials, as well as foundational support for testing and verification for performance and durability. • Four Lab-directed R&D projects focused on advanced manufacturing techniques for reducing the cost of envelope solutions and triple pane window	• Initiate one to two new projects on early stage material development based on the results of the FY 2018 scoping studies.	• Reduction in lab directed projects from four to two projects, focused on novel thermal insulation materials. Topic not included in BENEFIT FOA All Building Envelope R&D will be conducted primarily at the National Laboratories. • Elimination of ongoing work testing and verifying performance with industry partners; Eliminated

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
technologies. Ongoing activities and projects include testing of window attachments to support rating and certification programs and technologies that enable cost reductions and manufacturing improvements for highly insulating envelope components.		work includes the technical support of the Attachments Energy Rating Council's manufacturing optimization activities.
Building Energy Modeling Research $9,336,208	$2,000,000	-$7,336,208
• Three direct laboratory funding for R&D of analysis tools was merit reviewed, and a team consisting of NREL, LBNL, and ORNL will continue core work on a three-year project starting in FY 16. Leading a group of competitively solicited development contractors, the core laboratory team will continue to maintain and enhance the open-source industry-leading EnergyPlus whole-building energy simulation engine and will release an update supporting manufacturer-developed component models late in the year. ASHRAE Standard 140 "BESTEST" will publish the updated thermal fabric test suite. • Develop physics-based building energy models from measured experimental data characterizing physical phenomena and processes for building components and systems. Once governing equations are developed, model implementation and integration will be done to ensure flexibility, execution speed, maintainability and integration with other models.	• BEM activities will focus on treatment of uncertain and stochastic inputs, such as occupancy and infiltration, activities to incorporate building controls and grid-integration. This will include two to three direct funded laboratory projects.	• Eliminate the effort in the evolution of the EnergyPlus package towards a modular framework and descope OpenStudio expansion efforts.
Beyond Batteries ($0)	Beyond Batteries ($15,000,000)	Beyond Batteries (+$15,000,000)
• No funding requested	• New energy storage technologies: Solicit and award 5 to 6 FOA projects between industry, universities and National Laboratories and 3 to 4 small studies at the National Laboratories. • Secure and reliable hybrid systems: Solicit and award 3 to 4 projects between industry, universities and National Laboratories and 2 to 3 small studies for National Laboratory scientists	• This is a new activity in FY 2019.

Description

The U.S. commercial building sector (representing 5.6 million buildings and 90 billion square feet of real estate) uses nearly 7 quadrillion Btu of total site energy, roughly 18 percent of the Nation's total energy consumption; accounts for 36 percent of all U.S. electricity consumption.[1] This costs nearly $175 billion to power each year,[2] and over the next four years, the sector is projected to grow by more than 4 billion square feet of net new floor area.[3,4]

BTO has a goal to enable industry to reduce U.S. buildings energy use intensity (EUI, defined as primary energy consumption per floor space) by 50 percent and an interim goal of reducing building EUI 30 percent by 2030. The Commercial Building Integration (CBI) program's research, development, and evaluation helps advance a range of innovative building technologies and solutions, paving the way for industry to deploy high performing buildings that could use 50-70 percent less energy than typical buildings.

In FY 2019, the reduction in funding level for this sub-program reflects prioritization of the most critical early-stage activities, within the broader priorities of the Department and the Administration. Consideration and modeling of building technology integration will be emphasized in early-stage R&D projects.

Reflecting the shift in focus to early-stage research and development, no funding is requested for the Commercial Buildings Integration subprogram in FY 2019. Some management activities related to the execution of prior year appropriations will continue until completion.

[1] https://www.eia.gov/consumption/commercial/reports/2012/energyusage/ Note, this data includes Federal buildings.

[2] U.S. Energy Information Administration. *Annual Energy Outlook 2015 with projections to 2040*. DOE/EIA-0383(2015). Washington, DC: U.S. Department of Energy, April 2015. Accessed January 11, 2016: http://www.eia.gov/forecasts/aeo/pdf/0383(2015).pdf.

[3] U.S. Energy Information Administration. *Annual Energy Outlook 2017 with projections to 2050*. Washington, DC: U.S. Department of Energy, April 2015. Accessed April 11, 2017: https://www.eia.gov/outlooks/aeo/pdf/0383(2017).pdf.

[4] U.S. Energy Information Administration. *Annual Energy Outlook 2017 with projections to 2050*. Washington, DC: U.S. Department of Energy, April 2015. Accessed April 11, 2017: https://www.eia.gov/outlooks/aeo/pdf/0383(2017).pdf.

Commercial Buildings Integration

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Commercial Buildings Integration $25,662,000	**$0**	**-$25,662,000**
• National Laboratory led R&D projects examining systems efficiency and integrated building issues. Projects will focus on multi-system or multi-technology (groups of technologies), specifically targeting multiple technology areas and innovative saving-energy interactions across envelope, lighting/electrical, plug, process, heating, ventilation, cooling, refrigeration, energy management and information, and sensors and controls. • Initiate National Laboratory-led projects on 5 targeted priority & high-potential technologies, including research that answers questions related to energy saving validation and verification, integration complexities, performance specification development, and cost-benefit analysis. • Advance successful market partnership programs such as the BBC and BBA. The focus will be on developing robust partnerships with new industry organizations and market segments to extend the impact and reach of new accelerators that address specific barriers. • Supports a FOA for cost-shared technology demonstrations for small and medium sized existing commercial buildings that will have a positive impact on building energy use, operational costs, market readiness, market penetration outlook (including commercial availability, sales channel plans and competitive pricing outlook) and other quantifiable and non-quantifiable benefits. Demonstrations should result in the application of the technology and collection of performance data (for energy consumption, cost and other benefits) that can be shared across utility territories, publicly published and distributed in order to support and accelerate the deployment of the demonstrated packages.	• No funding requested. In FY 2019, the systems integration focus of activities previously funded through the Commercial Buildings Integration subprogram will be integrated into the early-stage R&D funded through the Building Energy Research and Development subprogram.	• No funding requested for this project in FY19. CBI efforts funded with prior year appropriations will be gradually reduced until funding has been depleted.

Building Technologies
Residential Buildings Integration

Description

The U.S. residential building sector (representing over 118 million single family homes, multi-family units, and mobile homes)[1] uses over 10 quadrillion Btu of total site energy,[2] accounting for roughly 22 percent of the Nation's total energy consumption.[3] The residential sector accounts for 38 percent of all U.S. electricity consumption, costing consumers over $157 billion in utility bills.[4] This is a growing sector, expected add more than 4 million new housing units over the next four years.[5]

The Residential Buildings Integration (RBI) program has a goal of enabling industry to develop and deploy cost-effective technologies and practices that can reduce the EUI of new single family homes by at least 60 percent and existing homes by at least 40 percent by 2020 (relative to a 2010 baseline).

In FY 2019, the reduction in funding level for this sub-program reflects prioritization of the most critical early-stage activities, within the broader priorities of the Department and the Administration. Consideration and modeling of building technology integration will be emphasized in early-stage R&D projects.

Reflecting the shift in focus to early-stage research and development, no funding is requested for the Residential Buildings Integration subprogram in FY 2019. Some management activities related to the execution of prior year appropriations will continue until completion.

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[1] U.S. Energy Information Administration. Residential Energy Consumption Survey 2015, Housing Characteristics (Table HC2.1). Accessed May 19, 2017: https://www.eia.gov/consumption/residential/data/2015/.

[2] U.S. Energy Information Administration. Residential Energy Consumption Survey 2009. Accessed May 19, 2017: https://www.eia.gov/consumption/residential/data/2009/.

[3] U.S. Energy Information Administration. March 2017. Monthly Energy Review. DOE/EIA-0035(2017/3). Accessed May 19, 2017: https://www.eia.gov/totalenergy/data/monthly/archive/00351703.pdf .

[4] U.S. Energy Information Administration. February 2017. Electric Power Monthly. Accessed May 19, 2017: https://www.eia.gov/electricity/monthly/current_year/february2017.pdf .

[5] U.S. Energy Information Administration. Annual Energy Outlook. Residential Sector Key Indicators and Consumption. Accessed May 19, 2017: https://www.eia.gov/outlooks/aeo/.

Residential Buildings Integration

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Residential Buildings Integration $21,079,000	**$0**	**-$21,079,000**
• Solicit and select 2 to 4 projects from a competitive Building America FOA that will focus on applied research through Building America and Better Buildings Residential Program. Technical research will address High Performance Enclosures, Optimal Comfort Solutions for Low-Load Homes and Healthy Efficient Ventilation & Indoor Air Quality Solutions in the remaining climate zones. This is a continuation of the investigation DOE is conducting to improve the overall energy efficiency of the nation's housing stock. • RBI will work with a range of partners including states, utilities, and home inspectors to scale up use of the Home Energy Score in the market. RBI will invest significantly in the underlying IT infrastructure (e.g., Scoring Tool, Assessor database, database of 30,000+ homes scored) to support this market expansion as well as improve usability; streamline and automate processes; and accommodate new applications of the Score (e.g., transferring a home's Score data to FHA to facilitate implementation of the new policy which allows higher debt-to-income ratios to borrowers based on a home's Score). Working in collaboration with real estate stakeholders, RBI will also increase efforts to make the Score and	• No funding requested. In FY 2019, the systems integration focus of activities previously funded through the Commercial Buildings Integration subprogram will be integrated into the early-stage R&D funded through the Building Energy Research and Development Subprogram.	• No funding requested for this project in FY19. RBI efforts funded with prior year appropriations will be gradually reduced until funding has been depleted.

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
related data (e.g., expected energy use) easily accessible during real estate transactions, including integration of the Score into multiple listing services (MLSs). • The RBI subprogram will demonstrate market-based cases through its Zero Energy Ready Homes Program to builders and homeowners. The RBI subprogram will also provide options for increasing lower-cost, high-volume single measure activities that increase efficiency in homes. Through Home Performance with ENERGY STAR, the RBI subprogram will help efficiency programs and their partners to more comprehensively address barriers to retrofits. Continue to support infrastructure development through Solution Centers, providing technical and programmatic solutions to the market. The RBI subprogram will support standards development.		

Buildings Technologies
Equipment and Buildings Standards

Description

The Equipment and Buildings Standards program generates cost-effective energy savings through the development of national appliance and equipment standards and test procedures, as required by statute. The program sets minimum energy and water conservation standards for products covered by statute that are manufactured or imported into the U.S., and can amend the standards over time if technology feasible and economically justified.

The Appliance and Equipment Standards program regulates the energy or water use (or efficiency) of new products that ultimately account for the vast majority of energy use in the building sector—nearly 90 percent of all energy used in residences and nearly 60 percent of all energy in commercial buildings.

DOE is committed to meeting its legislatively mandated deadlines for covered appliances and equipment. The Energy Policy and Conservation Act (as amended) legislatively mandates the program's test procedure and standards rulemaking activities. The rulemaking schedule, and thus the level of program activity, is determined by existing statute.

In FY 2019, for Appliance and Equipment Standards will fund all necessary and feasible steps to finalize legally required efficiency standards and test procedures, and meet all applicable judicial and statutory deadlines. DOE will, to the extent possible, maintain its activities regarding the certification and enforcement of existing energy conservation standards. Specifically, in FY 2019, Appliance and Equipment Standards activities will:

- Issue 3 energy conservation standards;
- Issue 10 test procedure final rules; and
- Enforce standards violations to the extent possible.

This program includes for Building Energy Codes. This activity fulfills a statutory requirement for DOE to participate in industry processes to develop new model building energy codes, which inform state and local building code processes, including making a formal determination as to whether new versions make buildings more efficient than preceding versions. Through this activity, DOE also assists states and localities when they adopt and enforce energy codes.

Equipment and Buildings Standards
Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Equipment and Buildings Standards $54,000,000	**$22,000,000**	**-$32,000,000**
• Program will meet statutory obligations for energy and water conservation standards and test procedures. Program will continue to issue test procedure waivers and enforce minimum standards as budget allows.	• The program will meet statutory obligations for energy and water conservation standards and test procedures. It will continue to issue test procedure waivers and enforce minimum standards as budget allows. Statutory requirements met will include: Ten test procedure final rules or determinations and three energy conservation standards final rules.	• Decrease reflects funding necessary to meet annual statutory requirements. Limit rule making and related activities, including enforcement, to the minimum required to maintain compliance with statute; Rely on reimbursable funding from the Environmental Protection Agency to cover costs related to ENERGY STAR test procedure development and performance verification.
• The Building Energy Codes will meet statutory obligations, including participation in national model code development and implementation.	• The Building Energy Codes will meet statutory obligations, including participation in national model code development and implementation.	• No change; this activity will meet statutory requirements; Limit technical assistance to state and local government regarding code adoption, compliance and enforcement; Limit participation in industry processes to review and modify national model codes to the minimum required for compliance with statute.

Weatherization and Intergovernmental Programs

Overview

The FY 2019 President's Budget eliminates funding for two subprograms, the Weatherization Assistance Program (WAP) and the State Energy Program (SEP), both managed by the Weatherization and Intergovernmental Programs (WIP). The rationale is to reduce Federal intervention in State-level energy policy and implementation and to focus funding on limited, early-stage applied energy research and development activities where the Federal role is stronger.

The mission of WIP was to partner with state and local organizations to facilitate strategic investments focused on states' energy priorities, including advancing policies to enable deployment of energy efficient and renewable energy technologies.

WIP subprograms have addressed the demand and supply sides of energy by providing states with funding in energy efficiency (demand), renewable energy generation (supply), and alternative transportation fuels and vehicles (supply and demand).

For decades, states have demonstrated leadership through their unique authorities to develop and implement energy efficiency and renewable energy policies and programs. State governments wield considerable influence in the building sector through upgraded building codes and incentives; in the utility sector through energy efficiency and renewable energy targets and customer programs; and in the industrial sector with policies that encourage efficiency and/or fuel substitutions (such as energy audits and combined heat and power). States advance these energy solutions through regional networks, strategic energy planning, executive orders, legislation, management of energy efficiency retrofit programs, and land use plans. Local governments are an important bridge between state action and community investment. They have a unique understanding of municipal ecosystems and community needs, and a significant role in revitalization, both of which are critical to integrating innovative energy thinking into the built environment.

Highlights of the FY 2019 Budget Request

WIP's FY 2019 Budget Request includes no funding for WAP and SEP. These programs are not aligned with EERE's focus in FY 2018 and FY 2019 on early-stage applied research and development for sustainable transportation, renewable energy, and energy efficiency technologies. Activities in FY 2019 will focus on completing work activities associated with existing financial and technical assistance awards and initiatives with states and local governments and stakeholder organizations, closing out awards and agreements as they come to the end of their periods of performance, and providing resources and institutional knowledge to state and local entities as practicable.

Weatherization and Intergovernmental Programs Funding ($K)

	FY 2017 Enacted	FY 2018 Annualized CR*	FY 2019 Request	FY 2019 Request vs FY 2017 Enacted
Weatherization and Intergovernmental Programs				
Weatherization Assistance Program				
Weatherization Assistance Grants	225,000	223,472	0	-225,000
Training and Technical Assistance	3,000	2,980	0	-3,000
Total, Weatherization	**228,000**	**226,452**	**0**	**-228,000**
State Energy Program	50,000	49,660	0	-50,000
Total, Weatherization and Intergovernmental Programs	**278,000**	**276,112**	**0**	**-278,000**

*A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution. (These amounts are shown only at the Congressional control level and above; below that level, a dash (—) is shown).

Weatherization and Intergovernmental Programs Explanation of Major Changes ($K)

	FY 2019 Request vs FY 2017 Enacted
Weatherization Assistance Program: The Budget eliminates funding for weatherization technical assistance and formula grants in FY 2019. This will allow DOE to focus limited resources on early-stage applied energy research and development activities.	**-228,000**
State Energy Program: The Budget Request eliminates funding for State Energy Program formula grants and competitive awards in FY 2019.	**-50,000**
Total, Weatherization and Intergovernmental Programs	**-278,000**

Description

The mission of Weatherization was to increase the energy efficiency of dwellings owned or occupied by low-income persons, reduce their total residential energy expenditures, and improve their health and safety. Through retrofitting residential buildings, Weatherization Assistance Program (WAP) grant activities reduced the cost of low-income household energy bills. Since 1976, WAP performed over 7 million upgrades to low-income households, including 1 million retrofits supported through American Recovery and Reinvestment Act of 2009[1] funding. In addition, through coordination with industry stakeholders, WAP developed and assisted in the implementation of voluntary and comprehensive national certifications and standards in retrofit worker training, energy audits, and weatherization methods.

WAP has allocated its funds on a statutory formula basis and made awards to states, the District of Columbia, select Native American Tribes and U.S. Territories, to increase the energy efficiency of homes occupied by families with household incomes of 200 percent or less of the poverty guidelines updated periodically in the Federal Register by the U.S. Department of Health and Human Services under the authority of 42 U.S.C. 9902(2). These agencies, in turn, contracted with approximately 740 Community Action Agencies and local governmental and nonprofit agencies to provide weatherization services to low-income families. Typical energy conservation measures included installing insulation, sealing ducts, repairing or replacing heating and cooling systems, reducing air infiltration, improving hot water production and use, and reducing electric base load consumption.

DOE completed a national evaluation of WAP in FY 2015. The evaluation covered the program year 2007 and 2008 and American Recovery and Reinvestment Act of 2009 performance periods. An impact analysis estimated national energy savings and program cost effectiveness, as well as, non-energy benefits and a comprehensive process evaluation addressed program characterization, operation, training, and quality assurance. Publicly released results include:

- Single-family home average annual energy cost savings of $283;
- 8,500 jobs supported;
- Program-wide savings-to-investment ratio of 1.4; and
- Program-wide benefit cost ratio when including health and safety benefits of 4.1.

In FY 2019, WAP will use existing resources to conduct close-out activities including administration of multi-year formula awards to 57 grantees (50 states, the District of Columbia, 5 U.S. Territories, and 1 Native American Tribe) made with FY 2017 and prior year funding.

Weatherization's Training and Technical Assistance (T&TA) activities supported the development and implementation of a variety of tools needed for work quality, training accreditation, and worker certification. These tools and standards are used by WAP; state and local low income weatherization programs; the home performance industry, which provides services to non-low income households; and, utility demand side management (DSM) programs. Examples include:

- Maintenance of the Standard Work Specifications (SWS) that define how a home is weatherized;
- Accreditation and support of 22 weatherization training centers; and
- Development of worker credentialing standards, which is a consensus process with industry and overseen by a private sector entity.

In FY 2019, T&TA will use existing resources to conduct close out activities including transferring or archiving tools and materials in a manner that ensures continued access to the public resources.

[1] http://www.gpo.gov/fdsys/pkg/PLAW-111publ5/pdf/PLAW-111publ5.pdf

Weatherization Assistance Program

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Weatherization $228,000,000	**$0**	**-$228,000,000**
Weatherization Assistance Grants ($225,000,000)		
• Award and actively manage 57 weatherization formula grantees, which will support approximately 35,700 comprehensive energy audits and residential energy retrofits.	• No funding is requested.	• Existing balances will be used to conduct close-out activities.
Training and Technical Assistance ($3,000,000)		
• Maintenance and improvement of the Guidelines for Home Energy Professional suite of resources including the Standard Work Specifications, Home Energy Professional Certifications, and Training Program Accreditation. • Expansion of Home Energy Professional certification program to include selected multifamily designations. • Enhancement and expansion of the multifamily capacity of the WAP network through coordination with training programs, local WAP agencies, and multifamily stakeholders. • Development and execution of research projects to improve the quality of services and enhancement of benefits to low-income WAP recipients. Specifically, WAP will utilize the results of the WAP National Evaluations to identify areas of program operation that could be improved through the development of best practices or further investigation. DOE will coordinate with partner Federal agencies to ensure that this research is, where possible, applicable to a wide range of programs. • Continue improvement of grantee and subgrantee performance through state plan process with expansion and enhancement of WAP Quality Management and Work Plans features. WIP will conduct a gap analysis of training needs and identify available resources to fill these needs. Tools will be developed for DOE staff and Grantees to aid in assessment of training needs and to develop curricula around management topics. WAP will also continue targeted technical assistance of the Quality Work Plan through the state plan process which includes a review of the current certified quality control inspectors by grantee.	• No funding is requested.	• Existing balances will be used to conduct close-out activities.

Weatherization and Intergovernmental Programs
State Energy Program

Description

State Energy Program (SEP) assisted states in establishing and implementing energy plans, policies, and programs to reduce energy costs, increase economic competitiveness, improve emergency planning and strengthen energy security, and improve the environment. SEP provided states with financial assistance, technical assistance, and best practice sharing networks to facilitate the adoption of plans, policies, and programs designed to address state and regional circumstances. Examples of the types of state programs supported with SEP funding, and developed and administered by state energy offices also include: energy savings performance contracting to retrofit state and local infrastructure including government buildings and facilities; comprehensive residential energy programs for homeowners; diverse financing mechanisms for public institution retrofit programs; loan programs; transportation programs that facilitate the use of alternative fuels; and programs that remove barriers and support supply side and distributed renewable energy.

SEP also funded competitive projects to develop and promote new policy approaches to address state and local energy challenges. Examples of successful SEP competitive projects include:

- Iowa's engagement of regional energy managers (REMs) throughout the state to work with local governments to assist 20 local governments to create energy plans and move forward with energy audits for 1.8 million of building space.
- New Mexico's work with four local governments to pilot a state energy savings performance contracting program and help them establish a pre-qualified list of providers. The first of the four local agencies has completed its retrofits and is realizing savings.
- Washington's efforts with its state legislature to strengthen its energy efficiency resources standard, which was implemented on April 6, 2015. Changes include removal of a formula based shortcut approach, a more flexible cost-effectiveness standard, and better documentation of measurement and verification protocols.
- Texas's successful launch of a tool to help combined heat and power (CHP) developers of distributed generation move through the interconnection process in a fraction of the time.

In FY 2019, SEP will use existing resources to conduct close-out activities including administration of multi-year formula financial assistance awards to 56 grantees (50 states, the District of Columbia, and 5 U.S. Territories). SEP will manage between $60 million to $80 million in combined formula funds from prior years. SEP will also use existing resources to complete a new round of competitive financial assistance awards initiated in FY 2018. This will result in SEP managing competitive awards of between $12 million and $17 million (based on prior year funding and FY 2018 House/Senate Mark).

DOE completed a national evaluation of SEP in FY 2015. The evaluation covered the FY 2008 and American Recovery and Reinvestment Act of 2009 performance periods and developed independent estimates of key program outcomes and metrics, including energy savings, employment impacts, renewable energy production, and environmental co-benefits. Preliminary evaluation results for program year 2008, which is representative of a normal year of funding, include:

- For every SEP dollar spent, program participants received $4.50 in bill savings over the lifetime of the measures installed.
- 2,044 SEP-attributable jobs were created or retained, which is equal to about 1 job per $12,500 in SEP dollars invested.
- The SEP investments resulted in lifetime energy savings and renewable generation of 9.7 trillion Btu (primary source), enough energy to power up to 52,000 homes per year.
- There were SEP-attributable lifetime cost savings of $94.6 million.
- Total costs of $37.4 million were avoided due to reduced emissions associated with program-induced energy savings and renewable generation.

In addition to the work outlined above, SEP recent accomplishments, in partnership with state and local governments include:

- Achieved $425 million in energy cost savings, reduced energy use by over 45 trillion Btu, and reduced water use by over 1.5 billion gallons in public sector buildings and facilities in partnership with 45 local governments, 27 K-12 school districts, and seven states through the Better Buildings Challenge;
- Assisted 25 public entities to develop replicable approaches for improving public buildings with over $2 billion in energy savings performance contracting (ESPC) investments by 18 states, 6 cities and 1 school district and created a publicly available ESPC toolkit;

- Facilitated the upgrade of 1.3 million street lights to high performance LED lighting by partnering with 3 states, 16 cities and 6 regional energy organizations between 2014 and 2016 with an expected annual savings of $48 million and developed a publicly available Outdoor Lighting Toolkit;
- Developed actions plans with more than 30 partners - 14 states, 10 local governments, and 14 community action and non-profits - to address barriers to lowering energy bills for underserved communities and created a suite of low to moderate income baselining tools;
- Established partnerships with 17 states, 7 local governments and 2 regional organizations to improve the energy efficiency of more than 80 water resource recovery facilities in their jurisdictions by at least 30 percent;
- Partnered with 44 local governments from more than 20 states and 31 affiliate organizations, including nongovernment organizations, foundations, for-profit businesses, and local government networks to deliver integrated, community-scale support that enables local governments to achieve their energy, economic and infrastructure goals, and replicate solutions; and
- Made available more than 300 tools, resources, and best practices for states and local governments as they plan for and implement energy projects through the State and Local Solution Center.

State Energy Program

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
State Energy Program $50,000,000	**$0**	**-$50,000,000**
• Award and actively manage 56 formula grants supporting $39 million in state energy projects. • Award and actively manage 30+ competitive awards focused on state planning, analysis and innovative strategies/practices to advance deployment of clean energy technologies and provide replicable models for state and local government entities. Innovative state/regional projects will be funded in a variety of areas including comprehensive energy planning, public-private efforts to expand use and development of new financing and PACE models, expanding use of performance contracting in underserved sectors and with local governments, state/local partnerships to lead by example on clean energy technology upgrades, benchmarking and disclosure and streamlining permitting and interconnection for renewable and other distributed energy resources, etc.	• No funding is requested.	• Existing balances will be used to conduct close-out activities.

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
• Technical assistance: DOE will provide additional technical assistance to states to enhance both their formula and competitive funded efforts, in addition to scaling up partnerships with state and local governments through initiatives such as Better Buildings, providing technical resources developed by DOE labs and other experts, and delivering replicable models and solutions through the State and Local Solution Center. The increase expands SEP's highly effective mechanisms for accelerating energy efficiency adoption through activities and strategic partnerships with state energy offices, including the public sector Better Buildings Challenge and technical assistance through its own activities and those of national state associations and regional organizations.		

Program Direction

Overview

Program Direction enables EERE to maintain and support a world-class Federal workforce that manages early-stage research and development and regulatory functions in sustainable transportation, renewable power, and energy efficiency to address our Nation's energy and environmental challenges. The FY 2019 Program Direction Budget Request provides essential resources for program and project management, oversight activities, contract administration, workforce management, IT support, stewardship of the National Renewable Energy Laboratory, and Headquarters (HQ) and field site non-laboratory facilities and infrastructure.

EERE will reduce Full-Time Equivalents (FTEs) by approximately 34 percent from its FY 2017 level to align with reductions in technology program budgets. Of EERE's current portfolio of approximately 2,500 multi-year (3-5 year) projects, at least two-thirds will remain active in 2019. EERE staff will ensure continuity of the essential oversight activities for EERE's project portfolio and maintain proper stewardship of taxpayer dollars. A limited amount of staff will remain in the Weatherization and Intergovernmental Program to provide minimum required oversight of existing projects. EERE will consolidate procurement and project management functions at the Golden Field Office (GFO), allowing for the elimination of staff support at the National Energy Technology Laboratory (NETL).

EERE will utilize a suite of available workforce reshaping options, including the Voluntary Separation Incentive Program (VSIP), the Voluntary Early Retirement Authority (VERA), extended administrative furloughs, and Reduction in Force (RIF) authority, to achieve staffing reductions. EERE does not expect to have prior year funds for use in FY 2019.

Highlights of the FY 2019 Budget Request

The FY 2019 EERE Program Direction Budget Request will:

- Support 450 FTEs at HQ and the GFO;
- Continue the EERE Program Information Center (EPIC) enterprise IT modernization effort to improve EERE's operational effectiveness and efficiency through an integrated IT-based platform for EERE's business processes, including: budget planning, formulation, and execution; Funding Opportunity Announcement development through award selection; project management of EERE projects with industry and university performers; and award and management of EERE's projects with the National Laboratories; overall EPIC developmental costs will be reduced through leveraging efforts with other DOE offices;
- Support project management and procurement across EERE's full portfolio of projects, including closing out completed financial assistance awards; and
- Maximize the efficient and effective use of available resources to accomplish EERE's core mission while reducing overall expenses and improving the delivery of EERE services to the public.

Program Direction Funding
($K)

	FY 2017 Enacted	FY 2018 Annualized CR *	FY 2019 Request	FY 2019 Request vs FY 2017 Enacted
Program Direction				
Washington Headquarters				
Salaries and Benefits	78,324	—	57,000	-21,324
Travel	3,584	—	2,150	-1,434
Support Services	9,302	—	7,410	-1,892
Other Related Expenses	28,238	—	38,380	10,142
Total, Washington Headquarters	**119,448**	—	**104,940**	**-14,508**
Golden Field Office				
Salaries and Benefits	20,600	—	18,000	-2,600
Travel	251	—	150	-101
Support Services	1,207	—	700	-507
Other Related Expenses	1,583	—	1,320	-263
Total, Golden Field Office	**23,641**	—	**20,170**	**-3,471**
National Energy Technology Laboratory				
Salaries and Benefits	5,478	—	0	-5,478
Travel	200	—	0	-200
Support Services	325	—	0	-325
Other Related Expenses	4,408	—	0	-4,408
Total, National Energy Technology Laboratory	**10,411**	—	**0**	**-10,411**
Total Program Direction				
Salaries and Benefits	104,402	—	75,000	-29,402
Travel	4,035	—	2,300	-1,735
Support Services	10,834	—	8,110[1]	-2,724
Other Related Expenses	34,229	—	39,700	+5,471

*A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution. (These amounts are shown only at the Congressional control level and above; below that level, a dash (—) is shown).

[1] Includes additional $110K target allocations for Security Investigations.

	FY 2017 Enacted	FY 2018 Annualized CR*	FY 2019 Request	FY 2019 Request vs FY 2017 Enacted
Total, Program Direction	**153,500**	**152,458**	**125,110**	**-28,390**
Federal FTEs	632	—	450	-182
Additional Office of Fossil Energy's (FE) FTEs at NETL[1]	48	—	0	-48
Total EERE-funded FTEs	**680**	—	**450**	**-230**

	FY 2017 Enacted	FY 2018 Annualized CR*	FY 2019 Request	FY 2019 Request vs FY 2017 Enacted
Support Services				
Technical Support	7,711	—	6,000	-1,711
Management Support	3,123	—	2,110[2]	-1,013
Total, Support Services	**10,834**	—	**8,110**	**-2,724**
		—		
Other Related Expenses		—		
Other Services	17,887	—	11,202	-6,685
Working Capital Fund (WCF)	16,342	—	28,498	12,156
Total, Other Related Expenses	**34,229**	—	**39,700**	**5,471**

*A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution. (These amounts are shown only at the Congressional control level and above; below that level, a dash (—) is shown).

[1] EERE funded 48 FTEs at NETL through a reimbursable agreement who supported EERE activities. These 48 FTEs were not included in the EERE FTE totals shown in the table.

[2] Includes additional $110 target allocations for Security Investigations.

Program Direction

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Program Direction $153,500,000	**$125,110,000**	**-$28,390,000**
Salaries and Benefits $104,402,000	**$75,000,000**	**-$29,402,000**
• Funding levels provide minimal resources for program and project management, administrative support, contract administration, and human capital management.	• Funding levels provide minimal resources for program and project management, administrative support, contract administration, and human capital management.	• EERE's Federal workforce will be reduced to approximately 450 FTEs, a decrease of 230 FTEs (34 percent) below the 680 FTEs supported in FY 2017. Funding reductions are not directly proportional to FTE reductions due to costs associated with staff leaving Federal service, e.g. leave payouts. • Includes the elimination of EERE support of NETL, significant staff reductions in the Office of Weatherization and Intergovernmental Programs, staff transfers to Departmental support offices (International Affairs, Public Affairs, Office of Technology Transitions), and Federal staff buyouts, furloughs and RIFs.
Travel $4,035,000	**$2,300,000**	**$-1,735,000**
• EERE's FY 2017 travel budget supports management of projects and close-outs, providing essential oversight of EERE-funded projects.	• EERE's FY 2019 travel budget supports management of projects and close-outs, providing essential oversight of EERE-funded projects.	• The 43 percent reduction reflects the decrease in anticipated site-visits and other travel related to managing a lower number of projects and financial assistance awards.
Support Services $10,834,000	**$8,110,000**	**-$2,724,000**
• Support services funding provides technical and administrative contract support, and information technology services. This funding also contributes to training, education, safety, health support, safeguards and security, computer configuration, and maintenance.	• Support services funding provides technical and administrative contract support, and information technology services. This funding also contributes to training, education, safety, health support, safeguards and security, computer configuration, and maintenance.	• The 25 percent reduction is a decrease in Legacy IT system support costs and other IT-related services, resulting from a smaller workforce, and a reduction of non-IT support contractors in HQ and the GFO.
Other Related Expenses $34,229,000	**$39,700,000**	**+$5,471,000**
• Other Related Expenses provides funds for office space and overhead at DOE Headquarters and the Golden Field Office through EERE's contribution to the WCF for common	• Other Related Expenses provides funds for office space and overhead at DOE Headquarters and the Golden Field Office through EERE's contribution to the WCF for common	• Growth is related to an increased investment in EERE's IT modernization project (i.e., EPIC) and the plan to fully fund the WCF costs in FY 2019,

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
administrative services and through direct payments in the field. Expenses covered include building operations, telecommunications, network connectivity, supplies/equipment, printing/graphics, copying, mail, contract closeout, purchase card surveillance, computer equipment (hardware, software, licenses, and support), utilities, postage, administrative expenses, security, and publications. Includes funding for EERE’s IT modernization project.	administrative services and through direct payments in the field. Expenses covered include building operations, telecommunications, network connectivity, supplies/equipment, printing/graphics, copying, mail, contract closeout, purchase card surveillance, computer equipment (hardware, software, licenses, and support), utilities, postage, administrative expenses, security, and publications. Also includes funding for EERE’s IT modernization project (i.e., EPIC).	whereas Program funds covered some of the WCF costs in FY 2017.

Strategic Programs

Overview
Strategic Programs funded high-impact, crosscutting, integrative activities most efficiently executed by a single cross-cutting organization in coordination with technology programs.

Highlights of the FY 2019 Budget Request
To eliminate redundancies and increase efficiencies across the department, staff will be centralized within corporate offices, including DOE's Office of International Affairs (IA), Office of Public Affairs (PA), and Office of Technology Transitions (OTT). Therefore, no funds are requested for Strategic Programs within the EERE program in FY 2019.

In FY 2019, Strategic Programs will transition the following activities as indicated:
- Technology-to-Market (T2M) subprogram activities will transfer to OTT.
- Strategic Priorities and Impact Analysis (SPIA) subprogram activities will be funded, as appropriate, by relevant EERE programs.
- International subprogram activities will transfer to IA.
- Communication and Outreach subprogram activities associated with external outreach will be transferred to PA. Internal communications activities, such as EERE-specific graphics and informational materials, will be funded, as appropriate, by relevant EERE programs.

Strategic Programs Funding ($K)

	FY 2017 Enacted	FY 2018 Annualized CR *	FY 2019 Request	FY 2019 Request vs FY 2017 Enacted
Strategic Programs				
Technology-to-Market	5,500	—	0	-5,500
Strategic Priorities and Impact Analysis	6,000	—	0	-6,000
International	3,500	—	0	-3,500
Communications and Outreach	4,000	—	0	-4,000
Total, Strategic Programs	**19,000**	**18,871**	**0**	**-19,000**

*A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution. (These amounts are shown only at the Congressional control level and above; below that level, a dash (—) is shown).

Strategic Programs
Explanation of Major Changes
($K)

	FY 2019 Request vs FY 2017 Enacted
Strategic Programs	
Technology-to-Market: No funds are requested for the T2M subprogram in FY 2019. Strategic Programs will transition activities currently funded by the T2M subprogram to OTT.	**-5,500**
Strategic Priorities and Impact Analysis: No funds are requested for the SPIA subprogram in FY 2018. Analysis activities will be funded, as appropriate, by relevant EERE technology programs.	**-6,000**
International: No funds are requested for the International subprogram in FY 2019. International activities will be transferred to IA.	**-3,500**
Communications and Outreach: No funds are requested for the Communications and Outreach subprogram in FY 2019. Communication activities associated with external outreach will be transferred to PA. Internal communications activities will be funded, as appropriate, by relevant EERE technology programs.	**-4,000**
Total, Strategic Programs	**-19,000**

Strategic Programs
Technology-to-Market

Description

The T2M subprogram's mission was to accelerate the successful commercialization of EERE technologies toward market adoption by overcoming key barriers in the U.S. energy technology innovation ecosystem. In support of this mission, the subprogram, in coordination with DOE's Office of Technology Transitions (OTT), worked across the entire ecosystem, including technology developers, startups, and small and medium enterprises, sources of capital, and other key stakeholders, and provided them with tools, resources, and expertise to address barriers to commercialize promising technologies or otherwise develop new commercialization pathways, especially those more particular to EERE technologies. The subprogram also supported development of the next generation of clean energy entrepreneurs at the National Laboratories, universities, and emerging companies. The Budget consolidates programs focused on bringing technologies to the market into one office, the OTT, and shifts the burden of technology commercialization more appropriately to industry and the capital markets.

No funds are requested for the T2M subprogram in FY 2019. Strategic Programs will transition all technology commercialization activities currently funded by the subprogram to OTT.

Technology-to-Market

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Technology-to-Market $5,500,000	**$0**	**-$5,500,000**
• Launch a new program to accelerate investment from a range of philanthropic organizations to clean technology development and commercialization. • Launch a new Clean Energy Jobs Initiative to develop classifications, career pathways, and analytical tools for jobs related to clean energy technologies and conduct outreach and education events that help accelerate education, workforce development, and hiring in the clean energy sector. • Scale the Lab-Corps Program from the FY 2014 ▪ FY 2015 pilot effort to a full program across all National Laboratories. Expand other laboratory impact and commercialization activities for continued acceleration of moving EERE technologies into the market. • Continue implementation and management of existing programs including NIICE and the National Student Entrepreneurship Prize (NSEP). • Provide ongoing support to the Energy Transition Initiative for islands and expand to other sectors, specifically local governments. • Develop a customizable, online, multidisciplinary energy mini-course for the public. • Continue minimal support of NTER as is necessary to complete transition to external entity. • Support the EERE Solar Decathlon, an award-winning program that challenges college teams to design, build, and operate cost-effective, energy-efficient, and attractive solar-powered houses. • Strategic Programs' management of the Solar Decathlon will include the exploration of alternative business models to ensure that this initiative is	• No funding is requested.	• T2M activities will be transferred to DOE Office of Technology Transitions.

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
sustainable as a workforce development and technology deployment activity.		

Strategic Programs
Strategic Priorities and Impact Analysis

Description

The SPIA subprogram supported EERE's cutting-edge, transformational research and development and ensured favorable short- and long-term returns on investment by Americans by providing evidence-based, portfolio-wide analysis for energy decision-makers in EERE and beyond. This was accomplished by performing cross-cutting, gap-filling, and corporate analyses associated with EERE technologies; developing tools and methods that enabled consistent evaluation and analysis across EERE; and providing analytical thought leadership across DOE, other government agencies, and external stakeholders.

No funds are requested for the SPIA subprogram in FY 2019. Analysis activities will be funded, as appropriate, by relevant EERE technology programs.

Strategic Priorities and Impact Analysis

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Strategic Priorities and Impact Analysis $6,000,000	**$0**	**-$6,000,000**
• Complete retrospective impact and ROI evaluation studies that quantify EERE impact and guide future EERE program implementation. • Launch new funding opportunity announcement (FOA) to partner with competitively selected cities to acquire data and perform analysis toward long-term clean energy roadmaps. • Continue to support and maintain the DOE Data Catalog on OpenEI.org developed in FY 2015 by EERE to ensure DOE datasets housed across various platforms are properly federated with Data.gov and OSTI in accordance with Project Open Data and open data priorities. • Provide analytical support to assess impact of potential climate related policies to internal DOE stakeholders. • Provide support for grid integration efforts, focusing on scenarios that can achieve maximum grid flexibility with high penetration of renewable technologies. • Support clean energy databases that contain real-world market data, modeled cost and performance data, and reviews of published studies as well as an inventory of state policies and incentives that impact the deployment of EERE technologies. • Complete an assessment of EERE technology program methodologies and assumptions for prospective impact analyses methods and assumptions for impact analyses and project data collection, identify best practices, and establish a standard approach across EERE to ensure consistent and comparable information is available to inform policy decisions.	• No funding is requested.	• Analysis activities will be conducted as appropriate, within relevant EERE technology programs, and corporate oversight of analysis methodologies will shift to the EERE Budget Office.

Strategic Programs
International

Description

The International subprogram's mission was to increase the speed and scale of clean energy deployment and facilitate market access for American companies through international collaboration with strategic partners. The subprogram funded only U.S.-based technical experts to lead engagement in targeted opportunity spaces. Project activities led to increased exports of U.S. clean energy technology and services, and improved energy security. The subprogram also facilitated R&D partnerships with strategic partners with developed economies, as identified by EERE technology programs, to leverage the funding and expertise of foreign governments and researchers to achieve EERE's domestic program goals. The subprogram's activities in the EERE mission space were fully coordinated with DOE's Office of International Affairs (IA) and the U.S. Departments of State and Commerce. The subprogram also coordinated and collaborated with U.S. clean energy technology manufacturers and service providers when appropriate.

No funds are requested for the International subprogram in FY 2019. International activities and program staff will be transferred to IA.

