DOE/CF-0153
Volume 3 Part 2

Department of Energy
FY 2020 Congressional Budget Request

Energy Efficiency and Renewable Energy
Nuclear Energy
Advanced Research Projects Agency - Energy
Office of Indian Energy Policy and Programs
Advanced Tech. Vehicles Manufacturing Loan Program
Title 17—Innovative Tech. Loan Guarantee Program
Tribal Energy Loan Guarantee Program
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FUNDING BY APPROPRIATION

Department of Energy Budget by Appropriation	FY 2018 Enacted ($K)	FY 2019 Enacted ($K)	FY 2020 Request ($K)	FY 2020 Request vs FY 2019 Enacted $	FY 2020 Request vs FY 2019 Enacted %
Energy and Water Development, and Related Agencies					
Energy Programs					
Energy Efficiency and Renewable Energy	2,321,778	2,379,000	343,000	-2,036,000	-85.6%
Electricity Delivery and Energy Reliability	261,329	0	0	0	N/A
Electricity	0	156,000	182,500	+26,500	+17.0%
Cybersecurity, Energy Security, and Emergency Response	0	120,000	156,500	+36,500	+30.4%
Nuclear Energy	1,205,056	1,326,090	824,000	-502,090	-37.9%
Fossil Energy Programs					
Fossil Energy Research and Development	726,817	740,000	562,000	-178,000	-24.1%
Naval Petroleum and Oil Shale Reserves	4,900	10,000	14,000	+4,000	+40.0%
Strategic Petroleum Reserve	260,716	235,000	174,000	-61,000	-26.0%
Strategic Petroleum Account	8,400	10,000	27,000	+17,000	+170.0%
Northeast Home Heating Oil Reserve	6,500	10,000	0	-10,000	-100.0%
Total, Fossil Energy Programs	**1,007,333**	**1,005,000**	**777,000**	**-228,000**	**-22.7%**
Uranium Enrichment Decontamination and Decommissioning (D&D) Fund	840,000	841,129	715,112	-126,017	-15.0%
Energy Information Administration	125,000	125,000	118,000	-7,000	-5.6%
Non-Defense Environmental Cleanup	298,400	310,000	247,480	-62,520	-20.2%
Science	6,259,903	6,585,000	5,545,972	-1,039,028	-15.8%
Advanced Research Projects Agency - Energy	353,314	366,000	-287,000	-653,000	-178.4%
Nuclear Waste Disposal (26M in DNWF 050)	0	0	90,000	+90,000	N/A
Departmental Administration	189,652	165,858	117,545	-48,313	-29.1%
Indian Energy Policy and Programs	0	18,000	8,000	-10,000	-55.6%
Inspector General	49,000	51,330	54,215	+2,885	+5.6%
International Affairs	0	0	36,100	+36,100	N/A
Title 17 - Innovative Technology Loan Guarantee Program	30,892	13,000	-160,659	-173,659	-1,335.8%
Advanced Technology Vehicles Manufacturing Loan Program	5,000	5,000	0	-5,000	-100.0%
Tribal Energy Loan Guarantee Program	1,000	1,000	-8,500	-9,500	-950.0%
Total, Energy Programs	**12,947,657**	**13,467,407**	**8,759,265**	**-4,708,142**	**-35.0%**
Atomic Energy Defense Activities					
National Nuclear Security Administration					
Federal Salaries and Expenses	407,595	410,000	434,699	+24,699	+6.0%
Weapons Activities	10,642,138	11,100,000	12,408,603	+1,308,603	+11.8%
Defense Nuclear Nonproliferation	1,999,219	1,930,000	1,993,302	+63,302	+3.3%
Naval Reactors	1,620,000	1,788,618	1,648,396	-140,222	-7.8%
Total, National Nuclear Security Administration	**14,668,952**	**15,228,618**	**16,485,000**	**+1,256,382**	**+8.3%**
Environmental and Other Defense Activities					
Defense Environmental Cleanup	5,988,048	6,024,000	5,506,501	-517,499	-8.6%
Other Defense Activities	840,000	860,292	1,035,339	+175,047	+20.3%
Defense Nuclear Waste Disposal (90M in 270 Energy)	0	0	26,000	+26,000	N/A
Total, Environmental and Other Defense Activities	**6,828,048**	**6,884,292**	**6,567,840**	**-316,452**	**-4.6%**
Total, Atomic Energy Defense Activities	**21,497,000**	**22,112,910**	**23,052,840**	**+939,930**	**+4.3%**
Power Marketing Administrations					
Southeastern Power Administration	0	0	0	0	N/A
Southwestern Power Administration	11,400	10,400	10,400	0	N/A
Western Area Power Administration	93,372	89,372	89,196	-176	-0.2%
Falcon and Amistad Operating and Maintenance Fund	228	228	228	0	N/A
Colorado River Basins Power Marketing Fund	-23,000	-23,000	-21,400	+1,600	+7.0%
Total, Power Marketing Administrations	**82,000**	**77,000**	**78,424**	**+1,424**	**+1.8%**
Federal Energy Regulatory Commission (FERC)	**0**	**0**	**0**	**0**	**N/A**
Subtotal, Energy and Water Development, and Related Agencies	**34,526,657**	**35,657,317**	**31,890,529**	**-3,766,788**	**-10.6%**
Excess Fees and Recoveries, FERC	-9,000	-16,000	-16,000	0	N/A
Title XVII Loan Guarantee Program Section 1703 Negative Credit Subsidy Receipt	0	-107,000	-15,000	+92,000	+86.0%
Sale of Northeast Gas Reserve	0	0	-130,000	-130,000	N/A
Sale of Northeast Home Heating Oil Reserve	0	0	-27,000	-27,000	N/A
Total, Funding by Appropriation	**34,517,657**	**35,534,317**	**31,702,529**	**-3,831,788**	**-10.8%**

Energy Efficiency and Renewable Energy

Energy Efficiency and Renewable Energy

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 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, **[**$2,379,000,000**]** *$696,000,000*, to remain available until expended*, of which $353,000,000 shall be derived from prior year unobligated balances previously appropriated under this heading*: *Provided*, That of **[**such amount**]** *the amount made available under this heading in this Act*, **[**$162,500,000**]** *$122,000,000* shall be available until September 30, **[**2020**]** *2021*, for program direction. *(Energy and Water Development and Related Agencies Appropriations Act, 2019.)*

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)

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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 resilience in the near- to mid-term.

The FY 2020 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. There will also be an emphasis to conduct research that can facilitate streamlining of siting and permitting of EERE technology deployment. Industry deployment of these technologies creates jobs, reduces U.S. reliance on imported oil, increases energy affordability, improves energy security and resilience, ensures environmental responsibility and offers Americans a broader range of energy choices.

EERE's budget request includes $105 million for the Advanced Energy Storage Initiative, which takes a holistic approach to energy storage. The Initiative is focused on developing technologies to create 1) more flexible generation and 2) more flexible load, thereby increasing the reliability and resilience of the U.S. electric grid. Built on and incorporating the EERE FY 2019 Beyond Batteries Initiative, the Advanced Energy Storage Initiative will drive improvements in bi-directional electrical energy storage and other technologies to increase the flexibility of energy supply and demand. The Initiative will be coordinated across the Department, including the Offices of Electricity (OE), Fossil Energy (FE), and Nuclear Energy (NE). Existing EERE, OE, FE, and NE activities create a foundation, including batteries, pumped storage, controllable loads, distributed energy resource management, microgrids, power system planning and operations, hybrid systems, power plant dispatchability, and more. On this foundation, the Advanced Energy Storage Initiative will build an integrated DOE R&D strategy and establish aggressive, achievable, and comparable goals for cost-competitive energy storage services and applications."

Under the Advanced Energy Storage Initiative, many EERE resources have the capability to provide flexibility and other grid services, but focused R&D can improve those capabilities. This includes R&D to improve the flexibility of utility-side generation resources such as Concentrating Solar Power (CSP), hydropower, and geothermal. It also includes efforts to drive advancements in the integration and control of Distributed Energy Resources (DER), and improve the integration of building and vehicle charging loads to maximize their value to the grid. The Initiative includes continued technology advances in certain storage technologies, including pumped-storage hydropower, thermal storage, and behind-the-meter battery systems. R&D focused on energy for transportation will drive advancements in battery and hydrogen storage technologies. This includes vehicle electrification, in particular R&D that will further accelerate cost reductions and performance improvements in advanced vehicle battery technologies and charging infrastructure, as well R&D for advanced hydrogen production and delivery technologies. Focusing these efforts within a single DOE-wide initiative will take advantage of the deep collaborations across the Department's applied research portfolio, as well as across the full suite of technologies that contribute to the reliability and resilience of the U.S. grid.

EERE's Budget Request also includes an expansion of the diverse capabilities of the National Wind Technology Center (NWTC) campus at the National Renewable Energy Laboratory into a fully integrated, large-scale experimental research platform that includes building an Enhanced Grid/Energy Systems Control Center and a High-Speed Data Link that connects the NWTC campus to the Energy Systems Integration Facility (ESIF) at NREL's main campus and to other National Laboratories. As part of the expansion of the NTWC, funding also invests in a Beyond Megawatt Scale Extreme Fast Charging Station to research, integrate, and evaluate fast charging station impacts on the grid. These investments supports research for DOE's Grid Modernization Initiative that includes reliably integrating an increasing amount of variable generation. These expanded capabilities will allow DOE to test a suite of technologies supported under the Advanced Energy Storage Initiative and leverage the NWTC's future power capacity of 19.9MW with the capabilities of the ESIF.

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. In addition, research and analyses will be conducted to reduce other regulatory barriers to industry's deployment of EERE technologies.

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 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), 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. For example, between 2010 and 2018, the average cost to utilities of power purchase agreements (PPAs) for utility scale photovoltaic electricity decreased by 83 percent,[1] and the cost for wind PPAs between 2010 and 2017 decreased by 69 percent.[2] Since 2008, modeled battery costs for electric vehicles have dropped by 80 percent[3], and in the past year alone, EERE-sponsored R&D has helped drive a 2.5% energy intensity reduction among industry partners.[4]

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[1] Utility Scale Solar 2018, Figure 21 (LBNL) https://emp.lbl.gov/sites/default/files/utility-scale-solar-2018-edition-public-data-file.xlsx. Note that 2018 data is provisional.