International

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
International $3,500,000	**$0**	**-$3,500,000**
• Provides U.S. contribution to support the U.S. -Israel Energy Cooperative Agreement. • Support market-priming and clean energy deployment activities with up to 10 core partner countries. Representative activities include: expand testing of PV reliability (U.S. –made panels) in Indian climates; develop an industrial • energy efficiency audit program and database of retrofit opportunities with Brazil; train experts in South Africa on simulation and testing of energy efficient building envelope components; facilitate project finance for up to 3 demonstration sites for renewables deployment in remote Indonesian grids, and develop a replication strategy; conduct technical review of proposed energy efficiency legislation in Chile and develop new programs to promote energy efficiency by large energy consumers.	• No funding is requested.	• International activities will be transferred to Departmental Administration's International Affairs Program.

Strategic Programs
Communications and Outreach

Description

The Communications and Outreach subprogram provided strategic communications leadership, coordination, and operation support for EERE and for the department by organizing, editing, and disseminating information and associated impacts to media and the public on EERE programs, activities, and technologies. This information fully leveraged EERE's technology investments by helping raise awareness and overcoming informational barriers to understanding EERE technologies, making stakeholders aware of resources and opportunities that may be available to them through EERE, and encouraging the accelerated adoption of EERE technologies.

No funds are requested for the Communications and Outreach subprogram in FY 2019. Communication activities associated with external outreach will be transferred to DOE's Office of Public Affairs. Internal communications activities, such as EERE-specific graphics and informational materials, and corporate level responses to DOE queries, will be funded, as appropriate, by relevant EERE programs.

Communications and Outreach

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Communications and Outreach $4,000,000	**$0**	**$-4,000,000**
• Maintains content for EERE web and social media presence. • Provides modest support for analysis of communications data. • Complete transition of subsites and content to the Energy.gov platform and maintain support for ongoing content management. • Maintain public inquiries and distribution function as digital publications strategy is executed. • Maintain support for legislative affairs and stakeholder engagement. • Expands support for high-priority crosscutting activities, including the Clean Energy • Manufacturing and National Laboratory impact initiatives. • Continues support to EERE senior leaders in developing presentation materials and messages for frequent speaking engagements.	• No funding is requested.	• External relations activities will be transferred to Departmental Administration's Public Affairs Program. • Internal communications activities will be managed within relevant EERE programs.

Facilities and Infrastructure (NREL)

Overview

The National Renewable Energy Laboratory (NREL) is the Office of Energy Efficiency and Renewable Energy's (EERE) Federally Funded Research and Development Center. EERE is NREL's steward and primary sponsor. NREL serves as the Nation's preeminent institution for delivering impactful scientific knowledge and technology innovations that transform renewable energy technologies, systems, and markets. NREL's research advances the science and engineering of energy efficiency, sustainable transportation, and renewable power technologies, and provides the scientific knowledge to integrate and optimize energy systems. To succeed in this mission, EERE's Facilities and Infrastructure Program (F&I) FY 2019 Budget Request ensures NREL's existing research and support infrastructure are maintained and upgraded in key areas, and provides new capabilities in emerging Research and Development (R&D) areas to attract world-class research scientists and to develop cutting-edge, innovative solutions to the most challenging technology issues.

The objectives of the F&I Program are to:

- Provide the laboratory with a safe, secure work environment for the protection of personnel, partners, and the public;
- Provide NREL with secure information networks with strong cybersecurity protocols;
- Maintain NREL's science and support infrastructure through regular reinvestments determined by age, condition, risk, and DOE and industry standards, ensuring the availability of a world-class R&D environment for ongoing EERE mission activities and emerging areas of R&D of interest throughout all of Government and industry;
- Acquire new mission-critical science and technology capabilities, when warranted;
- Provide direct funding for operational activities of major facilities and infrastructure and site-wide investments; and
- Develop and steward grid modernization and broader energy systems integration capabilities at the Energy Systems Integration Facility (ESIF), a DOE-designated user facility designed to inform early-stage research, utilizing high performance computing capabilities.

Highlights of the FY 2019 Budget Request

To posture NREL's capabilities to support emerging technologies and future requirements, the FY 2019 F&I Budget Request focuses on sustaining NREL's world-class R&D environment by maintaining and, where necessary, upgrading its equipment and facilities. NREL facilities are under increasing demand by Government and industry R&D activities. This request supports the second year of a four-year refresh/upgrade of the High Performance Computer (HPC) at the ESIF. Simulations conducted on the HPC have led to significant advances in clean energy technologies. However, demand for computing from R&D efforts has saturated the current HPC capabilities. Use of the ESIF HPC has grown to include more than 3X node hours allocated for job scheduling in FY 2017 as compared to FY 2014; the non-NREL user population has grown to nearly 8X of FY 2014 levels; and the current HPC system on-line utilization exceeds 90 percent of capacity.

Funding supports completion of a power generation upgrade at the National Wind Technology Center (NWTC) to increase grid interconnection capacity from 10MW to 19.9MW, overcoming current research curtailment impact due to capacity limitation and enabling experimentation with larger turbines and research on large-scale solar and energy storage systems. This upgrade will create a unique national grid integration capability at higher power levels (>1 MW) to complement the ESIF (>1 MW). Funding also supports laboratory upgrades, providing a capability to expand NREL's early-stage research while providing foundational knowledge to enable innovations that advance biofuels and bio products. Included in the laboratory upgrades is a leading-edge Microbial Energetic Laboratory for research in the energy flow in microorganisms. Breakthroughs in this area will contribute foundational knowledge to enable the design of next-generation organisms and processes to more efficiently produce biofuels and chemicals.

Cybersecurity requirements to reduce vulnerabilities and lessen the threat of successful cyber-attacks remain a high priority in the FY 2019 Budget Request. Funding provides for continuous monitoring, protection of networks and information, and detection, analysis, and mitigation of intrusions.

To ensure the continued support of diverse early-stage R&D activities, which require state-of-the-art facilities, the Operations & Maintenance and Facility Management requests remain at FY 2017 Enacted levels. The Site-Wide Facility Support request is reduced by $2 million associated with movement of requirements to indirect funding.

Facilities and Infrastructure (NREL) Funding ($K)

	FY 2017 Enacted	FY 2018 Annualized CR *	FY 2019 Request	FY 2019 Request vs FY 2017 Enacted
Facilities and Infrastructure (NREL)				
Operations and Maintenance	26,000	—	26,000	0
Facility Management	36,000	—	36,000	0
NREL Site-Wide Facility Support	30,000	—	28,000	-2,000
Total, Facilities and Infrastructure (NREL)	**92,000**	**91,375**	**90,000**	**-2,000**

Explanation of Major Changes ($K)

	FY 2019 Request vs FY 2017 Enacted
Facilities and Infrastructure (NREL)	
Operations and Maintenance: No change from FY 2017.	**0**
Facility Management: No change from FY 2017.	**0**
NREL Site-Wide Facility Support: This slight reduction relative to prior years begins a transition toward a more appropriate accounting of costs charged to other NREL users. This action re-categorizes $2 million into NREL indirect, which will result in a slight increase to other NREL customers.	**-2,000**
Total, Facilities and Infrastructure (NREL)	**-2,000**

*A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution. (These amounts are shown only at the Congressional control level and above; below that level, a dash (—) is shown).

Facilities and Infrastructure (NREL)
Operations and Maintenance

Description

The Operations and Maintenance subprogram provides the program planning and implementation required by DOE Order 430.1C, Real Property and Asset Management, to maintain real property assets at NREL. The subprogram includes General Plant Projects (GPP), General Plant Equipment (GPE), Maintenance and Repair (M&R), and Safeguards and Security (S&S).

GPP investments maintain and enhance the real property portfolio, renovate general science capabilities and buildings, and upgrade laboratories for technical advancements. Examples of GPP are laboratory refurbishments, laboratory reconfigurations, utility enhancements, facility additions, and projects to accommodate new research capabilities.

Major GPP activities include:

- Finalizing the electrical substation upgrade to increase power capacity from 10MW to 19.9MW at the National Wind Technology Center (NWTC) to enable experimentation with larger turbines and accommodate research on larger-scale grid integration experiments;
- Establishing a municipal water connection at the NWTC to address fire protection and domestic water needs (no potable water exists on-site requiring water to be trucked in); and
- Renovating and refurbishing high priority laboratories, including completion of the Microbial Energetic Laboratory to conduct research in order to understand the energy flow in microorganisms for foundational knowledge to design next-generations of organisms and processes.

GPE investments acquire and maintain shared science and support equipment to meet research mission needs, replace outdated technology, and provide for emergent research opportunities.

Specific GPE investments include:

- Grid simulator and load bank to support grid integration experiments involving megawatt-scale wind, PV, and storage systems;
- Autonomous vehicles sensor research assets to provide opportunities to increase vehicle fuel efficiency and safety; and
- Laboratory equipment updates and modifications at South Table Mountain laboratories to address changing and evolving program decisions and research priorities.

M&R funding sustains real property equipment, systems, and facilities in a condition suitable to ensure their availability for research activities and their effectiveness in supporting the safety and security of the personnel and DOE-owned assets on the campus. M&R funding is within the DOE control standard of two to four percent of Replacement Plant Value (RPV).

S&S funding provides for physical security and cyber protection of NREL personnel, information and property from threats and hazards, including the capability to respond to emergencies as well as protecting networks and information resources. The FY 2019 funding aligns additional resources to cyber needs due to the increasing and evolving cybersecurity risk environment.

Operations and Maintenance

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Operations and Maintenance $26,000,000	**$26,000,000**	**$0**
• Continues GPP and GPE level of investments similar to FY 2016. • Maintains operational readiness for M&R activities and keeps funding within the DOE control standard of 2-4 percent of RPV. • Maintains operational readiness for S&S activities, similar to FY 2016 levels, with an increased focus on cybersecurity.	• Continues GPP and GPE level of investments similar to FY 2017. • Maintains operational readiness for M&R activities and keeps funding within the DOE control standard of two to four percent of RPV. • Maintains operational readiness for S&S activities, similar to FY 2017 levels, with an increased focus on cybersecurity.	• There are no changes from FY 2017.

Facilities and Infrastructure (NREL)
Facility Management

Description

The Facility Management subprogram provides funding for core operations at the Energy Systems Integration Facility (ESIF), keeping the facility and research assets of this world-class DOE user facility as state of the art and available to support research across EERE's portfolio and with EERE's partners in other DOE offices, at other Federal agencies, at universities and in the private sector.

ESIF is a unique national asset providing the public and private sectors with the ability to conduct critical R&D on multiple technologies and energy sources in integrated energy systems. ESIF provides state-of-the-art laboratories and support infrastructure to advance innovation that enables design and energy systems performance optimization. A priority focus is to enable a resilient, secure modern grid that can accommodate a variety of domestic energy resources.

ESIF's High Performance Computer (HPC) supports research across nine EERE programs as well as the crosscutting Grid Modernization Initiative and produces computational experiments that advance critical NREL early-stage research efforts at temporal and spatial scales that evade direct observation. In addition, the HPC establishes a foundational scientific and engineering capability that attracts leading talent, collaborators, and partners, and demonstrates the world's most efficient HPC data center technologies. The FY 2019 request provides funding for the second year of the four-year refresh/upgrade.

The current HPC is over-subscribed and utilization exceeds 90 percent. Requirements for advanced modeling and simulation capabilities continue to trend upward as the variety of energy sources grow, placing new demands on power generation equipment, transmission, storage, cybersecurity, and grid modernization.

Specific anticipated scientific outcomes due to the HPC upgrade are:

- Energy Systems Integration: Modeling the Eastern Interconnect grid at native spatial scales under different renewable penetration scenarios;
- Wind: Model wake fields and inflow conditions in existing wind plants to reduce cost of electricity by up to 10 percent;
- Materials: Integrate ab initio calculations from HPC to guide experimental development of complex materials;
- PV Materials–Inverse Design: Develop new techniques to predict material properties of novel alloys and design materials of PV with prescribed physical properties;
- Automotive Applications: Investigate third-generation advanced high-strength steels;
- Electric Vehicles: Multi-scale simulations of electric drive vehicle battery systems to create cutting-edge battery simulation tools to aid safe, affordable designs;
- Buildings: Perform large-scale analysis of the U.S. residential building stock for potential energy-efficient projects;
- Renewable Fuels: Simulations of enzyme-plant cellulose interactions to reduce fuel costs; and
- Biomass Pyrolysis: Simulations guiding optimization of chemical and physical reactions and catalysts to reduce the cost of fuel production.

The table below describes the major categories funded by this subprogram.

Major ESIF Costs
ESIF Administration & Facility Management ($8,390K): ESIF Administration includes the ESIF operations director and administrative support. This also includes other labor and non-labor costs to implement a user program (e.g., user outreach, engagement and education; developing calls for proposal; conducting technical peer reviews of proposal; scheduling R&D projects and reporting ESIF status and progress). ESIF Facility Management includes functions to maintain the safety envelope of the ESIF and provides technical support to research activities. Ensures adherence to and implements Integrated Safety Management, Environmental Management, and Hazard Management requirements within the ESIF. Includes maintenance, repair, and modification connection for SCADA, lab safety, research chiller/boiler; research project equipment receiving, placement, setup, fabrication, and decommissioning; gas distribution, fuel distribution, and gas detection; and general logistics support (consumables procurement, equipment storage, material handling, and general maintenance activities).
Scientific Staff ($10,410K): ESIF-dedicated technical staff that steward individual capabilities, including experimental and high-performance computing. Technical staff supports users in designing, setting up and conducting experiments in ESIF. In the user-facility model, peer reviewed and selected projects receive facility-funded support for equipment and experimental configuration design, set-up, problem solving and operation.
HPC Equipment & Operations ($12,200K): HPC refresh/upgrade and expansion; HPC operations, HPC cybersecurity, user operations, data center operations, and HPC project management/scheduling.
Operations, Maintenance, & Utilities ($5,000K): Labor includes ESIF building engineers and the labor associated with other NREL site operations staff or service contractors to maintain facility systems and sustain readiness. Examples include custodial services, fire and emergency systems, HVAC maintenance, and small parts. This also includes a prorated share of NREL site operating costs, such as road maintenance and snow removal as well as maintenance and calibration for all user-program research equipment. Utilities include power, water, natural gas, dedicated exhaust, house nitrogen, and compressed air.

Facility Management

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Facility Management $36,000,000	**$36,000,000**	**$0**
• Invests in REDB upgrades and recapitalization of test equipment moved to ESIF in 2013. Maintains expanded high performance computing capacity commensurate with number of ESIF projects. • Provides systems engineers, area supervisors, health and safety personnel, and management for ESIF research activities. • Provides for utilities, building operations, and routine maintenance. • Provides experimental connections and enhanced data collection.	• Provides for the second year of a four-year refresh/upgrade of the HPC to meet growing mission needs. • Provides for utilities, building operations, and routine maintenance. • Provides for energy system security and resilience to ensure that activities at ESIF meet all cybersecurity requirements and needs of users. • Provides for systems engineers, area supervisors, health and safety personnel, and management for ESIF research activities. • Provides for experimental connections and enhanced data collection.	• There are no changes from FY 2017.

Facilities and Infrastructure (NREL)
NREL Site-Wide Facility Support

Description

The NREL Site-Wide Facility Support subprogram funding provides site services, functions, and infrastructure for site operations, which includes management, building operators and technicians, building and grounds maintenance, fire and emergency response, engineering and construction support, electrical safety program, utilities, facilities planning support; and activities within the sustainability and environmental health and safety portfolios. These are core functions for site operations, safety, environmental compliance, and sustainability at NREL. These activities ensure availability of critical facilities and capabilities for the growing demand of R&D mission needs.

NREL Site-Wide Facility Support

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
NREL Site-Wide Facility Support $30,000,000	**$28,000,000**	**-$2,000,000**
• Directly funded NREL Site-Wide Facility Support subprogram funding to provide basic site services, functions, and infrastructure for site operations in the Facilities and Infrastructure budget.	• Provides funding for building maintenance, facility operations, project management and engineering, utilities, intelligent campus, facility managers, and site services.	• This slight reduction relative to prior years begins a transition toward a more appropriate accounting of costs charged to other NREL users. This action re-categorizes $2 million into NREL indirect, which will result in a slight increase to other NREL users.

Facilities and Infrastructure (NREL) Capital Summary
($K)

	Total	Prior Years	FY 2017 Enacted	FY 2019 Request	FY 2019 Request vs FY 2017 Enacted
Capital Operating Expenses Summary (including Major Items of Equipment (MIE))[1]					
Capital Equipment > $500K (including MIE)	n/a	n/a	3,600	3,600	0
Plant Projects (GPP and IGPP)	n/a	n/a	7,800	7,800	0
Accelerator Improvement Projects (AIP) (<$5M)	0	0	0	0	0
Total, Operations and Maintenance Expenses	**n/a**	**n/a**	**11,400**	**11,400**	**0**
Capital Equipment > $500K (including MIE)					
Total Non-MIE Capital Equipment (>$500K)	n/a	n/a	3,600	3,600	0
Total, Capital Equipment (including MIE)	**n/a**	**n/a**	**3,600**	**3,600**	**0**
Plant Projects (GPP and IGPP)					
Total Plant Projects (GPP/IGPP) (Total Estimated Cost (TEC) <$5M)	n/a	n/a	7,800	7,800	0
Total, Plant Projects (GPP/IGPP)	**n/a**	**n/a**	**7,800**	**7,800**	**0**
Total, Capital Summary	**n/a**	**n/a**	**11,400**	**11,400**	**0**

[1] Each MIE Total Estimated Cost (TEC) > $2,000,000. Each Plant Project (GPP/IGPP) Total Estimated Cost (TEC) > $5,000,000.

Energy Efficiency and Renewable Energy
Facilities Maintenance and Repair

The Department's Facilities Maintenance and Repair activities are tied to its programmatic missions, goals, and objectives. The Facilities Maintenance and Repair activities funded by this budget and displayed below are intended to halt asset condition degradation.

Costs for Direct-Funded Maintenance and Repair (including Deferred Maintenance Reduction) ($K)

	FY 2017 Actual Cost	FY 2017 Planned Cost	FY 2018 Planned Cost	FY 2019 Planned Cost
National Renewable Energy Laboratory	8,731	10,839	12,462	11,272
Total, Direct-Funded Maintenance and Repair	**8,731**	**10,839**	**12,462**	**11,272**

Costs for Indirect-Funded Maintenance and Repair (including Deferred Maintenance Reduction) ($K)

	FY 2017 Actual Cost	FY 2017 Planned Cost	FY 2018 Planned Cost	FY 2019 Planned Cost
National Renewable Energy Laboratory	0	0	0	0
Total, Indirect-Funded Maintenance and Repair	**0**	**0**	0	**0**

Report on FY 2017 Expenditures for Maintenance and Repair

This report responds to legislative language set forth in Conference Report (H.R. 108-10) accompanying the Consolidated Appropriations Resolution, 2003 (Public Law 108-7) (pages 886-887), which requests the Department of Energy provide an annual year-end report on maintenance expenditures to the Committees on Appropriations. This report compares the actual maintenance expenditures in FY 2017 to the amount planned for FY 2017, including Congressionally-directed changes.

Energy Efficiency and Renewable Energy
Total Costs for Maintenance and Repair ($K)

	FY 2017 Actual Cost	FY 2017 Planned Cost
National Renewable Energy Laboratory	8,731	10,839
Total, Maintenance and Repair	**8,731**	**10,839**

The Planned Cost is an estimate developed at the beginning of the year and is a minimum target amount. The driver of the actual to planned cost variance is temporary delays in a few large M&R projects. We expect FY 2018 performance to make up for this difference.

Energy Efficiency and Renewable Energy Safeguards and Security ($K)

Safeguards and Security	FY 2017 Enacted	FY 2018 Annualized CR*	FY 2019 Request	FY 2019 Request vs FY 2017 Enacted
Protective Forces	3,100	3,100	2,750	-350
Physical Security Systems	750	750	750	0
Information Security	500	500	500	0
Cybersecurity	3,680	3,680	4,030	+350
Personnel Security	200	200	200	0
Material Control and Accountability	0	0	0	0
Program Management	800	800	800	0
Security Investigations	170	170	170	0
Transportation Security	0	0	0	0
Construction	0	0	0	0
Total, Safeguards and Security	**9,200**	**9,200**	**9,200**	**0**

*A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution. (These amounts are shown only at the Congressional control level and above; below that level, a dash (—) is shown).

Energy Efficiency and Renewable Energy Research and Development Research and Development
($K)

Research and Development	FY 2017 Enacted	FY 2018 Annualized CR*	FY 2019 Request	FY 2019 Request vs FY 2017 Enacted
Basic	0	0	0	0
Applied	878,360	881,321	533,180	-345,180
Development	604,874	606,913	112,774	-492,100
Subtotal, R&D	1,483,235	1,488,235	645,955	-837,280
Equipment	3,600	3,600	3,600	0
Construction	0	0	0	0
Total, R&D	**1,486,835**	**1,491,835**	**649,555**	**-837,280**

*A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution. (These amounts are shown only at the Congressional control level and above; below that level, a dash (—) is shown).

Energy Efficiency and Renewable Energy Research and Development
Small Business Innovative Research/Small Business Technology Transfer (SBIR/STTR)
($K)

	FY 2017 Enacted	FY 2018 Annualized CR*	FY 2019 Request	FY 2019 Request vs FY 2017 Enacted
Vehicles Technologies				
SBIR	8,706	8,647	2,128	-6,578
STTR	1,224	1,216	299	-925
Bioenergy Technologies				
SBIR	6,560	6,515	1,184	-5,376
STTR	923	917	167	-756
Hydrogen and Fuel Cell Technologies				
SBIR	2,528	2,511	1,856	-672
STTR	356	354	261	-95
Solar Energy				
SBIR	6,243	6,201	2,144	-4,099
STTR	878	872	302	-576
Wind Energy				
SBIR	824	818	1,056	+232
STTR	116	115	149	+33
Water Power				
SBIR	1,427	1,417	1,430	+3
STTR	200	199	201	+1
Geothermal Technologies				
SBIR	1,615	1,604	960	-655
STTR	227	225	135	-92
Advanced Manufacturing				
SBIR	8,000	7,946	2,400	-5,600
STTR	1,914	1,901	338	-1,576
Building Technologies				
SBIR	3,017	2,997	1,120	-1,897
STTR	424	421	158	-266

Energy Efficiency and Renewable Energy Research and Development
Small Business Innovative Research/Small Business Technology Transfer (SBIR/STTR)
($K)

	FY 2017 Enacted	FY 2018 Annualized CR*	FY 2019 Request	FY 2019 Request vs FY 2017 Enacted
Total, SBIR	38,920	38,656	14,278	-24,642
Total, STTR	6,262	6,219	2,010	-4,252

*A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution. (These amounts are shown only at the Congressional control level and above; below that level, a dash (—) is shown).

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($K)

Energy Efficiency and Renewable Energy	**FY 2017 Enacted**	**FY 2018 Annualized CR**	**FY 2019 Request**
Ames Laboratory			
Energy Efficiency and Renewable Energy			
Hydrogen & Fuel Cell Technologies	350	250	250
Vehicle Technologies	1,400	1,400	0
Advanced Manufacturing	25,000	25,000	0
Bioenergy Technologies	206	206	0
Total, Energy Efficiency and Renewable Energy	**26,956**	**26,856**	**250**
Total, Ames Laboratory	**26,956**	**26,856**	**250**
Argonne National Laboratory			
Energy Efficiency and Renewable Energy			
Wind Energy	1,601	1,601	427
Hydrogen & Fuel Cell Technologies	8,603	3,385	2,985
Water Power	1,552	365	320
Solar Energy	519	1,000	0
Vehicle Technologies	55,204	55,204	14,665
Building Technologies	1,329	1,320	263
Bioenergy Technologies	6,055	6,055	2,675
Total, Energy Efficiency and Renewable Energy	**74,863**	**68,930**	**21,335**
Total, Argonne National Laboratory	**74,863**	**68,930**	**21,335**
Brookhaven National Laboratory			
Energy Efficiency and Renewable Energy			
Geothermal Technologies	425	425	0
Hydrogen & Fuel Cell Technologies	1,252	300	300
Solar Energy	500	0	0
Vehicle Technologies	2,557	2,557	900
Total, Energy Efficiency and Renewable Energy	**4,734**	**3,282**	**1,200**
Total, Brookhaven National Laboratory	**4,734**	**3,282**	**1,200**
Chicago Operations Office			
Energy Efficiency and Renewable Energy			
Hydrogen & Fuel Cell Technologies	6	0	0
Vehicle Technologies	10	10	0
Total, Energy Efficiency and Renewable Energy	**16**	**10**	**0**
Total, Chicago Operations Office	**16**	**10**	**0**

Department of Energy

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($K)

Energy Efficiency and Renewable Energy	**FY 2017 Enacted**	**FY 2018 Annualized CR**	**FY 2019 Request**
Golden Field Office			
Energy Efficiency and Renewable Energy			
Wind Energy	40,000	4,000	5,000
Program Direction	23,641	23,641	20,170
Geothermal Technologies	7,578	7,578	18,628
Hydrogen & Fuel Cell Technologies	17,800	500	17,500
Water Power	47,596	52,096	18,459
Solar Energy	48,649	2,000	21,000
Vehicle Technologies	0	0	9,000
Building Technologies	18,401	18,276	15,206
Federal Energy Management Program	1,721	1,721	650
Weatherization	739	739	0
State Energy Program Grants	6,900	6,900	0
Advanced Manufacturing	48,884	48,884	17,914
Strategic Programs	3,827	500	0
Bioenergy Technologies	40,982	40,982	0
Total, Energy Efficiency and Renewable Energy	**306,718**	**207,817**	**143,527**
Total, Golden Field Office	**306,718**	**207,817**	**143,527**
Idaho National Laboratory			
Energy Efficiency and Renewable Energy			
Wind Energy	811	811	0
Geothermal Technologies	1,773	1,773	719
Hydrogen & Fuel Cell Technologies	4,993	625	625
Water Power	1,088	530	304
Vehicle Technologies	10,695	10,695	3,675
Federal Energy Management Program	400	400	200
Bioenergy Technologies	18,637	18,637	3,651
Total, Energy Efficiency and Renewable Energy	**38,397**	**33,471**	**9,174**
Total, Idaho National Laboratory	**38,397**	**33,471**	**9,174**

Department of Energy

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($K)

Energy Efficiency and Renewable Energy	FY 2017 Enacted	FY 2018 Annualized CR	FY 2019 Request
Lawrence Berkeley National Laboratory			
Energy Efficiency and Renewable Energy			
Wind Energy	2,102	2,102	636
Geothermal Technologies	3,570	3,570	3,721
Hydrogen & Fuel Cell Technologies	5,689	1,945	1,695
Solar Energy	6,961	1,300	0
Vehicle Technologies	15,318	15,318	4,700
Building Technologies	38,277	38,017	9,026
Federal Energy Management Program	3,803	3,803	1,025
Weatherization	150	150	0
State Energy Program Grants	562	562	0
Advanced Manufacturing	4,500	4,500	4,500
Strategic Programs	1,418	1,763	0
Bioenergy Technologies	10,316	10,316	3,322
Total, Energy Efficiency and Renewable Energy	**92,666**	**83,346**	**28,625**
Total, Lawrence Berkeley National Laboratory	**92,666**	**83,346**	**28,625**
Lawrence Livermore National Laboratory			
Energy Efficiency and Renewable Energy			
Wind Energy	902	902	615
Geothermal Technologies	1,180	1,180	165
Hydrogen & Fuel Cell Technologies	2,585	1,412	2,162
Solar Energy	1,789	0	0
Vehicle Technologies	3,974	3,974	1,430
Building Technologies	108	107	23
Advanced Manufacturing	5,829	5,829	6,000
Bioenergy Technologies	963	963	0
Total, Energy Efficiency and Renewable Energy	**17,330**	**14,367**	**10,395**
Total, Lawrence Livermore National Laboratory	**17,330**	**14,367**	**10,395**
Los Alamos National Laboratory			
Energy Efficiency and Renewable Energy			
Wind Energy	193	193	0
Geothermal Technologies	2,338	2,338	546
Hydrogen & Fuel Cell Technologies	8,573	3,310	2,710
Solar Energy	430	800	0
Vehicle Technologies	1,675	1,675	110
Building Technologies	293	291	56
Bioenergy Technologies	7,619	7,619	2,300
Total, Energy Efficiency and Renewable Energy	**21,121**	**16,226**	**5,722**
Total, Los Alamos National Laboratory	**21,121**	**16,226**	**5,722**

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($K)

Energy Efficiency and Renewable Energy	**FY 2017 Enacted**	**FY 2018 Annualized CR**	**FY 2019 Request**
National Energy Technology Lab			
Energy Efficiency and Renewable Energy			
Program Direction	10,411	10,411	0
Geothermal Technologies	35,309	35,309	0
Hydrogen & Fuel Cell Technologies	2,320	0	0
Solar Energy	291	0	0
Vehicle Technologies	101,442	101,442	0
Building Technologies	13,823	13,729	50
Bioenergy Technologies	231	231	200
Total, Energy Efficiency and Renewable Energy	**163,827**	**161,122**	**250**
Total, National Energy Technology Lab	**163,827**	**161,122**	**250**
National Renewable Energy Laboratory			
Energy Efficiency and Renewable Energy			
Wind Energy	28,187	28,187	14,676
Facilities and Infrastructure (NREL)	92,000	91,375	90,000
Geothermal Technologies	3,479	3,479	718
Hydrogen & Fuel Cell Technologies	19,999	7,946	7,746
Water Power	8,647	7,747	2,254
Solar Energy	28,657	47,869	6,500
Vehicle Technologies	28,642	28,642	8,523
Building Technologies	19,640	19,507	1,342
Federal Energy Management Program	6,563	6,563	2,872
Weatherization	1,124	1,124	0
State Energy Program Grants	730	730	0
Advanced Manufacturing	250	250	0
Strategic Programs	6,309	8,083	0
Bioenergy Technologies	57,748	57,748	13,700
Total, Energy Efficiency and Renewable Energy	**301,975**	**309,250**	**148,331**
Total, National Renewable Energy Laboratory	**301,975**	**309,250**	**148,331**
Oak Ridge Institute for Science & Education			
Energy Efficiency and Renewable Energy			
Geothermal Technologies	258	258	237
Solar Energy	3,566	0	0
Vehicle Technologies	142	142	100
Building Technologies	2,048	2,034	0
Federal Energy Management Program	204	204	0
Advanced Manufacturing	4,727	4,727	0
Bioenergy Technologies	236	236	0
Total, Energy Efficiency and Renewable Energy	**11,181**	**7,601**	**337**
Total, Oak Ridge Institute for Science & Education	**11,181**	**7,601**	**337**

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Funding by Appropriation by Site
($K)

Energy Efficiency and Renewable Energy	FY 2017 Enacted	FY 2018 Annualized CR	FY 2019 Request
Oak Ridge National Laboratory			
Energy Efficiency and Renewable Energy			
Wind Energy	398	398	110
Geothermal Technologies	463	463	407
Hydrogen & Fuel Cell Technologies	4,371	1,025	1,425
Water Power	4,465	3,638	4,657
Solar Energy	1,154	1,498	0
Vehicle Technologies	40,325	40,325	10,800
Building Technologies	25,734	25,559	5,971
Federal Energy Management Program	4,159	4,159	1,308
Weatherization	332	332	0
State Energy Program Grants	170	170	0
Advanced Manufacturing	29,045	29,045	11,000
Strategic Programs	75	75	0
Bioenergy Technologies	15,177	15,177	4,365
Total, Energy Efficiency and Renewable Energy	**125,868**	**121,864**	**40,043**
Total, Oak Ridge National Laboratory	**125,868**	**121,864**	**40,043**
Oak Ridge Office			
Energy Efficiency and Renewable Energy			
Hydrogen & Fuel Cell Technologies	589	130	130
Total, Oak Ridge Office	**589**	**130**	**130**
Office of Scientific & Technical Information			
Energy Efficiency and Renewable Energy			
Solar Energy	24	0	0
Total, Office of Scientific & Technical Information	**24**	**0**	**0**
Pacific Northwest National Laboratory			
Energy Efficiency and Renewable Energy			
Wind Energy	2,928	2,928	1,422
Geothermal Technologies	2,964	2,964	1,062
Hydrogen & Fuel Cell Technologies	6,938	1,740	2,440
Water Power	8,114	7,086	3,772
Solar Energy	3,863	900	0
Vehicle Technologies	15,779	15,779	5,925
Building Technologies	34,179	33,947	4,653
Federal Energy Management Program	2,797	2,797	1,445
Strategic Programs	265	450	0
Bioenergy Technologies	24,044	24,044	3,803
Total, Energy Efficiency and Renewable Energy	**101,871**	**92,635**	**24,522**
Total, Pacific Northwest National Laboratory	**101,871**	**92,635**	**24,522**

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($K)

Energy Efficiency and Renewable Energy	**FY 2017 Enacted**	**FY 2018 Annualized CR**	**FY 2019 Request**
Sandia National Laboratories			
Energy Efficiency and Renewable Energy			
Wind Energy	4,825	4,825	3,547
Geothermal Technologies	5,873	5,873	1,318
Hydrogen & Fuel Cell Technologies	8,637	2,790	4,140
Water Power	6,947	6,947	2,497
Solar Energy	11,689	4,000	0
Vehicle Technologies	12,004	12,004	4,912
Building Technologies	274	272	82
Strategic Programs	0	500	0
Bioenergy Technologies	7,592	7,592	2,984
Total, Energy Efficiency and Renewable Energy	**57,841**	**44,803**	**19,480**
Total, Sandia National Laboratories	**57,841**	**44,803**	**19,480**
Savannah River National Laboratory			
Energy Efficiency and Renewable Energy			
Hydrogen & Fuel Cell Technologies	2,615	330	580
Solar Energy	287	0	0
Vehicle Technologies	53	53	0
Bioenergy Technologies	444	444	0
Total, Energy Efficiency and Renewable Energy	**3,399**	**827**	**580**
Total, Savannah River National Laboratory	**3,399**	**827**	**580**
SLAC National Accelerator Laboratory			
Energy Efficiency and Renewable Energy			
Hydrogen & Fuel Cell Technologies	95	50	50
Solar Energy	3,830	333	0
Vehicle Technologies	1,700	1,700	900
Building Technologies	400	397	123
Total, Energy Efficiency and Renewable Energy	**6,025**	**2,480**	**1,073**
Total, SLAC National Accelerator Laboratory	**6,025**	**2,480**	**1,073**

Department of Energy

FY 2019 Congressional Budget

Funding by Appropriation by Site

($K)

Energy Efficiency and Renewable Energy	FY 2017 Enacted	FY 2018 Annualized CR	FY 2019 Request
Washington Headquarters			
Energy Efficiency and Renewable Energy			
Wind Energy	8,053	43,441	6,567
Program Direction	119,448	118,406	104,940
Geothermal Technologies	4,290	3,818	2,479
Hydrogen & Fuel Cell Technologies	5,585	74,577	13,262
Water Power	5,591	5,020	12,737
Solar Energy	95,391	146,490	39,500
Vehicle Technologies	16,039	13,954	2,860
Building Technologies	44,635	44,333	20,205
Federal Energy Management Program	7,353	7,170	2,500
Weatherization	225,655	224,107	0
State Energy Program Grants	41,638	41,298	0
Advanced Manufacturing	139,265	137,516	35,586
Strategic Programs	7,106	7,500	0
Bioenergy Technologies	14,750	13,358	0
Total, Energy Efficiency and Renewable Energy	**734,799**	**880,988**	**240,636**
Total, Washington Headquarters	**734,799**	**880,988**	**240,636**
Total, Energy Efficiency and Renewable Energy	**2,090,200**	**2,076,005**	**695,610**

Nuclear Energy

Nuclear Energy

Nuclear Energy

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Nuclear Energy

Proposed Appropriation Language

For Department of Energy expenses including the purchase, construction, and acquisition of plant and capital equipment, and other expenses necessary for nuclear energy activities in carrying out the purposes of the Department of Energy Organization Act (42 U.S.C. 7101 et seq.), including the acquisition or condemnation of any real property or any facility or for plant or facility acquisition, construction, or expansion, $757,090,000 to remain available until expended: Provided, That of such amount, $66,500,000 shall be available until September 30, 2019, for program direction.

Note.—A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115–56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution.

Nuclear Energy
($K)

FY 2017 Enacted[1,2]	FY 2018 Annualized CR[1,2,*]	FY 2019 Request
1,026,616	1,019,644	757,090

Overview

Nuclear energy is a key element of United States (U.S.) energy independence, energy dominance, electricity grid resiliency, national security, and clean baseload power. America's nuclear energy sector provides over 60 percent of the nation's annual clean electricity production, and generates nearly 20 percent of U.S. electricity from a fleet of 99 operating units in 30 states. America's nuclear energy sector also plays key national security and global strategic roles for the U.S., including nuclear nonproliferation.

The United States pioneered the development and peaceful use of nuclear power to produce around-the-clock, emission-free electricity as well as the development of what we know as the civilian nuclear fuel cycle. However, the Department recognizes that the U.S. nuclear energy sector is under historic downward pressure, has lost a tremendous amount of its once dominant global market share, and has seen a significant degradation in our manufacturing base. In addition, the U.S. no longer has an operating U.S.-owned (or U.S.-technology-based) fast spectrum test reactor. In response to this industry trend, the President, on June 29, 2017, announced that the U.S. would conduct a complete review of U.S. nuclear energy policy to help find new ways to revive and expand this crucial energy resource. This Civil Nuclear Review is currently underway, and the outcomes will inform how the Administration can best enable this important revitalization.

The Department believes it is not too late, and indeed possible, to reverse the downward trajectory of our nation's nuclear energy sector and once again become dominant by helping implement the President's June 29, 2017 announcement. Accordingly, the Department's fiscal year FY 2019 nuclear energy budget request funds an array of programs that will support reviving and expanding our nuclear energy sector and position it once again for dominance in the future.

The Office of Nuclear Energy (NE) focuses on three major mission areas; the nation's existing nuclear fleet, the development of advanced nuclear reactor concepts, and fuel cycle technologies. Utilizing the Department's greatest strengths, NE emphasizes early stage research and development (R&D), mobilizing our unique national laboratory capabilities, and implementing targeted R&D partnerships with the U.S. nuclear industry.

NE conducts early-stage R&D on existing and advanced reactor designs and technologies to enable industry to address technical challenges with maintaining the existing fleet of nuclear reactors and promote the development of a robust pipeline of advanced reactor designs and technologies and supply chain capabilities. Within this area, the FY 2019 Budget prioritizes work on advanced reactor technologies, including a new one-year subprogram that will fund cost-shared early-stage design-related technical assistance and R&D on small modular reactor technologies. NE also conducts early-stage applied R&D on advanced fuel cycle technologies, including a strong focus on the development of accident tolerant fuels. Advancements in fuel cycle technologies support the enhanced availability, economics, safety, and security of nuclear-generated electricity in the United States, further enhancing U.S. energy independence and economic competitiveness.

Highlights and Major Changes in the FY 2019 Budget Request

[1] Funding does not reflect the transfer of SBIR/STTR to the Office of Science, Congressionally directed $10,000,000 use of prior year balances to offset new FY 2017 appropriations, nor rescission of $795,270 of prior year appropriations.
[2] Funding does not reflect the transfer of approximately $75M from Naval Reactors for maintenance and operation of the Advanced Test Reactor.
[*] A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution. (These amounts are shown only at the Congressional control level and above; below that level, a dash (—) is shown).

- Within Reactor Concepts Research, Development and Demonstration (RC RD&D), a new subprogram, Advanced SMR R&D, is a new one-year early-stage R&D effort focused on small modular reactors. This effort will support cost-shared early-stage design-related technical assistance and R&D, the results of which are intended to be widely applicable to many reactor designs and adopted by nuclear technology development vendors for the purpose of accelerating the development of their technologies.
- Also within RC RD&D, work in the Versatile Advanced Test Reactor subprogram transitions from R&D planning to conduct of R&D and pre-conceptual design development for fast test reactor needs and concepts. For the United States to regain a global leadership role in development of next generation of advanced reactors, a fast spectrum test reactor may be an important experimental tool.
- Within Nuclear Energy Enabling Technologies (NEET), the computational tools and capabilities developed by the Modeling and Simulation Hub in support of light water reactor technologies, including advanced small modular reactors, are integrated into the ongoing Nuclear Energy Advanced Modeling and Simulation subprogram.
- Also within NEET, increased support is provided for additional competitive, cost-shared R&D projects in crosscutting areas such as advanced instrumentation and control, advanced manufacturing methods, and advanced cooling technologies, with an emphasis on advanced manufacturing projects.
- No new capital funding for the Sample Preparation Laboratory Project is request pending Critical Decision (CD)-2 approval.
- The Department met its SMR Licensing Technical Support (SMR LTS) program objectives and commitments in FY 2017 and the program has been brought to closure.
- No funding for STEP R&D is requested consistent with the Department's decision to focus on early-stage R&D and rely on the private sector for decisions about the scale up and commercialization of the technology.
- Light Water Reactor Sustainability efforts are focused on early stage R&D with industry covering a larger share of reactor-specific development activities.
- In FY 2019 activities associated with resuming the Nuclear Regulatory Commission licensing process for Yucca Mountain and initiation of a robust interim storage program activities are included in a new program, Yucca Mountain Nuclear Waste Repository and Interim Storage. Consistent with this, the Integrated Waste Management System subprogram is discontinued; limited interim storage and transportation planning scope is being moved under the new program. Program Direction funding for the associated federal staff and support (at NE Headquarters, Office of General Counsel, and in Las Vegas, Nevada) are also transferred to the new program.
- A limited Used Nuclear Fuel Disposition R&D effort is continued within the Nuclear Energy Fuel Cycle Research and Development program with a focus on the performance of the high burnup used nuclear fuel demonstration, single car testing of cask and buffer railcars, and initiation of the fabrication of one escort car in partnership with the U.S. Navy.

Nuclear Energy
Funding by Congressional Control
($K)

	FY 2017 Enacted[1,2]	FY 2018 Annualized CR[2,*]	FY2019 Request	FY 2019 Request vs FY 2017 Enacted
Integrated University Program	**5,000**	**4,966**	**0**	**-5,000**
STEP R&D	**5,000**	**4,966**	**0**	**-5,000**
SMR Licensing Technical Support	**95,000**	**94,355**	**0**	**-95,000**
Reactor Concepts Research, Development and Demonstration	**132,000**	**131,103**	**163,000**	**+31,000**
Fuel Cycle Research and Development	**207,500**	**206,091**	**60,000**	**-147,500**
Nuclear Energy Enabling Technologies	**115,100**	**114,319**	**116,000**	**+900**
Radiological Facilities Management	**17,000**	**16,884**	**9,000**	**-8,000**
Idaho Facilities Management				
Operations & Maintenance	231,713	230,139	204,000	-27,713
16-E-200, Sample Preparation Laboratory	6,000	5,959	0	-6,000
Total, Idaho Facilities Management	**237,713**	**236,098**	**204,000**	**-33,713**
Idaho Sitewide Safeguards and Security	**129,303**	**128,425**	**136,090**	**+6,787**
International Nuclear Energy Cooperation	**3,000**	**2,980**	**2,500**	**-500**
Program Direction	**80,000**	**79,457**	**66,500**	**-13,500**
Subtotal, Nuclear Energy	**1,026,616**	**1,019,644**	**757,090**	**-269,526**
Use of Prior Year Appropriations	-10,000	-9,932	0	+10,000
Rescission of Prior Year Balances	-795	-790	0	+795
Total, Nuclear Energy	**1,015,821**	**1,008,922**	**757,090**	**-258,731**
Federal FTEs	337	326	291	-46

SBIR/STTR:

- FY 2017 Transferred: SBIR $13,987; STTR $1,967
- FY 2018 Projected: SBIR $13,892; STTR $1,954
- FY 2019 Request: SBIR $10,848; STTR $1,526

[1] Funding does not reflect the transfer of SBIR/STTR to the Office of Science.
[2] Funding does not reflect the transfer of approximately $75M from Naval Reactors for maintenance and operation of the Advanced Test Reactor.
[*] A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution. (These amounts are shown only at the Congressional control level and above; below that level, a dash (—) is shown).

Integrated University Program

Overview
No funding is being requested in FY 2019 for the Integrated University Program (IUP).

All Department awards are fully funded in the year funding is received. As a result, multi-year student research fellowships do not require support by out-year funds after the appropriation year.

Integrated University Program
Funding
($K)

	FY 2017 Enacted	FY 2018 Annualized CR*	FY 2019 Request	FY 2019 Request vs FY 2017 Enacted
Integrated University Program				
Integrated University Program	5,000	4,966	0	-5,000
Total, Integrated University Program	**5,000**	**4,966**	**0**	**-5,000**

* A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution. (These amounts are shown only at the Congressional control level and above; below that level, a dash (—) is shown).

Integrated University Program
Explanation of Major Changes
($K)

	FY 2019 Request vs FY 2017 Enacted
Integrated University Program:	
No funding is being requested to continue this program in FY 2019.	**-5,000**
Total, Integrated University Program	**-5,000**

Integrated University Program

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Integrated University Program		
$5,000,000	**$0**	**-$5,000,000**
• Supported nuclear science and engineering study and research by fully funding 31 multi-year student fellowships and 58 single-year scholarships in the nuclear energy field of study.	• No funding is requested to continue this program in FY 2019.	• No funding is requested to continue this program in FY 2019.

SMR Licensing Technical Support

Overview

The Department fully met its Small Modular Reactor (SMR) Licensing Technical Support (LTS) program objectives and commitments to industry in FY 2017 and the program has been brought to closure.

The SMR LTS program was initiated in FY 2012 to support first-of-a-kind costs associated with design certification and licensing activities for small modular reactor (SMR) technologies and site licensing activities for SMRs through cost-shared arrangements with industry partners. The goal of the program was to support industry first-movers as they pursued the design development, certification, and licensing of SMRs for deployment in the mid-2020s.

SMR Licensing Technical Support
Funding
($K)

	FY 2017 Enacted	FY 2018 Annualized CR*	FY 2019 Request	FY 2019 Request vs FY 2017 Enacted
SMR Licensing Technical Support				
SMR Licensing Technical Support	95,000	94,355	0	-95,000
Total, SMR Licensing Technical Support	**95,000**	**94,355**	**0**	**-95,000**

* A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution. (These amounts are shown only at the Congressional control level and above; below that level, a dash (—) is shown).

SMR Licensing Technical Support
Explanation of Major Changes
($K)

	FY 2019 Request vs FY 2017 Enacted
SMR Licensing Technical Support:	
The decrease from $95,000,000 to $0 reflects the program ending.	**-95,000**
Total, SMR Licensing Technical Support	**-95,000**

SMR Licensing Technical Support

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
SMR Licensing Technical Support $95,000,000	**$0**	**$0**
• **NuScale Power** – NuScale Power conducted activities to design, engineer, and develop their reactor design resulting in the submittal of the design certification application to Nuclear Regulatory Commission (NRC) in January 2017, and subsequent support of the NRC review process. Key technical activities supported in FY 2017 included: • Finalizing the NuScale Power Module Design Certification Application (DCA) to the NRC. • Developing responses to NRC requests for additional information on the DCA. • Completed fuel testing, including critical heat flux test activities. • Completed reactor module inspection demonstrations. • Conducted primary system thermal-hydraulic and code verification testing. • Conducted helical coil steam generator and other primary system manufacturing and fabrication demonstrations. • Completed human factors engineering and testing. • **Site Permitting and Licensing** • During this period, Tennessee Valley Authority (TVA) supported the NRC review of their Early Site Permit Application, including conducting activities required to respond to requests for additional information. • TVA began development of a Combined License Application (COLA) to site the selected SMR technology at the Clinch River Site.	• No funding is requested.	• The decrease from $95,000,000 to $0 reflects the program ending.

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
• NuScale / Utah Associated Municipal Power Systems (UAMPS) completed site characterization activities on the selected site. • NuScale / UAMPS continued development of COLA documentation, including: - Security plan - Emergency plan - Environmental report - Geological and geotechnical investigations • **Program Management** – DOE continued support of analyses and studies important to improving SMR licensing and commercialization potential. This included initiating and completing specific aerosol deposition experiments important to establishing a technical/regulatory basis for a reduced emergency planning zone for SMRs.		

SMR Licensing Technical Support
Performance Measures

In accordance with the GPRA Modernization Act of 2010, the Department sets targets for, and tracks progress toward, achieving performance goals for each program.

	FY 2017	FY 2018	FY 2019
Performance Goal (Measure)	**SMR - Licensing Technical Support Program - Enable the submission of license application documentation to the Nuclear Regulatory Commission (NRC) by SMR vendors and utility partners by supporting design, engineering, certification, and licensing efforts for selected SMR projects.**		
Target	= 1 complete program milestones	N/A	N/A
Result	Met	N/A	N/A
Endpoint Target	Provide financial risk reduction to industry first-movers for the completion of design development, certification and licensing in a timeframe that supports SMR deployment in the early to mid-2020s.		

Supercritical Transformational Electric Power Research and Development

Overview

The Supercritical Transformational Electric Power Research and Development (STEP R&D) initiative was a collaborative Department of Energy (DOE) project to develop and scale up advanced Supercritical Carbon Dioxide (sCO_2) Brayton cycle energy conversion technology to facilitate commercial development. As a result of the large incentive for industry development of this technology, this scale-up effort is being terminated. DOE resources are being focused on earlier-stage research across the nuclear energy programs.

This transformative technology has the potential to significantly reduce costs of energy production by improving the efficiency of converting thermal energy to electrical energy using traditional steam-Rankine cycle systems, which are used for roughly 80% of the world's electricity generation. sCO_2 Brayton cycle technology utilizes smaller equipment and will be simpler to operate compared to Rankine cycle technology, resulting in lower capital and operating costs. These improvements could make advanced nuclear energy technologies more cost competitive.

Early stage research on Brayton cycle energy conversion technology issues specific to nuclear energy applications is continued within the Reactor Concepts, Research, Development and Deployment (RD&D) program.

Highlights of the FY 2019 Budget Request

No funding is requested for the STEP initiative, consistent with the Department's decision to shift scale up of the technology to the private sector.

Supercritical Transformational Electric Power Research and Development
Funding
($K)

	FY 2017 Enacted	FY 2018 Annualized CR*	FY 2019 Request	FY 2019 Request vs FY 2017 Enacted
Supercritical Transformational Electric Power Research and Development				
Supercritical Transformational Electric Power Research and Development	5,000	4,966	0	-5,000
Total, Supercritical Transformational Electric Power Research and Development	**5,000**	**4,966**	**0**	**-5,000**

SBIR/STTR:
- FY 2017 Transferred: SBIR $160; STTR $22
- FY 2018 Projected: SBIR $159; STTR $22
- FY 2019 Request: SBIR $0; STTR $0

* A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution. (These amounts are shown only at the Congressional control level and above; below that level, a dash (—) is shown).

Supercritical Transformational Electric Power Research and Development
Explanation of Major Changes
($K)

	FY 2019 Request vs FY 2017 Enacted
Supercritical Transformational Electric Power Research and Development:	
The decrease from $5,000,000 to $0 is consistent with the Department's decision to shift scale-up of the technology to the private sector. DOE resources are being focused on earlier stage research in FY 2019 within the Reactor Concepts Research, Development and Demonstration program.	**-5,000**
Total, Supercritical Transformational Electric Power Research and Development	**-5,000**

Supercritical Transformational Electric Power Research and Development

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Supercritical Transformational Electric Power Research and Development $5,000,000	**$0**	**-$5,000,000**
• Performed basic research and development (R&D) to develop Supercritical Carbon Dioxide (sCO2) recompression closed Brayton cycle (RCBC) to support the energy conversion of the sodium cooled fast reactor (SFR) by 2030 at commercial off-the-self scale. • Developed and maintained technology roadmaps, system engineering and economic models, science based steady state and dynamic models for specifying requirements, tracking results, and planning futures. • Developed and tested materials suitable to supporting the sCO2 RCBC for the SFR for the lifetime of the plant. • Developed heat exchangers for the SFR coupling the sodium to the sCO2 and understanding the consequences of sodium and sCO2 interactions. • Developed sCO2 components for the RCBC demonstration: including turbines, compressors, recuperators, seals, bearings, control valves, control systems, high speed electrical generators, and waterless heat rejection. • Continued to lead energy conversion collaboration efforts between the offices of Nuclear Energy, Energy Efficiency and Fossil Energy.	• No funding is requested.	• Early stage research specific to nuclear energy applications is continued within the Reactor Concepts, Research, Development and Deployment (RD&D) program.

Reactor Concepts Research, Development and Demonstration

Overview

The Reactor Concepts Research, Development and Demonstration (RD&D) program conducts early-stage research and development (R&D) on existing and advanced reactor designs and technologies to enable industry to address technical challenges with maintaining the existing fleet of nuclear reactors and to promote the development of a robust pipeline of advanced reactor designs and technologies and supply chain capabilities. Program activities are designed to address technical, cost, safety, and security issues associated with the existing commercial light water reactor fleet and advanced reactor technologies, such as small modular reactors (SMRs), fast reactors using liquid metal coolants and high temperature reactors using gas or liquid salt coolants.

In maximizing the benefits of nuclear power, work must be done to address the following challenges:

- Improving affordability of nuclear energy technologies;
- Enhancing safety and reducing technical risk;
- Minimizing proliferation risks of nuclear materials; and
- Enabling the improvement of the economic outlook for the American nuclear industry.

Reactor Concepts RD&D is key to enabling industry to reverse the downward trajectory of our nation's nuclear energy sector and regaining a leadership role. The Department's R&D activities help implement the President's June 29, 2017 announcement made at the Department of Energy to "begin to revive and expand our nuclear energy sector."

The Reactor Concepts RD&D program includes a new one-year early-stage R&D effort focused on SMRs. This new Advanced SMR R&D subprogram will support cost-shared early-stage design-related technical assistance and R&D, the results of which are intended to be widely applicable to many reactor designs and adopted by nuclear technology development vendors for the purpose of accelerating the development of their technologies. Funding will be awarded competitively to multiple recipients to encourage development and widely-applicable results across the spectrum of nascent reactor concepts.

Through cost-shared early-stage R&D and related technical assistance and R&D the Department will help enable industry to accelerate the timeline for commercialization of new, advanced, and more financeable reactor technologies which will help revive and expand the domestic nuclear industry while advancing America's leadership role in the global nuclear sector, as directed by the President. The Department believes it is not too late, and indeed possible, to reverse the downward trajectory of our nation's nuclear energy sector and once again become dominant.

The Light Water Reactor Sustainability (LWRS) subprogram conducts research in support of light water reactor (LWR) technologies so that LWR-based commercial nuclear power plants can continue to provide safe, clean, and reliable energy. The goal is to enable industry to enhance the efficient and economical performance of current nuclear power plants while enabling their extended operation. The primary focus is cost-shared, private-public partnerships to resolve the U.S. industry's highest priority and highest uncertainty technical issues that are not currently being addressed but where U.S. government partnership is appropriate. An example of such a partnership would be to perform R&D in methods of control room and plant modernization to address aging and obsolescence of existing analog instrumentation and controls and improve plant efficiency.

The Advanced Reactor Technologies (ART) subprogram conducts early-stage R&D on advanced reactor technologies, including SMRs, and supports work on generic topics that can apply to multiple advanced reactor concepts. This subprogram focuses on efforts in the following areas: fundamental technologies and design methods for advanced reactors, interactions of advanced reactor coolants with materials and components, advanced energy conversion, advanced instrumentation and controls, research to enhance safety and reduce regulatory risk, advanced materials development and codification, fuel development and graphite material qualification, and continued international collaborations.

In addition, the budget continues support for the early-stage R&D and related pre-conceptual design activities in the Versatile Advanced Test Reactor R&D subprogram. This effort will conduct R&D necessary as a prerequisite for future decisions on test reactor infrastructure. While a decision whether or not to deploy an advanced fast spectrum test reactor has not been made, such a reactor could accelerate innovation in advanced fuels and materials for U.S. vendors by enabling testing in an extreme environment and help pave the path to U.S. global leadership in advanced nuclear research and development (R&D) by reestablishing this capability.

Highlights of the FY 2019 Budget Request

The Advanced Small Modular Reactor (SMR) R&D subprogram will support a broad scope of cost-shared early-stage design-related technical assistance and R&D, such as thermal-hydraulic testing and analysis supporting reactor coolant system design, seismic analyses needed to inform generic plant structural design; emergency core cooling system and component research; development of fuel mechanical handling systems; instrumentation and control technology development; and design and development of early stage prototypical components.

Light Water Reactor Sustainability provides funding for competitively-awarded, cost-shared early-stage R&D projects with U.S. industry to solve significant, highest priority cost and technical problems threatening existing plants, as well as research on materials aging effects and digital plant modernization technologies.

Advanced Reactor Technologies continues early-stage R&D for advanced reactor concepts, including fast reactors, high temperature gas reactors and molten salt reactors. The program focuses on broad, non-design-specific support for concepts that could be demonstrated by industry by the early 2030s. Efforts include qualification of advanced materials; prototypic component testing capabilities; fundamental properties of molten salts, and associated research activities for molten salt reactors; and experimental validation of normal operation and transient conditions for high temperature gas reactors. The request supports industry-led innovative early-stage R&D activities through competitive industry awards. The request supports activities for advanced reactor fuels, including limited development and qualification of tristructural-isotropic (TRISO)-coated particle fuel for high-temperature advanced reactors, and explore nano-TRISO particle fuels for molten salt reactors. This subprogram also includes development and support for advanced reactor fuel and materials activities previously funded under the Advanced Fuels subprogram under the Fuel Cycle Research and Development Program.

The Versatile Advanced Test Reactor R&D subprogram will continue early-stage R&D and development of a pre-conceptual design. The information generated by this subprogram will help inform decisions about the Department's nuclear energy R&D infrastructure.

Reactor Concepts Research, Development and Demonstration
Funding
($K)

	FY 2017 Enacted	FY 2018 Annualized CR*	FY 2019 Request	FY 2019 Request vs FY 2017 Enacted
Reactor Concepts Research, Development and Demonstration				
Advanced Small Modular Reactor R&D	0	-	54,000	+54,000
Light Water Reactor Sustainability	40,000	-	20,000	-20,000
Advanced Reactor Technologies	87,000	-	74,000	-13,000
Versatile Advanced Test Reactor	5,000	-	15,000	+10,000
Total, Reactor Concepts Research, Development and Demonstration	**132,000**	**131,103**	**163,000**	**+31,000**

SBIR/STTR:

- FY 2017 Transferred: SBIR $4,224; STTR $594
- FY 2018 Projected: SBIR $4,195; STTR $590
- FY 2019 Request: SBIR $5,216; STTR $734

* A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution. (These amounts are shown only at the Congressional control level and above; below that level, a dash (—) is shown).

Reactor Concepts Research, Development and Demonstration
Explanation of Major Changes
($K)

	FY 2019 Request vs FY 2017 Enacted
Advanced Small Modular Reactor R&D:	
The increase from $0 to $54,000,000 supports a one-year effort addressing cost-shared early-stage design-related technical assistance and research and development (R&D) relevant to a broad spectrum of advanced small modular reactors.	**+54,000**
Light Water Reactor Sustainability:	
The decrease from $40,000,000 to $20,000,000 reflects the successful completion of Subsequent License Renewal activities and a reprioritization to support R&D that can help address the economic uncertainty of currently-operating nuclear power plants.	**-20,000**
Advanced Reactor Technology:	
The decrease from $87,000,000 to $74,000,000 supports continued refocusing of the program on early-stage R&D targeted toward the highest priority advanced reactor types. Tristructural-isotropic (TRISO)-coated particle fuel qualification activities for high-temperature advanced reactors will be focused on continued irradiation testing and conducting only the highest priority post irradiation examinations.	**-13,000**
Versatile Advanced Test Reactor:	
The increase from $5,000,000 to $15,000,000 supports efforts to transition from R&D planning to pre-conceptual design development.	**+10,000**
Total, Reactor Concepts Research, Development & Demonstration	**+31,000**

Reactor Concepts Research, Development and Demonstration
Advanced Small Modular Reactor R&D

Description

The Advanced Small Modular Reactor (SMR) Research and Development (R&D) subprogram is one key element of the Department's overall strategy to enable industry to reverse the downward trajectory of our nation's nuclear energy sector and once again become dominant. This subprogram will help implement the President's June 29, 2017, announcement made at the Department of Energy to "begin to revive and expand our nuclear energy sector." Significant risk remains in developing advanced SMR designs. Through this one-year Advanced SMR R&D effort, the Department will leverage its appropriate federal role and notable R&D expertise to facilitate industry's development of SMR designs that have the potential to provide safe and affordable energy generation options. The Department acknowledges the need to continue early-stage R&D to promote industry's acceleration of these technologies into the domestic and international markets and believes this one-year effort is essential to regain our leadership role. This effort will help industry reverse the downward trajectory of our nation's nuclear energy sector and regain a dominant position in the global market.

The Advanced SMR R&D subprogram will support cost-shared early-stage design-related technical assistance and R&D, the results of which are intended to be widely applicable and adopted by nuclear technology development vendors for the purpose of accelerating the development of their technologies. Specifically, Advanced SMR R&D will support cost-shared, private-public R&D partnerships to address technical challenges facing the United States (U.S.) nuclear industry to accelerate development of a variety of advanced designs, including R&D needed to promote domestic supply chain advancement. In so doing, the Advanced SMR R&D subprogram will promote U.S. energy independence, energy dominance, electricity grid resiliency, national security and clean baseload power. The program will require cost-shared, private-public funding in accordance with the provisions of the Energy Policy Act of 2005, Section 988 for the U.S. industry participants seeking to participate in this innovate subprogram. Funding will be awarded competitively to multiple recipients and this subprogram will seek to maximize leveraging of ongoing and planned R&D supported by the related Advanced Reactor Technologies subprogram.

For example, FY 2019 funding will support a broad scope of cost-shared early-stage design-related technical assistance and R&D supporting design development, such as thermal-hydraulic testing and analysis supporting reactor coolant system design; seismic analyses to inform SMR generic plant structural design; conducting emergency core cooling system and component research; development of fuel mechanical handling systems; instrumentation and control system technology development; and design and development of early-stage prototype components.

Advanced Small Modular Reactor R&D

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Advanced Small Modular Reactor R&D $0	**$54,000,000**	**+$54,000,000**
• No funding was requested.	• Supports a broad scope of cost-shared early-stage design-related technical assistance and research and development (R&D), such as, thermal-hydraulic testing and analysis supporting reactor coolant system designs; seismic analyses to inform Small Modular Reactor (SMR) generic plant structural design; conducting emergency core cooling system and component research; and design and development of early-stage prototype components.	• Funding provided to support one-year Advanced SMR R&D efforts.

Reactor Concepts Research, Development and Demonstration
Light Water Reactor Sustainability

Description

The existing U.S. commercial nuclear fleet has an excellent safety and performance record and today accounts for about 20 percent of the U.S. electricity supply. The Light Water Reactor Sustainability (LWRS) program conducts research and development (R&D) on technologies and other solutions that can improve economics, sustain safety, and maintain the technical reliability of the current fleet of commercial nuclear power plants. The LWRS program is also researching new technologies that can help gain efficiencies, address flexible plant operations and enhance cybersecurity.

LWRS collaborates with industry and the Nuclear Regulatory Commission to closely coordinate research needs. In FY 2019, the primary focus is working with U.S. industry in cost-shared, private-public partnerships to conduct early-stage R&D to resolve industry's highest priority and highest uncertainty issues that are not currently being addressed but where U.S. government partnership is appropriate. These high priority areas include developing the scientific basis for age-related material degradation management informing major component refurbishment and finalizing replacement strategies related to modern digital instrumentation and control systems. The program will ensure appropriate cost-sharing arrangements for its activities according to Section 988 of the Energy Policy Act of 2005.

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Light Water Reactor Sustainability $40,000,000	**$20,000,000**	**-$20,000,000**
• Research completed in FY 2017 was used to inform the Generic Aging Lessons Learned (GALL) Report which was issued by the Nuclear Regulatory Commission for industry use in Subsequent License Renewal (SLR) application development. Additionally, research completed has continued to inform the industry on their decisions on aging management of key plant components. • Materials Aging and Degradation – Research and development (R&D) activities were conducted to develop insights into the environmental mechanisms affecting aging and degradation of key materials and their performance in nuclear power plants. This included research into mechanisms of aging and degradation of reactor pressure vessel (RPV) metals, other primary system metals, and core internals. The research results from empirical studies on these materials were also used to develop models of material performance that will be employed to predict material performance during periods of long-term operation. Research was performed on structural materials, including concrete, in order to address their capabilities to continue to provide structural support, containment, and other functional performance characteristics. Research on harvested cable materials was performed to assess cable insulation health and for accelerated aging studies of cable insulation. Advances in computational techniques accompany many empirical studies of materials and are being used to develop models of	• Materials Aging and Degradation – Research is focused on the scientific basis for understanding and predicting long-term environmental degradation behavior of materials in nuclear power plants. Deliver a predictive capability for austenitic stainless steel components under extended service conditions. Deliver predictive capability for end-of-useful life for cables and cable insulation. • Safety Margin Characterization – Quantify and define resilience for nuclear power plants. Develop and enable industry to demonstrate applications to recover margins for nuclear power plants to reduce operating costs using risk informed approaches. • Instrumentation and Controls – Conduct R&D to develop advanced analytic methods and algorithms to process plant equipment, planning, and related outage management data to detect potential challenges to nuclear safety, limiting conditions of operation, and technical specifications. Develop an online integrated monitoring system to provide end users the status of the piping system including wall thickness and remaining life. • Systems Analysis and Emerging Issues – Address emerging issues. These issues may become subjects for future collaborations with industry, or may be solved as part of the traditional Light Water Reactor Sustainability pathways.	• The decrease in funding reflects a targeting of resources on addressing the key technical challenges behind economic uncertainty of currently operating nuclear power plants through early-stage R&D. • Materials Aging and Degradation – Examine highest priority core internal materials harvested from either current operating or ex-service plants. Adjust timeframe for development of the lower-priority predictive model capability for Irradiation Assisted Stress Corrosion Cracking. Results from this R&D pathway will continue to inform future SLR applications and long term aging management plans at an appropriate scale. • Safety Margin Characterization – Conclude work supporting the analysis of external events including flooding and seismic events. Transition work on the Risk Informed Safety Margin Characterization toolkit to the application of industry needs. • Reactor Safety Technologies – Transition the majority of work to industry to complete.

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
material performance during in-service use and to inform materials management programs in use by operating nuclear power plants. • Safety Margin Characterization – Development activities continued on risk-informed methods and codes to enable analysis and quantification of plant safety margins in order to provide new capabilities for risk assessment and management to nuclear power plants. Codes were developed and demonstrated to support the analysis of external events including flooding and seismic events and attendant multi-unit considerations in a single analysis framework (code tool). The Reactor Analysis and Virtual Control Environment modeling and simulation tool was further enhanced to improve selection and control of scenarios to enable Monte-Carlo type simulation of scenarios and event timing directly into probabilistic risk assessments. Enhanced physics-based tools for modeling and simulating specific accident phenomena (e.g., water damage during flooding, seismic wave propagation and effects on plant systems, etc.) were developed and integrated into the suite of risk-informed codes. The physical effects of aging continued to be developed in the simulation tool Grizzly that will provide a capability to account for component aging in future probabilistic risk assessments. • Instrumentation and Controls – Research and development continued in close cooperation with industrial partners to address the aging and obsolescence of analog instrumentation and controls technologies and their replacement with more modern digital instrumentation and controls. Research was carried out with and at		

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
several commercial nuclear plant sites serving as demonstration facilities for the commercial nuclear industry to develop and demonstrate methods for replacing analog instrumentation and controls in main control rooms with digital technologies. The sites represent a cross section of the commercial industry including regulated and merchant markets, fleet and single-site utilities, and are representative of the commercial nuclear power industry as a whole. Pilot plant research projects in other technologies were performed with commercial partners and included tests and evaluations of technologies of automated work package at participating utilities, development of an approach for a plant-wide digital architecture for achieving a seamless digital environment together with an Institute of Nuclear Power Operations working group, development of new approaches and technologies for enhanced data analytics to improve outage risk management, and methods to increase automation by allocating manually performed activities to automation in order to achieve cost reductions, and safety enhancements. • Systems Analysis and Emerging Issues – Research was performed to study the economic and market challenges that affect the nuclear industry, with a view of such issues from the perspective of costs and revenues of owner-operators in different segments of the U.S. electricity markets. Research was also performed, in close collaboration with leading industry organizations, to address the potential for different approaches to water chemistry		

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
control in pressurized water reactors that do not depend on Lithium-7 supply. • Reactor Safety Technologies – Research was performed to gain additional performance data on select plant equipment that may be capable of performing for longer durations during beyond design basis events. Data from these efforts are being used to establish the potential viability of Terry Turbopump operational capabilities during severe accidents and whether these systems may provide additional safety margins. Research was performed using the results of recent severe accident modeling and forensics from Fukushima and Three Mile Island-2 to improve the Emergency Response Guidelines for severe accidents. Research was performed on the comparison of results from the two primary accident analysis codes, Modular Accident Analysis Program and MELCOR – to resolve modeling and differences obtained from the results of employing these codes to simulate severe accident phenomena.		

Reactor Concepts Research, Development and Demonstration
Advanced Reactor Technologies

Description

The Advanced Reactor Technologies (ART) subprogram conducts early-stage, essential research to reduce technical risk associated with advanced reactor technologies and systems. The specific scope is identified in collaboration with industry, with a goal of helping enable industry to develop and ultimately demonstrate advanced reactor concepts by the early 2030's. Innovative advanced reactor concepts offer significant potential benefits versus existing technologies, including possible lower costs, enhanced safety and security, greater resource utilization, and easier operation. Such advantages could allow nuclear energy to increase its contributions to United States (U.S.) clean and resilient energy sources and to provide an associated supply of high-paying U.S. jobs. The ART subprogram supports efforts to reduce long-term technical barriers for multiple reactor technology concepts, including advanced small modular reactors, with a focus on innovative technologies. This subprogram will address high-value fundamental research for long-term concepts, early-stage research and development (R&D) needs of promising mid-range concepts, early-stage development of innovative technologies that benefit multiple advanced reactor concepts, and stimulation of new ideas for transformational future concepts.

Early-stage R&D efforts support innovative reactor concepts, including fast reactors using liquid sodium coolant (SFRs), high temperature gas-cooled reactors (HTGRs), and molten salt reactors (MSRs) using liquid salt coolants and/or fuels. The ART subprogram focuses on efforts that could provide wide benefits across many different advanced reactor concepts, including small modular reactors, including: fundamental technologies and design methods for advanced reactors, interactions of advanced reactor coolants with materials and components, advanced instrumentation and controls, research to enhance safety, advanced materials development and codification, and fuel development and graphite material qualification for high-temperature reactors. Other advanced reactor fuel research and development activities are included. Cross-cutting areas of support include advanced energy conversion technologies and research to support special purpose applications, such as micro-reactors for remote applications. The ART subprogram continues support for international activities in the Generation IV International Forum and international collaborations on advanced materials, advanced reactor operations and safety. Industry-led innovative early-stage cost-shared R&D activities are supported through competitive industry awards. The ART subprogram also supports systems analyses of advanced reactor options to help guide decision-making and prioritization of R&D activities. This subprogram will seek to maximize leveraging of its ongoing and planned R&D to avoid duplication and maximize effectiveness of the R&D conducted under the Advanced Small Modular Reactor R&D subprogram.

Advanced Reactor Technologies

Activities and Explanation of Changes

<table>
<tr><th>FY 2017 Enacted</th><th>FY 2019 Request</th><th>Explanation of Changes
FY 2019 Request vs FY 2017 Enacted</th></tr>
<tr><td>Advanced Reactor Technologies $87,000,000</td><td>$74,000,000</td><td>-$13,000,000</td></tr>
<tr><td>

Fast Reactor Technologies - The Mechanisms Engineering Test Loop (METL) completed fabrication and installation of piping, vessels, and insulation. Completed the four year International Atomic Energy Agency (IAEA) Coordinated Research Project on benchmark analysis of historical tests for safety validation. Started American Society of Mechanical Engineer qualification testing for the first commercial heat of Alloy 709. Began conversion of the Natural-convection Shutdown heat removal Test Facility (NSTF) to a water-cooled configuration.
Gas Reactor Technologies – Tristructural-isotropic (TRISO) fuels Advanced Gas Reactor (AGR)-5/6/7 compacts fabricated, ready to insert in the Advanced Test Reactor. Continued destructive post-irradiation examination and high temperature safety testing on TRISO fuel compacts. Alloy 617 American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code Case fully approved for nuclear construction in elastic design space up to 425°C. Code qualification of Alloy 617 for nuclear construction in time dependent deformation regime, up to 950°C and 100,000 hours is proceeding through ASME approval process. Completed shakedown testing and initial matrix testing in the High Temperature Test Facility.
ARC15 Awards - Southern Company completed design for the Integrated Effects

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Fast Reactor Technologies - Complete in-sodium testing of gear test assembly in METL and develop next experimental assembly. Continue to modernize and validate fast reactor safety codes for use in normal operation and transient analyses. Lead IAEA Coordinated Research Project on Fast Flux Test Facility Historical Safety Test Benchmark; continue ASME material qualification efforts. Complete the collection and qualification of binary metal fuel testing data, targeted by several U.S. vendors. Capture data into database for external use, and conduct initial discussion with the Nuclear Regulatory Commission (NRC) on data. Evaluate safety considerations for evolution to non-bonded fuels. Scope and design Transient Reactor Test Facility (TREAT) experiments for loss of flow conditions.
Gas Reactor Technologies - Perform modeling and simulation, including experimental validation of normal operation and transient conditions. Continue graphite irradiation and analysis. Continue ASME code qualification of Alloy 617. Continue high-priority irradiation testing and examination of TRISO fuels.
Molten Salt Reactor Technologies - Continue development of chemical monitoring requirements, methods, and instrumentation. Define modeling framework for salt characterization. Continue early qualification of materials for structural components. Collect fundamental data to understand fission product behavior in fluoride and chloride salt-fueled systems. Develop advanced instrumentation for monitoring fissile material inventory.
Cross-Cutting Technologies - Complete technology roadmaps for special purpose applications. Develop heat exchanger design specification for coupling reactors to

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The decrease includes a small reduction to the amount provided for competitive industry awards, and rebalances the remaining research and development (R&D) among the core areas. R&D effort is increased for molten salt reactors, based on increasing industry interest in deploying these concepts. A small new initiative is studying R&D needs for special purpose reactors such as micro-reactors for remote applications. This effort is based on increasing interest in micro-reactor applications from industry and potential users. TRISO fuel development and qualification is focused on the highest priority activities required to sustain the capability and to obtain results from testing already in progress. This funding level also adds limited advanced reactor fuels activities previously supported under the Advanced Fuels subprogram under the Fuel Cycle Research and Development Program. Other R&D areas continue at adjusted funding levels, with no significant impacts or changes.

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FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Test facility for its molten chloride fast reactor concept. Measured primary fuel salt properties to determine path forward. Demonstrated corrosion resistant components can be fabricated/joined and identified regulatory framework needs to support licensing. • X-Energy scaled up fuel fabrication processes for its high temperature gas reactor concept that uses pebble fuel compacts and moved from surrogate material to depleted and natural uranium. Developed graphite lifetime predictive models and heat transfer models, completed white papers for submission to the Nuclear Regulatory Commission (NRC) and performed engineering analyses of selected plant systems / operations.	sCO2 Power Cycle. Continue work on printed circuit heat exchangers, intermediate heat exchanger alloys and Brayton cycle plant analysis codes. • ART Industry Awards - Support innovation and competitiveness of the U.S. nuclear industry through cost-shared basic/fundamental, applied research and development (R&D), and demonstration/commercial application R&D activities for advanced small modular reactors. • Advanced Reactor Regulatory Framework – The Department will continue to engage with NRC and industry to conduct R&D needed to support NRC's development of a streamlined regulatory process for advanced reactor technologies. R&D will focus on resolving uncertainties on key issues.	

Reactor Concepts Research, Development and Demonstration
Versatile Advanced Test Reactor R&D

Description

The Versatile Advanced Test Reactor research and development (R&D) subprogram's focus is the conduct of R&D evaluation of options, and pre-conceptual design development for fast test reactor needs and concepts. The information generated by this subprogram will help inform decisions about the Department's nuclear energy R&D infrastructure. While a decision whether or not to deploy an advanced fast spectrum test reactor has not been made, such a reactor could accelerate innovation in advanced fuels and materials for U.S. vendors and help pave the path to U.S. global leadership in advanced nuclear R&D by reestablishing this capability. Overall, R&D infrastructure is a cornerstone for advancing the technologies needed to revive and expand the nuclear sector in the United States.

For the United States to regain a global leadership role in development of the next generation of advanced reactors, a fast spectrum test reactor may be an important experimental tool. Advanced reactors are key in providing a diverse portfolio of energy supply sources to ensure national security through energy independence and energy dominance. Advancements in the area of testing of advanced materials, such as long-life structural and cladding materials, and fuels in extreme environment, can further facilitate their development. Due to the very high neutron flux provided by such a fast test reactor the irradiation time for testing of new materials could be reduced by an order of magnitude compared to that for a standard thermal test reactor such as the Advanced Test Reactor at Idaho National Laboratory.

In FY 2017, a multi-laboratory team with university and industry participation was assembled to begin work on developing the capability requirements and technical details for versatile advanced fast test reactor concepts. In FY 2018, the needs analysis and capability requirements will be finalized and work will continue for specifying the technical attributes of a potential reactor. In FY 2019, the R&D activities will be focused on pre-conceptual design development to support the development highly credible cost estimates needed prior to any decision on whether to proceed with building an advanced fast test reactor. An alternatives analysis was begun in FY 2018 and will be completed in FY 2019. While the R&D program is proceeding, the subprogram will also evaluate the potential for establishing innovative cost-shared partnership arrangements involving other agencies, state and local governments, the private sector, academia, and international partners if the project ultimately continues beyond the current phase.

Versatile Advanced Test Reactor R&D

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Versatile Advanced Test Reactor $5,000,000	**$15,000,000**	**+$10,000,000**
• Established a multidisciplinary team across multiple national laboratories, universities, and industry to begin work on developing the capability requirements and potential design concepts for a versatile advanced fast test reactor. • Completed a user needs assessment to identify level of potential utility of a fast test reactor. • Completed an assessment of test reactor design concepts.	• Initiate highest priority research and development (R&D) activities, e.g. configuration of components inside the reactor vessel. • Continue development of plant pre-conceptual design details. • Develop a Virtual Design and Construction (VDC) model of a physical reactor plant. • Conduct an independent review to ensure quality of work products completed and adequate progress towards the end goal. • Complete alternative analysis that was begun in FY 2018.	• The increase supports development of pre-conceptual design details and significant progress on modeling development to support the ultimate goal of providing a highly credible cost and schedule estimates to inform future decisions about potential advanced fast test reactor deployment.

Reactor Concepts Research, Development and Demonstration
Performance Measures

In accordance with the GPRA Modernization Act of 2010, the Department sets targets for, and tracks progress toward, achieving performance goals for each program.

	FY 2017	FY 2018	FY 2019
Performance Goal (Measure)	**ART Activities - Complete 90% of annual program milestones to support the development of innovative reactor technologies that may offer improved safety, functionality and affordability, and build upon existing nuclear technology and operating experience.**		
Target	90 % annual milestones met	90 % annual milestones met	90 % annual milestones met
Result	Met - 100	TBD	TBD
Endpoint Target	Advanced Reactor Technologies (ART) performance endpoints range from the mid-term (2030s) to very long term. ART is focused on high value research for long term concepts, R&D needs of promising mid-range concepts, and development of innovative technologies that benefit multiple concepts and stimulation of new ideas for transformational future concepts.		
Performance Goal (Measure)	**Light Water Reactor Sustainability (LWRS) - Complete 90% of annual program milestones to improve the reliability and economic performance of existing nuclear plants and further extend their operational life.**		
Target	90 % annual program milestones met	90 % annual milestones met	90 % annual milestones met
Result	Met - 100	TBD	TBD
Endpoint Target	NE research, development, and demonstrations, will enable the continuing operation of light water reactors.		

Fuel Cycle Research and Development

Overview

The Fuel Cycle Research and Development (FCR&D) program conducts early-stage applied research and development (R&D) on advanced fuel cycle technologies that have the potential to enhance safety, improve resource utilization and energy generation, reduce waste generation, and limit proliferation risk. Advancements in fuel cycle technologies support the enhanced availability, economics, safety, and security of nuclear-generated electricity in the United States, further enhancing U.S. energy independence and economic competitiveness. The program conducts system analyses of advanced fuel cycle options to help guide decision-making and prioritization of R&D activities. The FCR&D program also provides technical support for the Department's uranium management policies to mitigate negative impacts on domestic producers from Departmental actions.

The FCR&D program participates in world-class R&D and employs internationally renowned technical experts. All FCR&D subprograms leverage their technical expertise by participating in international collaborations through bilateral and multilateral technical agreements. The program also participates in projects sponsored by the International Atomic Energy Agency and the Organisation for Economic Co-operation and Development/Nuclear Energy Agency which provides further leverage in key technical areas.

The FCR&D Advanced Fuels Accident Tolerant Fuels (ATF) program will continue its early stage support of efforts on the high-risk, high-reward concepts that require more research and development but have the potential to offer significant benefits over any of the near-term technologies. The ATF program also will continue to support the unique capabilities of the national laboratories that do not exist in industry to support both the near-term and long-term fuel concepts under industrial development.

Used Nuclear Fuel Disposition R&D identifies alternatives and conducts scientific research and technology development to enable long term storage, transportation, and permanent disposal of spent nuclear fuel and wastes generated by existing nuclear fuel cycles. Through its research, the program helps mitigate technological uncertainties that must be addressed to ensure and expedite progress on nuclear waste management.

Highlights of the FY 2019 Budget Request

The Advanced Fuels subprogram will focus exclusively on Accident Tolerant Fuel (ATF) activities and continue to make progress towards its goal of enabling industry's development of one or more light water reactor fuel concepts with significantly enhanced accident tolerance through early-stage R&D. Other advanced reactor fuel R&D will be conducted as needed within the advanced reactor programs that they support.

In FY 2019, Used Nuclear Fuel Disposition R&D supports the highest priority research including the study of the performance of the high burnup used nuclear fuel demonstration, single car testing of cask and buffer railcars in accordance with the Association of American Railroads Standard S-2043, and initiate the fabrication of one escort car in partnership with the U.S. Navy.