[2] 2017 Wind Technologies Market Report Figure 51 (LBNL), https://emp.lbl.gov/sites/default/files/2017_wtmr_data_file.xls.

[3] Energy Department Announces $15 Million for Batteries and Electrification to Enable Extreme Fast Charging https://www.energy.gov/eere/articles/energy-department-announces-15-million-batteries-and-electrification-enable-extreme.

[4] Better Plants Progress Update (Fall 2018) https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/Better-Plants-Progress-Update-2018.pdf.

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 2020 Budget Request

In developing the FY 2020 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 $696.0 million (which includes the use of $353 million in prior year balances) focused on early-stage research to strengthen our knowledge and understanding of innovative 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).

As resources continue to shift toward early-stage R&D, the Weatherization Assistance Program and State Energy Program are terminated in FY 2020. 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 2020 Budget Request for Program Direction provides sufficient resources for program and project management, oversight 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 2020.

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 26 percent from the planned FY 2019 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 maintain 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 2020, 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 2020 Budget Request

- Sustainable Transportation ($157,400,000) — 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 $73,400,000 in FY 2020 funding to support early-stage research 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. The Battery and Electrification Technologies subprogram will explore new battery materials; improve high-power, fast-charging methods; develop innovative chemistries beyond lithium ion technology; and advanced cell technologies, with a focus on reducing or eliminating the need for critical materials such as cobalt. This work supports the Department's Advanced Energy

Storage Initiative and has 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. The Energy Efficient Mobility Systems (EEMS) subprogram will create breakthrough modeling, simulations, and high performance computing-enabled data analytics to enable new transportation-system technologies with potential to improve energy productivity and affordability through new mobility solutions, including connected, shared, and automated vehicles. In Advanced Engine and Fuel Technologies, research will 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 of 36 miles per gallon. This includes research to improve natural gas engine efficiency and fuel storage capacity. Materials Technology research will focus on novel approaches to building lightweight, multi-material structures and creating new materials that can withstand the extreme temperatures and pressures (e.g., high compression engines) that the next generation of high-efficient vehicle engines will require. The Technology Integration subprogram will continue support for statutory requirements related to public information about alternative fuels and vehicle fuel economy, as well as state and alternative fuel provider fleets, and will support the new university student competition, "The EcoCAR Mobility Challenge." The Program's Analysis effort will use advanced vehicle and transportation data to conduct techno-economic and interdisciplinary analyses critical to informing Program targets and research planning.

- **Bioenergy Technologies:** The Budget Request provides \$40,000,000 in FY 2020 to support early-stage R&D that bolsters the body of scientific and engineering knowledge enabling industry to demonstrate 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 wastes such as municipal solid waste and their subsequent conversion to bioenergy and co-produced bioproducts, offers a tremendous opportunity to create American jobs across the supply chain, boost economic growth, and encourage affordable energy while reducing U.S. exposure to foreign oil imports. The program's early-stage 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 feedstocks and preprocessing steps necessary for high conversion rates; (2) biological development and molecular characterization of high performing algal strains; and (3) development of engineered organisms and novel catalysts to drive conversion efficiency. In collaboration with the Vehicles Technologies. Bioenergy will explore the co-optimization of fuels and engines to evaluate the most promising biofuel candidates to enable fuel economy, emissions reduction, and efficiency targets for advanced compression ignition engines.

- **Hydrogen and Fuel Cell Technologies:** The Budget Request provides \$44,000,000 in FY 2020 to support early-stage R&D to investigate novel hydrogen and fuel cell technologies that could enable American energy independence and domestic job growth through industry development and deployment. To be cost competitive with gasoline-powered internal combustion engines on a cents-per-mile driven basis, the cost of hydrogen delivered and dispensed needs to be less than \$4/gge (untaxed), and the cost of a durable fuel cell system to be less than \$40/kW. The program will continue to focus on the H2@Scale concept which will enable affordable and reliable hydrogen generation, transport, storage and utilization across sectors. This can avoid curtailing variable renewable sources like solar and wind, can optimize baseload operation of nuclear, coal, and natural gas plants, and can enable innovations in the industrial sector like steel manufacturing. In FY 2020, focus areas include: advanced characterization of hydrogen release behavior and materials compatibility R&D to address regulatory barriers; advanced concepts for affordable and reliable infrastructure component technologies; and R&D on hydrogen energy storage.

- Renewable Power (\$163,700,000) — 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 integration of renewable energy technologies with the grid. This improved integration is executed through the Advanced Energy Storage Initiative and the Grid Modernization Initiative. Through investments in DOE labs, industry, and academia, EERE's Renewable Power technology programs 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 2020 to support the DOE in improving the affordability, reliability, and performance of solar technologies on the grid. Funding will support early-stage R&D at the National Laboratories, in partnership with academia and industry. The program will increase the reliability and performance and decrease the cost of next-generation photovoltaics toward the 2030 target of $0.03/kWh for utility-scale solar power without subsidies, to make solar one of the least expensive forms of electricity. Funding for concentrating solar power will work to make solar power available on demand through the incorporation of thermal energy storage and the production of fuels for long-term energy storage. In addition, the program will support the Advanced Energy Storage Initiative and advance the state of knowledge necessary for industry to more effectively integrate solar into the electric grid, improving solar energy's ability to contribute to grid reliability, resilience and security. Funding will also support analytics, testing and modeling of power system integrity and potential cybersecurity issues related to integrating increasing amounts of solar power on the electric grid. In addition, the program will support an additional round of the American-Made Solar Prize and the last year of a university research center in collaboration with the National Science Foundation.

- **Wind Energy:** The Budget Request provides $23,700,000 in FY 2020 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 2020 activities will focus on improving the performance and reliability of next-generation wind plants by applying high-performance computing to investigate systems-level interactions influenced by atmospheric conditions, variable terrain, and machine-to-machine wake interactions for offshore, land-based and distributed wind applications. Continuing R&D will focus on controls, sensors, algorithms, materials, and manufacturing to lower wind energy costs and improve operational performance. Fundamental R&D will target U.S.-specific offshore wind technology barriers, including advanced substructure technology, reduction of installation cost and risks, technology to reduce on-site O&M, and design standards development for the extreme marine conditions unique to U.S. waters. Funding will continue to advance R&D and manufacturing improvements that directly reduce distributed wind LCOE and maximize the value and resiliency of microgrids utilizing wind energy. Funding will address wind/radar challenges; develop technical solutions to reduce environmental compliance costs, and support development of a robust domestic wind energy workforce. Funding for the National Wind Technology Center will be moved to Facilities and Infrastructure, consistent with the expanded scope of activities noted above.

- **Water Power:** The Budget Request provides $45,000,000 in FY 2020 to support early-stage R&D and strengthen the body of scientific and engineering knowledge that enables industry to develop new technologies that increase U.S. hydropower and marine and hydrokinetic energy generation. The program supports the Advanced Energy Storage Initiative and continues 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 and improve the flexibility and grid services provided by hydropower and/or PSH. The program continues National Laboratory and industry R&D efforts to develop standard, modular hydropower components and site designs for new opportunities at existing non-powered dams. It also continues its work to develop turbine design and evaluation tools that improve fish passage and turbine efficiency in order to reduce the time, cost and uncertainty in hydropower licensing. In marine and hydrokinetics (MHK), the program will competitively select industry-led projects to test and validate performance of up to two wave devices at PacWave, the Nation's first accredited grid-connected MHK test facility in a high-energy site. The program continues assistance to private industry to test early stage subscale marine energy systems, in collaboration with U.S. universities and the National Laboratories and through its partnerships with the Navy. 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. The program will scope funding opportunities or prizes to prove the feasibility of tidal devices in remote communities, and commences follow-on to previous work in non-utility scale markets by scoping and analyzing the viability of designing wave energy systems to distributed ocean applications, as well as continued R&D in advanced controls working with industry to validate the most promising systems.

- **Geothermal Technologies**: The Budget Request provides $28,000,000 in FY 2020 to support early-stage R&D of Geothermal Technologies. 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 through the end of FY 2024. Prior to testing in the high-value main injection production pair sites at the FORGE, in FY 2020, the EGS subprogram will identify "Wells of Opportunity" and conduct high-risk tests of wellbore stimulation, zonal isolation, and subsurface interrogation technologies in available unused geothermal wells across the U.S. The Hydrothermal subprogram will continue to conduct subsurface R&D in FY2020 with a focus on exploration topics, starting with research in subsurface imaging, particularly for current and pre-existing subsurface volcanic terrain. The program contributes to the Advanced Energy Storage Initiative through research on more flexible geothermal systems. The program will continue R&D in Reservoir Thermal Energy Storage (RTES) including deep direct use (DDU) engineering, design and systems research; this R&D is critical for modernizing the nation's electrical grid and minimizing impacts from variable energy sources, as RTES provides an on-demand "earth battery," holding hot water in storage. Combined efforts will strengthen the body of knowledge necessary to support industry efforts to achieve a cost target of 20.8 cents/kWh by 2022 for newly developed Enhanced Geothermal Systems, and support enhanced grid reliability and resiliency through geothermal power to be operated flexibly and provide essential grid reliability service energy contributions.

- Energy Efficiency ($145,900,000) — 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 $80,500,000 in FY 2020 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. The Budget Request includes funding for the Harsh Environment Materials Initiative, a new cross-cutting activity with the Offices of Fossil Energy and Nuclear energy to exploit synergies in materials and component manufacturing research for thermoelectric power plants. Specifically, the coordinated Harsh Environment Materials Initiative will align research on novel materials, such as for harsh and high temperature environments, integrated sensors and manufacturing technologies. 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 $8,400,000 in FY 2020 to support Federal Energy Management Program's core activities of tracking agencies' energy management performance and resources for facility optimization and resilient, secure portfolio planning that leverages performance contracting. FEMP activities will also focus specifically disseminating existing training resources that enhance the skills and agility of the existing Federal workforce. This includes disseminating best practices for measurement and verification.