Fuel Cycle Research and Development
Funding
($K)

	FY 2017 Enacted	FY 2018 Annualized CR*	FY 2019 Request	FY 2019 Request vs FY 2017 Enacted
Fuel Cycle Research and Development				
Material Recovery and Waste Form Development	33,400	-	5,000	-28,400
Advanced Fuels	68,000	-	40,000	-28,000
System Analysis and Integration	12,000	-	0	-12,000
Materials Protection, Accounting & Control Technology	5,400	-	5,000	-400
Used Nuclear Fuel Disposition R&D	62,500	-	10,000	-52,500
Integrated Waste Management System	22,500	-	0	-22,500
Fuel Resources	3,700	-	0	-3,700
Total, Fuel Cycle Research and Development	**207,500**	**206,091**	**60,000**	**-147,500**

SBIR/STTR:

- FY 2017 Enacted: SBIR $5,920; STTR $833
- FY 2018 Projected: SBIR $5,880; STTR $827
- FY 2019 Request: SBIR $1,920; STTR $270

* A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution. (These amounts are shown only at the Congressional control level and above; below that level, a dash (—) is shown).

Fuel Cycle Research and Development
Explanation of Major Changes
($K)

	FY 2019 Request vs FY 2017 Enacted
Material Recovery and Waste Form Development:	
The decrease from $33,400,000 to $5,000,000 reflects a refocusing of this subprogram on the highest priority research, primarily those that support maintaining the knowledge and capability in selected areas important to nonproliferation such as the CoDeContamination (CoDCon) project. Research and development (R&D) in areas applicable to advanced recycling technologies and waste forms development has been rescoped. Similarly, lower priority international collaborations on the back end of the nuclear fuel cycle will be refocused to support critical knowledge management.	**-28,400**
Advanced Fuels:	
The decrease from $68,000,000 to $40,000,000 reflects the refocusing of the program to fund only accident tolerant fuel activities. Other advanced reactor fuel R&D will be conducted as needed within the advanced reactor programs that they support.	**-28,000**
Systems Analysis and Integration:	
The decrease from $12,000,000 to $0 represents a realignment of activities within the office of Fuel Cycle Research and Development (FCRD). The essential crosscutting activities of the Systems Analysis and Integration program will continue with contributions from the R&D programs managed by FCRD.	**-12,000**
Materials Protection, Accounting & Control Technology:	
The decrease from $5,400,000 to $5,000,000 reflects some narrowing in the scope of research and development for advanced instrumentation to focus on the most promising technologies. Funding for support to electrochemical processing and safeguard by design continue to be priorities of this subprogram.	**-400**
Used Nuclear Fuel Disposition R&D:	
The decrease from $62,500,000 to $10,000,000 is a result of discontinuing most of this program’s activities. Interim storage and transportation planning scope are being moved under the new Yucca Mountain and Interim Storage program. Remaining funding will be focused on targeted R&D supporting preparation for large-scale transportation of spent nuclear fuel and high-level radioactive waste including cask and transportation technology and study of the performance of high burnup used nuclear fuel.	**-52,500**
Integrated Waste Management System:	
The decrease from $22,500,000 to $0 is a result of discontinuing most of this program’s activities with interim storage and transportation planning scope being moved under the new Yucca Mountain and Interim Storage program.	**-22,500**

	FY 2019 Request vs FY 2017 Enacted
Fuel Resources:	
The decrease from $3,700,000 to $0 reflects completion of this research and development (R&D) effort and no funding is required. The subprogram had successfully reached the initial goals of doubling the sorption capacities of uranium recovery from seawater, along with a significant reduction in the technical uncertainties.	**-3,700**
Total, Fuel Cycle R&D	**-147,500**

Fuel Cycle Research and Development
Material Recovery and Waste Form Development

Description

The Material Recovery and Waste Form Development (MRWFD) subprogram is being re-scoped to focus on critical research and development (R&D) in areas important to nonproliferation needs and objectives. The subprogram conducts targeted R&D activities related to the improvement of the current back end of the nuclear fuel cycle. Research topics that provide additional benefits beyond nonproliferation, such as those that have the potential to improve resource utilization and energy generation, reduce waste generation, or enhance safety will be prioritized. The program employs a long-term, science-based approach to foster innovative, and transformational technology solutions to achieve this objective.

Research to support advanced reactor technologies based on the use of molten salts as fuel and/or coolants as well as research on advanced and innovative analytical technologies, characterization technologies and on-line monitoring tools to support the back end of the nuclear fuel cycle will strengthen the sustainability of advanced nuclear fuel cycles.

MRWFD applies the unique expertise and technical capabilities to a broad range of applications such as a fundamental understanding of various chemical challenges related to civil nuclear applications.

Material Recovery and Waste Form Development

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Material Recovery and Waste Form Development **$33,400,000**	**$5,000,000**	**-$28,400,000**
• Pursued advanced material recovery technologies under the Sigma Team for Advanced Actinide Recovery of two-step process (heterogeneous) separation with a focus on co-extraction processing. • Continued work under the Sigma Team for Off-Gas with a focus on iodine-129 capture and immobilization. • Pursued the development and demonstration of the efficacy of solid-cathode U/TRU recovery as an alternative to liquid cadmium cathode in electro-refining operations. • Continued the international engagement on glass corrosion rate for reference glass. • Developed advanced on-line monitoring to enable better operation, faster upset recovery and to allow validation of dynamic models. • Provided the design, fabrication, qualification, and installation of the remote sampling/casting system in Hot Fuel Examination Facility. It includes subsequent equipment for the loading, welding, and weld inspection of rodlets in the Fuel Manufacturing Facility. • Continued the Phase II Integrated Recycling Test in the Joint Fuel Cycle Study, to demonstrate the integration of key unit operation in electrochemical recycling.	• Complete one CoDeContamination (CoDCon) demonstration test. • Continue the research on fission products gas and noble gas capture and immobilization. • Develop waste forms and processes applicable to molten salt. • International collaborative work will focus on knowledge management and transfer.	• The decrease from $33,400,000 to $5,000,000 reflects funding for maintaining the knowledge and capability in selected areas important to nonproliferation such as the CoDeContamination (CoDCon) project. Lower priority work, such as research and development (R&D) on advanced recycling technologies and waste forms development has been re-scoped to focus on knowledge management. Similarly, lower priority international collaborations will be refocused to support critical knowledge management and transfer.

Fuel Cycle Research and Development
Advanced Fuels

Description
The subprogram mission is enabling industry's development of one or more light water reactor fuel concepts with significantly enhanced accident tolerance through early-stage research and development (R&D). Beginning in FY 2019, the Advanced Fuels subprogram will be redirected to focus exclusively on Accident Tolerant Fuel (ATF) activities.

Following the accident at Fukushima and responding to a 2012 Congressional mandate, Advanced Fuels initiated a program to explore advanced light water reactor fuel with enhanced accident tolerance to benefit existing U.S. commercial nuclear power reactors. After five years of feasibility studies and assessments of potential fuel concepts, the program identified promising concepts that have the potential to significantly enhance accident tolerance. In FY 2019 the program will continue its early stage support of efforts on the high-risk, high-reward concepts that require more R&D but offer significant benefits over any of the near-term technologies. The accident tolerant fuel program also will continue to provide the unique capabilities of the national laboratories that do not exist in industry to support both the near-term and long-term fuel concepts under development by industry.

Every commercial nuclear power reactor in the United States is a light water reactor with fuel that consists of ceramic uranium dioxide pellets encased in zirconium alloy cladding. Early-stage research and development on other types of fuel that have the potential for significantly improved performance will be conducted as needed within the advanced reactor programs that they support.

Advanced Fuels

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Advanced Fuels $68,000,000	**$40,000,000**	**-$28,000,000**
• Performed cycle to cycle analysis and management of Accident Tolerant Fuel (ATF) concept irradiations. Capsules of potential ATF fuel concepts were inserted and removed from the Advanced Test Reactor (ATR) as needed. • Initiated Phase 2 development and testing of high-priority ATF fuel and cladding concepts. Fabricated and installed the test loop in the ATR and began qualification tests of the sensors and electronics prior to loading the test vehicle with ATF samples in FY 2018. • Continued lower-level, focused research on promising, but longer-term ATF fuel and cladding concepts. • Conducted research across multiple laboratory organizations supporting the development of innovative accident tolerant fuels such as high density, high performance ceramic fuels (silicide, nitride, boride, enhanced thermal conductivity) having enhanced performance in accident conditions for light water reactor. • Installed a high temperature steam exposure and oxidation apparatus for severe accident simulation in a radioactive hot cell environment. • Performed fuel fabrication to support the continued development of fabrication processes for minor actinide bearing metallic fuels. Includes fabrication of metal alloy compositions for irradiation testing, characterization, and testing. Conducted activities on minor actinide bearing metal alloy fuel composition characterization for	• Install lead fuel rods of Westinghouse's chromium-coated zirconium cladding loaded with uranium silicide pellets in Byron-2. • Install lead fuel assemblies of AREVA's chromium-coated zirconium cladding loaded with chromia doped pellets in Vogtle-2. • Continue irradiation testing of fuel rodlets in the central water loop of ATR. • In the Transient Reactor Test Facility, conduct dry capsule tests on unirradiated ATF samples and calibrate the multi-capsule, static environment, rodlet transient test apparatus. • Continue baseline post irradiation examination (PIE) of select fuel rodlets from Phase 1 irradiation testing. • Continue limited investment in fuel development capabilities at the national laboratories.	• The decrease from $68,000,000 to $40,000,000 reflects the prioritization of accident tolerant fuels research and development (R&D). Other advanced reactor fuel R&D will be conducted as needed within the advanced reactor programs that they support.

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
mechanical, physical, and thermal properties. • Continued collaborations with French Alternative Energies and Atomic Energy Commission/CEA on Am-Bearing Blanket irradiation test. • Performed irradiation and post irradiation examination (PIE) on advanced metallic fuel concepts. • Continued developments of modeling tool for analysis of transmutation fuels. • Conducted research and development (R&D) on advanced cladding for transmutation fuels. • Established a uniform framework for fuel system handbooks that provide material properties for fuel and cladding of importance to experimenters, analysts, designers, and modelers involved in fuel development and qualification. Issued new and revised handbooks on metal fuel and cladding, iron-chrome-aluminum (FeCrAl) cladding, silicon carbide cladding, and uranium silicide fuel. • Established the Nuclear Data Management and Analysis System (NDMAS) for use in the Accident Tolerant Fuel (ATF) program. NDMAS is a platform for storing, qualifying, and managing data collected from irradiation testing and PIE.		

Fuel Cycle Research and Development
Systems Analysis and Integration

Description

In FY 2019, the Systems Analysis and Integration subprogram will be eliminated. Funding for activities previously undertaken in this subprogram, such as strategic planning and analysis, program assessment and coordination, and integrated evaluation will be funded within other Fuel Cycle Research & Development funding sources, as appropriate.

Previously, the Systems Analysis and Integration subprogram provide the critical capability needed to analyze complex fuel cycle system options, assess overall performance under various scenarios, and improve understanding of the interdependencies between various subsystems and associated technologies. The objective was to develop and implement analysis processes and tools and perform integrated fuel cycle evaluations to provide information that can be used to objectively and transparently inform decision makers about overall research and development (R&D) directions and to integrate activities through R&D efforts on common fuel cycle goals.

Systems Analysis and Integration

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Systems Analysis and Integration $12,000,000	**$0**	**-$12,000,000**
• Refined and tested a technology system readiness assessment approach to help identify all of the critical technology elements and gaps in the research and development (R&D) portfolio. Tested the approach on sodium cooled fast reactor fuel development and aqueous reprocessing systems. • Continued to analyze advanced nuclear energy systems to gather information on systems characteristics and performance attributes. • Continued analysis of transition from the current fuel cycles to the smaller set of promising fuel cycles as identified by the Evaluation and Screening Study and analyzed sets of technology specific options for the most promising fuel cycle options. • Analyzed system impacts of candidate Accident Tolerant Fuel concepts in the Advanced Fuels subprogram leading up to the lead test assembly demonstration. • Developed improved cost estimates with lower uncertainty for assessment of economic competitiveness of the most promising fuel cycles. • Continued to maintain the publicly-available Fuel Cycle Catalog. • Completed a compendium report on regional and global analysis studies conducted over the past decade that evaluated penetration of nuclear in future energy markets, considering other energy sources and externalities. • Maintained the document management database for Fuel Cycle Research & Development (FCR&D) deliverables. Maintained portals, Sharepoint, and	• No funding is requested.	• The decrease from $12,000,000 to $0 represents a realignment of activities within the Fuel Cycle Research and Development (FCR&D) program. The essential crosscutting activities of the Systems Analysis and Integration program will continue within the R&D subprograms managed by FCR&D.

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
other technology for information exchange. • Continued to provide management and administration, program controls, and program support to the Fuel Cycle Research & Development (FCR&D) program.		

Fuel Cycle Research and Development
Materials Protection, Accounting & Control Technology

Description

The Materials Protection, Accounting and Control Technology (MPACT) subprogram develops the technologies and analysis tools to support the next generation of nuclear materials management and safeguards for planned and emerging U.S. nuclear fuel cycles. It also includes assessing vulnerabilities in current nuclear systems while managing and minimizing proliferation and terrorism risks. Addressing the energy security needs of the country will require innovative approaches to materials control and accounting to ensure that nuclear material is not misused, diverted, or stolen.

The Office of Nuclear Energy (NE) works closely with the National Nuclear Security Administration (NNSA), the Department of State, and the Nuclear Regulatory Commission on issues related to nuclear nonproliferation. NNSA has broad responsibilities in international nonproliferation and security matters for the present and into the future. MPACT is focused on research and development (R&D) as it relates to potential future fuel cycle facilities here in the United States.

Challenges facing nuclear materials accountancy generally include:

- Limitations of accuracy and timeliness of detection (especially in high radiation fields).
- Aggregating and integrating process data from large information streams.
- Assessment of new reactor designs and fuel cycle concepts, which require new nuclear material management approaches (Small Modular Reactors, Gas-Cooled Reactors, Thorium, etc.).
- Traditional material control and accountability challenges, such as uncertainty in large throughput facilities.

Materials Protection, Accounting & Control Technology

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Materials Protection, Accounting and Control Technology $5,400,000	**$5,000,000**	**-$400,000**
• Developed advanced sensors and instrumentation to fill gaps in materials protection, accounting and control. • Performed exploratory research and development (R&D) for new sensor materials and applications. • Executed field tests of sensors and instrumentation. • Developed and started the demonstration of an integrated suite of sensors, instruments, and analysis and performance assessment tools for electrochemical processing. • Developed and demonstrated concepts and approaches, and associated technologies and analysis tools for safeguards and security. • Optimized the safeguards and security efforts of the spent fuel storage facilities. • Initiated planning for distributed test bed lab-scale process monitoring and safeguards demonstration.	• Develop an integrated suite of sensors, instruments, and analysis and performance assessment tools for electrochemical processing as part of lab scale demonstration of an advanced safeguards and security system. • Continue with the development of a virtual facility, distributed test bed that incorporates the instruments, data, analysis tools, and models to provide a framework to link and normalize the data in a way that simulates a facility, including uncertainty quantification. • Field testing of different analyzers, and monitoring applications to assess their effectiveness and their performance relative to common non-destructive analysis and destructive analysis.	• The decrease from $5,400,000 to $5,000,000 reflects some narrowing the scope of research and development for advanced instrumentation to focus on the most promising technologies. Funding for support to electrochemical processing and safeguard by design continue to be priorities of this subprogram.

Fuel Cycle Research and Development
Used Nuclear Fuel Disposition R&D

Description
This subprogram supports research and development (R&D) to conduct scientific research and technology development to enable long term storage, transportation, and disposal of spent nuclear fuel and wastes. The primary focus of the subprogram's R&D will support the development of disposition-path-neutral waste management systems and options in the context of the current inventory of spent nuclear fuel and waste.

Research and Development
Full-Scale Storage Cask Demonstration – Although the nuclear power industry has used dry storage for many years, this storage option has been for low-burnup fuel; therefore, there is limited data available on the degradation of more contemporary high-burnup fuels. To address this data gap, the Department of Energy (DOE), the Nuclear Regulatory Commission (NRC), and nuclear industry have a collaborative agreement to investigate extended storage of high-burnup fuels (≥ 45 GWd/MTHM). DOE, in cooperation with the NRC and industry, is initiating a full-scale demonstration of storage for high-burnup fuel that will be beneficial by: 1) benchmarking the predictive models and empirical conclusions developed from short-term laboratory testing, and 2) building confidence in the ability to predict the performance of these systems over extended time periods.

Development of Cask, Buffer, and Escort Railcars – Activities continue to further the development of cask, buffer, and escort railcars for future spent nuclear fuel transportation. Railcars are destination independent and will be approved by the Association of American Railroads standard for the transport of radioactive materials (S-2043). Railcar development is done in coordination with the U.S. Navy to leverage resources.

Storage and Transportation R&D – In addition to the Full-Scale Storage Cask project, DOE will continue to support other lab testing, field studies, and modeling R&D related to the storage and transport of high-burnup fuel to include: testing of cladding response with hydride reorientation and embrittlement; the effects of atmospheric corrosion on storage welds; measuring the embrittlement of elastomer seals; determining thermomechanical degradation of bolts, welds, seals and poisons; analyzing thermal profiles of stored fuels; determining the stress profiles of fuels and casks; evaluating cask drying processes; laboratory post-irradiation examination of the fuel; and the development of sensors for internal and external cask monitoring. R&D will focus on contributing to the technical knowledge to support long-term storage and eventual transportation of high-burn-up fuels.

Disposal R&D – Activities continue to further the understanding of long-term performance of disposal systems in three main geologic rock types: clay/shale, salt, and crystalline rock. These activities include collaborations with international partners to leverage and integrate applicable R&D being conducted by other countries into the U.S. disposal R&D portfolio. Also, evaluations will be completed to determine the feasibility of directly disposing existing single (storage only) and dual-purpose (storage and transportation) used-fuel canisters in a mined repository.

Used Nuclear Fuel Disposition R&D

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Used Nuclear Fuel Disposition R&D $62,500,000	**$10,000,000**	**-$52,500,000**
• Collaborated with industry in designing/fielding and loading a dry storage cask demonstration. • Completed non-destructive testing and continued destructive testing of fuel rods that were pulled from a commercial power station to establish the performance baseline of the stored used fuel. • Characterized external loadings on fuel rods during normal conditions of transport. • Developed an understanding of material degradation phenomena in safety components associated with long term storage and transportation systems. This work will support licensing applications for extended dry storage and subsequent retrieval and transport of high burnup used nuclear fuel. • Evaluated integration and implementation methodologies of process-level models with performance assessment tools relating to argillite and crystalline media disposal. Integrated developed modeling tools with analysis software for uncertainty quantification and sensitivity analysis. • Continued science and engineering technical basis for the disposal of heat generating waste in salt. • Continued to support standardized canister work and the development of cask transloading capability of used fuel currently stored at the Idaho National Laboratory. • Designed and initiated testing and fabrication of prototype cask and buffer railcars, in accordance with the Association of American Railroads Standard for trains that carry high-level	• Study of the performance of the high burnup used nuclear fuel demonstration. • Fabrication and delivery of one cask railcar, two buffer railcars, and instrumented wheel sets to support single-car testing in accordance with the Association of American Railroads Standard S-2043. • Initiate fabrication of one escort car in partnership with the U.S. Navy. • Begin destructive testing on the 25 rods that will be used to determine the performance baseline.	• The funding decrease from $62,500,000 to $10,000,000 is a result of discontinuing most of this program's activities, with interim storage and transportation planning scope being moved under the new Yucca Mountain and Interim Storage program.

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
radioactive material. • Continued research and development (R&D) activities associated with exploring potential alternative disposal options for various waste and spent nuclear fuel forms, including collaboration with international partners to leverage R&D being conducted in various geologic media. • Issued evaluation of the feasibility of direct disposal of dual-purpose canisters to potentially eliminate the need for repackaging these canisters for disposal.		

Fuel Cycle Research and Development
Integrated Waste Management System

Description
The integrated Waste Management System will be discontinued. No funding is required for this activity in FY 2019. Interim storage and transportation planning scope is being moved under the new Yucca Mountain and Interim Storage program.

Previously, this subprogram supported the development of and design of an integrated waste management system (IWMS).

Integrated Waste Management System

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Integrated Waste Management System $22,500,000	**$0**	**-$22,500,000**
• Initiated a generic (not site-specific) Interim Storage Facility (ISF) design and associated Topical Safety Analysis Report (TSAR). • Developed and maintained functional and operational requirements for the overall waste management system, the initial ISF, the larger ISF, and the transportation system. • Determined and addressed Aging Management needs for the pilot ISF and beyond. • Reviewed existing transportation cask's certificates of compliance to identify items for confirmation and/or resolution prior to transportation. • Reviewed existing storage cask licenses to summarize their range of relevant licensing conditions and parameters. • Engaged Nuclear Regulatory Commission staff to discuss current regulatory requirements and guidance, identify and understanding emerging regulatory issues, and improve understanding relative to regulatory interpretations and implications for interim storage and transportation licensing. • Developed and evaluated potential National Environmental Policy Act strategies to inform policy makers. • Continued to work with State Regional Groups and Tribes to develop policy on how to provide funds and training to public safety officials of units of government through whose jurisdiction Spent Nuclear Fuel (SNF) may be transported. • Developed transportation routing analysis	• No funding is being requested.	• The subprogram is being discontinued. Interim storage and transportation planning scope is being moved under the new Yucca Mountain and Interim Storage program.

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
methodology. • Evaluated and developed plans to ship SNF from reactor sites. • Conducted system analyses to evaluate an integrated approach to transportation, storage, and disposal in the waste management system. • Identified and evaluated opportunities for standardization and integration within the nuclear waste management system, including developing design options for multi-purpose storage, transportation, and disposal components and systems. • Expanded and maintained the Used Nuclear Fuel Storage, Transportation & Disposal Analysis Resource and Data System (UNF-ST&DARDS) database.		

Fuel Cycle Research and Development
Fuel Resources

Description

This subprogram is being discontinued. It had successfully reached the goals of doubling the sorption capacities of uranium recovery from seawater, along with a significant reduction in the technical uncertainties.

Previously, the Fuel Resources subprogram sought to identify and implement actions the Department could take to assure that economic nuclear fuel resources remain available. The program evaluated nuclear fuel resources and developed recovery technologies to enable increased fuel resources. Priority attention focused on developing the technology for extraction of uranium from seawater. Seawater contains more than 4 billion tons of dissolved uranium. This unconventional uranium resource, combined with a suitable extraction cost, provided a price cap and ensured centuries of uranium supply even with aggressive world-wide growth in nuclear energy applications. A key objective was to develop advanced adsorbent materials that can simultaneously enhance uranium sorption capacity, selectivity, kinetics, and materials durability to reduce the technology cost and uncertainties.

The strategy was to take advantage of recent developments in (1) high performance computing, (2) advanced characterization instruments, and (3) nanoscience and nano-manufacturing technology to enable technical breakthroughs. The technology-driven, science-based research and development efforts were focused on: simulating and predicting structural and functional relationships using modern computational tools; applying advanced quantum beam characterization tools to understand dynamic chemical processes at the atomic and molecular levels; and synthesizing novel nanoscale adsorbent materials with architectures tailored for specific chemical performance.

Fuel Resources

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Fuel Resources $3,700,000	**$0**	**-$3,700,000**
• Advanced adsorbent development by irradiation-induced grafting - Prepared polymer-based adsorbents by irradiation (e-beam) induced and chemical grafting methods. • Improved uranium selectivity by studying the chemistry and mechanisms that enable the development of sites tailored for uranium retention. • Increased the reaction kinetics to reduce the time adsorbents are required to be exposed to seawater. • Continued to enhance material durability and reusability by reducing material degradation. • Marine Testing - Conducted off-shore marine testing to evaluate the performance of adsorbent materials in real seawater current conditions. • Performed advanced computer modeling for chemical speciation and ligand design to enhance uranium selectivity.	• No funding is being requested.	• The decrease from $3,700,000 to $0 reflects completion of this research and development (R&D) effort and no funding is requested. The subprogram had successfully reached the goals of doubling the sorption capacities of uranium recovery from seawater, along with a significant reduction in the technical uncertainties.

Fuel Cycle Research & Development
Performance Measures

In accordance with the GPRA Modernization Act of 2010, the Department sets targets for, and tracks progress toward, achieving performance goals for each program.

	FY 2017	FY 2018	FY 2019
Performance Goal (Measure)	**Fuel Cycle R&D (FCR&D) - Complete 90% of annual program milestones that advance fuel cycle technologies in order to support the enhanced availability, economics, safety, and security of nuclear-generated electricity in the United States.**		
Target	90 % annual milestones met	90 % annual milestones met	90 % annual milestones met
Result	Met - 96	TBD	TBD
Endpoint Target	Perform long-term R&D on advanced technologies that could lead to the next generation of sustainable fuel cycle options that have the potential to improve resource utilization and energy generation, reduce waste generation, enhance safety, and limit proliferation risk.		

Nuclear Energy Enabling Technologies

Overview

The Nuclear Energy Enabling Technologies (NEET) program conducts early-stage research and development (R&D) and makes strategic investments in research capabilities to develop innovative and crosscutting nuclear energy technologies to resolve nuclear technology development issues. NEET is a key element of the Department's overall strategy to reverse the downward trajectory of our nation's nuclear energy sector and once again become dominant by fully implementing the President's June 29 announcement made at the Department of Energy to "begin to revive and expand our nuclear energy sector." The Crosscutting Technology Development (CTD) subprogram focuses on innovative research that directly supports and enables the development of new, next generation reactor and fuel cycle technologies. Also, NEET includes a strong investment in modeling and simulation tools for existing and advanced reactor and fuel system technologies. Further, the program provides U.S. industry, U.S. universities, and national laboratories access to unique nuclear energy research capabilities through the Nuclear Science User Facilities (NSUF). Collectively, NEET-sponsored activities support the goals, objectives, and activities of the Gateway for Accelerated Innovation in Nuclear (GAIN) initiative to make these technology advancements accessible to U.S. industry through private-public partnerships. In so doing, NEET promotes U.S. energy independence, energy dominance, electricity grid resiliency, national security and clean baseload power.

Highlights of the FY 2019 Budget Request

NEET supports the revitalization and expansion of the U.S. nuclear industry by providing the crosscutting technologies and tools to maintain the current nuclear reactor fleet, advance the state of new advanced reactor technologies, including small modular reactors, and nuclear fuel cycle technologies, and help enable the re-establishment of the domestic supply chain necessary to support industry expansion.

NEET will continue to support next generation reactor and fuel cycle technologies through competitively awarded crosscutting research in advanced instrumentation and control technologies, innovative manufacturing, fabrication and construction technologies, advanced cooling concepts, and other stakeholder-identified areas.

NEET continues to support on-going research and capability development activities in advanced modeling and simulation through integration of the Nuclear Energy Advanced Modeling and Simulation and Modeling and Simulation Hub subprograms into a single inclusive advanced modeling and simulation program.

NSUF funds competitive selections for U.S. researcher access to unique and highly-specialized nuclear research capabilities, instrumentation, and scientific support through its multiple partner facilities. In addition, NSUF supports enhanced laboratory facilities and capabilities including, for example, Advanced Test Reactor sample irradiation, Transient Test Reactor fuel experiments, post-irradiation examination, and other advanced capabilities that are well beyond the domestic nuclear industry and necessary to accelerate advanced reactor technology deployment.

Nuclear Energy Enabling Tehcnologies
Funding
($K)

	FY 2017 Enacted	FY 2018 Annualized CR*	FY 2019 Request	FY 2019 Request vs FY 2017 Enacted
Nuclear Energy Enabling Technologies				
Crosscutting Technology Development	27,000	-	47,400	+20,400
Nuclear Energy Advanced Modeling and Simulation	28,300	-	34,000	+5,700
Energy Innovation Hub for Modeling and Simulation	24,300	-	0	-24,300
Nuclear Science User Facilities	35,500	-	34,600	-900
Total, Nuclear Energy Enabling Technologies	**115,100**	**114,319**	**116,000**	**+900**

SBIR/STTR:

- FY 2017 Transfer: SBIR $3,683; STTR $518
- FY 2018 Projected: SBIR $3,658; STTR $515
- FY 2019 Request: SBIR $3,712 ; STTR $522

* A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution. (These amounts are shown only at the Congressional control level and above; below that level, a dash (—) is shown).

Nuclear Energy Enabling Technologies
Explanation of Major Changes
($K)

	FY 2019 Request vs FY 2017 Enacted
Crosscutting Technology Development:	
The increase from $27,000,000 to $47,400,000 reflects funding for additional competitive, cost-shared research and development projects in areas such as advanced instrumentation and control, advanced manufacturing methods, fabrication and construction technologies, and advanced cooling technologies, with an emphasis on advanced manufacturing projects, to meet the most urgent reactor developer needs to significantly reduce the domestic advanced reactor deployment costs and time, including small modular reactors.	**+20,400**
Nuclear Energy Advanced Modeling and Simulation (NEAMS):	
The increase from $28,300,000 to $34,000,000 reflects additional funding to maintain and deploy M&S Hub tools within the NEAMS program as appropriate.	**+5,700**
Energy Innovation Hub for Modeling and Simulation (M&S Hub)	
The decrease from $24,300,000 to $0 reflects the successful completion of the M&S Hub. The Department will integrate tools from the M&S Hub with the NEAMS program beginning in FY 2018, therefore, no new or additional funds are requested for the M&S Hub in FY 2019. NE will integrate the products of the successful M&S Hub by expanding the applicability of NEAMS tools to a broader range of advanced reactor development, and initiate several high-impact modeling and simulation problems.	**-24,300**
Nuclear Science User Facilities (NSUF):	
The decrease from $35,500,000 to $34,600,000 reflects the need to access the most promising early-stage research through competitive selections to these unique and highly-specialized nuclear research capabilities located at NSUF's multiple partner facilities.	**-900**
Total, Nuclear Energy Enabling Technologies	**+900**

Crosscutting Technology Development

Description

The Crosscutting Technology Development (CTD) subprogram competitively awards innovative early-stage research and development (R&D) funding to U.S. industry, U.S. universities, and national laboratories to develop innovative solutions to crosscutting nuclear energy technology challenges, with a focus on resolving U.S. industry nuclear technology development issues and fill critical gaps. The CTD subprogram focuses on innovative research that directly supports and enables the development of new, next generation reactor designs and fuel cycle technologies. CTD conducts early-stage R&D on the technologies needed to maintain the current fleet of nuclear reactors and the innovative technology needed to support the development of advanced reactors, including small modular reactors, which could increase the domestic nuclear reactor pipeline. CTD is coordinated with NE's other R&D programs to ensure that developed technologies and capabilities are part of an integrated investment strategy aimed at improving safety, reliability, and economics of U.S. nuclear technologies.

Characteristics of the activities within this program include:

- Developing new capabilities needed by the domestic nuclear energy R&D enterprise, with focus on U.S. industry gaps;
- Conducting high-risk research that could overcome current technological limitations;
- Developing enabling technologies that have applicability across multiple technical areas; and,
- Conducting leading-edge R&D to improve the economics, quality, security, and efficiencies of nuclear technologies including hybrid applications

Crosscutting Technology Development

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Crosscutting Technology Development		
$27,000,000	**$47,400,000**	**+$20,400,000**
• Competitively solicited and awarded six three-year research and development (R&D) projects in advanced sensors and instrumentation, and advanced methods for manufacturing. • Initiated In-pile Instrumentation research on real-time, accurate, spatially resolved information regarding performance of nuclear fuels and materials. • Established Utility Advisory Committee to understand industry issues with hybrid energy systems implementation; performed dynamic assessments of hybrid energy systems cases; updated technology roadmap to reflect coordination with DOE Hydrogen Program. • Established a government and Industry joint research and development plan on nuclear energy cyber security with the Electric Power Research Institute.	• Competitively solicit and award new fully-funded R&D projects in high priority crosscutting R&D areas with applicability to next generation reactor and fuel cycle technologies: advanced sensors and instrumentation, advanced methods for manufacturing, advanced cooling technologies, and other stakeholder-identified areas. • Continues leading edge manufacturing and fabrication R&D, including a focus on economics, quality, and efficiencies, for nuclear component prototypic conditions. • Competitively award research on nuclear component manufacturing, fabrication, and plant construction of advanced reactor technologies. • Conduct research on hybrid energy systems to support nuclear and renewables co-generation and nuclear/industrial applications.	• Emphasis on funding additional competitive advanced manufacturing projects that provide cost and schedule improvements for advanced reactor and small modular reactor deployments. • Sponsors advanced manufacturing projects for unique prototype nuclear components. • Continue in-pile sensor and other advanced instrumentation research for advanced reactors based on FY 2018 workshop feedback.

Nuclear Energy Advanced Modeling and Simulation

Description

In FY 2019, NE's two previously separate and independent modeling and simulation subprograms, Nuclear Energy Advanced Modeling and Simulation (NEAMS), and the Energy Innovation Hub for Modeling & Simulation (M&S Hub) will be executed as a single integrated and inclusive subprogram under NEET. This integration is underway in FY 2018 and will be completed by 2019. Under this integrated effort, advanced modeling and simulation capabilities will be developed and deployed to enable industry to accelerate development and ultimate commercialization of early-stage advanced reactor concepts, and to solve high-impact technology problems that affect the economics of both existing and future reactor plants. This integrated approach will more effectively and efficiently leverage the advantages of advanced modeling and simulation across the full range of nuclear technologies, and provide for broader validation of computational tools. This integration will also support the use of the M&S Hub-developed tools for the development of advanced light-water reactors.

NEAMS develops and deploys a set of predictive analytic computer tools called the NEAMS ToolKit, which is primarily focused on non-light water reactor (LWR) technologies. NEAMS engages scientists and engineers in developing state-of-the-art, multi-scale models of physics and chemistry that drive advanced computational methods for simulations of advanced nuclear energy systems. Advanced modeling and simulation capabilities also support NE program priorities, such as the development of fuels with enhanced accident tolerance.

The M&S Hub developed and deployed a reactor simulation tool set called the Virtual Environment for Reactor Applications (VERA), which is primarily focused on LWR technologies for an improved understanding of important operational and safety issues in existing reactors. VERA tools are being used to model complex real world phenomena and conditions in the Nation's fleet of pressurized LWRs, and have been successfully used to analyze and understand key challenges to the safety and economics of reactor operations, comprising the successful completion of the M&S Hub's initial work scope. The VERA tools are also being used in analyzing light-water based small modular reactor designs currently under development in the U.S.

Through an integrated programmatic framework, VERA and NEAMS tools will be crucial in supporting NE's three priority areas: Existing Fleet, Advanced Reactor Pipeline, and the Fuel Cycle. For the existing fleet, NEAMS and VERA tools will be used to address significant core performance issues and accelerate development of accident tolerant fuels to help assure the long-term availability and market competitiveness of nuclear energy. For the advanced reactor pipeline, these tools will help accelerate advanced reactor development and also help meet otherwise cost-prohibitive data needs and support Nuclear Regulatory Commission (NRC) confirmatory analyses. For fuel cycle technologies, NEAMS and VERA tool development in FY 2019 will provide capabilities that can support future used nuclear fuel R&D, including development of strategies to burn less fuel, and high-fidelity analysis and prediction of fuel and cladding performance through the storage cycle.

Nuclear Energy Advanced Modeling and Simulation

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Nuclear Energy Advanced Modeling and Simulation		
$28,300,000	**$34,000,000**	**+$5,700,000**
• Continued enhancement of Nuclear Energy Advanced Modeling and Simulation (NEAMS) Fuels Product Line capabilities, particularly in simulation of Accident Tolerant Fuels (ATF); released MARMOT and BISON code updates and validation assessments. • Continued enhancement of NEAMS Reactors Product Line capabilities; released SHARP suite update with validation assessments. • Continued enhancement of NEAMS Integration Product Line capabilities, particularly with the NEAMS Workbench; demonstrated fuels-reactor integrated simulation by coupling BISON and Nek-5000 (thermal- fluids). • Continued expanded validation campaign; completed assessment of first two HIPs in collaboration with DOE and industry users; established ATF simulation capabilities, and provided FIV-capable tools for optimizing helical steam generator designs. • Continued Transient Reactor Test Facility (TREAT) mission support by applying NEAMS ToolKit to improve the operational efficiency and expand testing regimes of TREAT, with particular advances in full core simulation and Multi-SERTTA capabilities.	• Accelerate deployment and validation of NEAMS and the Virtual Environment for Reactor Applications (VERA) modeling and simulation (M&S) tools. - Expand engagement with industry through GAIN infrastructure and new competitively awarded projects focused on industry needs in both the existing nuclear fleet and advanced reactor development (including at least two additional High Impact Problem projects) - Apply advanced coupled capabilities to advanced thermal-fluids solutions needed by industry through the Center for Advanced Thermal-Hydraulics Simulations at INL - Enable acceleration of ATF development and qualification and demonstrate capabilities to support analysis of the insertion of ATF lead test assemblies and transition cores • Continue to enhance and expand application of NEAMS and VERA tools to enable industry to accelerate development and enhance marketability of existing and advanced reactor concepts. - Release code updates across the NEAMS and VERA suites - Expand engagement with NEAMS/VERA user groups for ongoing validation/maintenance of these tools • Collaborate with the Nuclear Regulatory Commission (NRC) on the interoperability of NEAMS and NRC tools to provide expanded analysis capabilities and enable NRC use of NEAMS developed tools, primarily focused on ATF and advanced reactor technologies.	• Completes integration of M&S Hub within NEAMS and funds remaining M&S Hub light water reactor research.

Energy Innovation Hub for Modeling and Simulation

Description

The Energy Innovation Hub for Modeling and Simulation (Hub) was initiated in FY 2010 to develop computational tools for the advanced simulation of Light Water Reactors (LWRs), and to demonstrate their application to industry-identified operational issues in the existing LWR fleet. Through the execution of several industry-defined challenge problems, the Hub has provided the insights and tools needed by industry to address these key issues. Consequently, the Department has fully met its Hub objectives, and the Hub is being brought to closure. Hub-developed capabilities, such as the Virtual Environment for Reactor Analysis (VERA) tool suite, will be integrated into the NE Advanced Modeling & Simulation (NEAMS) program, and deployed along with NEAMS tools to industry for commercial application to existing and advanced reactors.

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Energy Innovation Hub for Modeling and Simulation

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Energy Innovation Hub for Modeling and Simulation $24,300,0000	**$0**	**-$24,300,000**
• Released updated version of the Virtual Environment for Reactor Applications (VERA) including development enhancements and capabilities. • Established an industry-driven use of VERA in support of a Consortium for Advanced Simulation of Light Water Reactor (CASL) Test Stand deployment, such as NuScale, University of Illinois/Exelon, and Areva. • Completed and documented grid-to-rod fretting challenge problem. • Demonstrated Pressurized Water Reactor fuel performance modeling and simulation capabilities for loss of coolant accident conditions. • Completed and documented Watts Bar Nuclear Unit 2 Startup analysis.	• No funding is requested. • VERA tools are available to industry stakeholders. • Remaining VERA research activities will be consolidated within the Nuclear Energy Advanced Modeling and Simulation (NEAMS) subprogram to improve efficiencies by leveraging capabilities and resources.	• Remaining Hub activities are integrated and funded within the NEAMS program.

Nuclear Science User Facilities

Description

The Nuclear Science User Facilities (NSUF) subprogram is the nation's designated nuclear energy user facility. As a partner facility consortium, the NSUF connects a broad range of exceptional nuclear research capabilities, expert mentors and experimenters. The NSUF represents a "prototype laboratory for the future," promoting the use of unique nuclear research facilities located at multiple sites across the Nation and encouraging active university, industry, and laboratory collaboration in relevant nuclear science research. The NSUF, through competitive solicitations, provides a mechanism for research organizations to collaborate, conduct experiments and post-experiment analysis, and utilize high performance computing at facilities not normally accessible to these organizations. On an annual basis, researchers propose projects to be conducted at these unique facilities, with timelines ranging from a few months to several years. When projects are awarded, the NSUF program pays for experiment support and laboratory services at the partner user facilities. In this manner, researchers benefit from the introduction to new techniques, equipment, and personnel.

The NSUF provides access at no-cost to the user to the Idaho National Laboratory's Advanced Test Reactor (ATR), Transient Reactor Test (TREAT) facility, post-irradiation examination (PIE) facilities at the Materials and Fuels Complex, and high performance computing capabilities such as Falcon, complementing the existing Advanced Scientific Computing Research User Facilities. Additional NSUF capability includes PIE assets at the Center for Advanced Energy Studies; research reactors at Oak Ridge National Laboratory, Massachusetts Institute of Technology, North Carolina State University, and the Ohio State University; beam-line capabilities at the Advanced Photon Source in coordination with the Illinois Institute of Technology, the National Synchrotron Light Source II at the Brookhaven National Laboratory, and Los Alamos National Laboratory; ion irradiations at the Intermediate Voltage Electron Microscope at Argonne National Laboratory, Lawrence Livermore National Laboratory, and Texas A&M University; gamma irradiations at Sandia National Laboratories' Gamma Irradiation Facility; irradiation experiment design and fabrication capabilities at Pacific Northwest National Laboratory; hot cells and fabrication capabilities at Westinghouse; and examination facilities at the Universities of Wisconsin, Michigan, California-Berkeley, Purdue, Nevada-Las Vegas, and Florida, all partnered with the NSUF to bring additional user facilities to the research community.