  - **Building Technologies:** The Budget Request provides $57,000,000 in FY 2020 to support early-stage R&D of innovative building energy technologies such as lighting, space conditioning, refrigeration, windows, and envelope and their effective integration into smart, efficient, resilient, grid-interactive, affordable, and secure building systems. In support of the Advanced Energy Storage Initiative, particular focus will be placed building system interaction with the grid in terms of controllable loads and thermal energy storage technologies. The goal of the Buildings 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 cybersecure advanced sensors and controls will help strengthen the body of knowledge to enable industry to develop and deploy "smart" buildings capable of interacting with the power grid securely, in new and increasingly adaptive manners, to help with overall electric system efficiency, resilience and energy affordability. 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 2020 for the Weatherization Assistance Program or the State Energy Program due to a departmental shift in focus away from deployment activities and towards early-stage R&D. Activities in FY 2020 will encompass 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 crosscuts:

- Advanced Energy Storage Initiative: A coordinated effort across DOE that will accelerate the development of energy storage and system flexibility technologies. Leveraging the full suite of DOE technologies, the Advanced Energy Storage Initiative will focus the Agency's efforts to take a more holistic and system-wide perspective to address emerging challenges, improve the reliability and resilience of the electrical grid, and ensure the affordability and security of energy for transportation.
- Harsh Environment Materials Initiative: A coordinated effort to exploit synergies in materials and component manufacturing R&D for advanced thermoelectric power plants. Specifically, this initiative would leverage NE and FE R&D activities related to advanced reactor technologies and high efficiency low emissions modular coal plants, respectively, to align R&D of novel materials, integrated sensors, and manufacturing processes relevant for advanced thermoelectric power plants.
- 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 of EERE technologies. This latter area is executed through various EERE program activities. 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 2018 Enacted	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted	
				$	%
Discretionary Summary by Appropriation					
Energy Efficiency and Renewable Energy					
Energy Efficiency and Renewable Energy RDD&D					
Sustainable Transportation					
Vehicle Technologies	337,500	344,000	73,400	-270,600	-78.7
Bioenergy Technologies	221,545	226,000	40,000	-186,000	-82.3
Hydrogen and Fuel Cell Technologies	115,000	120,000	44,000	-76,000	-63.3
Renewable Power					
Solar Energy Technologies	241,600	246,500	67,000	-179,500	-72.8
Wind Energy Technologies	92,000	92,000	23,700	-68,300	-74.2
Water Power Technologies	105,000	105,000	45,000	-60,000	-57.1
Geothermal Technologies	80,906	84,000	28,000	-56,000	-66.7
Energy Efficiency					
Advanced Manufacturing	305,000	320,000	80,500	-239,500	-74.8
Federal Energy Management Program	27,000	30,000	8,400	-21,600	-72.0
Building Technologies	220,727	226,000	57,000	-169,000	-74.8
Weatherization and Intergovernmental Programs					
Weatherization Assistance Program	248,000	254,000	0	-254,000	-100.0
Training and Technical Assistance	3,000	3,000	0	-3,000	-100.0
State Energy Program	55,000	55,000	0	-55,000	-100.0
Total, Weatherization and Intergovernmental Programs	306,000	312,000	0	-312,000	-100.0
Corporate Support Programs					
Facilities and Infrastructure (NREL)	92,000	97,000	107,000	10,000	10.3
Program Direction	162,500	162,500	122,000	-40,500	-24.9
Strategic Programs	15,000	14,000	0	-14,000	-100.0
Subtotal, EERE	**2,321,778**	**2,379,000**	**696,000**	**-1,683,000**	**-71.0**
Use of Prior Year Balances	0	0	-353,000	-353,000	0.0
Total, EERE	**2,321,778**	**2,379,000**	**343,000**	**-2,036,000**	**-85.6**

SBIR/STTR:
- FY 2018 Transferred: SBIR $50,991,000; STTR: $7,171,000
- FY 2019 Projected: SBIR $51,331,000; STTR $7,218,000
- FY 2020 Request: SBIR $10,919,000; STTR: $1,535,000

Vehicle Technologies

Overview

Vehicles move our national economy. Annually, vehicles transport 11 billion tons of freight – about $35 billion worth of goods each day[1] – and move people more than 3 trillion vehicle-miles.[2] Growing our economy requires transportation and transportation requires energy. The transportation sector accounts for about 30 percent of total U.S. energy needs[3] and 70 percent of U.S. petroleum use. With twenty percent (net) of U.S. petroleum consumption being imported, the U.S. sends approximately $15 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.

To strengthen national security, promote future economic growth, support American energy dominance, and increase transportation energy affordability for Americans, the Vehicle Technologies Program funds early-stage, high-risk research. This 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 automated and connected 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 partnerships help the Program focus on research that industry 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. At the same time, the Program works with industry to ensure there are pathways for technology transfer from government to industry so that Federally-supported innovations have an opportunity to make their way into commercial application.

The Vehicle Technologies Program works closely with counterparts in the Bioenergy Technologies and Hydrogen and Fuel Cell Technologies Programs. Together, the three programs have developed common metrics to evaluate and compare the costs and energy consumption of advanced transportation technologies with today's technologies. On a lifecycle basis (vehicle manufacture, fuel production, and fuel use), future (~2030), modeled, conventional gasoline internal combustion engine vehicle (ICEV) technology is expected to cost approximately 27 cents per mile and consume 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 pay-back period expectations.

The request provides $30,000,000 in support of the Advanced Energy Storage Initiative, which coordinates R&D across the DOE applied energy offices to advance energy storage and technologies that provide similar capabilities. Energy storage is critical to realizing both a flexible, resilient electrical grid and a modern, affordable transportation system powered by a diverse suite of energy resources – and energy storage for the grid is complemented by a portfolio of generation and load technologies that provide

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[1] Bureau of Transportation Statistics, DOT, Transportation Statistics Annual Report 2017, Table 3-1. https://www.bts.gov/bts-publications/transportation-statistics-annual-reports/tsar-2017.

[2] Transportation Energy Data Book 36th Edition, ORNL, 2017. Table 3.7 Shares of Highway Vehicle-Miles Traveled by Vehicle Type, 1970-2015.

[3] Ibid. Table 2.1. U.S. Consumption of Total Energy by End-use Sector, 1973-2017.

[4] Ibid. Table 1.13 Consumption of Petroleum by End-use Sector; Table 1.6 U.S. Petroleum Imports, 1960–2017; Table 10.5 Prices for a Barrel of Crude Oil and a Gallon of Gasoline, 1978-2017. Overseas includes countries and territories outside the 50 States and the District of Columbia.

[5] Ibid. Table 10.1 Average Annual Expenditures of Households by Income, 2016.

[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 and are based on meeting VTO technical targets.

flexibility, essential reliability services, and system resilience. The Advanced Energy Storage Initiative will take advantage of these deep complementarities and ensure coordination across EERE and DOE to address system-wide challenges from a system-level, rather than technology-specific perspective.

Highlights of the FY 2020 Budget Request

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

- Advanced Battery R&D: In support of the Advanced Energy Storage Initiative, 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: Create breakthrough modeling, simulations, and high performance computing-enabled data analytics to support the development of new transportation-system 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, predictive modeling capability, 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. This includes engine efficiency research to reduce the cost premium of natural gas vehicles in medium and heavy-duty trucks, as well as gaseous fuel storage research in cooperation with related work in the Fuel Cell Technologies Program.
- 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 by 25 percent at less than $5/lb-saved by 2030 (vs. 2012 baseline of 2,430 lbs.). Focus on the development of high temperature materials to increase 25 percent of high temperature component strength for high-efficiency engines by 2025.
- Technology Integration: 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 2018 Enacted	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
Vehicle Technologies				
Battery and Electrification Technologies	160,000	163,200	39,400	-123,800
Energy Efficient Mobility Systems	41,000	40,500	15,000	-25,500
Advanced Engine and Fuel Technologies	65,200	64,000	9,000	-55,000
Materials Technology	25,000	30,000	5,000	-25,000
Technology Integration	41,300	41,300	3,500	-37,800
Analysis	5,000	5,000	1,500	-3,500
Total, Vehicle Technologies	**337,500**	**344,000**	**73,400**	**-270,600**

SBIR/STTR:
- FY 2018 Transferred SBIR $10,102,000; STTR $1,421,000
- FY 2019 Projected: SBIR: $9,990,400; STTR: $1,405,000
- FY 2020 Request: SBIR: $2,285,000; STTR: $321,000

Vehicle Technologies
Explanation of Major Changes
($K)

	FY 2020 Request vs FY 2019 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 EERE and the Department. In support of the Advanced Energy Storage Initiative and the Grid Modernization initiatives, the Behind the Meter Storage activity will expand to develop innovative, critical materials-free battery energy storage technologies applicable to plug-in electric vehicles and high power charging systems. No new funds are provided for battery development work through the U.S. Advanced Battery Consortium. Funds are eliminated for battery safety and thermal performance testing and minimized for performance testing of new battery cell innovations. Funds are reduced for Advanced Battery Materials and Electrochemical Optimization Research. The Program will downselect two multi-lab research teams focused on intermetallic anodes to one group in order to focus on higher priority areas and promising developments. The Program will also downselect the next generation cathode portfolio to focus on low- or no cobalt materials. Electrification R&D projects will be reduced in scope and number to support high-priority projects that are on the critical path of advancing vehicle electrification. Electric Drive R&D will focus on high-power density electronics research with the potential to significantly reduce cost and volume and electric motor research that significantly reduces or eliminates dependence on critical materials and utilizes recycled material feedstocks.	**-123,800**
Energy Efficient Mobility Systems (EEMS): The reduction in funding level for this subprogram reflects the prioritization of the most critical early-stage applied mobility research activities within the broader priorities of EERE and the Department. Research within the SMART Mobility National Laboratory Consortium (a multi-disciplinary approach to push the boundaries of understanding the energy productivity impacts from future mobility technologies and transportation systems) will emphasize work in three research pillars focused on connected and automated multi-modal solutions for personal and freight mobility. Data science and strategic computing capabilities developed in the previous year will be applied to a real-world transportation case study to validate their performance. A new advanced mobility technology research project will be initiated to accelerate the benefits of laboratory research discoveries in the transportation system. The subprogram will also maintain a critical set of core vehicle modeling and validation tools and capabilities that enable research across multiple subprograms.	**-25,500**

	FY 2020 Request vs FY 2019 Enacted
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 EERE and the Department. Research on 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 vehicles. A new, multi-lab initiative will consolidate fundamental combustion research, including experimental, computational, and modeling work. The initiative's goal will be to use exsascale computing to fully model, simulate, and optimize combustion in vehicle engines. Research on emission reduction from diesel engines will be reduced within Catalyst R&D for Emission Control/After-treatment to focus on fundamental catalysis that cost-effectively reduces emissions from multi-mode engines. A multi-lab initiative for medium- and heavy-duty on- and off-road vehicles will focus on early-stage research to improve engine and vehicle efficiency. Natural gas engine efficiency research will be conducted on medium- and heavy-duty truck engines to approach parity with diesel engine efficiency and gaseous fuel storage research will be conducted in coordination with the Hydrogen and Fuel Cell Technologies Program.	**-55,000**
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 EERE and the Department. Early-stage research will focus on reducing the cost of specific lightweight, high-strength materials. A multi-lab research effort on joining of dissimilar materials will develop innovative joining technologies and increase fundamental understanding of the underlying science to support the increased use of lightweight materials in vehicles. A multi-lab research effort for powertrain materials research will support weight reduction and powertrain system efficiency improvements over a wide range of vehicle classes, including heavy-duty, medium-duty, and light-duty, by addressing the high temperature materials needs of advanced engine design components. This early-stage research will support the development of new alloys with resistance to high temperature corrosion/oxidation of engine components operating in the combustion chamber and exhaust system.	**-25,000**
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 EERE and the Department. Funds support statutory requirements and activities that provide data and lessons-learned to inform future research needs. Minimal support is provided for the advanced vehicle technology competition for university students.	**-37,800**
Analysis: The reduction in funding level for this subprogram reflects the prioritization of the most critical early-stage activities, within the broader priorities of EERE and the Department. Funds will support 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.	**-3,500**
Total, Vehicle Technologies	**-270,600**

Vehicle Technologies
Battery and Electrification Technologies

Description

The Battery and Electrification Technologies subprogram supports early-stage research to identify new battery chemistries, including critical materials-free chemistries, and cell technology with the potential to reduce the cost of electric vehicle batteries by more than half to less than $100/kWh, while increasing vehicle range to 300 miles and decreasing charge time to less than 15 minutes by 2028. The cost target supports a levelized cost of driving (LCD) of a 300-mile battery electric vehicle (BEV) of $0.28/mile, which is comparable to a future internal combustion engine vehicle 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 support industry to significantly reduce the cost, weight, volume, and charge time of plug-in electric vehicle (PEV) batteries. Through its key activities supporting battery energy storage – Advanced Battery Materials Research, Advanced Battery Cell R&D, and Behind the Meter Storage – this subprogram supports the Advanced Energy Storage Initiative, which is focused on a flexible, resilient electrical grid and a modern, affordable transportation system powered by a diverse suite of energy resources. The subprogram also focuses on fast, secure, and resilient PEV charging through its Electrification R&D activity, and extreme high power density motor and power electronics for PEV traction drive systems in its Electric Drive R&D activity.

Advanced Battery Materials Research ($20,000,000) will focus on early-stage research of new lithium-ion cathode, anode, and electrolyte materials, which currently account for 50-70 percent of PEV battery cost. 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 selected, cost-shared projects, in addition to research conducted as part of the Lithium Battery Recycling Prize and National Laboratory-led Recycling Center launched in fiscal year 2019. Recycling Prize activities will focus on Phase II Prototyping and Partnering, in which the Phase I winners selected in fiscal year 2019 will validate their concepts through prototyping, testing, and/or simulation while establishing business relationships with potential pilot partners in order to develop and demonstrate a full end-to-end solution for the recovery, safe storage, and transportation of end-of-life lithium-ion batteries. In addition, the subprogram will continue the Battery500 research consortium, which includes industry, university, and national laboratories and is focused on the development of "beyond lithium-ion" technologies that have the potential to significantly reduce weight, volume, and cost by three times ($80/kWh). The activity seeks to design novel electrode and cell architectures that use a lithium anode, combined with a compatible electrolyte system and high capacity cathodes that prohibit lithium dendrite growth or polysulfide dissolution to achieve 500 Wh/kg and 1000 cycles at the lab cell level. New research will support batteries and electrification in large trucks, which may require unique technology based on the charging patterns, daily usage, range, and overall length of vehicle life.

The Advanced Battery Cell R&D effort ($6,000,000) 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. Work will be carried out through competitively selected, cost-shared projects. This activity also supports high-fidelity battery performance, life, fast charging, and safety testing of innovative battery technologies at the National Laboratories and the lithium-ion battery recycling center.

The Behind the Meter Storage (BTMS) effort ($4,000,000) supports the Advanced Energy Storage Initiative and Grid Modernization Initiative (GMI) by focusing on innovative solutions capable of mitigating potential grid impacts of PEV high-power charging systems, such as critical materials-free battery energy storage technologies. As part of GMI, this work will be coordinated with the Office of Fossil Energy (FE), the Office of Nuclear Energy (NE), the Office of Electricity (OE), and the Office of Cybersecurity, Energy Security, and Emergency Response (CESER) as part of the Energy Storage and System Flexibility focus area. Solutions in the 1-10 MWh range will support optimal charging system design, eliminate potential grid impacts of high-power PEV charging systems, and lower installation costs and costs to the consumer. BTMS systems have their own calendar-life, cycle-life, and cost challenges, but many lessons learned from PEV battery development may be applied to BTMS systems. BTMS electrochemical solutions could be optimized for these applications with less focus on energy density in mass and volume; the potential for novel battery solutions is very appealing. Furthermore, the balance-of-plant for a BTMS battery system, or the cost of everything minus the battery cells, is thought to be more than 60 percent of the total energy storage system cost, while the PEV balance-of-plant costs comprise roughly 30 percent of the total battery cost. Therefore, BTMS will also need to focus on balance-of-plant cost reduction through system optimization in order to realize desired cost targets. Efforts will include research and development of advanced power electronics and controls to assure seamless integration of energy storage, vehicle charging, and behind-the-meter power transmission.

The Electrification R&D effort ($5,000,000) will focus on early-stage research to support fast, secure, and resilient PEV charging on the Nation’s electric grid. This work will be carried out through National Laboratory Annual Operating Plans and competitively selected, cost-shared projects. Specifically, projects will increase the reliability of charging by focusing on smart-charging technology to support secure and cost-effective charging of large volumes of PEVs. Research will also focus on extreme fast-charging at power levels greater than 350kW to support charging a PEV in 10-15 minutes and support heavy-duty truck charging as well. Impacts of PEV charging at scale for light-, medium-, and heavy-duty vehicles will be minimized through technologies that provide better flexibility and control, such as wireless charging approaches and chargers that use distributed energy resources, further supporting the GMI and leveraging developments in battery energy storage technologies through BTMS.

Electric Drive Research ($4,400,000) conducts R&D to reduce the cost of electric traction drive systems that can deliver at least 55kW of peak power to $7/kW by 2022, enabling cost-competitive technologies for vehicle electrification. Early-stage research will focus on extreme high power density motor and power electronics technologies that have the potential to support radical new vehicle architectures by dramatic volume/space reductions and increased durability and reliability. This work will be carried out through National Laboratory Annual Operating Plans and competitively selected, cost-shared projects. This work will emphasize a ten-fold reduction in the volume of electric traction drive systems, which combine power electronics and motors using high-density integration technologies. Approaches will include wide bandgap devices, dense power electronics packaging, novel circuit topologies, and new materials for high-density electric motors. Electric traction drive system integration based on power electronics and electric motor innovations will also be a priority.

Battery and Electrification Technologies

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Battery and Electrification Technologies $163,200,000	**$39,400,000**	**-$123,800,000**
Advanced Battery Materials Research & Battery500 $65,000,000	$20,000,000	-$45,000,000
• 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 will focus on mitigation of lithium dendrite formation, polysulfide dissolution, and solid-state materials research. The 15 seedling projects selected in FY 2017 will be down-selected to ten of the most promising technologies and innovations.	• Continue support for the Battery500 Consortium to significantly increase energy density/reduce cost through "beyond lithium-ion" technology. In FY 2020, the three Battery500 Consortium keystone research projects will focus on mitigation of lithium dendrite formation, polysulfide dissolution, and solid-state materials research.	• No significant change to three Battery500 keystone R&D projects. Prior year obligations will continue to fund the ten Battery500 Seedling projects downselected in FY 2019.
• Funding will support 18 projects at the National Laboratories focused on beyond lithium-ion technologies. Specifically, they will focus 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 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 competitively selected, cost-shared projects that focus on lithium metal, lithium sulfur, and solid-state battery technology.	• Funding will support up to ten projects at the National Laboratories focused on beyond lithium-ion technologies in the following "beyond lithium-ion battery" focus areas: development and synthesis of metallic lithium, lithium sulfur, lithium air, sodium ion, and solid electrolyte materials; modeling and first principles calculations of electrode materials, solid-electrolyte interphase (SEI) layer and electrode microstructure; and assembly of high density low tortuosity electrodes.	• Laboratory materials research will be down-selected from 18 to up to ten National Laboratory projects offering the most promising technologies and innovations. Prior year obligations will continue to support university and industry projects awarded through a competitive solicitation in FY 2019.
• Funding will support two multi-disciplined, multi-laboratory research teams focused on next-generation intermetallic anodes for lithium-ion batteries that address critical barriers in achieving	• Funding will support one multi-disciplined, multi-laboratory research team to advance next-generation intermetallic anodes for lithium-ion batteries that address critical barriers in achieving	• Higher priority areas of improving the intermetallic anode solid-electrolyte interphase will be addressed by merging the two multi-Laboratory research teams into one. Eliminate in-

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
high energy density and long cycle and calendar life. Team one will gain a better fundamental understanding of the silicon electrolyte interphase and through this knowledge develop strategies to stabilize this surface. Team 2 will try to reduce silicon particle and electrode expansion, develop stabilized coating technologies, and explore novel binder and processing techniques. In addition, National Laboratory-based silicon particle synthesis and scale-up tasks will aim to develop a stable consistent source of active material that will support uninterrupted R&D at National Laboratories and industry.	high energy density and long cycle and calendar life. Research is expected to gain, and test, a better fundamental understanding of the silicon electrolyte interphase and how this relates to water content in the cell as well as soluble reaction components.	house silicon particle synthesis and scale up activities. Prior year obligations will continue to fund projects focused on particle coating technologies and binder materials.
• Funding will support approximately 20 laboratory projects to develop and synthesize high voltage/high capacity cathode materials and high-voltage electrolytes. Develop processes to scale up two to three cathode materials and one to two electrolyte components from lab quantities (grams) to batch quantities of (tens of kg).	• Funding will support 10-14 laboratory projects focused on the development and synthesis of high voltage/high capacity cathode materials, high voltage electrolytes, and low or “no” cobalt cathode materials. Develop processes to scale up these materials from lab quantities (grams) to batch quantities (tens of kilograms). Research will focus on the engineering and batch scale-up of one to three new, innovative cathode or electrolyte materials.	• Downselect 10-14 laboratory projects (from 21) focusing on low cobalt or critical materials-free cathodes over high voltage and high capacity materials. Prior year obligations will continue to fund industry, university, and laboratory projects that were competitively selected in FY 2018 to develop new cathode materials that contain significantly less critical materials (such as cobalt).
• Establish a Lithium Battery R&D Recycling Center focused on cost-effective recycling processes to recover critical lithium battery materials from current and future electric vehicle batteries. Specifically, work will commence with an analysis of cathode and associated battery material recycling and reuse issues affecting battery recycling; material supply, transportation, and regulatory issues.	• Funding will support two to four projects from the 2018 laboratory call through the Lithium Battery R&D Recycling Center. Research will focus on developing cost-effective material recovery innovations for recycling to next generation battery materials.	• Support two to four laboratory research projects through the Lithium Battery R&D Recycling Center to assure sustainability of lithium-ion battery materials, support long-term availability of critical materials, and identify research pathways to further reduce the cost of battery materials.
• Launch Lithium Battery Recycling Prize, a competition with a series of progressive down selections to incentivize the nation’s innovators and entrepreneurs to develop and demonstrate	• Downselect up to ten Lithium Battery Recycling Prize Phase II winners and invite them to Phase III.	• Continue operations and evaluations for the Lithium Battery Recycling Prize. Move from Phase I to Phase II.