Nuclear Science User Facilities

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Nuclear Science User Facilities **$35,500,000**	 **$34,600,000**	 **-$900**
• Fully funded 15 irradiation/post-irradiation examination projects (5 university, 5 industry, 5 national laboratories). • Provided 72.45 million core hours of high performance computing capabilities to users through the FY 2017 Consolidated Innovative Nuclear Research (CINR) funding opportunity announcement. • Made the Nuclear Science User Facility (NSUF) Sample Library database (now known as the NSUF Nuclear Fuels and Material Library) accessible to the research community through the NSUF website. • Awarded 92 rapid turnaround experiments. • Completed limited-view hodoscope refurbishment and initiate design and procurement of a data acquisition system that supports operation of the full-view hodoscope. • Initiated design and fabrication of other experiment-supporting equipment such as preparation benches, transport casks, and digital image capture system. • Continued development of the Nuclear Energy Knowledge and Validation Center.	• Provide facility access awards in the three FY 2019 Rapid Turnaround Experiment solicitations, the FY 2019 CINR solicitation, and in support of the Funding Opportunity Announcement issued in FY 2018. All fully funded. • Invest in select domestic infrastructure capabilities to better support the advancement of applied research and development, including Transient Reactor Test Facility capability enhancements. • Continue and expand NSUF's access to unique nuclear science capabilities and expertise. These collaborations will allow more efficient use of the NSUF program funds by leveraging facility and capability investments. • Continue to enhance the Nuclear Fuels and Materials Library (NFML) by filling gaps in sample selection via purchases or other acquisition methods including irradiating materials identified in conjunction with industry.	• Focuses researcher access to NSUF capabilities on the most promising early-stage R&D through competitive selections to unique and highly-specialized nuclear research capabilities located at NSUF's multiple partner facilities.

Nuclear Energy Enabling Technologies
Performance Measures

In accordance with the GPRA Modernization Act of 2010, the Department sets targets for, and tracks progress toward, achieving performance goals for each program.

	FY 2017	FY 2018	FY 2019
Performance-Goal (Measure)	**NEET- Mod & Sim Hub - Complete 90% of annual research and development milestones to support the wider applicability and deployment of virtual reactor modeling and simulation tools set for predictive simulation of Light Water Reactors by 2020.**		
Target	90 % annual milestones met	N/A	N/A
Results	Met - 100	N/A	N/A
Endpoint Target	These milestones represent annual progress toward virtual reactor modeling and simulation tools set for predictive simulation of Light Water Reactors by 2020.		
Performance Goal (Measure)	**Advanced Modeling and Simulation - Complete 90% of annual integrated program milestones to support deployment of advanced modeling and simulation (M&S) tools that will help solve important Light Water Reactor (LWR) performance and cost issues, accelerate advanced reactor concept development and support NRC regulatory processes as requested.**		
Target	N/A	N/A	90 % annual milestones met
Result	N/A	N/A	TBD
Endpoint Target	On an ongoing basis, meet annual targets to enable industry to reduce operational costs and improve market competitiveness of existing Light Water Reactors (LWRs), and to expand commercial deployment of advanced reactors.		
Performance Goal (Measure)	**Nuclear Science User Facilities (NSUF) - Complete 90% of annual program milestones in order to provide industry, universities, and national laboratories access to unique nuclear energy research capabilities and expertise not normally accessible to the nuclear energy user community.**		
Target	N/A	N/A	90 % annual milestones met
Result	N/A	N/A	TBD
Endpoint Target	The Nuclear Science User Facilities (NSUF) represents a "prototype laboratory for the future," promoting the use of unique nuclear research facilities and encouraging active university, industry, and laboratory collaboration in relevant nuclear science research. On an ongoing basis, the NSUF, through competitive solicitations, provides a mechanism for research organizations to collaborate, conduct experiments and post-experiment analysis, and utilize high performance computing at facilities not normally accessible to these organizations.		

Radiological Facilities Management

Overview

Within the Radiological Facilities Management (RFM) program, the Research Reactor Infrastructure (RRI) subprogram supports the continued operation of U.S. university research reactors by providing university research reactor fuel services, as well as maintenance of, and safety upgrades to, supporting fuel fabrication equipment and facilities.

Highlights of the FY 2019 Budget Request

In FY 2019, in support of its mission and objectives, the RRI subprogram will provide project management, technical support, quality engineering and inspection, and nuclear material support to 25 research reactors located at 24 U.S. universities. Major program deliverables will be to procure new plate fuel elements and ship them to supported universities and also procure new Training, Research, Isotopes, General Atomics (TRIGA) fuel elements from the TRIGA International fuel fabrication facility in Romans, France. Also, the program ships used plate and TRIGA reactor fuel elements from supported universities to Department of Energy (DOE) used fuel receipt facilities. Continued delays and uncertainties associated with the schedule for resumption of production at the TRIGA International fuel fabrication facility has the potential to disrupt the continued operability of a subset of the 12 TRIGA U.S. university research reactors serviced by the RRI subprogram. To partially mitigate this uncertainty, the Department will continue its policy of reusing lightly-irradiated TRIGA fuel in DOE inventory that was initiated in FY 2017 and other initiatives to evaluate alternatives to the current TRIGA reactor fuel sole-source supply issue.

Radiological Facilities Management
Funding
($K)

	FY 2017 Enacted	FY 2018 Annualized CR*	FY 2019 Request	FY 2019 Request vs FY 2017 Enacted
Radiological Facilities Management				
Space and Defense Infrastructure	10,000	-	0	-10,000
Research Reactor Infrastructure	7,000	-	9,000	+2,000
Total, Radiological Facilities Management	**17,000**	**16,884**	**9,000**	**-8,000**

* A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution. (These amounts are shown only at the Congressional control level and above; below that level, a dash (—) is shown).

Radiological Facilities Management
Explanation of Major Changes
($K)

	FY 2019 Request vs FY 2017 Enacted
Space and Defense Infrastructure: The decrease from $10,000,000 to $0 represents no funding requested in FY 2019 for Oak Ridge Infrastructure. Infrastructure used for Office of Nuclear Energy research and development is fully funded through associated program budgets.	**-10,000**
Research Reactor Infrastructure: The increase from $7,000,000 to $9,000,000 offsets annual increases to fresh plate type fuel prices imposed by vendors and awards a purchase contract of new Training, Reactor, Isotope, General Atomics (TRIGA) fuel elements.	**+2,000**
Total, Radiological Facilities Management	**-8,000**

Radiological Facilities Management
Space and Defense Infrastructure

Description

Consistent with Congressional direction, this subprogram provided funds in FY 2017 to support Oak Ridge National Laboratory (ORNL) hot cells. In FY 2019, Office of Nuclear Energy use of these facilities is fully funded through associated program budgets.

Space and Defense Infrastructure

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Space and Defense Infrastructure $10,000,000	**$0**	**-$10,000,000**
• Completed design of lazy susan glovebox for Building 7920. • Removed existing ventilation system components to support installation of the Building 3525 ventilation system upgrades. • Continued maintenance and end-of-life replacement of critical hot cell equipment and infrastructure. • Managed Oak Ridge National Laboratory (ORNL)'s nuclear infrastructure to applicable regulations, Department of Energy (DOE) Orders, and DOE Directives. • Performed corrective and routine preventative maintenance on several thousand nuclear safety and facility support components and equipment.	• No funding is requested.	• Decrease represents no funding requested in FY 2019 for Oak Ridge Infrastructure. Infrastructure used for Office of Nuclear Energy research and development is fully funded through associated program budgets.

Radiological Facilities Management
Research Reactor Infrastructure

Description
The Research Reactor Infrastructure (RRI) subprogram provides fresh reactor fuel to, and removes used fuel from, 25 operating university research reactors to support their continued operation. This provides continued research and training reactor capability to U.S. universities to ensure their continued ability to support U.S. nuclear energy initiatives in the areas of research, development, and educational opportunities.

The continued operation of U.S. university research reactors directly supports the successful execution of the Nuclear Energy research mission and also plays an important role in developing future scientists and engineers in the U.S. This subprogram sustains unique capabilities for research and development and educational opportunities supporting U.S. energy initiatives. Used nuclear fuel shipments support U.S. and Department of Energy non-proliferation and national security objectives.

Research Reactor Infrastructure

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Research Reactor Infrastructure		
$7,000,000	**$9,000,000**	**+$2,000,000**
• Continued funding safety upgrades to allow resumption of fuel fabrication operations at Training, Reactor, Isotope, General Atomics (TRIGA) International in Romans, France. • Procured 40 and delivered 33 plate fuel elements required annually by University of Missouri (MURR) and Massachusetts Institute of Technology (MIT) as determined by need and fuel availability. • Shipped 19 lightly irradiated 8.5 wt% standard TRIGA fuel elements from the Irradiated Fuel Storage Facility at Idaho National Laboratory (INL) to a selected U.S. university research reactor facility. • Completed 3 used fuel shipments to Savannah River Site (SRS). • Continued Research Reactor Infrastructure (RRI) project management, quality assurance, nuclear material accountability, and transportation cask maintenance.	• Procure 40 and deliver between 33 and 36 plate fuel elements required annually by MURR and MIT as determined by need and fuel availability. • Ship up to two cask loads of lightly-irradiated 8.5 wt% standard TRIGA fuel elements from the Irradiated Fuel Storage Facility at INL to selected U.S. university research reactor facilities. • Procure additional TRIGA fuel elements from the TRIGA International fuel fabrication facility in Romans, France upon resumption of operations. • Complete up to 5 used fuel shipments to SRS and the INL, pending resolution of moratorium on such shipments to the INL. • Continue RRI project management, quality assurance, nuclear material accountability, and transportation cask maintenance. • If required, continue funding for the installation and final testing of fuel fabrication equipment at TRIGA International in Romans, France.	• The increase in sub-program funding offsets annual increases to fresh fuel prices imposed by vendors. • Funds the award of a contract to procure new TRIGA fuel elements from TRIGA International. • Provides funding to support the shipment of up to two cask loads of lightly-irradiated TRIGA Fuel shipments from the Irradiated Fuel Storage Facility (IFSF) at INL to selected U.S. university research reactor facilities.

Idaho Facilities Management

Overview

The mission of the Idaho Facilities Management (IFM) program is to manage the planning, acquisition, operation, maintenance, and disposition of the Office of Nuclear Energy (NE)-owned facilities and capabilities at the Idaho National Laboratory (INL). The IFM program maintains Department of Energy (DOE) mission-supporting facilities and capabilities at the INL in a safe, compliant status (with DOE Orders, federal laws and regulations, and state agreements) to enable technological advancement in the existing nuclear fleet, advanced reactor pipeline, and fuel cycle mission areas. The availability of these key facilities and capabilities to support NE research and development (R&D) is critical to the ongoing effort to revitalize nuclear energy in the United States. INL facilities and capabilities also support testing of naval reactor fuels and reactor core components and a diverse range of national security technology programs that support the National Nuclear Security Administration and other federal agencies such as the Department of Homeland Security in the areas of critical infrastructure protection, nuclear nonproliferation, and incident response. The IFM program integrates and closely coordinates with research programs to ensure proper alignment and prioritization of infrastructure investments, as well as infrastructure availability for programmatic work.

The IFM program enables long-term nuclear R&D activities by providing the expertise, facilities, equipment, and nuclear materials necessary to conduct a wide array of experimental activities in a safe and compliant manner. The Advanced Test Reactor (ATR) provides unique irradiation capability to further nuclear fuel and reactor component research in support of advanced nuclear reactor design activities. The Materials and Fuels Complex (MFC) contains a comprehensive range of fuel and experiment fabrication and pre- and post-irradiation examination capabilities used to assess material and fuel characteristics and performance in varying reactor environments. A limited number of facilities at the Idaho Nuclear Technology and Engineering Center are utilized to support material consolidation and storage, fuel cycle R&D, and National and Homeland Security activities.

Highlights of the FY 2019 Budget Request

The focus of IFM program activities remains on the safe and compliant operation of the INL's nuclear research reactor and non-reactor research facilities while continuing to realize improvements in the condition of aging INL infrastructure. In FY 2019, these activities include:

- Operating and maintaining the ATR Complex and key nuclear facilities at the MFC in a safe and compliant manner, including the Transient Reactor Test Facility following startup in FY 2018 and the Remote-Handled Low-Level Waste Disposal Facility following turnover to operations in FY 2019.
- Improving the reliability and availability of the ATR and Advanced Test Reactor Critical Facility in order to meet research customer demands. This strategy, jointly developed with Naval Reactors, will increase efficiency and irradiation days by prioritizing plant, equipment, and experimental loop investments.
- There is no new capital funding requested for Sample Preparation Laboratory pending Critical Decision-2 approval.

Idaho Facilities Management
Funding
($K)

	FY 2017 Enacted	FY 2018 Annualized CR*	FY 2019 Request	FY 2019 Request vs FY 2017 Enacted
Idaho Facilities Management				
INL Nuclear Research Reactor Operations and Maintenance	112,845	-	100,682	-12,163
INL Non-Reactor Nuclear Research Facility Operations and Maintenance	82,507	-	87,699	+5,192
INL Engineering and Support Facility Operations and Maintenance	22,055	-	6,500	-15,555
INL Regulatory Compliance	14,306	-	9,119	-5,187
Construction	6,000	-	0	-6,000
Total, Idaho Facilities Management[1]	**237,713**	**236,098**	**204,000**	**-33,713**

* A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution. (These amounts are shown only at the Congressional control level and above; below that level, a dash (—) is shown).

[1] Funding does not reflect the transfer of approximately $75M from Naval Reactors for maintenance and operation of the Advanced Test Reactor.

Idaho Facilities Management
Explanation of Major Changes
($K)

	FY 2019 Request vs FY 2017 Enacted
INL Nuclear Research Reactor Operations and Maintenance:	
The decrease from $112,845,000 to $100,682,000 reflects the completion of the Resumption of Transient Testing Program as well as the exclusion of one-time funding that was provided in FY 2017 for the Advanced Test Reactor (ATR) Maintenance Support Building. The request provides funding for operating and maintaining ATR, investments to improve ATR and Advanced Test Reactor Critical Facility (ATRC) availability and reliability, and base operations at the Transient Reactor Test Facility (TREAT) following startup in FY 2018.	**-12,163**
INL Non-Reactor Nuclear Research Facility Operations and Maintenance:	
The increase from $82,507,000 to $87,699,000 reflects full funding for operating and maintaining key nuclear facilities at the Materials and Fuels Complex (MFC), as well as Remote-Handled Low-Level Waste (RHLLW) Disposal Facility base operations.	**+5,192**
INL Engineering and Support Facility Operations and Maintenance:	
The decrease from $22,055,000 to $6,500,000 reflects completion of planned disposition of non-nuclear excess facilities and completion of Idaho National Laboratory (INL) major primary road resurfacing, reconstruction, and sealing.	**-15,555**
INL Regulatory Compliance:	
The decrease from $14,306,000 to $9,119,000 reflects transition of RHLLW Disposal Facility Project from nuclear facility operational readiness activities to base operations in FY 2019.	**-5,187**
Construction:	
The decrease from $6,000,000 to $0 reflects no funding for the Sample Preparation Laboratory (SPL) construction project in FY 2019. The project will continue to develop project documentation to support Critical Decision (CD)-2, Approve Performance Baseline, as funded under INL Non-Reactor Nuclear Research Facility Operations and Maintenance.	**-6,000**
Total, Idaho Facilities Management	**-33,713**

Idaho Facilities Management
INL Nuclear Research Reactor Operations and Maintenance

Description
This subcategory supports nuclear research reactor operations and maintenance at the Advanced Test Reactor (ATR) for the Idaho National Laboratory (INL), including the associated support infrastructure, the ATR Critical Facility (ATRC), the Transient Reactor Test Facility (TREAT), and the Neutron Radiography Reactor (NRAD). The NRAD and TREAT facilities are both located at the Materials and Fuels Complex (MFC).

ATR is the primary research reactor at the INL. The ATR supports the majority of NE research and development (R&D) programs, as well as Naval Reactors (NR) Program work in support of the U.S. Navy nuclear fleet and National Nuclear Security Administration (NNSA) programs. The ATR is also used by universities, laboratories, and industry, and is the primary scientific capability of the Nuclear Science User Facilities. Research and development demand for neutron irradiation at ATRC and neutron radiography and small component test irradiation at NRAD has increased significantly over the past several years. All programmatic work is funded by the sponsoring federal programs. The cost to other users is determined in accordance with Department of Energy (DOE) regulations and depends upon the demands on the reactor and the nature of the user.

To satisfy the irradiation needs of ATR users, efforts will continue in FY 2019 to refurbish and replace major ATR components and systems in order to improve the availability and reliability of ATR. This strategy, jointly developed with Naval Reactors (NR), will address a significant portion of the Top 100 Plant Heath Committee items and eliminate the majority of ATR deferred maintenance items by the completion of the next Core Internals Change-out. ATR operations and maintenance activities are jointly funded by NE and NR.

This subcategory also provides funding to support a domestic transient fuel testing capability utilizing the TREAT Reactor. TREAT successfully resumed operations in FY 2018 a year ahead of schedule.

INL Nuclear Research Reactor Operations and Maintenance

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
INL Nuclear Research Reactor Operations and Maintenance $112,845,000	**$100,682,000**	**-$12,163,000**
• Continued investments to improve Advance Test Reactor (ATR) availability and reliability including initiating crane refurbishments and design for critical computer based control systems. • Maintained and operated the Idaho National Laboratory (INL) reactors and supporting infrastructure while accommodating business model impacts. • Maintained a two year minimum ATR fuel inventory and sufficient ATR critical spares. • Continued preparatory activities for the ATR Core Internals Change-out (CIC), currently planned for 2021. • Completed 110 operating days at the ATR with an operating efficiency of 62%. • Continued replacement of electrical equipment at ATR that is past the end of useful life. • Initiated planning activities for the ATR Maintenance Support Building. • Completed mock operation at the Transient Reactor Test Facility (TREAT) to support training and prepare for reactor operations. • Completed the remaining refurbishments of major TREAT equipment. • Completed final readiness activities to resume operations at TREAT.	• Maintain an ATR operating efficiency greater than 80% with a target of 169 irradiation days. • Continue investments to improve ATR and ATR Critical Facility (ATRC) availability and reliability such as refurbishments and replacements of reactor systems and components. • Continue preparatory activities for the ATR CIC, currently planned for 2021. • Continue transient testing operations at TREAT.	• The decrease reflects the completion of the Resumption of Transient Testing Program as well as the exclusion of one-time funding that was provided in FY 2017 for the ATR Maintenance Support Building.

Idaho Facilities Management
INL Non-Reactor Nuclear Research Facility Operations and Maintenance

Description

This subprogram provides funding for operations, maintenance, and support for non-reactor nuclear and radiological research facilities primarily located at the Materials and Fuels Complex (MFC). Activities within this category support sustainment of unique nuclear and radiological capabilities that are required to support Nuclear Energy's (NE) essential research and development programs. Work scope focuses on maintaining a safe operating envelope while conducting corrective and cost-effective preventative maintenance activities necessary to sustain this core infrastructure. The non-reactor nuclear research facilities support core programmatic research capabilities including:

- Post-Irradiation Examination (PIE) and Fresh Fuel Characterization – Receipt of irradiated fuels/materials, non-destructive examination, destructive examinations and analyses, and mechanical testing of highly radioactive materials.
- Experimental Fuel Fabrication – Glovebox lines, fume hoods, and hot cell capabilities; unique fabrication capabilities; and instrumentation and testing equipment that support research and development (R&D) on multiple fuel types and hazard levels.
- Advanced Separation and Waste Forms – Aqueous separations and pretreatment technologies, and electrochemical separations and waste form development (engineering scale).

Funding is also provided for the management of NE-owned special nuclear material (SNM), including the characterization, packaging, storage, and disposition of surplus SNM. Access to and responsible management of SNM is fundamental to ensuring nuclear material is readily available to support mission activities.

Funding also supports base operations for the Remote-Handled Low-Level Waste (RHLLW) Disposal Facility.

INL Non-Reactor Nuclear Research Facility Operations and Maintenance

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
INL Non-Reactor Nuclear Research Facility Operations and Maintenance $82,507,000	**$87,699,000**	**+$5,192,000**
• Operated and maintained Materials and Fuels Complex (MFC) infrastructure and facilities to support facility operations and programmatic work activities. • Performed maintenance within the MFC nuclear facilities and infrastructure consistent with the approved safety bases. • Completed final design, acceptance testing, and first procurement for next generation hot cell manipulators. • Continued off-site disposition of surplus Nuclear Energy (NE)-owned special nuclear material consistent with programmatic needs and approved nuclear material allotment forecasts. • Completed the MFC upgraded documented safety analysis implementation for the Hot Fuels Examination Facility (HFEF) and the last physical upgrades for the Zero Power Physics Reactor (ZPPR). • Continued development of documentation to establish the Sample Preparation Laboratory (SPL) Project performance baseline.	• Operate and maintain MFC infrastructure and facilities to support facility operations and programmatic work activities. • Perform maintenance within the MFC nuclear facilities and infrastructure consistent with the approved safety bases. • Continue off-site disposition of surplus NE-owned special nuclear material consistent with programmatic needs and approved nuclear material allotment forecasts. • Operate and maintain the Remote-Handled Low-Level Waste (RHLLW) Disposal Facility to provide newly-generated waste disposal capability. • Prepare project documentation to support Critical Decision (CD)-2, *Approve Performance Baseline*, for the SPL Project.	• Increase in funding reflects full funding for operating and maintaining key nuclear facilities at the MFC to support research needs and address emergent conditions, as well as RHLLW Disposal Facility base operations.

Idaho Facilities Management
INL Engineering and Support Facility Operations and Maintenance

Description

This subcategory provides funds to support Federally-funded program activities and community regulatory support activities, such as site environmental monitoring and Payment in Lieu of Taxes, to meet obligations defined in crosscutting agreements and contracts. Examples of entities this subprogram has agreements or contracts with include Shoshone-Bannock Tribes, the Defense Contract Audit Agency, and the National Oceanic and Atmospheric Administration.

INL Engineering and Support Facility Operations and Maintenance

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
INL Engineering and Support Facility Operations and Maintenance $22,055,000	**$6,500,000**	**$-15,555,000**
• Continued support of Federally funded activities to maintain operations at the Idaho National Laboratory (INL) such as Nuclear Regulatory Commission (NRC) certificates for casks, payment-in-lieu-of-taxes, and environmental monitoring to support State requirements. • Initiated the resurfacing, reconstruction, and sealing of major sections of INL's major primary roads that are in poor condition, including Monroe Boulevard and Lincoln Boulevard. • Completed planned disposition work for non-nuclear excess buildings including the last of five historic Arco Naval Proving Ground facilities. • Continued hazard abatement and demolition preparations of the Radiological Environmental Laboratory (CF-690) and office buildings CF-688 and CF-689.	• Continue to support Federally funded activities to maintain operations at the INL such as NRC certificates for casks, payment-in-lieu-of-taxes, and environmental monitoring to support State requirements.	• Decrease in funding reflects completion of planned disposition of non-nuclear excess facilities and completion of INL major primary road resurfacing, reconstruction, and sealing.

Idaho Facilities Management
INL Regulatory Compliance

Description

This subcategory supports activities for continued compliance with State and Federal environmental laws and other regulations that are under the purview of the Office of Nuclear Energy. Compliance activities focus on air, soil, and water monitoring and waste disposal consistent with Federal and State permit requirements and agreements such as the Idaho National Laboratory (INL) Site Treatment Plan. Regulatory activities also include efforts that support continued compliance with the 1995 Settlement Agreement with the State of Idaho, which governs management and disposition of used nuclear fuel and transuranic wastes at the INL.

INL Regulatory Compliance

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
INL Regulatory Compliance $14,306,000	**$9,119,000**	**-$5,187,000**
• Continued regulatory compliance program management. • Treated 2.21 cubic meters of mixed low level waste (MLLW), ahead of the Idaho National Laboratory (INL) Site Treatment Plan requirement for 2 cubic meters • Completed 10 transfers of used nuclear fuel from wet storage in accordance with the 1995 Idaho Settlement Agreement and consistent with material requirements for the treatment of Experimental Breeder Reactor II (EBR-II) used nuclear fuel. • Initiated treatment of four EBR-II fuel batches in the electrorefiner. • Supported Remote-Handled Low-Level Waste (RHLLW) Disposal Facility Project operational activities including preparation for nuclear facility operational readiness.	• Continue regulatory compliance program management. • Meet INL Site Treatment Plan milestones for treatment of two cubic meters of MLLW. • Complete a minimum of 10 transfers of used nuclear fuel from wet storage in accordance with the 1995 Idaho Settlement Agreement and consistent with material requirements for the treatment of EBR-II used nuclear fuel.	• Decrease in funding reflects transition of RHLLW Disposal Facility Project from nuclear facility operational readiness activities to base operations in FY 2019.

Idaho Facilities Management
Construction

Description
Line-item capital projects are sometimes required at the Idaho National Laboratory (INL) to maintain its ability to support mission goals. These projects help achieve the Department's and the Nuclear Energy's (NE) strategic objectives by maintaining site services and providing critical information for future decisions. This activity is focused on two primary objectives: (1) identification, planning, and prioritization of projects required to meet NE program objectives, and (2) development and execution of these projects within approved cost and schedule baselines as such projects are deemed necessary. While the Department's acquisition management process does not guarantee that a project will be completed once the initial information gathering and preliminary design phase are complete, it does provide an important decision-making framework that, when well executed, allows only the most critically necessary, cost-effective projects to proceed to construction.

The Sample Preparation Laboratory (SPL) Project is currently NE's only line-item capital project. No additional capital funding is required for the SPL construction project until Critical Decision (CD)-2, Approve Performance Baseline, is approved. The CD-2 decision point, as defined by DOE Order 413.3B, Program and Project Management for the Acqusition of Capital Assets, is the point at which the Department approves the project cost and schedule baseline. If approved for construction, the SPL would provide sample preparation for micro-/nano-scale structural, chemical, mechanical, and thermal properties analyses. This capability will augment non-destructive examination, elemental analysis, and radiological capabilities already present or being developed at INL. The SPL is expected to, when coupled with existing facilities and recapitalization efforts, fulfill near-term capabilities for conducting the advanced post-irradiation examination needed to improve understanding of nuclear fuels and material performance at the micro-, nano-, and atomic scales.

Construction

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Construction $6,000,000	**$0**	**-$6,000,000**
Sample Preparation Laboratory (16-E-200) ($6,000,000) • Awarded the subcontract for architecture/engineering support for Sample Preparation Laboratory (SPL) preliminary and final design. • Continued SPL preliminary design and performance baseline development activities in support of Critical Decision (CD)-2, "Approve Performance Baseline."	*Sample Preparation Laboratory (16-E-200) ($0)* • No funding is requested.	*Sample Preparation Laboratory (16-E-200) (-$6,000,000)* • Decrease in funding reflects that no additional capital funding is required for the SPL construction project until CD-2, Approve Performance Baseline, is approved. Project documentation required to support CD-2 will be prepared and funded under Idaho National Laboratory (INL) Non-Reactor Nuclear Research Facility Operations and Maintenance.

Idaho Facilities Management
Capital Summary
($K)

	Total	Prior Years	FY 2017 Enacted	FY 2017 Current	FY 2018 Annualized CR*	FY 2019 Request
Capital Operating Expenses Summary (including (Major Items of Equipment (MIE))						
Plant Projects (GPP) (<$10M)	n/a	0	0	0	0	0
Total, Capital Operating Expenses	**n/a**	**0**	**0**	**0**	**0**	**0**
Plant Projects (GPP) (Total Estimated Cost (TEC) <$10M)						
Total Plant Projects (GPP) (Total Estimated Cost (TEC) <$5M)	n/a	3,867	0	0	0	0
ATR Maintenance Support Building	10,000	0	10,000	10,000	0	0
Total, Plant Projects (GPP) (Total Estimated Cost (TEC) <$10M)	**n/a**	**3,867**	**10,000**	**10,000**	**0**	**0**
Total, Capital Summary	**n/a**	**3,867**	**10,000**	**10,000**	**0**	**0**

* A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution. (These amounts are shown only at the Congressional control level and above; below that level, a dash (—) is shown).

Idaho Facilities Management
Construction Projects Summary
($K)

	Total	Prior Years	FY 2017 Enacted	FY 2017 Current	FY 2018 Annualized CR*	FY 2019 Request
13-D-905, Remote-Handled Low-Level Waste Disposal Project, INL (Summary represents NE costs; Project is co-funded with NR)						
Total Estimated Cost (TEC)	21,767	21,767	0	0	0	0
Other Project Costs (OPC)*	18,996	16,056	2,940	2,940	0	0
Total Project Cost (TPC) Project Number 13-D-905	**40,763**	**37,823**	**2,940**	**2,940**	**0**	**0**
16-E-200, Sample Preparation Laboratory, INL						
Total Estimated Cost (TEC)	83,000	2,000	6,000	6,000	5,897	0
Other Project Costs (OPC)*	12,000	2,090	2,800	2,800	0	1,600
Total Project Cost (TPC) Project Number 16-E-200	**95,000**	**4,090**	**8,800**	**8,800**	**5,897**	**1,600**
Total All Construction Projects						
Total Estimated Cost (TEC)	104,767	23,767	6,000	6,000	5,897	0
Total Other Project Costs (OPC)	30,996	18,146	5,740	5,740	0	1,600
Total Project Cost (TPC) All Construction Projects	**135,763**	**41,913**	**11,740**	**11,740**	**5,897**	**1,600**

*Indicates a project where the cost of the Conceptual Design Report is estimated to exceed $3M.

* A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution. (These amounts are shown only at the Congressional control level and above; below that level, a dash (—) is shown).

Idaho Facilities Management
Performance Measures

In accordance with the GPRA Modernization Act of 2010, the Department sets targets for, and tracks progress toward, achieving performance goals for each program.

	FY 2017	FY 2018	FY 2019
Performance Goal (Measure)	**Facility Availability - Idaho Facilities Management Program - Enable nuclear research and development activities by providing operational facilities and capabilities, as measured by availability percentages.**		
Target	80 % availability	80 % availability	80 % availability
Result	Not Met - 76	TBD	TBD
Endpoint Target	Maintain the percentage of facilities and capabilities that are available for research and development activities at 90% or better.		
Performance Goal (Measure)	**Plant and Construction: Cost and Schedule Baseline Variance - Execute line item construction projects within approved cost profiles and schedules, using cost performance index and schedule performance index (using earned value measurement systems), with the green level maintaining indexes between 0.9 and 1.10, the yellow level between 0.8 and 1.20 and the red level less than 0.8 or greater than 1.20.**		
Target	90 % of projects with cost performance indexes and schedule performance indexes between 0.9 and 1.15	90 % of projects with cost performance indexes and schedule performance indexes between 0.9 and 1.15	90 % of projects with cost performance indexes and schedule performance indexes between 0.9 and 1.15.
Result	Met - 100	TBD	TBD
Endpoint Target	Maintain the total percentage of projects with good cost and schedule indexes at 90% or better.		

Idaho Sitewide Safeguards and Security

Overview

The Idaho Sitewide Safeguards and Security (S&S) program supports the Idaho National Laboratory (INL) complex nuclear facility infrastructure and enables the Office of Nuclear Energy (NE) to conduct research and development (R&D) in support of multiple program missions. The S&S program benefits the site infrastructure and users by providing the safeguards and security functions required at DOE sites to enable R&D utilizing nuclear materials and protected information. In addition to NE R&D activities, S&S enables a range of national security programs that support the National Nuclear Security Administration (NNSA) and other Federal agencies including the Department of Homeland Security in the areas of critical infrastructure protection, nuclear nonproliferation and incident response. Safeguards and security functions through the INL S&S program also enable the Department of the Army, the Department of the Navy, and NNSA Naval Reactors mission activities.

The FY 2019 Budget Request provides direct funding for the INL S&S base program. Strategic Partnership Projects (SPP) will continue to fund an allocable share of the S&S program via full cost recovery. Extraordinary security requirements, such as dedicated security for special projects or exercises, will be a direct charge to DOE and SPP customers.

Highlights of the FY 2019 Budget Request

In FY 2019, the S&S program will continue to sustain program functionality at the level necessary to assure high confidence in the protection of INL assets and a high degree of customer service by maintaining effective staffing levels, proactive preventative and corrective maintenance programs, and a robust cybersecurity program. The FY 2019 Budget Request will focus on continued implementation of infrastructure investments, capital improvements, emerging technology investments, and enhanced cybersecurity program capabilities to adequately secure site assets; including:

- Completing critical physical security infrastructure investments and hiring protective force staff required to maintain an S&S program consistent with Departmental requirements such as initiating designs, related analyses, and modifications to support a multi-year effort to enhance physical security infrastructure across several INL complexes.
- Supporting physical security systems life-cycle replacement including preventative and corrective maintenance on critical security systems, subsystems, and components.
- Supporting implementation of the new Design Basis Threat and Departmental Orders and the additional force-on-force exercises and equipment required to analyze and validate changes to security models to provide data for risk-informed decision making and directly test the efficacy of the protection methodology and posture.
- Maintaining an effective cybersecurity program through the addition of lifecycle hardware/software upgrades and replacements including continuous monitoring, maintaining Industrial Control Systems, essential cybersecurity positions and associated training.

Idaho Sitewide Safeguards and Security
Funding
($K)

	FY 2017 Enacted	FY 2018 Annualized CR*	FY 2019 Request	FY 2019 Request vs FY 2017 Enacted
Idaho Sitewide Safeguards and Security				
Protective Forces	65,865	-	76,881	+11,016
Security Systems	11,190	-	10,075	-1,115
Security Infrastructure	10,478	-	6,839	-3,639
Information Security	5,285	-	4,674	-611
Personnel Security	7,522	-	7,714	+192
Material Control & Accountability	4,654	-	4,876	+222
Program Management	8,051	-	8,175	+124
Cybersecurity	16,258	-	16,856	+598
Total, Idaho Sitewide Safeguards and Security	**129,303**	**128,425**	**136,090**	**+6,787**

* A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution. (These amounts are shown only at the Congressional control level and above; below that level, a dash (—) is shown).

Idaho Sitewide Safeguards and Security
Explanation of Major Changes
($K)

	FY 2019 Request vs FY 2017 Enacted
Protective Forces:	
The increase from $65,865,000 to $76,881,000 reflects costs for additional protective force staff to support certain security infrastructure Phase IIA Implementation Plan activities consistent with Departmental protection requirements. Funding also supports additional protective force equipment, training, facilities, and management.	**+11,016**
Security Systems:	
The decrease from $11,190,000 to $10,075,000 reflects completion of physical security systems life-cycle replacement of vehicle explosive detection technology and implementation of a rapid deployment security system for incident response. Funding continues to implement rapid deployment intrusion detection capabilities, complete preventative/corrective maintenance, and scheduled lifecycle replacements of physical security systems such as installation of the Argus Host and network equipment upgrade and Delta Barriers.	**-1,115**
Security Infrastructure:	
The decrease from $10,478,000 to $6,839,000 reflects completion of Phase I improvements and transition to continued Implementation Plan Phase IIA activities to support a multi-year effort to enhance physical security infrastructure across several Idaho National Laboratory (INL) complexes.	**-3,639**
Information Security:	
The decrease from $5,285,000 to $4,674,000 reflects completion of Transmission Security Countermeasures (TSCM) equipment installation (purchased in 2017) and continued support for information security services for key INL facilities consistent with the site operational needs.	**-611**
Personnel Security:	
The increase from $7,522,000 to $7,714,000 reflects funds to maintain personnel security services for Office of Nuclear Energy headquarters staff and key INL facilities consistent with the site operational needs including Homeland Security Presidential Directive 12 (HSPD-12) badging and smart card administration requirements.	**+192**
Material Control & Accountability:	
The increase from $4,654,000 to $4,876,000 provides funds to maintain accounting and control of special nuclear material (SNM) at key INL facilities consistent with the site operational needs.	**+222**

	FY 2019 Request vs FY 2017 Enacted
Program Management: The increase from $8,051,000 to $8,175,000 supports analyses required by the new Design Basis Threat and Departmental Orders in addition to life-cycle replacement of equipment and ammunition as well as planned performance assurance activities and eight force-on-force exercises including two related to security enhancements.	**+124**
Cybersecurity: The increase from $16,258,000 to $16,856,000 supports the addition of essential cybersecurity specialists, lifecycle hardware/software upgrades for classified and unclassified systems, including maintaining Industrial Control Systems, and network forensics capabilities for increased intrusion detection and response.	**+598**
Total, Idaho Sitewide Safeguards and Security	**+6,787**

Idaho Sitewide Safeguards and Security

Description

The S&S program funds Office of Nuclear Energy (NE) base physical and cybersecurity activities for the Idaho National Laboratory (INL), providing protection of the Department of Energy's (DOE) nuclear materials, classified and unclassified matter, government property, personnel and other vital assets from theft, diversion, sabotage, espionage, unauthorized access, compromise, and other hostile acts that may cause adverse impacts on our national security; program continuity; or the health and safety of employees, the public, or the environment.

Protective Forces

Protective Forces provides security police officers (SPO's) and other specialized personnel, equipment, training, and management needed during normal and security emergency conditions for adequate protection of site assets consistent with site security plans. Protective force personnel are deployed 24 hours a day, 7 days a week, across 890 square miles to deter, detect, delay, and respond to adversarial threats.

Security Systems

Physical Security Systems provides preventative and corrective maintenance and performance testing of intrusion detection and assessment systems, entry and search control equipment, barriers, secure storage, lighting, sensors, entry/access control devices, locks, explosives detection, and tamper-safe monitoring. Ensures 24 hours a day, 7 days a week operation of approximately 4,600 security alarms and 6,100 security locks at multiple security areas.

Security Infrastructure

Security Infrastructure provides critical security infrastructure investments and protection enhancements necessary to ensure adequate protection of assets consistent with Departmental requirements. These include, but are not limited to: upgrades, refurbishments or replacement of protective force training and muster facilities; physical security systems or equipment required by Departmental Orders, such as perimeter intrusion detection and assessment systems, closed-circuit televisions, central and/or secondary alarm stations; and other similar activities.

Information Security

Information Security provides for the protection and control of classified and sensitive matter that is generated, received, transmitted, used, stored, reproduced, and/or destroyed. The Classified Matter Protection and Control Program and Operations Security Program ensure that classified and sensitive unclassified matter is appropriately managed and adequately protected and controlled to prevent access by unauthorized individuals and that those individuals that do have access are trained to handle classified matter. Information Security executes the Technical Security Countermeasures (TSCM) program and conducts TSCM surveys.

Personnel Security

Personnel Security provides access to classified and sensitive information and assignment of personnel in sensitive positions through the clearance program, adjudication, security awareness and education, U.S. citizen and foreign visitor control, Human Reliability Program, psychological/medical assessments, and administrative review costs. Personnel security includes both contractor and federally funded activities.

Materials Control and Accountability

Material Control & Accountability (MC&A) provides the personnel, equipment, and services required to account for and control special nuclear materials (SNM) from diversion. MC&A is accomplished through the administration of a robust formal inventory process that allows security personnel to locate and track specific quantities of SNM in real time, state of the art measurement equipment, non-destructive analysis, and a robust tamper indicating device program.

Program Management

Program Management includes policy oversight, development, and update of site security plans; vulnerability assessments and performance testing to ensure adequate protection of SNM; investigations into incidents of security concern; and issuance of security infractions. The activities completed within Program Management allow for risk-informed decision making, support a performance-based Safeguards and Security (S&S) program, and directly test the efficacy of the protection methodology/posture.

Cybersecurity

Cybersecurity maintains the staffing, computing infrastructure, and network security configuration necessary to support classified and unclassified information and electronic operations. The Cybersecurity program uses a graduated risk approach based on data sensitivity and impact of loss/compromise to ensure that electronic or computer information systems, are protected in a manner consistent with upholding key priorities; including importance to national security, support of Department of Energy (DOE) missions and programs, vulnerability to threats, and the magnitude of harm that would result from an information system and industrial control systems compromise.

Idaho Sitewide Safeguards and Security

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Protective Forces $65,865,000	**$76,881,000**	**+$11,016,000**
• Provided funds to maintain a Protective Force consistent with the Site Security Plan, approved site labor wage agreement, and Idaho National Laboratory (INL) cost model changes, including associated training activities and facilities required to maintain protective force qualifications. The INL completed two Security Police Officer classes. • Provided funding to purchase Protective Force equipment including ammunition, weapons, protective gear and vehicles.	• Provides funds for additional protective force staff to support security infrastructure Phase IIA Implementation Plan activities consistent with the Site Security Plan, approved site labor wage agreement, and INL cost model, including associated training activities and facilities required to maintain protective force qualifications. • Provides funding to purchase Protective Force equipment such as ammunition, weapons, protective gear and vehicles.	• Increase reflects costs for additional protective force staff to support security infrastructure Phase IIA Implementation Plan activities consistent with Departmental protection requirements. Funding also supports additional protective force equipment, training, facilities, and management.
Security Systems $11,190,000	**$10,075,000**	**-$1,115,000**
• Provided funds for staff and equipment to plan and conduct preventative and corrective maintenance on physical security systems at multiple security areas. The INL reduced the security systems beyond life cycle to less than 16% for FY2017. • Completed security system upgrades at eight separate INL facilities.	• Provides full funding for staff and equipment to plan and conduct preventative and corrective maintenance on physical security systems at multiple security areas. • Supports the operation of INL central alarm stations, development and modification of security alarm systems and life cycle replacement of systems.	• Reflects completion of physical security systems life cycle replacement and implementation of rapid deployment intrusion detection capabilities.
Security Infrastructure $10,478,000	**$6,839,000**	**-$3,639,000**
• Provided funds for the refurbishment of critical life-safety upgrades necessary to allow long-term use of facilities within the INL complex. • Performed designs, related analyses, and modifications to support a multi-year effort to enhance physical security infrastructure across several INL complexes. • Completed the remodel project of the Materials and Fuels Complex (MFC) Central Alarm Station (CAS). • Completed the MFC Perimeter Intrusion Detection and Assessment System (PIDAS).	• Supports planned Implementation Plan Phase IIA activities by performing design work, related analyses, and modifications to support a multi-year effort to enhance physical security infrastructure across several INL complexes.	• Reflects funding to partially execute Implementation Plan Phase IIA physical security enhancement activities.