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
processes that, when scaled, have the potential to profitably capture 90 percent of all lithium-based battery technologies in the United States. Select up to 25 Phase I winners invited to enter Phase II.		
Advanced Battery Cell R&D $42,500,000	$6,000,000	-$36,500,000
• Funding will support competitively selected, 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 are capable of fast charge in less than 15 minutes. This work will focus on lower-cost batteries capable of fast charge in less than 15 minutes and novel prelithiation techniques to advance silicon materials.	• No funding is requested in FY 2020 for new DOE/USABC projects.	• Prior year obligations will fund USABC projects awarded in FY 2018-2019. The research portfolio will be down selected to four to six of the most promising projects in FY 2020.
• Continue support for five National Laboratory research projects competitively selected from the 2018 Lab Call to understand and support battery extreme fast charging capability. Research will focus on understanding the electrochemical factors that inhibit fast charging (15 minutes or less) in lithium-ion batteries. This research activity will identify factors primarily responsible for battery degradation due to extreme fast charging conditions and identify research pathways with the highest potential to support extreme fast charge in PEVs.	• Fund National Laboratory projects to extend and refine the fidelity of computational models as they relate to the fundamental limits of battery performance during fast charge. Specifically, enhancements to the microstructure, electrolyte transport and cathode models will be developed through laboratory annual operating plans.	• Support will be reduced from five National Laboratories to one.
	• Support competitively selected, cost-shared research projects focused on technologies with the potential to achieve cost targets and that significantly reduce or eliminate dependence on critical materials (such as cobalt) and utilize recycled material feedstocks.	• Support new technologies with the potential to achieve cost targets and that significantly reduce or eliminate dependence on critical materials (such as cobalt) and utilize recycled material feedstocks.
• Support 25-30 high fidelity battery performance, life, thermal response, and safety testing projects at four National Laboratories.	• Consolidate high fidelity performance and life battery testing from four to one National Laboratory and down select 8 to 12 of the most promising projects.	• Reduce high fidelity performance and life battery testing to one National Laboratory and support from 8 to 12 of the most promising advanced battery cell testing projects.

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Behind the Meter Storage (BTMS) $2,500,000	$4,000,000	+$1,500,000
• Launch the Behind the Meter Storage (BTMS) effort by developing metrics and targets for battery storage systems, PV energy generation, and energy-efficient buildings within the BTMS application space through National Laboratory projects. A systems level approach will develop standardized testing procedures, baseline power electronics requirements, and perform initial cost analysis.	• The National Laboratory project will explore, develop, and test alternative, critical materials-free energy storage technologies applicable to PEVs and that have the potential to reduce the cost and potential grid impacts of high power charging systems.	• Move from system concepts and requirements stage to research and testing on concepts identified in FY 2019.
	• Through competitively selected, cost-shared projects, research innovative critical materials-free battery designs with the potential to overcome the technical barriers and achieve cost goals.	• Support technology research and system development.
Electrification R&D $31,200,000	$5,000,000	-$26,200,000
• This activity will focus on the higher power, extreme fast charging (300-400 KW) communications, controls, and cybersecurity research related to vehicle and charging equipment through two laboratory and three competitively selected projects.	• The two laboratory cybersecurity projects will reduce tasking and limit R&D focus to the most critical areas identified through risk assessments and threat analysis.	• No new laboratory work initiated. Funds will support continuing two laboratory projects at reduced scope, to focus on the most critical areas identified through risk assessments and threat analysis.
• Three National Laboratory projects will focus on enabling extreme fast charging by identifying barriers and reducing grid impacts of EV charging through control and optimization.	• Continue the three laboratory-led projects to create hardware and system models as well as develop power and charge control methods and hardware.	• Laboratory projects focused on characterizing power requirements for medium and heavy duty vehicles will complete.
• Support research at two National Laboratories to develop innovations in dynamic wireless charging technologies including dynamic speed limitations and measuring stray fields.	• Continue to fund two wireless charging research projects at National Laboratories, but focus effort on increasing power transfer rates through elevated or concentrating fields. Design, assemble, and functional components to validate high power transfer capability.	• Narrow the scope of both National Laboratory projects to emphasize research on wireless power transfer and eliminate research focused on electromagnetic field reduction techniques.
Electric Drive Technologies R&D $22,000,000	$4,400,000	$-17,600,000
• Support three multi-lab/university teams to develop high-power density electric drive systems. Initiate two to four competitively awarded projects	• Continue to fund Laboratory/university teams only targeting individual drive system component and subcomponent improvements.	• Laboratory/university teams will reduce overall tasking by delaying system level research and instead develop subsystem level advancements.

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
supporting early-stage research of extreme high power density motor and power electronics that have the potential to support radical new vehicle architectures by dramatic volume/space reductions and increased durability and reliability.		
• Fund competitively awarded, cost-shared projects that support broad electrification across vehicle platforms including advancements in vehicle charging and mitigating grid impacts. Leverage National Laboratory capabilities to develop innovative technologies and systems to manage electric vehicle fast charging power and energy needs and assure grid reliability, integrity, resiliency, and efficiency.	• No funding will be requested for this area in 2020. Projects initiated in FY 2019 will provide data on electrification benefits including potential grid support and services.	• Prior year obligations will fund the projects competitively awarded in FY 2019.

Description

The Energy Efficient Mobility Systems (EEMS) subprogram supports early-stage research to support industry innovation that improves the affordability and energy productivity of the overall transportation system. Initial DOE analysis 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 data science and artificial intelligence, and high-performance computing capabilities unique to DOE National Laboratories to explore the energy and mobility impacts 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 productivity, lower costs for families and business, and support the use of secure, domestic energy sources. The EEMS subprogram consists of four primary activities: the SMART Mobility National Laboratory Consortium, high performance computing-enabled data analytics, advanced mobility technology research, and core evaluation and simulation tools. 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 completing the development of a quantitative metric for mobility energy productivity, which measures the affordability, efficiency, convenience, and economic opportunity derived from the mobility system, which will be used by the program to evaluate success, and by the transportation community to inform planning decisions. The metric will be applicable to both light-duty and heavy-duty vehicles and systems.

The SMART (**S**ystems and **M**odeling for **A**ccelerated **R**esearch in **T**ransportation) Mobility National Laboratory Consortium ($7,000,000) will develop new knowledge and understanding of the energy efficiency and mobility opportunities from future transportation technologies and applications, and it will 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 multi-laboratory SMART Mobility Consortium are organized into three coordinated research thrusts, 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.
- Multi-Modal Freight Transportation: Research focuses on identifying and removing barriers to new cost-effective, efficient modes of freight transportation, including long-distance transport and last-mile delivery.
- Infrastructure, Land-Use, and Traveler Response: Research evaluates the infrastructure requirements and traveler response to new mobility technologies and services, including fueling, charging, communication, traffic management, and new transportation modes, and analyzes the long-term evolution of land-use and the built environment as it relates to mobility and quality of life.

The high performance computing-enabled data analytics effort ($3,500,000) will use unique National Laboratory capabilities to 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. The EEMS subprogram 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-laboratory 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.

Through competitively selected projects, the advanced mobility technology research activity ($3,000,000) will support private sector efforts to accelerate the transfer of laboratory mobility research results and discoveries from the SMART

Mobility Consortium and the high performance computing-enabled data analytics activity. By partnering with industry, the EEMS subprogram will identify barriers and create novel solutions to improve the transition of efficient automated vehicle technologies, optimized transportation planning and operational tools and methods, and breakthrough connected mobility systems to practical use. This will be accomplished through the use of state-of-the-art mobility testbeds to generate real-world validation data and collaboration to ensure that EEMS research is aligned with stakeholder needs.

In partnership with the National Laboratories, the core evaluation and simulation tools activity ($1,5000,000) will develop and maintain a critical set of modeling, simulation, and experimental evaluation capabilities that support Vehicle Technologies' early-stage research, development, and analysis of advanced vehicle components, powertrains, vehicles, and transportation systems. Fundamental to all other EEMS research activities, these capabilities include vehicle and component test procedure development, highly instrumented proof-of-concept hardware evaluation, transportation system controls algorithm validation, high-fidelity physical simulation, and transportation data management.

Energy Efficient Mobility Systems

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Energy Efficient Mobility Systems $40,500,000	**$15,000,000**	**-$25,500,000**
• Perform modeling, simulation, analysis, and experimental testing in the SMART Mobility Laboratory Consortium through 35 projects coordinated under five research pillars: connected and automated vehicles, urban science, multi-modal freight transport, and advanced fueling infrastructure.	• Funds will support the following three priority research pillars of the SMART Mobility Laboratory Consortium: connected and automated vehicles, multi-modal freight transportation, and infrastructure, land use, and traveler response. Efforts will build upon the first phase and focus on creating more robust results through improved models that represent additional transportation technologies and services, applied to more locations, and evaluate additional future scenarios.	• The first phase of SMART Mobility Laboratory Consortium will conclude with a series of five capstone reports summarizing the methods, results, insights, and conclusions of each of the research pillars. For the second phase, SMART Mobility research will consolidate the urban science, mobility decision science, and advanced fueling infrastructure pillars.
• 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	• In the second year of three previously selected National Laboratory projects, apply high performance computing-enabled data science methods to a single regional mobility system, and demonstrate faster-than-real-time transportation system simulations that support predictive analytics for large-scale system optimization.	• Data science and computational methods developed in FY 2019 will be applied to a real-world transportation case study to validate their performance.
• Initiate two to four advanced research and development projects to develop cost-effective approaches to improve the system-level efficiency of a traffic network.	• Competitively selected, cost-shared projects will identify real-world barriers and develop solutions for a single mobility concept through test-bed validation and data dissemination.	• New projects focused on transitioning the highest impact results from laboratory-based research to the real world.
• Update core vehicle modeling and simulation tools, including the Autonomie software, and establish new connected and automated vehicle validation capabilities. Initiate a new National Laboratory effort to develop a transportation data management and sharing platform.	• Maintain and operate core vehicle energy consumption and data management tools critical to support early-stage mobility research.	• Support core laboratory modeling and simulation activities, with a focus on maintenance of critical vehicle modeling and validation capabilities required to support system-level research.

Vehicle Technologies
Advanced Engine and Fuel Technologies

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, generating 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 apply the 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 Laboratory, Advanced Photon Source at Argonne National Laboratory, Institute for Integrated Catalysis at Pacific Northwest National Laboratory, detailed fuel chemistry expertise at the National Renewable Energy Laboratory, chemical kinetic modeling and mechanism development at Lawrence Livermore National Laboratory, and the Spallation Neutron Source at Oak Ridge National Laboratory, 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 build on basic research results. It will use a multi-laboratory initiative, including high performance computing and hardware in-the-loop resources, for early-stage research to optimize the efficiency of on- and off-road medium- and heavy-duty vehicles. The subprogram has four major activities: predictive modeling, experimental combustion including fuels and engines, emissions control, and crosscutting medium- and heavy-duty vehicle and engine technologies.

Funds will support National Laboratory development of predictive, high-fidelity submodels and simulation tools ($1,700,000) that are scalable and can leverage future exascale computing capabilities. These tools will use high performance computing to simulate and accurately predict the fundamental processes that occur in engines, including fuel injection sprays, heat transfer, turbulence, flame propagation, and emissions formation, to achieve results that are comparable to detailed experiments. The subprogram will fund early-stage research of fuel properties utilizing chemical kinetics modeling of different molecules to determine their impact on combustion efficiency and emissions. It will also develop numerical routines and sub-models of complex chemical reactions 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 ($3,900,000) will support the new exascale modeling initiative through development of experimental 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 help companies develop a new generation of multi-mode and low-temperature combustion engines with higher efficiency and lower emissions.

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.

Funds will also support early-stage research to improve the efficiency of natural gas engines ($1,000,000) while reducing their cost. The subprogram will conduct research on topics including high-efficiency lean-burn engine technologies; on-board fuel storage, coordinated with related research in the Fuel Cell Technologies Program; and accompanying emission control systems that have the potential to increase efficiency by 15-25 percent, making them comparable to diesel engines and reducing the payback period to attract fleet buyers.

The subprogram will fund experiments conducted by the National Laboratories ($1,200,000) 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 reaction rates using high performance computing will be developed.

A multi-laboratory consortium ($1,200,000) will focus 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 consortium is to conduct coordinated early-stage research at National Laboratories having unique facilities and capabilities specific to heavy-duty vehicles. Technologies will include both traditional combustion engine architectures as well as new opportunities to partially or fully electrify truck operations or use systems approaches to reduce energy during operation. The subprogram will coordinate with and utilize expertise from other subprograms as needed.

Advanced Engine and Fuel Technologies

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Advanced Engine and Fuel Technologies $64,000,000	**$9,000,000**	**-$55,000,000**
Predictive Modeling of Engine Combustion and Fuels $4,300,000	$1,700,000	-$2,600,000
• Develop computer simulations and submodels of engine combustion and fuels, including adaption for future exascale-based high performance computing using facilities at the National Laboratories. Includes 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, and numerical techniques to reduce processing time.	• Develop high fidelity submodels for fuel sprays and in-cylinder turbulence for adaption to future exascale-based high performance computing at the National Laboratories. Develop detailed chemical kinetic models of fuel reactions and emissions formation in the combustion process.	Focus on high fidelity submodels and detailed chemical kinetic models while maintaining some effort to develop numerical techniques that decrease processing time. Defer work on predictive engine models, heat transfer submodels.
Lean/Next Generation Combustion Engines and Fuels R&D and Heavy-Duty Combustion Engines and Fuels R&D $24,700,000	$3,900,000	-$20,800,000
• Conduct engine and fuels research at National Laboratories through ten projects focused on single-cylinder engines and two projects focused on multi-cylinder engines. This work supports fundamental combustion research in optically accessible engines using laser, high intensity X-Ray, and neutron-based diagnostics for fuel injection spray visualization and advanced ignition systems to provide experimental validation for simulation models. Generate chemical kinetics data using a rapid compression machine.	• Use advanced research tools at the National Laboratories (e.g., laser, X-ray light source) to improve the fundamental understanding of advanced combustion processes and emissions formation inside an operating engine. Use experimental results from three single-cylinder engines to validate and enhance engine simulations and submodels.	• Prioritize efforts on applying advanced research tools to validate engine simulations and submodels. Reduce efforts to generate experimental chemical kinetics data. Defer lower priority work on seven single- and two multi-cylinder engines for experimental validation of simulation models.
• Support more than 40 projects at National Laboratories, with industry, and universities on	• Support approximately 10 Co-Optima projects at National Laboratories. Focus fuel research on	• Reduce support for Co-Optima work at National Laboratories to focus on multi-mode and

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
the Co-Optimization of Engines and Fuels (Co-Optima). Focus fuel research on performance tailored bio-derived, synthetic and petroleum-based blend stocks to improve combustion efficiency. Focus engine research on multi-mode (kinetically controlled/spark ignition) engine technologies and on determining fuel properties that maximize engine performance under kinetically controlled operation. Investigate kinetically controlled combustion for heavy-duty application.	performance tailored bio-derived, synthetic and petroleum-based blend stocks to improve combustion efficiency. Focus engine research on multi-mode (kinetically controlled/spark ignition) engine technologies.	kinetically controlled combustion; eliminate heavy-duty research within Co-Optima.
Catalyst R&D for Emission Control/After-Treatment $4,000,000	$1,200,000	-$2,800,000
• Support four cost-shared CRADAs with industry to address advanced emission control technologies.	• Support up to two cost-shared CRADAs with industry to address advanced emission control technologies.	• Eliminate two to three lower-priority CRADAs with industry.
• Conduct two atomistic-scale design projects and scalable synthesis of multi-functional catalyst for emissions reduction at low exhaust temperatures.	• Conduct one research project on single atom catalysis to improve conversion efficiency and reduce precious metal content at the National Laboratories.	• Focus efforts on key priorities related to emissions control and catalysis.
• Develop computer models needed to produce the kinetics and mechanistic information for simulating chemical reactions within and on catalyst surfaces to predict the performance of lean NOx trap (LNT) and selective catalytic reduction (SCR) catalysts, as well as advanced multi-functional emission control systems.	• Conduct research to develop kinetic and mechanistic models of catalyst and substrate materials to predict performance of emissions control systems for multi-mode combustion.	• Eliminate support for advanced multi-functional emission control systems research and NOx traps for diesel engines at National Laboratories.
On- and Off-road Medium/Heavy duty Vehicle and Engine Technologies $10,000,000	$1,200,000	-$8,800,000
• Establish new multi-lab research consortium focused on engine- and vehicle-level technologies applicable to both on- and off-road medium- and heavy-duty vehicles. The consortium will integrate and coordinate related work in the areas of waste	• Utilize a multi-laboratory consortium to conduct early-stage analysis, modeling and experimentation on engine and vehicle technologies applicable to both on and off road medium- and heavy-duty vehicles, including	• Discontinue research focus on waste heat recovery systems.

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
heat recovery, combustion, electrified driveline systems and powertrain hybridization, and operational systems that can reduce fuel consumption through more efficient operation.	combustion, electrified driveline systems and hybridization of the powertrain, and efficient operational systems that can reduce fuel consumption by bringing these technologies together in a coordinated effort.	
• Initiate up to two new competitively selected industry/university awards for off-road vehicles based on stakeholder input.	• No funding requested.	• Activities will continue to cost obligated carryover until completion.
Natural Gas Engine Technology R&D $15,000,000	$1,000,000	-$14,000,000
• Conduct natural gas engine technology R&D focused on reducing vehicle total cost of ownership, improving natural gas engine efficiency and emissions, and expanding natural gas engine and vehicle availability through nine awards to industry and universities.	• Conduct two to three early-stage research projects at the National Laboratories to improve the efficiency of natural gas engines while reducing their cost.	• Focus only on early-stage research at the National Laboratories to improve engine efficiency to approach diesel efficiency.
• Initiate three to six new competitively-awarded projects in cooperation with the Hydrogen and Fuel Cell Technologies Program, focused on advanced gas storage technologies.	• Conduct one to two research projects at the National Labs for improved natural gas storage technologies in coordination with related work in the Hydrogen and Fuel Cell Technologies Program.	• Focus only on early-stage research at the National Laboratories to identify innovative on-board natural gas storage technologies.
• Complete a multi-lab study of research opportunities and potential benefits associated with medium- and heavy-duty natural gas vehicles.	• No funding requested.	• Multi-lab study completed in FY 2019.
SuperTruck II		
• Through five competitively-awarded projects, 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 greater than 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.	• Activities will continue to cost obligated carryover until completion. Some portions of the originally awarded cost share projects to build a physical prototype will be reduced or eliminated.

Vehicle Technologies
Materials Technology

Description

The Materials Technology subprogram supports early-stage R&D of technologies for vehicle lightweighting and improved propulsion (powertrain) efficiency applicable to 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 ten percent results in a six to eight percent improvement in fuel economy, and similar benefits are achieved for battery electric and heavy-duty vehicles. 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.