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
• Initiated construction upgrades on the Fuel Conditioning Facility (FCF).		
Information Security $5,285,000	**$4,674,000**	**-$611,000**
• Provided funds to implement information security activities to protect classified and sensitive unclassified matter including Classified Matter Protection and Control, Technical Surveillance Countermeasures, Classification/ Declassification, and Operations Security programs. • Upgraded classified matter destruction equipment and purchased Transmission Security Countermeasures (TSCM) equipment.	• Provides funds to implement information security activities to protect classified and sensitive unclassified matter including Classified Matter Protection and Control, Technical Surveillance Countermeasures, Classification/Declassification, and Operations Security programs.	• Reflects targeting of funds to highest priority activities to maintain information security services consistent with site operational demands.
Personnel Security $7,522,000	**$7,714,000**	**+$192,000**
• Provided funds for federal and contractor personnel security programs including processing, tracking and adjudication of security investigations, Homeland Security Presidential Directive-12 (HSPD-12) badging and smart card administration, foreign visits and assignments, and management of the human reliability program including medical examinations. • Upgraded Idaho National Laboratory (INL) badging office capabilities to improve delivery of services in support of Multi-Factor Authentication (MFA) program mandates for logical and physical access.	• Provides partial funding for federal and contractor personnel security programs including processing, tracking and adjudication of security investigations, HSPD-12 badging and smart card administration, foreign visits and assignments, and management of the human reliability program including medical examinations. • Supports personnel security services for Office of Nuclear Energy headquarters staff.	• Reflects funds necessary to maintain personnel security services consistent with the site operational demands and the addition of Office of Nuclear Energy headquarters staff support.
Material Control & Accountability (MC&A) $4,654,000	**$4,876,000**	**+$222,000**
• Provided funds to maintain the site's special nuclear material (SNM) database and tracking systems, coordinate on-and off-site material movements, and to conduct SNM inventories. • Purchased Material Control & Accountability (MC&A) scanning equipment	• Provides funds to maintain the site's SNM database and tracking systems, coordinate on-and off-site material movements, and to conduct SNM inventories.	• Reflects funds necessary to maintain MC&A services consistent with the site operational demands.

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Program Management $8,051,000	**$8,175,000**	**+$124,000**
• Provided funds to maintain and develop, update, and maintain security program documentation, vulnerability/risk assessments and to conduct performance testing to assure program effectiveness. • Conducted analysis required to support the Design Basis Threat (DBT) requirements.	• Provides funding to develop, update, and maintain security program documentation, vulnerability/risk assessments and to conduct performance testing to assure program effectiveness including implementation of Departmental Orders. • Provides funds to support force-on-force exercises which directly test the efficacy of the protection methodology and posture and allow for risk-informed decision making.	• Reflects increased performance assurance activities and life-cycle replacement of equipment and ammunition.
Cybersecurity $16,258,000	**$16,856,000**	**+$598,000**
• Provided funds to maintain an effective cyber security program consistent with the Department's measured risk management and vulnerability and incident management strategies including staffing, training, tools, hardware and software lifecycle replacement, and certification and accreditation for classified and unclassified systems. • Completed Industrial Control Systems assurance program implementation and moved to maintenance and operations phase. • Implemented enhanced network forensics capabilities for increased intrusion detection and response. • Completed phase of vulnerability management enhancements program and implemented penetration testing of internal network.	• Provides funding to maintain an effective cybersecurity program consistent with the Department's measured risk management and vulnerability and incident management strategies including staffing, training, tools, hardware/software lifecycle replacement, and certification and accreditation for classified and unclassified systems. • Continue to maintain and operate the Idaho National Laboratory (INL) Industrial Control Systems cybersecurity program. • Continue to implement the formal cloud assurance program across INL.	• Reflects funds necessary to maintain cybersecurity services consistent with the site operational demands and provide increased intrusion detection and response capabilities to mitigate dynamic cybersecurity threats. Threat landscape is changing exponentially with more sophisticated malware and attacks. Continue to focus on new areas such as Industrial Control Systems.

Idaho Sitewide Safeguards and Security

Capital Summary
($K)

	Total	Prior Years	FY 2017 Enacted	FY 2018 Annualized CR*	FY 2019 Request
Capital Operating Expenses Summary (including (Major Items of Equipment (MIE))					
Capital Equipment > $500K (including MIE)	n/a	3,000	1,500	1,500	1,500
Plant Projects (GPP)	n/a	0	3,875	5,150	5,339
Total, Capital Operating Expenses	**n/a**	**3,000**	**5,375**	**6,650**	**6,839**
Capital Equipment > $500K (including MIE)					
Total Non-MIE Capital Equipment (>$500K)	n/a	3,000	1,500	1,500	1,500
Total, Capital Equipment (including MIE)	**n/a**	**3,000**	**1,500**	**1,500**	**1,500**
Plant Projects (GPP)					
Live Fire Shoot House Refurbishment	3,875	0	3,875	0	0
Security Infrastructure Phase IIA project 1	5,700	0	0	3,900	1,800
Security Infrastructure Phase IIA project 2	5,300	0	0	1,250	3,539
Total, Plant Projects (GPP)	**n/a**	**0**	**3,875**	**5,150**	**5,339**
Total, Capital Summary	**n/a**	**3,000**	**5,375**	**6,650**	**6,839**

* A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution. (These amounts are shown only at the Congressional control level and above; below that level, a dash (—) is shown).

International Nuclear Energy Cooperation

Overview

International Nuclear Energy Cooperation's (INEC) mission is to lead the Department's international engagement related to civil nuclear energy, including analysis, development, coordination and implementation of international civil nuclear energy policy and the integration of the Office of Nuclear Energy's (NE) international nuclear technical activities. These activities contribute to international bilateral and multilateral engagement and civil nuclear energy research and development (R&D) activities with countries who are considering development of, or currently have, a civilian nuclear power sector. INEC utilizes workshops and expert-based exchange fora to engage industry, stakeholders and foreign governments on international civil nuclear issues such as training, financing, safety and multinational cooperation on used nuclear fuel disposal.

A key element of INEC's mission is its support to advocacy for the U.S. commercial nuclear sector, including industry vendors and utilities, via direct engagement with foreign governments. Such support can lead to increased nuclear exports, which in turn contribute to domestic infrastructure development and job creation.

INEC provides the Department the ability to meet demands for engagement with international partners on civil nuclear policy, research, development and demonstration (RD&D) and related activities. INEC engages both bilaterally and multilaterally to support broader U.S. policy and commercial goals related to the safe and secure deployment of nuclear energy globally and allow more effective integration of NE international RD&D and policy interests, including increasing proliferation resistance of new and existing technologies. INEC also leverages nuclear energy efforts in coordination with the Department of Energy's (DOE) National Nuclear Security Administration, Office of Environmental Management, and Office of International Affairs; the National Security Council; Department of State; the Department of Commerce; and the Nuclear Regulatory Commission to facilitate U.S. nuclear energy RD&D, nuclear safety, policy, and commercial interests internationally.

Highlights of the FY 2019 Budget Request

In FY 2019, INEC will continue to support existing international engagement with advanced and developing nuclear energy countries in coordination with the Department of State and other agencies. INEC will continue to advance multilateral collaboration with the International Atomic Energy Agency (IAEA), the Organisation for Economic Co-operation and Development/Nuclear Energy Agency (OECD/NEA), the International Framework for Nuclear Energy Cooperation (IFNEC), and other fora focusing on concepts such as multinational cooperation on used fuel disposal. INEC will also continue its support for international nuclear safety activities with a focus on improving our domestic commercial nuclear safety and promoting global use of U.S. nuclear safety practices.

International Nuclear Energy Cooperation
Funding
($K)

	FY 2017 Enacted	FY 2018 Annualized CR*	FY 2019 Request	FY 2019 Request vs FY 2017 Enacted
International Nuclear Energy Cooperation				
International Nuclear Energy Cooperation	3,000	2,980	2,500	-500
Total, International Nuclear Energy Cooperation	**3,000**	**2,980**	**2,500**	**-500**

* A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution. (These amounts are shown only at the Congressional control level and above; below that level, a dash (—) is shown).

International Nuclear Energy Cooperation
Explanation of Major Changes
($K)

	FY 2019 Request vs FY 2017 Enacted
International Nuclear Energy Cooperation:	
The decrease from $3,000,000 to $2,500,000 reflects the elimination of lower priority international engagements. Funding continues support for bilateral and multilateral engagement; continued engagement in nuclear safety, including coordination with nuclear industry to learn and apply knowledge from the ongoing Fukushima Daiichi accident follow-on activities; and maintenance of near term assessment capabilities to provide Department of Energy leadership with additional characterizing information about unexpected international civil nuclear events. This funding level will accommodate $1,175,000 for bilateral and multilateral engagement, and $460,000 for nuclear safety activities.	**-500**
Total, International Nuclear Energy Cooperation	**-500**

International Nuclear Energy Cooperation

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
International Nuclear Energy Cooperation		
$3,000,000	**$2,500,000**	**-$500,000**
• Provided country-specific policy and logistical support required to effectively implement NE's bilateral nuclear energy research and development (R&D) activities with expert support from national laboratory lead country coordinators. • Provided support for bilateral engagement, including workshops, laboratory visits, and trips that NE supports for nuclear newcomer countries. • Provided expertise and technical assistance to the Department of Commerce in its efforts to support U.S. civil nuclear exports. • Continued to support the transition of the International Framework for Nuclear Energy Cooperation (IFNEC) Secretariat to Organisation for Economic Co-operation and Development/Nuclear Energy Agency (OECD/NEA). • Continued to advance multilateral collaboration with the International Atomic Energy Agency (IAEA) and OECD/NEA on key issues such as multinational cooperation on used nuclear fuel disposal and continued analytical studies supporting this engagement. • Supported IFNEC Reliable Nuclear Fuel Services Working Group efforts in developing multinational approaches in used nuclear fuel disposal. • Continued to support NE's participation in multilateral fora such as the International Atomic Energy Agency (IAEA) and Organisation	• Provide country-specific policy and logistical support required to effectively implement NE's bilateral nuclear energy R&D activities by employing the expertise of national laboratory country coordinator. Manage implementation of existing bilateral and multilateral cooperation commitments. Continue technical cooperation with advanced and developing nuclear energy countries globally to support Office of Nuclear Energy and U.S. Government strategic priorities and objectives. • Continue to contribute expertise and technical assistance to the interagency efforts supporting U.S. civil nuclear exports and nuclear supply chain, including serving as the lead nuclear organization in support of U.S. nuclear commercial exports. • Support Secretary and senior DOE leadership on all international nuclear matters, including numerous bilateral meetings and support for international nuclear related missions such as the IAEA. • Continue to manage International Nuclear Research Initiatives (INERI) collaborative partnerships on research and development projects with EURATOM and Republic of Korea that focus on advanced nuclear technologies for improving the cost, safety and proliferation-resistance of nuclear energy systems. • Continue ongoing activities with IAEA, IFNEC exploring multinational cooperation on used	• Reduces or eliminates funding for lower priority and lower value activities, including: o The IFNEC Secretariat to OECD/NEA. o The Joint Convention involving safety and responsibility when developing a multinational repository. o The International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO) Roadmaps For a Transition to Globally Sustainable Nuclear Energy Systems (ROADMAPS) and Key Indicators for Innovative Nuclear Energy Systems (KIND). o The international nuclear energy education outreach program.

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
for Economic Co-operation and Development/Nuclear Energy Agency (OECD/NEA). • Organized and participated in a Joint Convention Topical Meeting to consider safety and responsibility challenges involved in developing a multinational repository. • Supported participation in International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO) Roadmaps for a Transition to Globally Sustainable Nuclear Energy Systems (ROADMAPS) and Key Indicators for Innovative Nuclear Energy Systems (KIND). • Supported bilateral engagement, including workshops, lab visits, and trips that NE supports for nuclear newcomer countries. • Conducted workshops and training with Ukraine, such as curricula development for new nuclear training institute and additional safety related work to ensure the reactors are able to safely manage instability in the grid due to the conflict. • Developed new international nuclear energy education outreach program.	fuel disposal, including analytical studies supporting this work. • Develop new collaboration opportunities with the United Kingdom, France, India, and Japan through mechanisms such as research and development (R&D) Agreements, implementing arrangements and Action Plans. Support U.S. - China Nuclear Power Plant Operational Safety Collaboration (PUNT) activities on Working Groups 1 and 6. Conduct cooperative study under the U.S.-South Korean High Level Bilateral Commission on the reliability of supply for the nuclear fuel cycle. • Provide near term and long term assessments of international civil nuclear events to support the office's international nuclear safety mission. • Continue to participate in and coordinate Fukushima Forensics activities that support improved operation and safety of U.S. domestic nuclear power plants.	

Program Direction

Overview

Program Direction provides the federal staffing resources and associated costs required to support the overall direction and execution of the Office of Nuclear Energy (NE) programs. NE has staff strategically located in multiple locations: Washington, D.C., the Idaho Operations Office, and Oak Ridge Operations Office. Activities within the site offices support inherently federal functions that facilitate the efficient execution of DOE programs or directly execute DOE mandated safety, security and business functions. In addition to NE federal personnel, Program Direction supports select federal staff and support for the Office of Human Capital Service Center.

The Support Services subprogram allows the Department to cost-effectively hire the best available industry experts to support federal staff in managing the nuclear programs and complex activities. The ability to acquire expertise quickly and on an "as needed basis" provides flexibility in team composition as the needs of NE evolve. Program Direction also includes the Other Related Expenses subprogram, which provides NE's directed funding contribution to the Department's Working Capital Fund (WCF). The WCF supports specific Departmental services and activities that are shared across DOE including: enhanced cyber security architecture, employee health and testing services, and consolidated training and recruitment initiatives; all established in previous fiscal years and supported in FY 2019.

In addition to appropriated funds, NE also manages approximately $180.0 million dollars annually from other activities including: Strategic Partnerships Program and reimbursable funding from the National Aeronautics and Space Administration (NASA) and the Department of Defense (DoD).

The Program Direction request reflects NE's continued effort to optimize support for its federal programs through continued efficiency and cost-effectiveness; and to ensure a measured and effective oversight of NE mission activities. Federal staff supported by the Program Direction account are responsible for ensuring the appropriate planning, oversight, and execution of all activities within the responsibility of the Office of Nuclear Energy.

Highlights of the FY 2019 Budget Request

The Nuclear Energy Program Direction Budget Request reflects a decrease of $13.5 million from the FY 2017 Enacted Budget. This decrease reflects the transfer of 46 federal staff and associated support activities to the new Yucca Mountain and Interim Storage Program.

Program Direction
Funding
($K)

	FY 2017 Enacted	FY 2018 Annualized CR*	FY 2019 Request	FY 2019 Request vs FY 2017 Enacted
Program Direction				
Salaries and Benefits	55,781	-	46,712	-9,069
Travel	1,588	-	1,387	-201
Support Services	6,823	-	4,574	-2,249
Other Related Expenses	15,808	-	13,827	-1,981
Total, Program Direction	**80,000**	**80,000**	**66,500**	**-13,500**

* A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution. (These amounts are shown only at the Congressional control level and above; below that level, a dash (—) is shown).

Program Direction
Explanation of Major Changes
($K)

	FY 2019 Request vs. FY 2017 Enacted
Salaries and Benefits:	
The decrease from $55,781 to $46,712 reflects the transfer of funding for personnel costs of 46 employees to support the Yucca Mountain and Interim Storage Program.	**-9,069**
Travel:	
The decrease from $1,588 to $1,387 reflects the transfer of travel funding associated with the 46 employees to the Yucca Mountain and Interim Storage Program.	**-201**
Support Services:	
The decrease from $6,823 to $4,574 reflects the transfer of support service funding associated with the needs of the Yucca Mountain and Interim Storage Program.	**-2,249**
Other Related Expenses:	
The decrease from $15,808 to $13,827 reflects the transfer of funds for WCF, Training, and Rent charges to support the needs of the Yucca Mountain and Interim Storage Program.	**-1,981**
Total, Program Direction	**-13,500**

Program Direction Funding ($K)

	FY 2017 Enacted	FY 2018 Annualized CR*	FY 2019 Request
Program Direction Summary			
Washington Headquarters			
Salaries and Benefits	28,984	-	21,252
Travel	1,081	-	955
Support Services	5,148	-	3,010
Other Related Expenses	8,484	-	6,914
Total, Washington Headquarters	**43,697**	**-**	**32,131**
Oak Ridge Operations Office			
Salaries and Benefits	425	-	447
Travel	7	-	7
Support Services	75	-	75
Other Related Expenses	138	-	138
Total, Oak Ridge Operations Office	**645**	**-**	**667**
Nevada Site Office			
Salaries and Benefits	2,375	-	0
Travel	0	-	0
Support Services	0	-	0
Other Related Expenses	161	-	0
Total, Nevada Site Office	**2,536**	**-**	**0**
Idaho Operations Office			
Salaries and Benefits	23,997	-	25,013
Travel	500	-	425
Support Services	1,600	-	1,489
Other Related Expenses	7,025	-	6,775
Total, Idaho Operations Office	**33,122**	**-**	**33,702**

* A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution. (These amounts are shown only at the Congressional control level and above; below that level, a dash (—) is shown).

	FY 2017 Enacted	FY 2018 Annualized CR*	FY 2019 Request
Total Program Direction			
Salaries and Benefits	55,781	-	46,712
Travel	1,588	-	1,387
Support Services	6,823	-	4,574
Other Related Expenses	15,808	-	13,827
Total, Program Direction	**80,000**	**80,000**	**66,500**
Federal FTEs	**327**	**326**	**291**
Support Services			
Technical Support			
Mission Related	2,885	-	1,914
Advisory and Assistance	185	-	144
Total, Technical Support	3,070	-	2,058
Management Support			
Administrative	2,064	-	1,132
IT	1,689	-	1,384
Total Management Support	3,753	-	2,516
Total, Support Services	**6,823**	**-**	**4,574**
Other Related Expenses			
Working Capital Fund	7,170	-	6,100
Training	300	-	260
Miscellaneous	6,609	-	5,930
Rents and Utilities	1,729	-	1,537
Total, Other Related Expenses	**15,808**	**-**	**13,827**

Program Direction

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Program Direction $80,000,000	**$66,500,000**	**-$13,500,000**
Salaries and Benefits $55,781,132	**$46,712,042**	**-$9,069,090**
• Provides salaries and benefits for 327 federal staff.	• Provides salaries and benefits for 291 federal staff.	• Change reflects an increase of up to 10 new hires to support NE, as well as, the transfer of 46 NE funded employees to establish the new Yucca Mountain and Interim Storage Program. All associated costs for these employees are included in this transfer.
• **Travel $1,588,466**	• **$1,387,000**	• **-$201,466**
• Provides for travel of the federal staff including any necessary permanent change of duty status costs.	• Provides for travel of the federal staff including any necessary permanent change of duty status costs.	• Change reflects current workforce needs, as well as transfers funds to support employee travel of the Yucca Mountain and Interim Storage Program.
• **Support Services $6,822,721**	• **$4,574,358**	• **-$2,248,363**
• Provides for technical and administrative support services for the NE federal staff including access to and participation with external and international nuclear energy organizations.	• Provides for technical and administrative support services for the NE federal staff.	• Funding for external nuclear energy organizations that supports the mission of the new Yucca Mountain and Interim Storage Program have been transferred accordingly.
• **Other Related Expenses $15,807,681**	• **$13,826,600**	• **-$1,981,081**
• Provides for NE's share of goods and services procured through the Department's Working Capital Fund (WCF); rents and utilities associated with the Idaho Operations Office and allocated share of such costs for the Nevada Site Office; federal	• Provides for NE's share of goods and services procured through the Department's WCF; rents and utilities associated with the Idaho Operations Office; federal training expenses; and other miscellaneous expenses.	• Decrease reflects a transfer of funds to support WCF, training, rent, and other miscellaneous expenses associated with new Yucca Mountain and Interim Storage Program.

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
training expenses; and other miscellaneous expenses.		

Nuclear Energy
Small Business Innovative Research/Small Business Technology Transfer (SBIR/STTR)
($K)

	FY 2017 Transferred	FY 2018 Annualized CR Projected Transfer	FY 2019 Request Projected Transfer
STEP R&D			
SBIR	160	159	0
STTR	22	22	0
Reactor Concepts RD&D			
SBIR	4,224	4,195	5,216
STTR	594	590	734
Fuel Cycle R&D			
SBIR	5,920	5,880	1,920
STTR	833	827	270
Nuclear Energy Enabling Technologies			
SBIR	3,683	3,658	3,712
STTR	518	515	522
Total, SBIR	**13,987**	**13,892**	**10,848**
Total, STTR	**1,967**	**1,954**	**1,526**

Nuclear Energy
Research and Development
($K)

	FY 2017 Enacted	FY 2018 Annualized CR	FY 2019 Request
Basic	0	0	0
Applied	688,464	675,606	481,041
Development	202,787	199,556	273,308
Subtotal, R&D	**891,251**	**875,162**	**754,349**
Equipment	0	0	0
Construction	0	0	0
Total, R&D	**891,251**	**875,162**	**754,349**

Nuclear Energy
Safeguards and Security
($K)

	FY 2017 Enacted	FY 2018 Annualized CR*	FY 2019 Request
Idaho Sitewide Safeguards and Security			
Protective Forces	65,865	-	76,881
Security Systems	11,190	-	10,075
Security Infrastructure	10,478	-	6,839
Information Security	5,285	-	4,674
Personnel Security	7,522	-	7,714
Material Control & Accountability	4,654	-	4,876
Program Management	8,051	-	8,175
Cybersecurity	16,258	-	16,856
Total, Idaho Sitewide Safeguards and Security	**129,303**	**128,425**	**136,090**

* A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution. (These amounts are shown only at the Congressional control level and above; below that level, a dash (—) is shown).

Nuclear Energy
Facilities Maintenance and Repair

The Department's Facilities Maintenance and Repair activities are tied to its programmatic missions, goals, and objectives. The Facilities Maintenance and Repair activities funded by this budget are displayed below are intended to halt asset condition degradation.

Costs for Direct-Funded Maintenance and Repair (including Deferred Maintenance Reduction)
($K)

	FY 2017 Actual Cost	FY 2017 Planned Cost	FY 2018 Planned Cost	FY 2019 Planned Cost
Idaho National Laboratory	33,699	34,007	30,441	25,186
Total, Direct-Funded Maintenance and Repair	33,699	34,007	30,441	25,186

Costs for Indirect-Funded Maintenance and Repair (including Deferred Maintenance Reduction)
($K)

	FY 2017 Actual Cost	FY 2017 Planned Cost	FY 2018 Planned Cost	FY 2019 Planned Cost
Idaho National Laboratory	19,577	21,258	28,726	30,178
Total, Indirect-Funded Maintenance and Repair	19,577	21,258	28,726	30,178

Report on FY 2017 Expenditures for Maintenance and Repair

This report responds to legislative language set forth in Conference Report (H.R. 108-10) accompanying the Consolidated Appropriations Resolution, 2003 (Public Law 108-7) (pages 886-887), which requests the Department of Energy provide an annual year-end report on maintenance expenditures to the Committees on Appropriations. This report compares the actual maintenance expenditures in FY 2017 to the amount planned for FY 2017, including Congressionally directed changes.

Nuclear Energy
Total Costs for Maintenance and Repair
($K)

	FY 2017 Actual Cost	FY 2017 Planned Cost
Idaho National Laboratory	53,276	55,265
Total, Maintenance and Repair	**53,276**	**55,265**

Each year, the "Planned Cost" for maintenance and repair is a minimum target amount. The Nuclear Energy program met its planned minimum target in FY 2017.

Department of Energy
FY 2019 Congressional Budget Funding
by Appropriation by Site
($K)

Nuclear Energy	FY 2017 Enacted	FY 2018 Annualized CR	FY 2019 Request
Argonne National Laboratory			
Fuel Cycle R & D			
Fuel Cycle R & D	14,463	13,391	1,212
Nuclear Energy Enabling Technologies			
Nuclear Energy Enabling Technologies	6,368	5,385	6,230
Reactors Concepts RD&D			
Reactors Concepts RD&D	15,316	13,787	11,800
International Nuclear Energy Cooperation			
International Nuclear Energy Cooperation	738	325	70
Total, Argonne National Laboratory	**36,885**	**32,888**	**19,312**
Bechtel Marine Propulsion Center			
Fuel Cycle R & D			
Fuel Cycle R & D	2,500	0	0
Total, Bechtel Marine Propulsion Center	**2,500**	**0**	**0**
Brookhaven National Laboratory			
Fuel Cycle R & D			
Fuel Cycle R & D	2,084	1,959	733
Nuclear Energy Enabling Technologies			
Nuclear Energy Enabling Technologies	0	150	150
Reactors Concepts RD&D			
Reactors Concepts RD&D	75	98	85
International Nuclear Energy Cooperation			
International Nuclear Energy Cooperation	0	0	5
Total, Brookhaven National Laboratory	**2,159**	**2,207**	**973**
Chicago Operations Office			
Nuclear Energy Enabling Technologies			
Nuclear Energy Enabling Technologies	40	400	400
Total, Chicago Operations Office	**40**	**400**	**400**

Department of Energy
FY 2019 Congressional Budget Funding
by Appropriation by Site
($K)

Nuclear Energy	FY 2017 Enacted	FY 2018 Annualized CR	FY 2019 Request
Idaho National Laboratory			
Fuel Cycle R & D			
Fuel Cycle R & D	44,411	39,846	14,439
Radiological Facilities Management			
Radiological Facilities Management	6,934	6,813	8,933
Idaho Facilities Management			
Idaho Facilities Management	230,415	229,298	197,200
Idaho Sitewide Safeguards and Security			
Idaho Sitewide Safeguards and Security	125,208	123,552	132,478
Nuclear Energy Enabling Technologies			
Nuclear Energy Enabling Technologies	50,959	45,233	42,833
Reactors Concepts RD&D			
Reactors Concepts RD&D	51,181	57,678	53,200
International Nuclear Energy Cooperation			
International Nuclear Energy Cooperation	597	540	448
SMR Licensing Technical Support			
SMR Licensing Technical Support	525	0	0
Supercritical Transformational Electric Power Generation			
Supercritical Transformational Electric Power Generation	45	0	0
Total, Idaho National Laboratory	**510,275**	**502,960**	**449,531**

Department of Energy
FY 2019 Congressional Budget Funding
by Appropriation by Site
($K)

Nuclear Energy	FY 2017 Enacted	FY 2018 Annualized CR	FY 2019 Request
Idaho Operations Office			
University Research Program			
University Research	4,984	4,898	0
Fuel Cycle R & D			
Fuel Cycle R & D	51,297	53,456	26,374
Radiological Facilities Management			
Radiological Facilities Management	43	42	42
Idaho Facilities Management			
Idaho Facilities Management	5,800	5,500	5,500
Idaho Sitewide Safeguards and Security			
Idaho Sitewide Safeguards and Security	3,673	3,100	3,100
Program Direction-NE			
Program Direction-NE	33,122	33,702	33,702
Nuclear Energy Enabling Technologies			
Nuclear Energy Enabling Technologies	13,821	24,789	45,025
Reactors Concepts RD&D			
Reactors Concepts RD&D	36,424	23,662	72,630
International Nuclear Energy Cooperation			
International Nuclear Energy Cooperation	1,265	1,379	1,285
SMR Licensing Technical Support			
SMR Licensing Technical Support	94,178	93,163	0
Supercritical Transformational Electric Power Generation			
Supercritical Transformational Electric Power Generation	36	0	0
Total, Idaho Operations Office	**244,643**	**243,691**	**187,658**
Kansas City Site Office			
Idaho Facilities Management			
Idaho Facilities Management	250	0	0
Total, Kansas City Site Office	**250**	**0**	**0**
Lawrence Berkeley National Laboratory			
Fuel Cycle R & D			
Fuel Cycle R & D	3,547	3,699	572
Nuclear Energy Enabling Technologies			
Nuclear Energy Enabling Technologies	50	0	0
Total, Lawrence Berkeley National Laboratory	**3,597**	**3,699**	**572**

Department of Energy
FY 2019 Congressional Budget Funding
by Appropriation by Site
($K)

Nuclear Energy	FY 2017 Enacted	FY 2018 Annualized CR	FY 2019 Request
Lawrence Livermore National Laboratory			
Fuel Cycle R & D			
Fuel Cycle R & D	651	992	142
Nuclear Energy Enabling Technologies			
Nuclear Energy Enabling Technologies	850	475	475
Reactors Concepts RD&D			
Reactors Concepts RD&D	50	58	50
Total, Lawrence Livermore National Laboratory	**1,551**	**1,525**	**667**
Los Alamos National Laboratory			
Fuel Cycle R & D			
Fuel Cycle R & D	9,622	11,888	3,000
Nuclear Energy Enabling Technologies			
Nuclear Energy Enabling Technologies	2,449	3,850	2,350
Reactors Concepts RD&D			
Reactors Concepts RD&D	117	0	0
Total, Los Alamos National Laboratory	**12,188**	**15,738**	**5,350**
National Energy Technology Lab			
Reactors Concepts RD&D			
Reactors Concepts RD&D	50	50	0
Total, National Energy Technology Lab	**50**	**50**	**0**
Nevada Field Office			
Program Direction-NE			
Program Direction-NE	2,536	2,517	0
Total, Nevada Field Office	**2,536**	**2,517**	**0**
Oak Ridge National Laboratory			
Fuel Cycle R & D			
Fuel Cycle R & D	27,265	19,203	4,593
Radiological Facilities Management			
Radiological Facilities Management	9,969	9,796	0
Nuclear Energy Enabling Technologies			
Nuclear Energy Enabling Technologies	30,314	23,688	10,735
Reactors Concepts RD&D			
Reactors Concepts RD&D	15,005	18,503	12,800
International Nuclear Energy Cooperation			
International Nuclear Energy Cooperation	271	250	280
Total, Oak Ridge National Laboratory	**82,824**	**71,440**	**28,408**

Department of Energy
FY 2019 Congressional Budget Funding
by Appropriation by Site
($K)

Nuclear Energy	FY 2017 Enacted	FY 2018 Annualized CR	FY 2019 Request
Oak Ridge Office			
Fuel Cycle R & D			
Fuel Cycle R & D	0	272	40
Program Direction-NE			
Program Direction-NE	645	667	667
Total, Oak Ridge Office	**645**	**939**	**707**
Pacific Northwest National Laboratory			
Fuel Cycle R & D			
Fuel Cycle R & D	12,178	12,902	1,652
Nuclear Energy Enabling Technologies			
Nuclear Energy Enabling Technologies	1,586	575	605
Reactors Concepts RD&D			
Reactors Concepts RD&D	1,370	1,040	900
International Nuclear Energy Cooperation			
International Nuclear Energy Cooperation	0	20	0
Total, Pacific Northwest National Laboratory	**15,134**	**14,537**	**3,157**
Sandia National Laboratories			
Fuel Cycle R & D			
Fuel Cycle R & D	19,100	23,360	2,790
Nuclear Energy Enabling Technologies			
Nuclear Energy Enabling Technologies	988	2,100	150
Reactors Concepts RD&D			
Reactors Concepts RD&D	2,171	3,894	3,000
International Nuclear Energy Cooperation			
International Nuclear Energy Cooperation	0	45	0
Supercritical Transformational Electric Power Generation			
Supercritical Transformational Electric Power Generation	4,721	4,750	0
Total, Sandia National Laboratories	**26,980**	**34,149**	**5,940**
Savannah River National Laboratory			
Fuel Cycle R & D			
Fuel Cycle R & D	4,346	4,554	261
Total, Savannah River National Laboratory	**4,346**	**4,554**	**261**
SLAC National Accelerator Laboratory			
Fuel Cycle R & D			
Fuel Cycle R & D	50	0	0
Total, SLAC National Accelerator Laboratory	**50**	**0**	**0**

Department of Energy

FY 2019 Congressional Budget

Funding by Appropriation by Site

($K)

Nuclear Energy	FY 2017 Enacted	FY 2018 Annualized CR	FY 2019 Request
Washington Headquarters			
University Research Program			
University Research	16	68	0
Fuel Cycle R & D			
Fuel Cycle R & D	15,986	20,569	4,192
Radiological Facilities Management			
Radiological Facilities Management	54	233	25
Idaho Facilities Management			
Idaho Facilities Management	1,248	1,300	1,300
Idaho Sitewide Safeguards and Security			
Idaho Sitewide Safeguards and Security	422	1,773	512
Program Direction-NE			
Program Direction-NE	43,697	42,571	32,131
Nuclear Energy Enabling Technologies			
Nuclear Energy Enabling Technologies	7,675	7,674	7,047
Reactors Concepts RD&D			
Reactors Concepts RD&D	10,241	12,333	8,535
International Nuclear Energy Cooperation			
International Nuclear Energy Cooperation	129	421	412
SMR Licensing Technical Support			
SMR Licensing Technical Support	297	1,192	0
Supercritical Transformational Electric Power Generation			
Supercritical Transformational Electric Power Generation	198	216	0
Total, Washington Headquarters	**79,963**	**88,350**	**54,154**
Total, Nuclear Energy	**1,026,616**	**1,019,644**	**757,090**

Yucca Mountain and Interim Storage
Proposed Appropriation Language

NUCLEAR WASTE DISPOSAL

For Department of Energy expenses necessary for nuclear waste disposal activities to carry out the purposes of the Nuclear Waste Policy Act of 1982, Public Law 97–425, as amended (the ''NWPA''), including the acquisition of any real property or facility construction, or expansion, and interim storage activities, $90,000,000, to remain available until expended, and to be derived from the Nuclear Waste Fund: Provided, That of the funds made available in this Act for nuclear waste disposal and defense nuclear waste disposal activities, 1.62 percent shall be provided to the Office of the Attorney General of the State of Nevada solely for expenditures, other than salaries and expenses of State employees, to conduct scientific oversight responsibilities and participate in licensing activities pursuant to the NWPA: Provided further, that of the funds made available in this Act for nuclear waste disposal and defense nuclear waste disposal activities, 2.91 percent shall be provided to affected units of local government, as defined in the NWPA, to conduct appropriate activities and participate in licensing activities under Section 116(c) of the NWPA: Provided further, That of the amounts provided to affected units of local government, 7.5 percent of the funds provided for the affected units of local government shall be made available to affected units of local government in California with the balance made available to affected units of local government in Nevada for distribution as determined by the Nevada affected units of local government: Provided further, That of the funds made available in this Act for nuclear waste disposal and defense nuclear waste disposal activities, 0.16 percent shall be provided to the affected federally-recognized Indian tribes, as defined in the NWPA, solely for expenditures, other than salaries and expenses of tribal employees, to conduct appropriate activities and participate in licensing activities under section 118(b) of the NWPA: Provided further, that of the funds made available in this Act for nuclear waste disposal and defense nuclear waste disposal activities 3.0 percent shall be provided to Nye County, Nevada, 0.05 percent shall be provided to Clark County, Nevada, and 0.46 percent shall be provided to the State of Nevada as payment equal to taxes under section 116(c)(3) of the NWPA: Provided further, that within 90 days of the completion of each Federal fiscal year, the Office of the Attorney General of the State of Nevada, each affected federally-recognized Indian tribe, and each of the affected units of local government shall provide certification to the Department of Energy that all funds expended from such payments have been expended for activities authorized by the NWPA and this Act: Provided further, that failure to provide such certification shall cause such entity to be prohibited from any further funding provided for similar activities: Provided further, that none of the funds herein appropriated may be: (1) used for litigation expenses; or (2) used to support multi-State efforts or other coalition building activities inconsistent with the restrictions contained in this Act: Provided further, that all proceeds and recoveries realized by the Secretary in carrying out activities authorized by the NWPA, including but not limited to any proceeds from the sale of assets, shall be credited to this account, to remain available until expended, for carrying out the purposes of this account.

DEFENSE NUCLEAR WASTE DISPOSAL

For nuclear waste disposal activities to carry out the purposes of Public Law 97–425, as amended, including the acquisition of real property or facility construction or expansion, and interim storage activities, $30,000,000, to remain available until expended.

Yucca Mountain and Interim Storage
($K)

FY 2017 Enacted	FY 2018 Annualized CR*	FY 2019 Request	FY 2019 Request vs FY 2017 Enacted
0	0	120,000	+120,000

Overview
The mission of the Yucca Mountain and Interim Storage Program is to accelerate progress on fulfilling the Federal Government's obligations to address nuclear waste, enhance national security, and reduce future taxpayer burden.

Preface
With the resumption of the Yucca Mountain licensing process and initiation of a robust interim storage program, the FY 2019 Budget Request proposes resuming funding through two separate appropriation accounts: Nuclear Waste Disposal and Defense Nuclear Waste Disposal. The overview narrative and detailed justification for the program, as supported by both accounts, is presented here.

The Program funds activities needed to support the resumption of the Yucca Mountain license application process for disposal of spent nuclear fuel (SNF) and high level waste (HLW) as well as the implementation of a robust interim storage capability. The FY 2019 Budget Request provides for essential management, subject matter expertise, and other capabilities needed for the Department of Energy's (DOE) participation in the Nuclear Regulatory Commission (NRC) licensing process.

The Yucca Mountain and Interim Storage Program is critical to enhancing the national and economic security goals of the nation. The management of SNF and HLW must protect the health, safety of citizens and the environment in the United States. The Program is also essential for supporting national security objectives, along with DOE strategic goals.

The Nation's commercial and defense spent nuclear fuel and high level waste must be safely and permanently isolated to minimize the risk to human health and the environment. Effective management of these materials will ensure that our country continues to have a strong commercial nuclear fleet, maintains national security, supports cleanup of weapons sites, continues operation of the U.S. Navy's nuclear-powered vessels, and advances our international non-proliferation goals. Ultimately, the success of the program ensures the safe and secure management of SNF and HLW currently located at numerous above ground sites across the United States.

Highlights and Major Changes in the FY 2019 Budget Request
The FY 2019 Yucca Mountain and Interim Storage Program FY 2019 Budget Request is dedicated to continuing the resumption of the NRC licensing process for Yucca Mountain and initiation of a robust interim storage program. Prior year activities that supported the participation in the NRC licensing process were suspended in FY 2010, but are being continued under the FY 2019 Budget Request.

This request provides for a program office to provide policy direction and perform functions necessary to the licensing process. This request provides for legal support to represent the Department in the licensing process, as well as to respond to litigation and other legal matters. It provides for technical and scientific support necessary to support an affirmative case for the license and to respond to any challenges to the license application. It also provides for the document management activities associated with the licensing process.

The FY 2019 Budget Request includes funding for research, planning, and implementation of robust interim storage enabling consolidation of nuclear waste to complement the disposal system.

* A full year 2018 appropriation was not enacted at the time the budget was prepared; therefore, the budget assumes operating under the Continuing Appropriations Act, 2017 (Division D of P.L. 115-56). The amounts included for 2018 reflect the annualized level provided by the continuing resolution. These amounts are shown only at the congressional control level and above, below that level, a dash (-) is shown.

The Program Direction budget has been structured to support both licensing and interim storage. Program Direction is needed for a variety of activities including the salaries of Federal Employees working in furtherance of the Nuclear Waste Policy Act (NWPA).

($ in Thousands)

	Yucca Mountain	Interim Storage	Total
Yucca Mountain	90,400		90,400
Interim Storage		6,600	6,600
Program Direction	19,600	3,400	23,000
Total	110,000	10,000	120,000

Financial Assistance and Payments-Equal-to-Taxes
Based on the full funding request of $120 Million and consistent with the percentages identified within the Appropriation language, the following table represents a total of $9,835,000 in funding to provide financial assistance to the State of Nevada, Affected Units of Local Government (AULG), affected Native American tribes, and Payments-Equal-to-Taxes (PETT). The proposed FY 2019 funding profile is as follows.

Funding Purpose	Proposed Amount (in thousands)
Oversight § 116(c), State of Nevada	$1,940
Oversight § 116(c), AULG	$3,493
Oversight § 118(b), Timbisha Shoshone	$194
PETT § 116(c), State of Nevada	$549
PETT § 116(c), Nye County	$3,598
PETT § 116(c), Clark County	$61
TOTAL	$9,835

Yucca Mountain and Interim Storage
Funding by Congressional Control
($K)

	FY 2017 Enacted	FY 2018 Annualized CR*	FY 2019 Request	FY 2019 Request vs FY 2017 Enacted
Yucca Mountain and Interim Storage				
Yucca Mountain	**0**	**0**	**90,400**	**+90,400**
Interim Storage	**0**	**0**	**6,600**	**+6,600**
Program Direction	**0**	**0**	**23,000**	**+23,000**
Total, Yucca Mountain and Interim Storage	**0**	**0**	**120,000**	**+120,000**
Federal FTEs				83

* A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution. (These amounts are shown only at the Congressional control level and above; below that level, a dash (—) is shown).

Yucca Mountain and Interim Storage

Overview

The Yucca Mountain and Interim Storage programs will continue licensing activities for the Yucca Mountain nuclear waste repository and continue a robust interim storage program. These programs will accelerate progress on fulfilling the Federal Government's obligations to address nuclear waste, enhance national security, and reduce future taxpayer burden.