Propulsion Materials Technology ($2,500,000) supports research at National Laboratories 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 (HPC), to accelerate discovery and early-stage development of cutting-edge structural and high temperature materials for more efficient powertrains. In FY 2020, research will focus on (1) the development of high temperature materials for high efficiency engines for heavy-duty and light-duty vehicles, (2) the development of predictive models for powertrain materials, and (3) Integrated Computational Materials Engineering (ICME) tools that use HPC capabilities, multi-length (atoms to components) material models, and boundary layer resolved thermo-kinetic models. Each of these activities will be led by 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.

Lightweight Materials Technology ($2,500,000) supports National Laboratory 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 2020, the subprogram will fund research conducted by the National Laboratories with a focus on new joining technologies for multi-material structures in vehicles. 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 among 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.

Materials Technology

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Materials Technology $30,000,000	**$5,000,000**	**-$25,000,000**
Lightweight Materials Technology $14,000,000	$2,500,000	$11,500,000
• Expand the Joining Core Program, a multi-lab research effort, to include new research on galvanic corrosion of dissimilar joints, in-line process control of joining technologies, and exploratory seedling projects in addition to continuing the development of joining methods for Carbon Fiber Reinforced Plastics (CFRP) to Steel, Mg to Steel, and CFRP to Mg material pairs through advanced computer modeling of the material interfaces expected to result in at least six peer reviewed publications.	• Support the Joining Core Program research effort to build upon advanced computational modeling of interfaces completed in FY 2019 to further develop novel joining technologies for Mg-Steel, CFRP-Steel, and CFRP-Mg material pairs.	• Joining Core Program research on galvanic corrosion of dissimilar joints, in line process control of joining technologies, and exploratory seedling projects will be deprioritized. Exploratory seedling projects initiated in FY 2019 will continue using prior-year funds.
• Support composite materials research at the National Laboratories, including the operation of the CFTF at ORNL, funding three to five new projects on composite materials targeting specific on-vehicle applications, and continued funding for one research project focused on novel additively manufactured hierarchical composite materials.	• No funding requested.	• FY 2019 projects will continue to outlay obligated carryover until completed.
• Initiate one National Laboratory research project on solid phase processing techniques that result in lightweight automotive metal alloys with novel microstructure and properties. Initiate research on solid phase processing techniques that result in lightweight automotive metal alloys with novel microstructures and properties.	• No funding requested.	• FY 2019 projects will continue to outlay obligated carryover until completed.
• Initiate five new CRADA projects utilizing the LightMAT Consortium to engage the automotive industry in accelerating the discovery and development of advanced materials technology. Initiate five new CRADA projects utilizing the	• No funding requested.	• FY 2019 projects will continue to outlay obligated carryover until completed.

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
LightMAT Consortium to engage the automotive industry in accelerating the discovery and development of advanced materials technology.		
Propulsion Materials Technology $16,000,000	$2,500,000	-$13,500,000
• Launch the Powertrain Core Program, a multi-lab research effort, to support five research areas to enable powertrain weight reductions and efficiency improvements over a wide range of vehicle classes, and utilize integrated computational materials engineering (ICME) approach to address materials needs for developing a suite of next generation powertrain materials.	• Fund two research tasks focused on the development of high temperature materials for high-efficiency engines for both heavy- and light-duty vehicles through the National Laboratory Powertrain Core Program resulting from 2018 Lab Call.	• Research of additive manufacturing for powertrain materials, advanced characterization and computational methods, and exploratory seedling projects initiated in FY 2019 through the Powertrain Core Program will be deprioritized.
• Through two to four competitively selected, cost-shared research projects, design and demonstrate a lightweight high-efficiency engine to enable a 25 percent fuel economy improvement and 15 percent powertrain weight reduction relative to a 2015 baseline.	• No funding requested.	• Research on this topic will be conducted by the National Laboratories only through the Powertrain Core Program. No new competitively selected projects will be initiated; projects started in FY 2019 will continue using prior-year funds.

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 support energy resiliency with affordable alternatives to conventional fuels that may face unusually high demand in emergency situations.

In FY 2020, the subprogram will provide minimal support to Data and Systems Research activities ($2,000,000), which include "living lab" projects – competitively selected, cost-shared projects to validate data, technologies, and systems in the field and inform future research – as well as statutory requirements related to alternative fuels, the annual Fuel Economy Guide, [1] and the State and Alternative Fuel Provider Fleet regulatory program. [2] Technology Integration also includes the Advanced Vehicle Competitions activity, which supports science, technology, engineering, and mathematics (STEM) and workforce development interests. The Advanced Vehicle Technology Competitions activity ($1,500,000) 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 Technology 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.

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[1] Vehicle Technologies' Alternative Fuels Data Center (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.

Vehicle Technologies
Technology Integration

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Technology Integration $41,300,000	**$3,500,000**	**-$37,800,000**
Data and Systems Research $38,000,000	$1,500,000	-$36,500,000
• In accordance with "Public Information Program" requirements in section 405 of the Energy Policy Act of 1992, update 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.
• Initiate Technology Integration Living Lab projects to collect data, validate technology, and provide real-world technology usage feedback to inform Vehicle Technologies research planning efforts.	• Support up to two small living lab projects to collect data and provide feedback on real-world technology usage to inform future Vehicle Technologies research plans.	• Support fewer and smaller-scale living lab projects that will collect data and provide feedback to the research program for future needs.
• In accordance with requirements in the Energy Policy and Conservation Act of 1975, publish and distribute the new model year Fuel Economy Guide, in partnership with the U.S. Environmental Protection Agency, update data and tools (e.g. Find-a-Car, Fuel Cost & Savings Calculator) and fuel economy information on www.fueleconomy.gov.	• Support vehicle fuel economy information for the new model year Fuel Economy Guide, in accordance with the Energy Policy and Conservation Act of 1975.	• Support for the Fuel Economy Guide limited to only what is required by the Energy Policy and Conservation Act of 1975; limited mid-year updates and other fuel economy information to consumers eliminated.
• Support cooperative agreements with Clean Cities coalitions to align local activities with national objectives for energy security and cost-effective transportation energy. Provide training and technical assistance support, leveraging National Laboratory expertise, to overcome technical barriers to alternative fuel vehicle adoption at the local level.	• No funding requested for coalition support, training, technical assistance, and partnership activities.	• Activity terminated to address other program priorities. Some activities will continue to cost obligated carryover until completion.
State and Fuel Provider Fleet Requirements $800,000	$500,000	-$300,000

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
• Track 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.
Advanced Vehicle Technology Competitions $2,500,000	**$1,500,000**	**-$1,000,000**
• Launch a new university student competition, "The EcoCAR Mobility Challenge," that provides science and technology training for the future advanced automotive workforce. Support student teams' initial design phase, integrating advanced powertrain technologies, electrification, Level 2 automation, and connectivity.	• Support a second year of the EcoCAR Mobility Challenge, during which student teams will continue to refine designs developed in FY 2019 and begin hardware implementation.	• Support efforts enabling an additional phase of student teams' vehicle design, development, and engineering.

Vehicle Technologies
Analysis

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 2020 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 and energy accounting of the entire transportation 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 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Analysis $5,000,000	**$1,500,000**	**-$3,500,000**
• 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 10 to 12 projects.	• Continue support for analytical capabilities and tools and the use of vehicle and transportation data and models for technology-, economic-, and interdisciplinary- analyses that can inform and prioritize technology investments and research portfolio planning. Funds will support four to six projects.	• The request focuses resources on the highest priority analysis projects. Lower priority projects will be deferred.

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] to enhance U.S. energy security and energy affordability. Price-competitive, advanced technologies to convert the Nation's abundant domestic, renewable biomass and waste resources into biofuels, biopower, and co-produced bioproducts 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, products and power where they can enhance the economics of biofuel production and learn from the successful petroleum refinery model.

The transportation sector accounts for 70 percent of U.S. petroleum consumption.[3] With 20 percent (net) of U.S. petroleum consumption being imported, the U.S. sends approximately $15 billion per month[4] overseas for crude oil. Transportation is the second most expensive spending category, after housing.[5] Increasing domestic production of biofuels, biopower and co-products can strengthen U.S. energy security by increasing domestic energy supply and increase the diversity of energy sources to safeguard against supply disruptions and volatility. Additionally, the production of biofuels and biopower from domestic biomass and waste feedstocks offers an opportunity to create American jobs across the supply chain and boost economic growth.

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.[6] This could potentially produce up to 50 billion gallons of biofuels (25 percent of U.S. transportation fuels), while also generating: up to 50 billion pounds of co-produced, high-value chemicals and materials, up to 75 billion kWh of electricity (enough to power 7 million homes) and $260 billion to the U.S. economy.[7] 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 there is too much technology uncertainty to merit sufficient industry focus.

To improve transportation energy affordability, strengthen national security, support energy dominance, and promote 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)

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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] Transportation Energy Data Book Edition 36, ORNL, Table 1.12.

[4] Transportation Energy Data Book Edition 36, ORNL, Table 1.6, Table 1.7 and Table 10.3; 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] U.S. Billion Ton Update https://energy.gov/sites/prod/files/2016/12/f34/2016_billion_ton_report_12.2.16_0.pdf.

[7] 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.*

future (~2030) modeled conventional technology of a gasoline internal combustion engine vehicle (ICEV) is expected to cost approximately 27 cents per mile and consume 4,700 Btu per mile.[1] 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.

In FY 2020, the Bioenergy Technologies Program will work towards the goal of improving affordability of transportation by achieving the following subprogram goals:

- The Feedstock Supply and Logistics subprogram will improve identified feedstock quality parameters and lower modeled feedstock harvesting and logistics costs to $86 per dry ton (versus the FY 2015 baseline of $120 per dry ton) for biorefineries that meet design case criteria of 800,000 dry tons/year.
- The Advanced Algal Systems subprogram will develop technologies that support mature model algae yields of 3,700 gallons of biofuel intermediate per acre per year, an increase over the previous FY 2018 milestone of 2,500 gallons per acre per year.
- 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/gge, a reduction of $0.46/gge compared to the FY 2018 state of technology baseline of $3.46/gge.
- The Conversion Technologies subprogram will increase yield of upgradeable co-products from an industrially relevant lignin waste stream to 53 percent by mass.
- The Strategic Analysis and Crosscutting Sustainability subprogram will verify a 10 percent reduction in water consumption for at least one biofuel production pathway versus its 2018 state of technology baseline.

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 includes Basic Research (TRL 1) and Applied Research (TRL 2-4), which primarily acquire new knowledge at laboratory scale. Experimental Development (TRL 5-6) includes systems research, technology integration, and scaling beyond the laboratory-scale in order to gather performance data that can reduce technology uncertainty and support subsequent industry efforts to scale up the technology.[2] This can involve 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 earlier-stage (TRL 2-4) research needs. The program will rely on the private sector to fund later stage demonstration and deployment of fully-integrated biorefineries.

Highlights of the FY 2020 Budget Request

- All Bioenergy Technologies Program research funding in the FY 2020 Request will support research and development conducted through lab calls and the annual operating plans (AOPs) with the National Laboratories and through targeted competitive solicitations to industry and universities.
- The Feedstock Supply and Logistics subprogram will continue to support the Feedstock Conversion Interface Consortium (FCIC) of 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 support 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 through an inclusive and thoroughly integrated approach within the consortium.
- The Advanced Algal Systems subprogram will fund early-stage applied research by DOE National Laboratories and by universities and industry on new strain development, approaches to culture management, and 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

[1] See Record #17008 which can be accessed at:
https://www.hydrogen.energy.gov/pdfs/17008_levelized_cost_driving_future_icev.pdf. Both energy and cost per mile are based on a 15-year vehicle lifetime and are based on meeting VTO technical targets.
[2] 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.

Bioenergy (ChemCatBio) consortium to support industry to improve yields and selectivity of drop-in biofuels and renewable chemicals. In addition, the subprogram will continue to investigate co-produced performance-advantaged bioproducts, including bio-derived plastics, with the potential to improve the economics and efficiency of biomass utilization. The program will also fund exploratory work at the DOE National Laboratories, universities and industry in the area of CO_2 and other waste stream utilization for production of fuels and chemicals in collaboration with the Office of Fossil Energy. The Conversion Technologies subprogram will also develop new and more efficient enzymes for breaking down existing plastics to ease recycling and conversion to biofuels and co-produced bioproducts.

- 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 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. Support of the integrated testing and pilot-scale work will continue in FY 2020 as BETO will leverage previous investments in integrated process development/pilot-scale/systems research capabilities at the DOE National Laboratories, universities and industry.
- The Strategic Analysis and Crosscutting Sustainability subprogram will conduct integrative analyses to inform R&D priorities and program goals.

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. The program's transformational research and development is fostering partnerships that will support 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 2018 Enacted	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
Bioenergy Technologies				
Feedstock Supply and Logistics	29,000	30,500	5,500	-25,000
Advanced Algal Systems	30,000	32,000	4,000	-28,000
Conversion Technologies	103,000	96,000	17,500	-78,500
Advanced Development and Optimization (Formerly Demonstration and Market Transformation)	54,545	57,500	8,000	-49,500
Strategic Analysis and Crosscutting Sustainability	5,000	10,000	5,000	-5,000
Total, Bioenergy Technologies	**221,545**	**226,000**	**40,000**	**-186,000**

SBIR/STTR:

- FY 2018 Transferred: SBIR $7,089,000; STTR $997,000
- FY 2019 Projected: SBIR $7,232,000; STTR $1,017,000
- FY 2020 Request: SBIR $1,280,000; STTR $180,000

Bioenergy Technologies
Explanation of Major Changes ($K)

	FY 2020 Request vs FY 2019 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 EERE and the Department. The subprogram will prioritize research on model feedstocks such as corn stover and pine residues through the Feedstock-Conversion Interface Consortium to develop tools that can improve operational reliability. The subprogram will support small, targeted competitive selections to engage industry and academic partners on projects to improve efficiency and reliability of renewable carbon feedstocks. National Laboratory R&D will focus on harvest logistics and quality assurance, biomass densification, and biomass analytics for high-impact woody and herbaceous lignocellulosic feedstocks, including wastes. No funds are requested for infrastructure upgrades at National Laboratory facilities.	**-25,000**
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 EERE and the Department. The subprogram will continue to prioritize early-stage research that shows the greatest promise for improving algae productivity, namely strain development and culture management. The subprogram will fund modest efforts in 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 will be de-emphasized. The subprogram will support small competitive selections for development of biological tools to improve algal productivity.	**-28,000**
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 EERE and the Department. The Conversion Technologies subprogram will continue its support of the Agile BioFoundry (ABF), Chemical Catalysis for Bioenergy, and Bioprocessing Separations multi-laboratory consortia which broadly advance multiple conversion strategies. Small, targeted competitive selections to support industry and academic partners to collaborate with the ABF consortium will be emphasized in FY 2020 as opposed to significant additional laboratory work. The subprogram will focus laboratory work on performance advantaged bioproducts, specifically bio-derived plastics, in addition to predictive model development. The subprogram will prioritize laboratory research in the areas of lignin valorization, cellulase enzyme development, a reduced suite of biochemical fermentation organisms, and identifying and synthesizing bioproducts that can support the production of biofuels. The program will support waste feedstock utilization at a reduced level, including wet waste streams, municipal solid wastes (MSW), and carbon dioxide. Efforts to develop enzymes that can improve recyclability of existing plastics for conversion to biofuels and co-produced bioproducts will also continue at reduced levels. No funds are requested for aerobic upgrading, for Conversion subprogram portions of the Feedstock Conversion Interface Consortium, or for the joint R&D initiative with USDA. No funding is requested for laboratory	**-78,500**

research on processing of municipal solid waste (MSW) feedstocks; all MSW funding will be devoted to competitive selections for early stage research strategies to lower biofuel and biopower production costs from waste feedstocks.	
Advanced Development and Optimization (Formerly Demonstration and Market Transformation): The reduction in funding level for this subprogram reflects the prioritization of the most critical early-stage activities within the broader priorities of EERE and the Department. Funding for the Co-optimization of Fuels and Engines, in conjunction with the Vehicle Technologies Program, will prioritize research on bio-based fuels for advanced compression ignition and de-emphasize research on bio-based fuels for spark-ignition. The program will leverage previous investments to support integrated process development and pilot-scale systems research at the National Laboratories, universities and industry. The subprogram will de-emphasize new private sector research related to performance of integrated systems to lower the cost of drop-in biofuels as well as systems R&D including co-processing and materials research. No funding is requested in FY 2020 for demonstration scale projects.	**-49,500**
Strategic Analysis and Crosscutting Sustainability: The reduction in funding level for this subprogram reflects the prioritization of the most critical early-stage activities within the broader priorities of EERE and the Department. 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 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.	**-5,000**
Total, Bioenergy Technologies	**-186,000**

Bioenergy Technologies
Feedstock Supply and Logistics

Description

The primary goal of the Feedstock Supply and Logistics (FSL) subprogram is to conduct early stage research and development focused on supporting industry as they develop and supply high-quality, energy-dense, and sustainable conversion-ready feedstocks. 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 2020, has goals to expand high-quality 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.

The FCIC is a consortium involving eight National Laboratories and is directed toward solving obstacles encountered by integrated biorefinery projects. 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 and co-product yield, quality, and minimum fuel selling price (MFSP) targets.[2]

Feedstock Conversion Interface Consortium ($3,000,000): The Feedstock Conversion Interface Consortium (FCIC) is the primary activity of the Feedstock subprogram in FY 2020. 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 and co-product yield, quality, and minimum fuel selling price (MFSP) targets. The FCIC will develop a framework based on first principles through which technology developers will be able to assess the quality, composition and value of various streams in their processes for the purpose of improving operational reliability within biorefineries. To accomplish this, the FCIC connects core capabilities across eight National Laboratories. The FCIC is organized into eight 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, and an external industry advisory board also meets with the executive committee and the Bioenergy Technologies Program regularly.

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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] MFSP is defined as the fuel selling price (leaving the biorefinery gate) that supports 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.

The FCIC is organized around four objectives:

- Quantify, understand, and manage variability in biomass to understand fundamental mechanisms underlying how biomass composition, structure, and behavior impacts unit operations through the value chain.
- Develop first principles hypotheses/mechanistic models related to physical and chemical conversion in each of the steps through which the feedstock has to traverse, from field to products. Validate these models using bench scale and pilot scale data.
- Develop transfer functions (or scaling rules) which are based not only on experimental data or experience but are also based on first principles conversion mechanisms that feedstock undergoes in the value chain from field to products.
- Develop technoeconomic and life-cycle assessment models which can be used to determine the value of feedstock as it undergoes conversion through the value chain and is converted to forms where it can become a commodity product.

In FY 2018, FCIC screened and obtained corn stover and pine residue samples with four various sets of moisture and ash conditions (low moisture, low ash; low moisture, high ash, high moisture, low ash; high moisture, high ash) for baseline experiments that were conducted at the at Idaho National Laboratory (INL) and the National Renewable Energy Laboratory (NREL). These experiments generated a matrix of biomass chemical, physical, and mechanical properties that affect performance and reliability across the biomass value chain. FCIC also completed a modeled baseline data collection list and a gap analysis for identification of feedstock attributes causing impacts to throughput, yields, and costs for individual equipment. During the course of its first year, FCIC has developed new and improved existing analytical methods for biomass properties, including crystallinity, surface area, surface energy, spectroscopy compositional analysis, rheological properties, particle size distribution, particle shape, feeding and shear testing, etc. In addition, FCIC launched a Directed Funding Opportunity (DFO) that seeks to enhance collaboration of industry with the National Laboratories to help identify the factors affecting feed handling into pressurized reactors at integrated biorefineries.

In FY 2020, consortium research will continue focus on the molecular deconstruction of cell wall biopolymers in the initial steps of conversion processes to support 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 knowledgebase on solids handling, develop new fundamental 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. The FCIC will heavily prioritize early-stage, fundamental R&D, and the subprogram will rely upon the private sector for later-stage R&D and scale-up. Because of a de-emphasis from the Conversion sub-program, the FCIC will reduce focus on developing tools to produce homogeneous, quality controlled intermediates that can be converted into market-ready products, and will instead focus on first-principles R&D to develop tools that quantify and understand sources of feedstock variability.

National Laboratory Feedstock Supply and Logistics R&D ($2,000,000): 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 harvest logistics and quality assurance, biomass densification, and biomass analytics tools. Activities will focus on model feedstocks such as corn stover and pine residues. Research on dedicated energy crops, waste streams, and other renewable carbon sources (municipal solid waste, biosolids, sludges, etc.) will be limited.

In addition, the Feedstock Supply and Logistics subprogram is dedicating funds ($500,000) to support a competitive opportunity to engage industry and academic partners on projects that address conversion efficiency