The Nuclear Waste Policy Act (NWPA) of 1982 made the Department of Energy (DOE) responsible for the permanent disposal of U.S. spent nuclear fuel and high-level nuclear waste. The adoption of P.L. 107-200 in July of 2002, designated Yucca Mountain as the site for the national repository.

Consistent with the NWPA and Public Law 107-200, the Department of Energy prepared and submitted to the Nuclear Regulatory Commission (NRC) on June 3, 2008, a License Application (LA) for authorization to construct a repository at Yucca Mountain, which was accepted for docketing by the NRC on September 8, 2008. Subsequently, the previous administration terminated work on the project and sought to withdraw the license application. In 2013, the Court of Appeals for the District of Columbia Circuit issued a writ of mandamus requiring the NRC to complete its review of the license application, subject to the availability of appropriated funds. The Department is requesting funds to continue supporting the licensing review process outlined in the NWPA, as amended.

Highlights of the FY 2019 Budget Request

In FY 2019, the primary focus of the Yucca Mountain and Interim Storage programs is the continuation of support for the NRC License Application process and to continue efforts to initiate a robust interim storage program.

The Program Direction budget has been structured to support both licensing and interim storage. Program Direction is needed for a variety of activities including the salaries of federal employees working in furtherance of the NWPA.

The FY 2019 Budget Request proposes funding from two separate appropriation accounts, Nuclear Waste Disposal ($90 million) and Defense Nuclear Waste Disposal ($30 million).

Yucca Mountain and Interim Storage
Funding
($K)

	FY 2017 Enacted	FY 2018 Annualized CR*	FY 2019 Request	FY 2019 Request vs FY 2017 Enacted
Yucca Mountain and Interim Storage				
Yucca Mountain	0	0	90,400	+90,400
Interim Storage	0	0	6,600	+6,600
Program Direction	0	0	23,000	+23,000
Total, Yucca Mountain and Interim Storage	0	0	120,000	+120,000

* A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution. (These amounts are shown only at the Congressional control level and above; below that level, a dash (—) is shown).

Yucca Mountain and Interim Storage
Explanation of Major Changes ($K)

	FY 2019 Request vs FY 2017 Enacted
Yucca Mountain:	
The increase from $0 to $90,400,000 reflects support for the resumption of the Yucca Mountain licensing process to help accelerate progress on fulfilling the Federal Government's obligations to address nuclear waste, enhance national security, and reduce future taxpayer burden.	**+90,400**
Interim Storage:	
The increase from $0 to $6,600,000 reflects support to develop an interim storage capability for earlier acceptance of spent nuclear fuel to help accelerate progress on fulfilling the Federal Government's obligations to address nuclear waste, enhance national security, and reduce future taxpayer burden.	**+6,600**
Program Direction:	
The increase from $0 to $23,000,000 reflects the program direction support required to resume the Yucca Mountain licensing process and support an interim storage program.	**+23,000**
Total, Yucca Mountain and Interim Storage Program	**+120,000**

Yucca Mountain and Interim Storage Programs
Yucca Mountain

Description
The Yucca Mountain program requests $90.4 million to restart Nuclear Regulatory Commission (NRC) licensing activities for the Yucca Mountain nuclear waste repository. This subprogram includes the following activities: Licensing Support, Litigation, Balance of Plant Infrastructure, Project Support, Program Management and Integration, and Transportation.

Licensing Support
The Budget Request supports participation in the following activities that will occur during the NRC License Application (LA) review and hearing phase. These activities include: supporting the NRC administrative hearing process; providing technical and regulatory support of licensing; Safety Analysis Report updates and ongoing LA-configuration control; and consistent managing of all the technical documents, external correspondence, and external communications supporting the above activities. This Budget Request also includes funding for discovery support required during the licensing proceeding. The Budget Request supports the migration of hardware that houses legacy systems to support accurate and timely records and information management.

As the license applicant to the NRC, the Department of Energy (DOE) must comply with the licensing process and schedule established by the Nuclear Waste Policy Act (NWPA) and applicable NRC regulations. Moreover, DOE has the burden of proof in the hearing process. To meet this burden effectively and provide NRC an appropriate and sufficient basis on which it can fulfill its statutory obligations, the DOE Office of the General Counsel staff will represent DOE in the administrative litigation aspects of the licensing process. The Office of the General Counsel also will be supported by outside legal counsel. Federal staff will address technical issues with the support of contractors and scientists from entities such as the National Laboratories. Likely activities in support of the licensing process will include:

- Appearance before the Atomic Safety Licensing Boards (ASLBs) as issues are identified and addressed through interactions with the regulator and interveners in the adjudicatory hearing process;
- Identification of likely topics for interrogatories;
- Response to admitted contentions;
- Preparation of anticipatory response plans, responses, and draft testimony and assistance in the preparation of witnesses; and
- Presentation of affirmative case in support of license application and demonstration of compliance with applicable regulatory requirements.

Activities in the following areas may be undertaken in FY 2019 if required to support the NRC licensing proceeding:

Balance of Plant Infrastructure

Balance of Plant infrastructure includes license applicant requirements for continuation of Performance Confirmation Program testing at the site in accordance with requirements under 10 CFR 63, Subpart F, and ability to support access requests under 10 CFR 2 for the NRC or interveners. Activities in FY 2019 will include maintaining the safety at the Yucca Mountain site at appropriate levels to support performance confirmation and site access requests in support of the NRC licensing process. Yucca Mountain site activities will ensure implementation of applicable minimal requirements to ensure safe operations, and maintaining regulatory compliance.

Project Support

Project Support includes project management, project support, and coordination activities. Project Management functions include using project management and integration for technical development and control of products, and establishing and maintaining engineering and scientific processes and procedures. Project support functions include project controls, systems engineering, information management, procurement, environmental, safety and health, and general project services (e.g., administrative services, technical support services, communications, facility and fleet operational services). It also includes compliance with National Environmental Policy Act requirements and other compliance management activities and supports and maintains databases for public sharing and systems analysis.

Also included under Project Support is funding to provide financial assistance to the State of Nevada, Affected Units of Local Government (AULG), affected Native American tribes, and Payments-Equal-to-Taxes (PETT).

Program Management and Integration

The Program Management and Integration activity provides strategic integration and planning, guidance, quality assurance, budgeting, management of the Nuclear Waste Fund, and program management support in executing the Program's Mission.

A consolidated Quality Assurance (QA) program ensures effective implementation of requirements under 10 CFR 63.21(c)(2), and 10 CFR 63, Subpart G for nuclear quality assurance and as specified as a commitment in the License Application (LA) section 5.01. Effective implementation of the QA program is performed at the line level incorporating and embracing a nuclear quality culture in all work activities. A QA oversight program is maintained which performs surveillance, audits, and inspections to verify the quality of work in progress; develops and maintains the QA Requirements Description (QARD), identifies conditions adverse to quality; assures that prompt corrective actions are taken by management responsible for performing the work; and verifies the timely implementation, adequacy, and effectiveness of corrective actions.

Program Management and Control will ensure meeting requirements for effective interaction and responsiveness to questions and inquiries by the U.S. Congress, the Office of Management and Budget (OMB), regulatory and oversight bodies, other federal, state, and local government agencies, international entities, program customers and stakeholders, and the public at large. The program will support, as appropriate, international agreements and collaborations. Implementation of an appropriate investment strategy and the prudent management of the Nuclear Waste Fund investment portfolio are also essential to fulfilling the program's fiduciary responsibility under the Nuclear Waste Policy Act (NWPA).

Safeguards and Security (S&S) functions necessary to support Nuclear Regulatory Commission (NRC) licensing will be resumed. Department of Energy (DOE) Order requirements for physical security and access control (e.g., badging) will be met. Development of safeguard and security strategies to meet LA commitments, NRC requirements, and Department of Homeland Security requirements will resume in a limited fashion.

The Fee Adequacy Assessment is a requirement of Section 302(a) of the NWPA 1982, as amended, where by the Secretary is to determine annually the adequacy of the fee charged to generators of commercial spent nuclear fuel. The FY 2019 fee adequacy assessment will utilize the prior information used to prepare prior cost estimates until new information is available. The assessment of the fee will utilize updated economic projections and the existing defense and civilian share calculations to ensure that the program remains a full cost recovery program, as required by the NWPA. Activities include interfacing with the Nuclear Waste Fund managers for investment projections, updating the economic forecasts, and interfacing with external auditors for the Department. Additional activities include responding to inquiries on the adequacy of the fee.

Litigation
The FY 2019 Budget Request provides funding for support of litigation related to the NWPA. This includes litigation related to the Standard Contract for the disposal of commercial spent nuclear fuel. Also, included is support for the management of settlement claims resulting from Standard Contract litigation.

Yucca Mountain

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
$0	**$90,400,000**	**+$90,400,000**
• No funding requested.	• Support participation in the Yucca Mountain licensing proceeding. • Undertake pre-closure and post-closure analytical activities, as required, to respond to potentially multiple rounds of highly technical, detailed questions. • Provide technical, scientific, and legal support for court challenges. • Maintain and update the License Application (LA) and supporting documents as issues resulting from contentions are resolved. • Ensure effective LA configuration control and consistency with supporting documents. • Prepare and review depositions. • Prepare DOE witnesses and testimony for Atomic Safety and Licensing Board (ASLB) hearings. • Address discovery, including derivative discovery. • Prepare and respond to interrogatories. • Provide support for motions and other legal actions. • Maintain control of all geologic specimens and facilities needed to support licensing efforts. • Develop a comprehensive communications strategy that will support the Department's obligation to provide effective and responsive communications with other government agencies, affected units of local government, and Native American tribes and the public.	• The increase from $0 to $90,400,000 is for activities necessary to support the Yucca Mountain licensing process.

Yucca Mountain and Interim Storage
Interim Storage

Description

The primary mission of the Interim Storage program is to develop an interim storage capability for spent nuclear fuel (SNF) that complements the overall disposal system.

Nuclear technology has been used in the United States for national defense, research and development, and electric power generation. These activities have produced a large quantity of SNF and high-level radioactive waste (HLW). The largest inventory of SNF comes from commercial electricity generation: approximately 80,000 metric tons of uranium (MTU) through the end of 2017 with potential growth to 140,000 MTU with the current reactor fleet. Nearly all the existing commercial SNF is being stored at the reactor sites where it was generated. Of the 74 commercial reactor sites, 14 sites no longer have an operating reactor. Under current law, the federal government, and specifically the Department of Energy (DOE), is responsible for providing the safe and permanent disposal of SNF and HLW. Under the Nuclear Waste Policy Act (NWPA), DOE was to begin accepting SNF and removing it from sites by 1998.

Implementation of interim storage can bring the following benefits:

- Earlier acceptance of commercial fuel by the federal government;
- Reduction in the number of dispersed storage sites;
- Added system flexibility and opportunity for better integration; and
- Near-term development and demonstration of institutional and technical infrastructures for large-scale management of SNF.

Under this program, activities will be pursued to:

- Further develop knowledge and technology gap analysis, activities, milestones, and resources needed to develop, evaluate, and acquire consolidated interim storage capabilities and associated transportation.
- Further evaluate technical, economic, and other factors associated with federal and non-federal interim storage system concepts.
- Maintain engagement with regional, state, and tribal transportation authorities to prepare for SNF and HLW shipments.

Interim Storage

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
$0	**$6,600,000**	**+$6,600,000**
• No funding requested.	• Develop plans to include activities, milestones, and resources needed to develop, evaluate, and acquire consolidated interim storage capabilities and associated transportation. • Continue development of the basis for potential acquisition of spent nuclear fuel storage and transportation capabilities. • Maintain important engagement with regional, state, and tribal transportation authorities to prepare for future spent nuclear fuel (SNF) and high-level radioactive waste (HLW) shipments. • Maintain minimal support for logistical requirements and analytical capabilities.	• The increase from $0 to $6,600,000 reflects support to develop an interim storage capability for earlier acceptance of spent nuclear fuel.

Program Direction

Overview

Program Direction provides the federal staffing resources and associated costs required to support the overall direction and execution of the Yucca Mountain and Interim Storage programs. The programs have staff located in two locations: Washington, D.C. and Las Vegas, NV.

Washington D.C. staff for the Yucca Mountain and Interim Storage programs includes the Office of the General Counsel and Energy Information Administration staff responsible for administrative activities and judicial litigation associated with the restart of the Yucca Mountain Nuclear Waste Repository project, legal issues related to the standard contract, and the Department's responsibilities regarding spent nuclear fuel (SNF) and high level waste (HLW).

The Support Services subprogram allows the Department to cost-effectively hire the best available industry experts to support federal staff in managing the nuclear programs and complex activities. The ability to acquire expertise quickly and on an “as needed basis” provides flexibility in team composition as the needs of the Yucca Mountain and Interim Storage programs evolve. Program Direction also includes the Other Related Expenses subprogram, which provides funding to the Department’s Working Capital Fund (WCF) for common administrative services at Headquarters (HQ). The Department is working to achieve economies of scale through an enhanced WCF. The WCF supports specific Departmental services and activities that are shared across DOE including: enhanced cyber security architecture, employee health and testing services, and consolidated training and recruitment initiatives. These were all established in previous fiscal years and are supported in FY 2019.

Highlights of the FY 2019 Budget Request

The Yucca Mountain and Interim Storage programs’ Program Direction request supports 83 federal staff and associated activities. The program requires a significant commitment of human capital to assure consistency with federal policies and strategies in the planning, engagement, responsiveness, and the adaptation of plans that address changing and dynamic conditions. The Budget Request includes additional staffing for the program office to ensure there is appropriate guidance and oversight throughout the program. Of the 83 funded staff, 53 will be re-aligned from staff currently funded by other DOE Program Direction budgets. 30 new staff members will be hired to provide additional Yucca Mountain license application support activities.

Funding in Program Direction is allocated between Yucca Mountain licensing activities and development of a consolidated interim storage program as shown in the table below.

($ in Thousands)

	Yucca Mountain	Interim Storage	Total
Yucca Mountain	90,400		90,400
Interim Storage		6,600	6,600
Program Direction	19,600	3,400	23,000
Total	110,000	10,000	120,000

Program Direction
Funding
($K)

	FY 2017 Enacted	FY 2018 Annualized CR*	FY 2019 Request	FY 2019 Request vs FY 2017 Enacted
Program Direction				
Salaries and Benefits	0	0	18,840	+18,840
Travel	0	0	650	+650
Support Services	0	0	1,750	+1,750
Other Related Expenses	0	0	1,760	+1,760
Total, Program Direction	**0**	**0**	**23,000**	**23,000**

* A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution. (These amounts are shown only at the Congressional control level and above; below that level, a dash (—) is shown).

Program Direction
Funding
($K)

	FY 2017 Enacted	FY 2018 Annualized CR*	FY 2019 Request	FY 2019 Request vs FY 2017 Enacted
Program Direction Summary				
Washington Headquarters				
Salaries and Benefits	0	0	12,372	+12,372
Travel	0	0	475	+475
Support Services	0	0	1,277	+1,277
Other Related Expenses	0	0	1,540	+1,540
Total, Washington Headquarters	**0**	**0**	**15,664**	**+15,664**
Las Vegas, NV				
Salaries and Benefits	0	0	6,468	+6,468
Travel	0	0	175	+175
Support Services	0	0	473	+473
Other Related Expenses	0	0	220	+220
Total, Las Vegas, NV	**0**	**0**	**7,336**	**+7,336**
Total Program Direction				
Salaries and Benefits	0	0	18,840	+18,840
Travel	0	0	650	+650
Support Services	0	0	1,750	+1,750
Other Related Expenses	0	0	1,760	+1,760
Total, Program Direction	**0**	**0**	**23,000**	**23,000**
Federal FTEs	**0**	**0**	**83**	**83**

* A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution. (These amounts are shown only at the Congressional control level and above; below that level, a dash (—) is shown).

	FY 2017 Enacted	FY 2018 Annualized CR*	FY 2019 Request	FY 2019 Request vs FY 2017 Enacted
Support Services				
Technical Support				
Mission Related	-	0	520	+520
Advisory and Assistance	-	0	120	+120
Total, Technical Support	-	0	640	+640
Management Support				
Administrative	-	0	510	+510
IT	-	0	600	+600
Total, Management Support	-	0	1,110	+1,110
Total, Support Services	**-**	**0**	**1,750**	**+1,750**

* A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution. (These amounts are shown only at the Congressional control level and above; below that level, a dash (—) is shown).

Program Direction

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Program Direction $0	**$23,000,000**	**+$23,000,000** The increase from $0 to $23,000,000 reflects the program direction support required to resume the Yucca Mountain licensing process and support an interim storage program.
Salaries and Benefits $0	**$18,840,000**	**+$18,840,000**
	Supports the salaries and benefits of 83 employees located in Washington, DC and Las Vegas, NV.	46 employees funded in FY 2017 within other program direction budgets are transferred to support this new program. An additional 37 employees will be required to support this new program.
Travel $0	**$650,000**	**+$650,000**
	Supports necessary travel required for evolving programmatic requirements of this new program.	Supports necessary travel required for evolving programmatic requirements of this new program.
Support Services $0	**$1,750,000**	**+$1,750,000**
	Provides for technical and administrative support services for the Nuclear Energy federal staff including access to and participation with external and international nuclear energy organizations such as the Organisation for Economic Co-operation and Development/Nuclear Energy Agency.	Provides for technical and administrative support services for the Nuclear Energy federal staff including access to and participation with external and international nuclear energy organizations such as the Organisation for Economic Co-operation and Development/Nuclear Energy Agency.
Other Related Expenses $0	**$1,760,000**	**+$1,760,000**
	Services procured through the Working Capital Fund (WCF) will be required to support the administrative functions of the new program as well as training, rent and utilities associated with the Nevada Site Office, along with other miscellaneous costs.	Services procured through the WCF will be required to support the administrative functions of the new program as well as training, rent and utilities associated with the Nevada Site Office, along with other miscellaneous costs.

Yucca Mountain and Interim Storage
Performance Measures

In accordance with the GPRA Modernization Act of 2010, the Department sets targets for, and tracks progress toward, achieving performance goals for each program.

	FY 2017	FY 2018	FY 2019
Performance Goal (Measure)	**Nuclear Waste Management - Complete 90% of annual program milestones to restart licensing activities for the Yucca Mountain nuclear waste repository and initiate a robust interim storage program.**		
Target	N/A	N/A	90 % annual milestones met
Result	N/A	N/A	TBD
Endpoint Target	An Endpoint Target cannot be developed at this time.		

Department of Energy
FY 2019 Congressional Budget Funding
by Appropriation by Site
($K)

Nuclear Waste Disposal	FY 2017 Enacted	FY 2018 Annualized CR	FY 2019 Request
Argonne National Laboratory			
Yucca Mountain and Interim Storage			
Yucca Mountain and Interim Storage	0	0	800
Total, Argonne National Laboratory	**0**	**0**	**800**
Idaho National Laboratory			
Yucca Mountain and Interim Storage			
Yucca Mountain and Interim Storage	0	0	10
Total, Idaho National Laboratory	**0**	**0**	**10**
Idaho Operations Office			
Yucca Mountain and Interim Storage			
Yucca Mountain and Interim Storage	0	0	2,940
Total, Idaho Operations Office	**0**	**0**	**2,940**
Lawrence Berkeley National Laboratory			
Yucca Mountain and Interim Storage			
Yucca Mountain and Interim Storage	0	0	840
Total, Lawrence Berkeley National Laboratory	**0**	**0**	**840**
Los Alamos National Laboratory			
Yucca Mountain and Interim Storage			
Yucca Mountain and Interim Storage	0	0	840
Total, Los Alamos National Laboratory	**0**	**0**	**840**
Nevada Field Office			
Yucca Mountain and Interim Storage			
Yucca Mountain and Interim Storage	0	0	40,736
Total, Nevada Field Office	**0**	**0**	**40,736**
Oak Ridge National Laboratory			
Yucca Mountain and Interim Storage			
Yucca Mountain and Interim Storage	0	0	1,130
Total, Oak Ridge National Laboratory	**0**	**0**	**1,130**
Pacific Northwest National Laboratory			
Yucca Mountain and Interim Storage			
Yucca Mountain and Interim Storage	0	0	910
Total, Pacific Northwest National Laboratory	**0**	**0**	**910**
Sandia National Laboratories			
Yucca Mountain and Interim Storage			
Yucca Mountain and Interim Storage	0	0	35,480
Total, Sandia National Laboratories	**0**	**0**	**35,480**

Department of Energy
FY 2019 Congressional Budget Funding
by Appropriation by Site
($K)

Nuclear Waste Disposal	FY 2017 Enacted	FY 2018 Annualized CR	FY 2019 Request
Savannah River Operations Office			
Yucca Mountain and Interim Storage			
Yucca Mountain and Interim Storage	0	0	1,050
Total, Savannah River Operations Office	**0**	**0**	**1,050**
Washington Headquarters			
Yucca Mountain and Interim Storage			
Yucca Mountain and Interim Storage	0	0	35,264
Total, Washington Headquarters	**0**	**0**	**35,264**
Total, Nuclear Waste Disposal	**0**	**0**	**120,000**

Advanced Research Projects Agency-Energy

Advanced Research Projects Agency-Energy

Advanced Research Projects Agency - Energy
($K)

FY 2017 Enacted	FY 2018 Enacted Annualized CR*	FY 2019 Request
305,245	303,172	0

*A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution. (These amounts are shown only at the Congressional control level and above; below that level, a dash (—) is shown).

The U.S. Department of Energy's Advanced Research Projects Agency-Energy (ARPA-E) was established by the America COMPETES Act of 2007 (Public Law 110–69), as amended. ARPA-E will wind down operations in FY 2018 with the expectation that it will shut down in FY 2019, with remaining monitoring and contract closeout activities transferred elsewhere within DOE.

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

Overview
As defined by its authorization under the America COMPETES Act, the Advanced Research Projects Agency-Energy (ARPA-E) catalyzes transformational energy technologies to enhance the economic and energy security of the United States. ARPA-E funds high-potential, high-impact energy projects that are too early for private sector investment but could significantly advance the ways we generate, store, distribute and use energy. ARPA-E plays a unique role in DOE's research and development R&D organization, complementing and expanding the impact of DOE's basic science and applied energy programs.

As of February 2018, ARPA-E has funded over 650 projects with approximately $1.8 billion through 44 focused programs and open funding solicitations.

Highlights and Major Changes in the FY 2019 Budget Request
Under the Budget Request for FY 2019, ARPA-E requests no additional appropriation and will execute the multi-year termination of the program as described in the FY 2018 President's Budget Request. ARPA-E will utilize reprogrammed carryover to actively manage its $439 million[1] portfolio of forward-funded projects. ARPA-E will not invest in new R&D technologies in FY 2019 and as such will not make additional Small Business Innovation Research / Small Business Technology Transfer (SBIR/STTR) program investments.

[1] "ARPA-E Projects" uncosted balance as of the December 2017

Advanced Research Projects Agency - Energy Funding by Congressional Control ($K)

	FY 2017 Enacted	FY 2018 Enacted Annualized CR*	FY 2019 Request	FY 2019 Request vs FY 2017 Enacted
ARPA-E Projects	276,750	274,871	0	-276,480
Program Direction	29,250	29,051	0	-29,520
Subtotal, Advanced Research Projects Agency - Energy	**306,000**	**303,922**	**0**	**-306,000**
Use of Prior Year Reprogrammed Funds	-755	-750	0	-755
Total, Advanced Research Projects Agency - Energy	**305,245**	**303,172**	**0**	**-305.245**
Federal FTEs	**56**	**56**	**0**	**-56**

*A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution. (These amounts are shown only at the Congressional control level and above; below that level, a dash (—) is shown).

ARPA-E Projects
Funding
($K)

	FY 2017 Enacted	FY 2018 Enacted Annualized CR*	FY 2019 Request	FY 2019 Request vs FY 2017 Enacted
ARPA-E Projects:				
Transportation Systems	138,375	137,435	0	-138,375
Stationary Power Systems	138,375	137,435	0	-138,375
Total, ARPA-E Projects	**276,750**	**274,871**	**0**	**-276,750**

*A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution. (These amounts are shown only at the Congressional control level and above; below that level, a dash (—) is shown).

SBIR/STTR

- FY 2017 Current: $9,214 total (SBIR $8,251 / STTR $963)
- FY 2018 Projected: $0 total (SBIR $0 / STTR $0)
- FY 2019 Request: $0 total (SBIR $0 / STTR $0)

ARPA-E Projects
Explanation of Major Changes ($K)

	FY 2019 Request vs FY 2017 Enacted
Transportation Systems: The Transportation Systems request for FY 2018 is a $104,700 decrease over the FY 2016 enacted level to execute the termination of the program.	**-138,375**
Stationary Power Systems: The Stationary Power Systems request for FY 2018 is a $157,050 decrease over the FY 2016 enacted level to execute the termination of the program.	**-138,375**
Total, ARPA-E Projects	**-276,750**

ARPA-E
Advanced Research Projects Agency - Energy
Performance Measures

In accordance with the GPRA Modernization Act of 2010, the Department sets targets for, and tracks progress toward, achieving performance goals for each program.

	FY 2017	FY 2018	FY 2019
Performance Goal (Measure)	**Award Funding - Cumulative percentage of award funding committed 45 days after award selections are announced**		
Target	≥ 70 %	N/A	N/A
Result	Met - 100	N/A	N/A
Endpoint Target	On an ongoing basis, annually commit ≥70% of award funding within 45 days of announcement of award selections.		
Comment	ARPA-E is proposed for elimination in the FY 2018 Budget.		
Performance Goal (Measure)	**New Company Formation - Number of new companies formed as a direct result of ARPA-E funding. This is a new performance measure for ARPA-E in FY 2015. As of the end of FY 2013 ARPA-E funded research has led to the formation of at least 24 new companies. That is the baseline from which we would expect to add at least 3 new companies per year.**		
Target	≥ 3 new companies founded	N/A	N/A
Result	Met	N/A	N/A
Endpoint Target	On an ongoing basis, ARPA-E funding will support the formation of ≥ 3 new companies each year.		
Comment	ARPA-E is proposed for elimination in the FY 2018 Budget.		

Department of Energy

FY 2019 Congressional Budget

Funding by Appropriation by Site

($K)

Advanced Researched Projects Agency-Energy	**FY 2017 Enacted**	**FY 2018 Annualized CR**	**FY 2019 Request**
Washington Headquarters			
Advanced Researched Projects Agency-Energy			
Projects	276,750	274,871	0
Program Direction	29,250	29,051	0
Total, Advanced Researched Projects Agency-Energy	**306,000**	**303,922**	**0**
Total, Washington Headquarters	**306,000**	**303,922**	**0**
Total, Advanced Researched Projects Agency-Energy	**306,000**	**303,922**	**0**

Advanced Technology Vehicles Manufacturing Loan Program

Advanced Technology Vehicles Manufacturing Loan Program

Advanced Technology Vehicles Manufacturing Loan Program
Proposed Appropriation Language

For Department of Energy administrative expenses necessary in carrying out the Advanced Technology Vehicles Manufacturing Loan Program, $1,000,000, to remain available until September 30, 2020: Provided That [Of] the unobligated balances available from amounts appropriated for the cost of direct loans in section 129 of the Consolidated Security, Disaster Assistance, and Continuing Appropriations Act, 2009 (Public Law 110–329) [, $4,311,615,000 is] *are* hereby permanently cancelled.

Note.— A full-year 2018 appropriation was not enacted at the time the budget was prepared; therefore, the budget assumes operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution.

Explanation of Changes

The FY 2019 Budget eliminates the ATVM Loan Program and proposes to cancel all remaining loan volume authority and appropriated credit subsidy. The Budget provides $1,000,000 to cover loan portfolio monitoring and administrative expenses: including salaries for its full time employees as well as the cost of outside advisors for financial, legal, engineering, credit, and market analysis. The Loan Programs Office (LPO) will wind down operations in FY 2019 with the expectation that it will shut down in FY 2020 with remaining loan monitoring and closeout activities transferred to another office. All activities not essential for the continued monitoring of the portfolio will be terminated.

Public Law Authorizations

- P.L. 110-140, Energy Independence and Security Act of 2007
- P.L. 110–329, Consolidated Security, Disaster Assistance, and Continuing Appropriations Act of 2009

Advanced Technology Vehicles Manufacturing Loan Program
($K)

	FY 2017 Enacted	FY 2018 Annualized CR*	FY 2019 Request	FY 2019 Request vs FY 2017 Enacted
Administrative Expenses	5,000	4,966	1,000	-4,000
Rescission[1]	-1,117	0	0	1,117
Total	**3,883**	**4,966**	**1,000**	**-2,883**
Loan Subsidy Cancelation[2]	0	0	-4,333,500	-4,333,500

[1]Recission of administrative appropriations from FY 2012 (Pub. L. 115-31)
[2]The Budget proposes to cancel $4.3 billion in unobligated balances appropriated by the Consolidated Security, Disaster Assistance, and Continuing Appropriations Act of 2009 (Pub. L. 110-329)

*A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution. (These amounts are shown only at the Congressional control level and above; below that level, a dash (—) is shown).

Overview
The Budget proposes the elimination of the Advanced Technology Vehicle Manufacturing Loan Program because the private sector is better positioned to finance the deployment of commercially viable projects. The Federal role in supporting advanced technologies is strongest in the early stages of research and development. The Government should not be in the business of picking which technologies “win” the commercialization race and displacing private sector investment opportunities. Instead, the Government should recognize the private sector’s primary role in taking risks to finance projects in the automobile manufacturing sector. In addition, the relative inactivity of this program indicates it is ineffective at attracting borrowers with viable projects who are unable to secure private sector financing.

History
Section 136 of the Energy Independence and Security Act of 2007 established the Advanced Technology Vehicles Manufacturing (ATVM) Loan Program, consisting of direct loans of up to $25 billion in total loan authority to support the development and manufacturing of advanced technology vehicles and associated components in the U.S. The ATVM Loan Program issued 5 total loans, of which $7.28 billion has been obligated[1] and $7.28 billion has been disbursed.

Organization
LPO currently utilizes three divisions to proactively monitor the portfolio: Portfolio Management Division (PMD), Technical and Project Management Division (TPMD), and Legal division. The elimination of the Loan Programs Office’s loan origination activities will reduce functional organizations to core functions with corporate services provided from other departmental elements.

The Portfolio Management Division (PMD) lead LPO’s monitoring functions by approving disbursements, repayments, operating budgets, and long-term forecasts. In the event of non-payment and/or default, PMD leads activities to maximize recoveries either through bankruptcy, note sale, or compromise of the claim. PMD will monitor the portfolio in accordance regulatory requirements.

The Technical and Project Management Division (TPMD) supports PMD by evaluating the technical performance of assets and project management throughout the entire lifecycle of the loan to ensure that the technical requirements of the loan agreement are met. TPMD conducts site visits, provides expertise on project construction status and budget, and identifies potential technical risks that inhibit the borrower’s ability to meet requirements and repay the loan.

LPO Legal Division supports PMD in all on-going monitoring activities, negotiations and documentations of waivers, consents, routine loan amendments, approvals and denials of transfer withdrawals, and legal aspects of any project developments.

[11] Net of recoveries

In FY 2019 LPO will continue to consolidate and streamline the organizational structure of monitoring activities to effectively manage the portfolio of loans while minimizing the administrative burden. In addition, LPO will explore options to reduce or mitigate the expected administrative cost of monitoring over the tenor of the remaining loans. LPO will wind down operations in FY 2019 with the expectation that it will shut down in FY 2020 with remaining loan monitoring and closeout activities transferred to another office.

Highlights and Major Changes in the FY 2019 Budget Request
In FY 2019, LPO will commence termination of ATVM direct loan activities and continue to monitor the existing portfolio.

Advanced Technology Vehicles Manufacturing Loan
Program Funding by Congressional Control
($K)

	FY 2017 Enacted	FY 2018 Annualized CR*	FY 2019 Request	FY 2019 Request vs FY 2017 Enacted
Advanced Technology Vehicles Manufacturing Loan Program				
Administrative Expenses	5,000	4,966	$1,000	-4,000
Rescission[1]	-1,117	0	0	1,117
Total, Advanced Technology Vehicles Manufacturing Loan Program	**3,883**	**4,966**	**$1,000**	**-2,883**
Federal FTEs	**16**	**4**	**3**	**-13**
Loan Subsidy Cancelation[2]	0	0	-4,333,500	-4,333,500

[1]Recission of administrative appropriations from FY 2012 (Pub. L. 115-31)

[2]The Budget proposes to cancel $4.3 billion in unobligated balances appropriated by the Consolidated Security, Disaster Assistance, and Continuing Appropriations Act of 2009 (Pub. L. 110-329)

*A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution. (These amounts are shown only at the Congressional control level and above; below that level, a dash (—) is shown).

Advanced Technology Vehicles Manufacturing Loan Program
Administrative Expenses
Funding
($K)

	FY 2017 Enacted	FY 2018 Annualized CR*	FY 2019 Request	FY 2019 Request vs FY 2017 Enacted
Administrative Expenses				
Salaries & Benefits	2,400	-	400	-2,000
Travel	150	-	50	-100
Support Services	1,630	-	325	-1,305
Other Related Expenses	820	-	225	-595
Total, Administrative Expenses	**5,000**	**4,966**	**1,000**	**-4,000**

*A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution. (These amounts are shown only at the Congressional control level and above; below that level, a dash (—) is shown).

Administrative Expenses
Explanation of Major Changes
($K)

	FY 2019 Request vs FY 2017 Enacted
Administrative Expenses	
Salaries and Benefits: In addition to the $400,000 requested for salaries and benefits, LPO will utilize unobligated balances carried forward from prior appropriations to provide salaries and benefits for 3 full time equivalent employees (FTEs).	-2,000
Travel: In addition to the $50,000 requested for travel, LPO will utilize unobligated balances carried forward from prior appropriations to support the travel of staff members for site visits, training, and attending meetings and conferences.	-100
Support Services: In addition to the $325,000 requested for support services, LPO will utilize unobligated balances carried forward from prior appropriations to support outside expertise in finance, legal, engineering, technology, credit analysis, and market assessments.	-1,305
Other Related Expenses: In addition to the $225,000 requested for other related expenses, LPO will utilize unobligated balances carried forward from prior appropriations to support DOE working capital, DOE IT services, and training requirements.	-595
Total, Administrative Expenses	**-4,000**

Administrative Expenses

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Administrative Expenses $5,000,000	**$1,000,000**	**-$4,000,000**
Salaries and Benefits $2,400,000	**$400,000**	**-$2,000,000**
• Provide salaries and benefits to 16 full time equivalent employees to administer the following functions to the office: Director, Legal, Loan Origination, Management Operations, Environmental Compliance, Portfolio Management, Risk Management, and Technical and Project Management.	• In addition to prior year funds, this request will support the salaries and benefits of 3 full time equivalent employees to administer the following functions to the office: Director, Legal, Management Operations, Environmental Compliance, Portfolio Management, Risk Management, and Technical and Project Management.	• In FY 2019 program all activities not essential for the continued monitoring of the portfolio will be terminated. Resultantly, the decrease is in accordance to the termination of origination activities and to match expected salary requirements.
Travel $150,000	**$50,000**	**-$100,000**
• Continuation of FY 2016 activities. Supports the travel of staff members for site visits, training, and attending meetings and conferences.	• Supports the travel of staff members for site visits, as well as attending meetings and conferences.	• The decrease is in accordance to the termination of origination activities and to match expected travel requirements.
Support Services $1,630,000	**$325,000**	**-$1,305,000**
• Continuation of FY 2016 activities. Provides range of contract services including administrative support, subject matter experts, legal services, information technology, and publications.	• Supports range of contract services including administrative support, subject matter experts, legal services, information technology, publications, credit analysis and market assessments.	• The decrease is in accordance to the termination of origination activities to match expected support service requirements.
Other Related Expenses $820,000	**$225,000**	**-$595,000**
• Continuation of FY 2016 activities. Supports DOE Working Capital Fund, DOE IT services and expenses, and ATVM federal staff training.	• Supports DOE Working Capital Fund, DOE IT Services expenses, and LPO federal staff training.	• The decrease is in accordance to the termination of origination activities and to match expected working capital, DOE IT services, and training requirements.

Advanced Technology Vehicles Manufacturing
Loan Program
Performance Measures

In accordance with the GPRA Modernization Act of 2010, the Department sets targets for, and tracks progress toward, achieving performance goals for each program.

	FY 2017	FY 2018	FY 2019
Performance Goal (Measure)	**ATVM Battery Production Capacity - Battery production capacity of 100,000 lithium-ion EV batteries (2,400,000 kWh) established**		
Target	≥ 100,000 Batteries	≥ 100,000 Batteries	N/A
Result	Met - 100,000	TBD	N/A
Endpoint Target	Assist in the development of advanced battery manufacturing capacity to support electric vehicles.		
Comment	This goal is ending in FY 2019. The borrower has repaid the direct loan used to increase the production capacity of lithium-ion EV batteries. As a result, the program will no longer monitor the performance outputs for battery production capacity.		
Performance Goal (Measure)	**ATVM Reduction in Petroleum Usage - Reduction in petroleum usage achieved through the use of advanced technology vehicles manufactured (at least in part) with funding provided through the ATVM loan program as compared to vehicles available in the base year.**		
Target	290 Million Gallons	270 Million Gallons	N/A
Result	Data Not Available	TBD	N/A
Endpoint Target	Annually assist in the reduction in petroleum usage achieved through the use of advanced technology vehicles manufactured (at least in part) with funding provided through the ATVM loan program as compared to vehicles available in the base year.		
Comment	The President's FY 2019 Budget eliminates the origination of any new loans under the ATVM Loan Program. Resultantly, the program will only monitor and report outputs for the reduction in petroleum usage from current borrowers.		
FY 2019 Note	This goal is ending in FY 2019. The borrower is no longer obligated to submit performance reports to the ATVM program in FY 2019. This performance metric measures the annual gasoline saved from vehicles manufactured by Ford using manufacturing components that were financed by ATVM direct loans. Ford used the remaining balance of ATVM direct loans to purchase manufacturing components for 2015 model vehicles. Ford manufacturing components are unique to each make and model. Ford typically changes its models every 3-4 years. As a result, in accordance to the loan agreement, Ford will no longer be obligated to submit performance reports to the ATVM program in FY 2019 because it will no longer utilize manufacturing components that were financed from ATVM direct loans.		

Department of Energy

FY 2019 Congressional Budget

Funding by Appropriation by Site

($K)

Advance Technology Vehicles Man Loan Program	**FY 2017 Enacted**	**FY 2018 Annualized CR**	**FY 2019 Request**
Washington Headquarters			
Energy Transformation Acceleration Fund			
Administrative Expenses	5,000	4,966	1,000
Total, Washington Headquarters	**5,000**	**4,966**	**1,000**
Total, Advance Technology Vehicles Man Loan Program	**5,000**	**4,966**	**1,000**

Title 17 Innovative Technology Loan Guarantee Program

Title 17 Innovative Technology Loan Guarantee Program

Title 17 Innovative Technology Loan Guarantee Program
(Including Cancellation of Funds)
Proposed Appropriation Language[1]

Such sums as are derived from amounts received from borrowers pursuant to section 1702(b) of the Energy Policy Act of 2005 under this heading in prior Acts, shall be collected in accordance with section 502(7) of the Congressional Budget Act of 1974: *Provided*, That for necessary administrative expenses to carry out this Loan Guarantee program, **[**$2,000,000**]***$10,000,000* is appropriated *from fees collected in prior years pursuant to section 1702(h) of the Energy Policy Act of 2005 which are not otherwise appropriated*, to remain available until September 30, **[**2019**]***2020*: *Provided further*, That *if the amount in the previous proviso is not available from such fees, an amount for such purposes is also appropriated from the general fund so as to result in a total amount appropriated for such purpose of no more than* **[**$2,000,000**]***$10,000,000: Provided further, That* **[**of the **]**fees collected pursuant to *such* section 1702(h) *for fiscal year 2019* **[**of the Energy Policy Act of 2005 **]**shall be credited as offsetting collections *under this heading and* **[**to this account to cover administrative expenses and shall remain available until expended, so as to result in a final fiscal year 2018 appropriation from the general fund estimated at not more than $0: *Provided further*, That fees collected under section 1702(h) in excess of the amount appropriated for administrative expenses **]**shall not be available until appropriated: *Provided further*, That the Department of Energy shall not subordinate any loan obligation to other financing in violation of section 1702 of the Energy Policy Act of 2005 or subordinate any Guaranteed Obligation to any loan or other debt obligations in violation of section 609.10 of title 10, Code of Federal Regulations: *Provided further,* That the authority provided in prior year appropriations Acts for commitments to guarantee loans under title XVII of the Energy Policy Act of 2005, excluding amounts for *loan guarantee* commitments*, as defined in the Federal Credit Reform Act of 1990 (2 U.S.C. 661a),* made by October 1, **[**2017**]***2018*, is hereby permanently cancelled: *Provided further,* That of the unobligated balances from prior year appropriations available under this heading in the American Recovery and Reinvestment Act of 2009 (Public Law 111–5) for the cost to guarantee loans, $383,433,000 is hereby permanently cancelled.

Note.—A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115–56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution.

Explanation of Changes

The FY 2019 Budget eliminates the Title XVII program and proposes to cancel all remaining loan volume authority. In addition to $10,000,000 in appropriation offset by $3,000,000 in collections, the Loan Programs Office will utilize unobligated balances carried forward from prior year appropriations to cover loan portfolio monitoring and administrative expenses; including salaries for its full time employees as well as the cost of outside advisors for financial, legal, engineering, credit, and market analysis. The LPO will wind down operations in FY 2019 with the expectation that it will shut down in FY 2020 with remaining loan monitoring and closeout activities transferred to another office. All activities not essential for the continued monitoring of the portfolio will be terminated.

Public Law Authorizations

- P.L. 109-58, Energy Policy Act of 2005
- P.L. 110-5, Revised Continuing Appropriations Resolution, 2007
- P.L. 111-5, American Recovery and Reinvestment Act of 2009
- P.L. 111-8, Omnibus Appropriations Act, 2009
- P.L. 112-10, Department of Defense and Full-Year Continuing Appropriations Act, 2011

[1] The language in the third proviso corrects an error in the Budget Appendix that was not identified prior to typesetting of the President's Budget. The proviso should read "That fees collected pursuant to such section 1702(h) for fiscal year **2019**…" instead of "fiscal year **2018**…" as stated in the Appendix.

Title 17 Innovative Technology Loan Guarantee Program
($K)

	FY 2017 Enacted	FY 2018 Annualized CR[4]	FY 2019 Request
Administrative Expenses	$37,000	$36,749	$10,000
Rescissions[1]	-$9,861	$0	$0
Offsetting Collections[5]	-$27,000	-$20,000	-$3,000
Total	**$139**	**$16,749**	**$7,000**
FY2011 Loan Subsidy Recission[2]	-$9,000	-$9,000	$0
ARRA Loan Subsidy Cancelation[3]	$0	$0	-$383,433

[1]Recission of administrative appropriations from FY 2012 and FY 2013 (Pub. L. 115-31)

[2]Due to FY 2018 appropriations uncertainty, the Budget does not assume the availability of unobligated balances appropriated by the Department of Defense and Full-Year Continuing Appropriations Act of 2011 (Pub. L. 112-10) for cancelation. However, rescission of these balances would be consistent with the proposal to eliminate the Title 17 program.

[3]The Budget proposes to cancel $383 million in unobligated balances appropriated by the American Reinvestment and Recovery Act of 2009 (Pub. L. 111-5).

[4]A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution. (These amounts are shown only at the Congressional control level and above; below that level, a dash (—) is shown).

[5] The FY 2017 Budget estimate for offsetting collection was $27 million. The FY2017 Congressional estimate for offsetting collections was $30 million. Actual offsetting collections was $14.2 million.

Overview

The Budget proposes the elimination of the Title XVII Innovative Technology Loan Guarantee Program because the private sector is better positioned to finance the deployment of commercially viable projects. The Federal role in supporting advanced technologies is strongest in the early stages of research and development. The Government should not be in the business of picking which technologies "win" the commercialization race and displacing private sector investment opportunities. Instead, the Government should recognize the private sector's primary role in taking risks to finance projects in the energy sector. In addition, the relative inactivity of this program indicates it is ineffective at attracting borrowers with viable projects who are unable to secure private sector financing.

History

Section 1703 of the Energy Policy Act of 2005 authorizes DOE to provide loan guarantees for innovative energy projects in categories including advanced nuclear facilities, coal gasification, carbon sequestration, energy efficiency, renewable energy systems, and various other types of projects. Projects supported by DOE loan guarantees must avoid, reduce, or sequester air pollutants or anthropogenic emissions of greenhouse gases; employ new or significantly improved technologies compared to commercial technologies in service in the United States at the time the guarantee is issued; and offer a reasonable prospect of repayment of the principal and interest on the guaranteed obligation. Section 406 of the American Recovery and Reinvestment Act of 2009, Pub. L. No. 111-5 (Recovery Act) amended Title XVII of the Energy Policy Act of 2005 by establishing Section 1705 as a temporary program for the rapid deployment of renewable energy and electric power transmission projects, as well as leading edge biofuels projects. The authority to enter into new loan guarantees under Section 1705 expired on September 30, 2011, but LPO continues to administer and monitor the portfolio of loan guarantees obligated prior to the expiration date.

The Title XVII Loan Guarantee Program issued 37 total loan guarantees, of which $21.24 billion has been obligated[2] and $18.46 billion has been disbursed to date.

Organization

LPO currently utilizes three divisions to proactively monitor the portfolio: Portfolio Management Division (PMD), Technical and Project Management Division (TPMD), and Legal division. The elimination of the Loan Programs Office's loan origination activities will reduce functional organizations to core functions with corporate services provided from other departmental elements.

The Portfolio Management Division (PMD) lead LPO's monitoring functions by approving disbursements, repayments, operating budgets, and long-term forecasts. In the event of non-payment and/or default, PMD leads activities to maximize recoveries either through bankruptcy, note sale, or compromise of the claim. PMD will monitor the portfolio in accordance regulatory requirements.

The Technical and Project Management Division (TPMD) supports PMD by evaluating the technical performance of assets and project management throughout the entire lifecycle of the loan to ensure that the technical requirements of the loan agreement are met. TPMD conducts site visits, provides expertise on project construction status and budget, and identifies potential technical risks that inhibit the borrower's ability to meet requirements and repay the loan.

LPO Legal Division supports PMD in all on-going monitoring activities, negotiations and documentations of waivers, consents, routine loan amendments, approvals and denials of transfer withdrawals, and legal aspects of any project developments.

In FY 2019 LPO will continue to consolidate and streamline the organizational structure of monitoring activities to effectively manage the portfolio of loans while minimizing the administrative burden. In addition, LPO will explore options to reduce or mitigate the expected administrative cost of monitoring over the tenor of the remaining loans. LPO will wind down operations in FY 2019 with the expectation that it will shut down in FY 2020 with remaining loan monitoring and closeout activities transferred to another office.

Highlights and Major Changes in the FY 2019 Budget Request.

In FY 2019, LPO will commence termination of Title XVII loan guarantee activities and continue to monitor the existing portfolio.

[2] Net of recoveries

Title 17 Innovative Technology Loan Guarantee Program Funding by Congressional Control
($K)

	FY 2017 Enacted	FY 2018 Annualized CR[4]	FY 2019 Request	FY 2019 Request vs FY 2017 Enacted
Title 17 Innovative Technology Loan Guarantee Program				
Administrative Expenses				
Appropriation	37,000	36,749	10,000	-27,000
Offsetting Collections[5]	-27,000	-20,000	-3,000	24,000
Rescission (Administrative Balances)[1]	-9,861	0	0	9,861
Total, Title 17 Innovative Technology Loan Guarantee Program	**139**	**16,749**	**7,000**	**6,861**
Federal FTEs	**118**	**80**	**68**	**-50**
FY2011 Loan Subsidy Rescission[2]	**-$9,000**	**-$9,000**	**$0**	**$0**
ARRA Loan Subsidy Cancelation[3]	**$0**	**$0**	**$0**	**-$383,433**

[1]Recission of administrative appropriations from FY 2012 and FY 2013 (Pub. L. 115-31)

[2] Due to FY 2018 appropriations uncertainty, the Budget does not assume the availability of unobligated balances appropriated by the Department of Defense and Full-Year Continuing Appropriations Act of 2011 (Pub. L. 112-10) for cancelation. However, rescission of these balances would be consistent with the proposal to eliminate the Title 17 program.

[3]The Budget proposes to cancel $383 million in unobligated balances appropriated by the American Reinvestment and Recovery Act of 2009 (Pub. L. 111-5).

[4] A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution. (These amounts are shown only at the Congressional control level and above; below that level, a dash (—) is shown).

[5] The FY 2017 Budget estimate for offsetting collection was $27 million. The FY2017 Congressional estimate for offsetting collections was $30 million. Actual offsetting collections was $14.2 million.

Administrative Expenses Funding ($K)

	FY 2017 Enacted	FY 2018 Annualized CR*	FY 2019 Request	FY 2019 Request Vs FY 2017 Enacted
Administrative Expenses				
Salary & Benefits	21,240	-	5,120	-16,120
Travel	1,000	-	120	-880
Support Services	7,680	-	3,000	-4,680
Other Related Expenses	7,080	-	1,760	-5,320
Total, Administrative Expenses	**37,000**	36,749	**10,000**	**-27,000**

*A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution. (These amounts are shown only at the Congressional control level and above; below that level, a dash (—) is shown).

Administrative Expenses
Explanation of Major Changes
($K)

	FY 2019 Request vs FY 2017 Enacted
Administrative Expenses	
Salaries and Benefits: In addition to the $5,120,000 requested for salaries and benefits, LPO will utilize unobligated balances carried forward from prior appropriations to provide salaries and benefits for 68 full time equivalent employees (FTEs).	**-16,120**
Travel: In addition to the $120,000 requested for travel, LPO will utilize unobligated balances carried forward from prior appropriations to support the travel of staff members for site visits, training, and attending meetings and conferences.	**-880**
Support Services: In addition to the $3,000,000 requested for support services, LPO will utilize unobligated balances carried forward from prior appropriations to support outside expertise in finance, legal, engineering, technology, credit analysis, and market assessments.	**-4,680**
Other Related Expenses: In addition to the $1,760,000 requested for other related expenses, LPO will utilize unobligated balances carried forward from prior appropriations to support DOE working capital, DOE IT services, and training requirements.	**-5,320**
Total, Administrative Expenses	**-27,000**

Administrative Expenses

Activities and Explanation of Changes

FY 2017Enacted	FY 2019 Request	Explanation of Changes FY 2019 vs FY 2017
Administrative Expenses $37,000,000	**$10,000,000**	**-$27,000,000**
Salaries and Benefits $21,240,000	**$5,120,000**	**-$16,120,000**
• To provide salaries and benefits to 118 full time equivalent employees to administer the following functions to the office: Director, Legal, Loan Origination, Management Operations, Environmental Compliance, Portfolio Management, Risk Management, and Technical and Project Management.	• In addition to prior year funds, this request will support the salaries and benefits of 68 full time equivalent employees to administer the following functions to the office: Director, Legal, Management Operations, Environmental Compliance, Portfolio Management, Risk Management, and Technical and Project Management.	• In FY 2019 program all activities not essential for the continued monitoring of the portfolio will be terminated. Resultantly, the decrease is in accordance to the termination of origination activities and to match expected salary requirements.
Travel $1,000,000	**$120,000**	**-$880,000**
• Continuation of FY 2018 activities. Supports the travel of staff members for outreach to applicants, site visits, as well as attending meetings and conferences.	• Supports the travel of staff members for site visits, as well as attending meetings and conferences.	• The decrease is in accordance to the termination of origination activities and to match expected travel requirements.
Support Services $7,680,000	**$3,000,000**	**-$4,680,000**
• Continuation of FY 2018 activities. Provides range of contract services including administrative support, subject matter experts, legal services, information technology, and publications.	• Supports range of contract services including administrative support, subject matter experts, legal services, information technology, publications, credit analysis and market assessments.	• The decrease is in accordance to the termination of origination activities to match expected support service requirements.
Other Related Expenses $7,080,000	**$1,760,000**	**-$5,320,000**
• Continuation of FY 2018 activities. Supports DOE Working Capital Fund, Energy IT Services - Desktop Services, expenses, and LGP federal staff training.	• Supports DOE Working Capital Fund, DOE IT Services expenses, and LPO federal staff training.	• The decrease is in accordance to the termination of origination activities and to match expected working capital, DOE IT services, and training requirements.

Title 17 Innovative Technology Loan Guarantee Program
Performance Measures

In accordance with the GPRA Modernization Act of 2010, the Department sets targets for, and tracks progress toward, achieving performance goals for each program.

	FY 2017	FY 2018	FY 2019
Performance Goal (Measure)	CO2 Reductions Loans Guarantee - Estimated annual CO2 emissions reductions of projects receiving loan guarantees that have achieved commercial operations.		
Target	≥ 21,200,000 mt	≥ 21,200,000 mt	≥ 21,200,000 mt
Result	Met - 22,500,000	TBD	TBD
Endpoint Target	On an ongoing basis, projects receiving loan guarantees that have achieved commercial operations will have lower estimated annual CO2 emissions reductions compared to “business as usual” energy generation.		
Comment	The President’s FY 2019 Budget eliminates the origination of any new loans under the Title XVII Innovative Technology Loan Guarantee Program.		
Performance Goal (Measure)	**Generation Capacity of Projects Receiving Loan Guarantees - Increase annual generation capacity from projects receiving DOE loan guarantees that have achieved commercial operations. (Gigawatts, GW)**		
Target	≥ 4 GW	≥ 4 GW	≥ 4.0 GW
Result	Met - 4	TBD	TBD
Endpoint Target	Continue to meet annual target until the loans are repaid.		
Comment	The President’s FY 2019 Budget eliminates the origination of any new loans under the Title XVII Innovative Technology Loan Guarantee Program.		

Department of Energy

FY 2019 Congressional Budget

Funding by Appropriation by Site

($K)

	FY 2017 Enacted	FY 2018 Annualized CR	FY 2019 Request
Innovative Tech Loan Guarantee Prog			
Washington Headquarters			
Administrative Operations			
Administrative Operations	37,000	36,749	10,000
Total, Washington Headquarters	**37,000**	**36,749**	**10,000**
Total, Innovative Tech Loan Guarantee Prog	**37,000**	**36,749**	**10,000**

Tribal Energy Guarantee Loan Program

Tribal Energy Guarantee Loan Program

Tribal Energy Loan Guarantee Program
Proposed Appropriation Language

Of the unobligated balances available under this heading for the cost of loan guarantees, $8,500,000 are hereby permanently cancelled.
Note.—A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115–56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution.

Explanation of Changes

Section 2602 of the Energy Policy Act of 1992, as amended by the Energy Policy Act of 2005, authorized a loan guarantee program at the Department of Energy to support energy development by Indian tribes. The program was first appropriated funding by the Consolidated Appropriations Act of 2017 which provided $8,500,000 for the cost of loan guarantees and $500,000 for the administrative expenses. Rules detailing how the program would be implemented have not been promulgated. The Budget eliminates the Tribal Energy Loan Guarantee program and proposes to cancel the $8,500,000 appropriated for the cost of loan guarantees.

Public Law Authorizations

- P.L.102-486, Energy Policy Act of 1992, as amended

Tribal Energy Loan Guarantee Program
($K)

	FY 2017 Enacted	FY 2018 Annualized CR*	FY 2019 Request	FY 2019 Request vs FY 2017 Enacted
Administrative Expenses	500	497	0	-9,000
Loan Subsidy	8,500	8,442		
Cancellation	0	0	-8,500	-8,500
Total	**9,000**	**8,939**	**-8,500**	**-500**

*A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution. (These amounts are shown only at the Congressional control level and above; below that level, a dash (—) is shown).

Overview

Originally authorized in 2005, the Tribal Energy Loan Guarantee Program was first appropriated funding in FY 2017. Rules detailing how the program would be implemented have not been promulgated; however, the program authorization is redundant with loan and loan guarantee programs administered by other agencies with missions to serve Tribal entities. The Budget proposes to eliminate this program and cancel unobligated balances.

Department of Energy

FY 2019 Congressional Budget

Funding by Appropriation by Site

($K)

Tribal Indian Energy Loan Guarantee Program	FY 2017 Enacted	FY 2018 Annualized CR	FY 2019 Request
Washington Headquarters			
Tribal Indian Energy Loan Guarantee Program			
Administrative Operations	500	497	0
Loan guarantee credit subsidy costs	8,500	8,442	0
Total, Tribal Indian Energy Loan Guarantee Program	**9,000**	**8,939**	**0**
Total, Washington Headquarters	**9,000**	**8,939**	**0**
Total, Tribal Indian Energy Loan Guarantee Program	**9,000**	**8,939**	**0**

Energy Information Administration

Energy Information Administration

U.S. Energy Information Administration

Proposed Appropriation Language

For necessary expenses in carrying out the activities of the U.S. Energy Information Administration, $115,035,000, to remain available until expended.

Explanation of Change

No changes.

Public Law (P.L.) Authorizations

P.L. 83-703, Atomic Energy Act (1954)
P.L. 93-275, 15 U.S.C. 761, Federal Energy Administration Act (1974)
P.L. 93-319, Energy Supply and Environmental Coordination Act (1974)
P.L. 94-163, Energy Policy and Conservation Act (1975)
P.L. 94-385, 15 U.S.C. 790, Energy Conservation and Production Act (1976)
P.L. 95-91, 42 U.S.C. 7135, Department of Energy Organization Act (1977)
P.L. 95-620, 42 U.S.C. 8301, Powerplant and Industrial Fuel Use Act (1978)
P.L. 95-621, Natural Gas Policy Act (1978)
P.L. 96-294, Energy Security Act (1980)
P.L. 97-229, 42 U.S.C. 6245, Energy Emergency Preparedness Act (1982)
P.L. 97-415 Nuclear Regulatory Commission Authorization Act (1983)
P.L. 99-58, National Coal Imports Reporting Act (1985)
P.L. 99-58, 42 U.S.C. 6201, Energy Policy and Conservation Act Amendments of 1985
P.L. 100-42, 42 U.S.C. 8312, Powerplant and Industrial Fuel Use Act Amendments of 1987
P.L. 102-486, 42 U.S.C. 13385, Energy Policy Act (1992)
P.L. 107-347, Title V of E-Government Act of 2002, Confidential Information Protection and Statistical Efficiency Act of 2002
P.L. 109-58, 42 U.S.C. 15801, Energy Policy Act of 2005
P.L. 110-140, Energy Independence and Security Act (2007)
P.L. 112-81, National Defense Authorization Act for Fiscal Year 2012
P.L. 112-158, Iran Threat Reduction and Syria Human Rights Act of 2012
P.L. 113-125, Reliable Home Heating Act of 2014
P.L. 114-11, Energy Efficiency Improvement Act of 2015

Energy Information Administration
Congressional Control: National Energy Information System (NEIS)
($K)

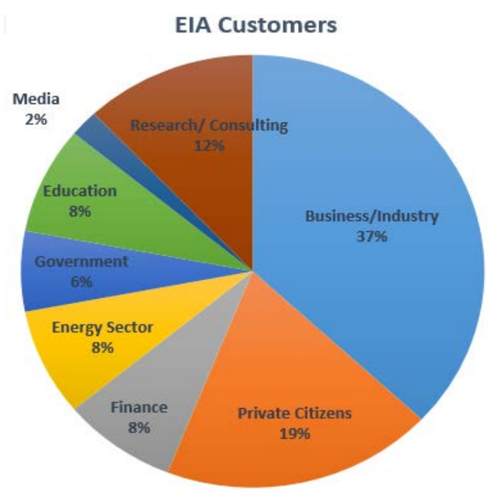
FY 2017 Enacted	FY 2018 Annualized CR*	FY 2019 Request	FY 2019 Request vs FY 2017 Enacted
122,000	121,171	115,035	-6,965

*A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution. (These amounts are shown only at the Congressional control level and above; below that level, a dash (—) is shown).

Overview
The U.S. Energy Information Administration (EIA) is the statistical and analytical agency within the U.S. Department of Energy (DOE). EIA collects, analyzes, and disseminates independent and impartial energy information to promote sound policymaking, efficient markets, and public understanding of energy and its interaction with the economy and the environment. EIA is the nation's premier source of energy information and, by law, its data, analyses, and forecasts are independent of approval by any other officer or employee of the U.S. Government.

EIA conducts a wide range of data collection, analysis, forecasting, and dissemination activities to ensure that its customers, including Congress, federal and state government, the private sector, public, and the media, have ready access to timely, reliable, and relevant energy information. EIA's data and analysis help inform important energy-related decisions, including utilization strategies; availability of energy sources; government, business and personal investment decisions; and policy development.

Highlights of the FY 2019 Budget Request
The FY 2019 Request is $115,035 for continuing operations. EIA has evolved its program in recent years to provide an expanding customer base with coverage of increasingly complex and interrelated energy markets. For example, EIA has addressed new energy developments such as the advent of shale gas, tight oil, and distributed solar, as well as the changing economics of nuclear energy, and the removal of restrictions on U.S. crude oil exports. The agency's ability to adapt to a changing industry landscape has been essential to the nation's ongoing dialogue on important energy issues.



Source: 2017 EIA Web Customer Survey

The FY 2019 budget request will enable EIA to continue core statistical and analysis activities that produce reports critical to EIA's customer base, including:

- Weekly Natural Gas Storage Report (WNGSR), which is designated as one of the nation's Principal Federal Economic Indicators
- Weekly Petroleum Status Report (WPSR), which provides statistics on oil and petroleum product stocks, imports, and production
- Short-Term Energy Outlook (STEO), which provides monthly forecasts of U.S. and global supply, consumption, trade, stocks, and prices with a horizon of 12 to 24 months
- Annual Energy Outlook (AEO), which projects U.S. energy supply, consumption, and trade over a 25- to 30-year period

The FY 2019 budget request will also enable EIA to follow through on planned cybersecurity initiatives and maintain recent program enhancements that have improved its coverage of a dynamic U.S. energy sector.

Energy Data Program
EIA's comprehensive energy data program conducts surveys of energy suppliers and consumers and then processes and integrates the data to produce a full range of publicly available reports spanning the energy landscape. EIA strives to make high-quality data available in formats and structures that serve the analytical needs of its customers. The energy data program also provides the basis for EIA's energy analysis and forecasting activities, including key inputs for its short- and long-term energy models.

Energy Supply Surveys
The energy supply survey program represents EIA's data foundation and largest operational area, publishing more than 300 reports a year across weekly, monthly, quarterly, and annual product lines. Most recently, EIA also began collecting and disseminating near real-time electricity demand data from the nation's balancing authorities, a first for a government statistical agency. The program collects comprehensive data that collectively illustrate the complex flows of energy production, distribution, and end-uses across sectors, including oil and gas, coal, refined products, nuclear power, renewables, biofuels, and electric power. The energy supply survey program employs a broad range of statistical expertise in support of its data collection efforts, including sampling, imputation, estimation, survey frame management, quality assurance, and periodic development of new data collection and survey instruments. Producers, consumers, investors, traders, and analysts use a wealth of EIA energy statistics in their day-to-day activities in the global energy marketplace. For example, the WPSR and WNGSR typically spur price formation activity to balance markets.

Energy Consumption and Efficiency Surveys
EIA collects and publishes definitive, national, end-use consumption data for commercial buildings, residential buildings, and manufacturing through the use of three complex, large-scale, multi-year surveys. The *Commercial Buildings Energy Consumption Survey (*CBECS) provides the only comprehensive, statistically reliable source of information on energy consumption, expenditures, and end-uses in U.S. commercial buildings. The *Residential Energy Consumption Survey* (RECS) collects information from a nationally representative sample of housing units, including data on energy characteristics of homes, usage patterns, and household demographics. Linked with production and employment data from Census Bureau economic surveys, the *Manufacturing Energy Consumption Survey* (MECS) provides information on energy throughput and economic and operational characteristics of U.S. manufacturers. These surveys are critical to understanding changes in energy use and are the basis for benchmarking. Because of the scale and complexity of these surveys, EIA continues to explore innovative methodologies for collecting valid survey samples at lower cost through different modes (e.g., telephone, mail, web, and third party validated data).

Energy Analysis Program
EIA conducts a robust energy analysis program to bring meaning and context to a rapidly-evolving energy marketplace. The program maintains and operates the *National Energy Modeling System* (NEMS,) the nation's preeminent tool for developing long-term projections of U.S. energy production, consumption, prices, and technologies. EIA's modeling outputs underpin its flagship projections, including the AEO, *International Energy Outlook* (IEO), and STEO, as well as other special and periodic topical analyses. Analysts across the energy community benchmark against these analyses.

In addition to its modeling and forecasting work, the program produces a range of recurring reports, such as *Today in Energy*, *Drilling Productivity Report,* and *This Week in Petroleum.* Regional data are also used in analysis like the *Refinery Outages Report* assessing risk and oil-related supply conditions, and monthly reporting on movements of crude oil, ethanol, and propane by rail. The program is staffed with experts in all areas of the energy sector, including fossil fuels, nuclear, renewables, electricity, transportation, and energy efficiency.

EIA has expanded the depth and breadth of its international energy coverage, in particular with regard to international trade flows and their impact on U.S. domestic energy markets. For example, EIA has produced analysis of the implications of removing restrictions on U.S. crude oil and natural gas exports, including modeling of prices, production, and trade effects, and has also published updated country and regional reports on major energy economies. Cooperation with Canada has led to greater homogenization of crude oil trade data, for example.

Communications
EIA's comprehensive communications program interfaces with diverse external customer groups and manages the public website (www.eia.gov), press and media relations, marketing and outreach services, and an employee intranet. EIA's website features state-of-the-art technologies such as customizable data browsers, interactive state, national, and North American energy infrastructure maps, and open data initiatives like Application Programming Interfaces (APIs) that have greatly increased information accessibility to EIA's customers. The design and customization of EIA's website and multimedia content features are updated based on external feedback mechanisms, including web traffic analytics and input from the annual web customer survey. The program also maintains EIA's award-winning educational products, such as *Energy Kids*, and executes a robust social media and state outreach strategy.

Resource and Technology Management
This function provides overall business management, analysis, and mission support to EIA and in response to requests from other components of DOE. Activities include workforce development and administration, financial and budget management, acquisition of support services, project management, and program evaluation. The program also manages EIA's information technology (IT) functions to ensure a stable, operable IT infrastructure that meets data confidentiality and cybersecurity requirements.

Cybersecurity
EIA will provide sufficient funding to ensure a robust cybersecurity program while continuing to modernize its IT processing platform. EIA is assessing its cybersecurity posture to identify vulnerabilities and outline mitigation strategies.

Accomplishments
In FY 2017, EIA continued to deliver on new initiatives that have closed crucial gaps in its information program and provided new insights into the nation's energy future. For example, EIA:

- Redesigned its three flagship reports on energy projections, the AEO, IEO, and STEO, to better serve customer needs and increase operational efficiencies; the STEO's coverage of energy markets was also expanded to include forecasts for rooftop solar generation
- Completed fuel market studies that allowed EIA to support the Department's hurricane relief efforts by providing timely data and analyses about regional energy infrastructure and logistics
- Released data from MECS, an effort conducted in conjunction with the U.S. Census Bureau to collect and publish data on energy use and energy intensity in the domestic manufacturing sector
- Published characteristics data from the recent RECS, including tables, summary reports, and a public-use microdata file
- Released a fall/winter version of the *Southern California Daily Energy Report* focusing on dynamically generated natural gas data to complement the electricity-based summer version
- Launched, in collaboration with the states of the Groundwater Protection Council, the *National Oil and Gas Gateway*, which is the first publicly available national database of well level oil and gas data; EIA also made the software available to the states to improve accessibility on their own websites
- Expanded EIA's open data program by adding new data on state energy-related emissions and water consumption in the electricity generation sector to EIA's application programming interface
- Provided critical information and support for the Secretary of Energy's grid reliability report

Program Direction Funding
($K)

	FY 2017 Enacted	FY 2018 Annualized CR*	FY 2019 Request	FY 2019 Request vs FY 2017 Enacted
Program Direction				
Salaries and Benefits	56,389	--	54,250	-2,139
Travel	278	--	278	0
Support Services	44,870	--	40,009	-4,861
Other Related Expenses	20,463	--	20,498	35
Total, Program Direction	**122,000**	**121,171**	**115,035**	**-6,965**
Federal FTEs	**375**	**375**	**370**	**-5**
Support Services				
Technical Support				
Administrative Support Services	9	--	9	0
Human Resources Support Services	4	--	4	0
E-Government Support Services	1	--	1	0
Scientific/Technical and IT Training	40	--	40	0
Data Center (Application Hosting/Housing)	180	--	180	0
IT Management Services	5,508	--	5,508	0
Other Advisory and Assistance Services	37,698	--	32,837	-4,861
Total, Technical Support	**43,440**	**--**	**38,579**	**-4,861**
Management Support				
Program Management	1,430	--	1,430	0
Total, Management Support	1,430	--	1,430	0
Total, Support Services	**44,870**	**--**	**40,009**	**-4,861**
Other Related Expenses				
Communications, utilities, and misc. charges	4,257	--	4,257	0
Training	466	--	466	0
Other goods and services from Federal sources	310	--	345	35
Working Capital Fund	9,694	--	9,694	0
O&M of IT systems or equipment	1,144	--	1,144	0
Printing, supplies and materials	1,300	--	1,300	0
Equipment	2,967	--	2,967	0
Grants, subsidies, and contributions	325	--	325	0
Total, Other Related Expenses	**20,463**	**--**	**20,498**	**35**

*A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution. (These amounts are shown only at the Congressional control level and above; below that level, a dash (—) is shown).

Program Direction

Activities and Explanation of Changes

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Salaries and Benefits $56,389,000	**$54,250,000**	**-$2,139,000**
Provide salaries and benefits for 375 FTEs supporting: • Administrator's office (8 FTEs) • Energy data program (157 FTEs) • Energy analysis (126 FTEs) • Communications (32 FTEs) • Resource and technology management (52 FTEs)	Provide salaries and benefits for 370 FTEs supporting: • Administrator's office (8 FTEs) • Energy data program (154 FTEs) • Energy analysis (124 FTEs) • Communications (32 FTEs) • Resource and technology management (52 FTEs)	Reduced salary and benefit costs with 5 fewer FTE. Vacancies will be re-established at lower grades.
Travel $278,000	**$278,000**	**$0**
Provide essential travel for EIA stakeholder engagement—both for representing EIA in public forums and engaging with industry experts.	Provide essential travel for EIA stakeholder engagement—both for representing EIA in public forums and engaging with industry experts.	Maintain travel costs at FY 2017 level.
Support Services $44,870,000	**$40,009,000**	**- $4,861,000**
Energy Supply Surveys $15,965,000 Operate core supply data collection program. • Produce more timely data on petroleum product exports, including gasoline, diesel fuel, and propane • Set the framework for more granular petroleum supply surveys • Continue partnership with the Ground Water Protection Council (GWPC) to host well-level data	*Energy Supply Surveys $15,465,000* Operate core supply data collection program. • Adopt and begin implementation of Statistical Methods Improvement Plan	*Energy Supply Surveys -$500,000* Maintain current scope of data program's coverage.
Energy Consumption and Efficiency Surveys $9,321,000 Conduct commercial, residential, and manufacturing surveys. • Publication of 2016 MECS data • Award CBECS 2018 and begin project	*Energy Consumption and Efficiency Surveys $8,421,000* Conduct commercial, residential, and manufacturing surveys. • Conduct field survey collection phase of CBECS.	*Energy Consumption and Efficiency Surveys -$900,000* Deliver RECS in a six year cycle.
Energy Modeling and Analysis $9,326,000 Continue core forecasting and analysis work leading to the AEO, IEO, STEO and other reports and international capabilities. • Produce full IEO and AEO with updated reference cases • Maintain the flexibility and expertise base to respond to ad-hoc policy analysis needs	*Energy Modeling and Analysis $7,115,000* Deliver core analysis, forecasts, and projections (e.g., AEO, IEO, and STEO).	*Energy Modeling and Analysis -$2,211,000* Maintain current energy modeling capabilities.

FY 2017 Enacted	FY 2019 Request	Explanation of Changes FY 2019 Request vs FY 2017 Enacted
Communications $1,662,000 Maintain communication activities and invest in flexible web platforms to enhance data delivery. Maintain scope of energy mapping system, and continue to integrate mapping with relevant EIA time-series data sets.	*Communications $1,162,000* Maintain flexible web platforms to enhance data delivery. Maintain scope of energy mapping system, and continue to integrate mapping with relevant EIA time-series data sets.	*Communications -$500,000* Maintain current levels of information accessibility on EIA's website.
Resource and Technology Management $8,596,000 Provide overall business management, IT and network services, and administrative support to EIA offices and staff.	*Resource and Technology Management $7,846,000* Continue providing business management, IT and network services, and administrative support to EIA's offices and staff.	*Resource and Technology Management -$750,000* Continue IT systems and infrastructure modernization efforts.
Other Related Expenses $20,463,000	**$20,498,000**	**+$35,000**
Support the mission by paying for rent and shared services through the DOE Working Capital Fund, IT equipment and licenses, subscriptions, and employee training among other areas.	Support the mission by paying for rent and shared services through the DOE Working Capital Fund, IT equipment and licenses, subscriptions, and employee training among other areas.	Increased costs associated with Congressionally mandated Headquarters Security Investigations.

Performance Measures

In accordance with the GPRA Modernization Act of 2010, the Department sets targets for, and tracks progress toward, achieving performance goals for each program.

	FY 2017	FY 2018	FY 2019
Performance Goal (Measure)	**Quality of EIA Information Products - Percentage of customers who are satisfied or very satisfied with the quality of EIA information.**		
Target	≥ 90 % of customer satisfaction rating	≥ 90 % of customer satisfaction rating	≥ 90 % of customer satisfaction rating
Result	Met - 91	TBD	TBD
Endpoint Target	This is an ongoing annual performance measure, as information quality is central to EIA's mission.		
Performance Goal (Measure)	**Timeliness of EIA Information Products - Percentage of selected EIA recurring products meet their release date targets (all product types).**		
Target	≥ 95 % of products released on schedule	≥ 95 % of products released on schedule	≥ 95 % of products released on schedule
Result	Met - 96	TBD	TBD
Endpoint Target	This is an ongoing annual performance measure, as timely delivery of energy information is central to EIA's mission.		

Department of Energy
FY 2019 Congressional Budget
Funding by Appropriation by Site
($K)

Energy Information Administration	FY 2017 Enacted	FY 2018 Annualized CR	FY 2019 Request
Washington Headquarters			
Energy Information Administration			
National Energy Information System	122,000	121,171	115,035
Total, Washington Headquarters	**122,000**	**121,171**	**115,035**
Total, Energy Information Administration	**122,000**	**121,171**	**115,035**

GENERAL PROVISIONS—DEPARTMENT OF ENERGY
(INCLUDING TRANSFER OF FUNDS)

SEC. 301. (a) No appropriation, funds, or authority made available by this title for the Department of Energy shall be used to initiate or resume any program, project, or activity or to prepare or initiate Requests For Proposals or similar arrangements (including Requests for Quotations, Requests for Information, and Funding Opportunity Announcements) for a program, project, or activity if the program, project, or activity has not been funded by Congress.

(b) (1) Unless the Secretary of Energy notifies the Committees on Appropriations of both Houses of Congress at least 3 full business days in advance, none of the funds made available in this title may be used to—

(A) make a grant allocation or discretionary grant award totaling $1,000,000 or more;

(B) make a discretionary contract award or Other Transaction Agreement totaling $1,000,000 or more, including contract covered by the Federal Acquisition Regulation;

(C) issue a letter of intent to make an allocation, award, or Agreement in excess

(D) of the limits in subparagraph (A) or (B); or announce publicly the intention to make an allocation, award, or Agreement in excess of the limits in subparagraph (A) or (B).

(2) The Secretary of Energy shall submit to the Committees on Appropriations of both Houses of Congress within 15 days of the conclusion of each quarter a report detailing each grant allocation or discretionary grant award totaling less than $1,000,000 provided during the previous quarter.

(3) The notification required by paragraph (1) and the report required by paragraph (2) shall include the recipient of the award, the amount of the award, the fiscal year for which the funds for the award were appropriated, the account and program, project, or activity from which the funds are being drawn, the title of the award, and a brief description of the activity for which the award is made.

(c) The Department of Energy may not, with respect to any program, project, or activity that uses budget authority made available in this title under the heading "Department of Energy—Energy Programs", enter into a multiyear contract, award a multiyear grant, or enter into a multiyear cooperative agreement unless—

(1) the contract, grant, or cooperative agreement is funded for the full period of performance as anticipated at the time of award; or

(2) the contract, grant, or cooperative agreement includes a clause conditioning the Federal Government's obligation on the availability of future year budget authority and the Secretary notifies the Committees on Appropriations of both Houses of Congress at least 3 days in advance.

(d) Except as provided in subsections (e), (f), and (g), the amounts made available by this title shall be expended as authorized by law for the programs, projects, and activities specified in the "Final Bill" column in the "Department of Energy" table included under the heading "Title III—Department of Energy" in the explanatory statement accompanying this Act.

(e) The amounts made available by this title may be reprogrammed for any program, project, or activity, and the Department shall notify the Committees on Appropriations of both Houses of Congress at least 30 days prior to the use of any proposed reprogramming that would cause any program, project, or activity funding level to increase or decrease by more than $5,000,000 or 10 percent, whichever is less, during the time period covered by this Act.

(f) None of the funds provided in this title shall be available for obligation or expenditure through a reprogramming of funds that—

(1) creates, initiates, or eliminates a program, project, or activity;

(2) increases funds or personnel for any program, project, or activity for which funds are denied or restricted by this Act; or

(3) reduces funds that are directed to be used for a specific program, project, or activity by this Act.

(g) (1) The Secretary of Energy may waive any requirement or restriction in this section that applies to the use of funds made available for the Department of Energy if compliance with such requirement or restriction would pose a substantial risk to human health, the environment, welfare, or national security.

(2) The Secretary of Energy shall notify the Committees on Appropriations of both Houses of Congress of any waiver under paragraph (1) as soon as practicable, but not later than 3 days after the date of the activity to which a requirement or restriction would otherwise have applied. Such notice shall include an explanation of the substantial risk under paragraph (1) that permitted such waiver.

SEC. 302. The unexpended balances of prior appropriations provided for activities in this Act may be available to the same appropriation accounts for such activities established pursuant to this title. Available balances may be merged with funds in the applicable established accounts and thereafter may be accounted for as one fund for the same time period as originally enacted.

SEC. 303. Funds appropriated by this or any other Act, or made available by the transfer of funds in this Act, for intelligence activities are deemed to be specifically authorized by the Congress for purposes of section 504 of the National Security Act of 1947 (50 U.S.C. 3094) during fiscal year 2019 until the enactment of the Intelligence Authorization Act for fiscal year 2019.

SEC. 304. None of the funds made available in this title shall be used for the construction of facilities classified as high-hazard nuclear facilities under 10 CFR Part 830 unless independent oversight is conducted by the Office of Enterprise Assessments to ensure the project is in compliance with nuclear safety requirements.

SEC. 305. None of the funds made available in this title may be used to approve critical decision–2 or critical decision–3 under Department of Energy Order 413.3B, or any successive departmental guidance, for construction projects where the total project cost exceeds $100,000,000, until a separate independent cost estimate has been developed for the project for that critical decision.

SEC. 306. Notwithstanding section 301(c) of this Act, none of the funds made available under the heading "Department of Energy—Energy Programs—Science" in this or any subsequent Energy and Water Development and Related Agencies appropriations Act for any fiscal year may be used for a multiyear contract, grant, cooperative agreement, or Other Transaction Agreement of $1,000,000 or less unless the contract, grant, cooperative agreement, or Other Transaction Agreement is funded for the full period of performance as anticipated at the time of award.

SEC. 307. (a) NEW REGIONAL RESERVES.—The Secretary of Energy may not establish any new regional petroleum product reserve unless funding for the proposed regional petroleum product reserve is explicitly requested in advance in an annual budget submission and approved by the Congress in an appropriations Act.

(b) The budget request or notification shall include—

(1) the justification for the new reserve;

(2) a cost estimate for the establishment, operation, and maintenance of the reserve, including funding sources;

(3) a detailed plan for operation of the reserve, including the conditions upon which the products may be released;

(4) the location of the reserve; and

(5) the estimate of the total inventory of the reserve.

SEC. 308. Treatment of Lobbying and Political Activity Costs as Allowable Costs under Department of Energy Contracts.

(a) Allowable Costs.—

(1) Section 4801(b) of the Atomic Energy Defense Act (50 U.S.C. 2781(b)) is amended—

(A) by striking "(1)" and all that follows through "the Secretary" and inserting The Secretary"; and

(B) by striking paragraph (2).

(2) Section 305 of the Energy and Water Development Appropriation Act, 1988, as contained in section 101(d) of Public Law 100–202 (101 Stat. 1329–125), is repealed.

(b) Regulations Revised.—The Secretary of Energy shall revise existing regulations consistent with the repeal of 50 U.S.C. 2781(b)(2) and section 305 of Public Law 100–202 and shall issue regulations to implement 50 U.S.C. 2781(b), as amended by subsection (a), no later than 150 days after the date of the enactment of this Act. Such regulations shall be consistent with the Federal Acquisition Regulation 48 C.F.R. 31.205–22.

SEC. 309. Not to exceed 5 percent of any appropriation made available for Department of Energy activities funded in this Act may be transferred between such appropriations, but no such appropriation, except as otherwise provided, shall be increased or decreased by more than 5 percent by any such transfers, and notification of any such transfers shall be submitted promptly to the Committees on Appropriations of the House of Representatives and the Senate.

SEC. 310. Notwithstanding section 161 of the Energy Policy and Conservation Act (42 U.S.C. 6241), the Secretary of Energy shall draw down and sell one million barrels of refined petroleum product from the Strategic Petroleum Reserve during fiscal year 2019. Proceeds from sales under this section shall be deposited into the general fund of the Treasury during fiscal year 2019.

SEC. 311. The Secretary of Energy may draw down and sell up to 1 million barrels of crude oil from the Strategic Petroleum Reserves during fiscal year 2019. The proceeds of such sale shall be deposited into the SPR Petroleum Account and shall remain available until expended.

Title V—General Provisions

Sec. 501. None of the funds appropriated by this Act may be used in any way, directly or indirectly, to influence congressional action on any legislation or appropriation matters pending before Congress, other than to communicate to Members of Congress as described in 18 U.S.C. 1913.

Sec. 502. None of the funds made available by this Act may be used in contravention of Executive Order No. 12898 of February 11, 1994 (Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations).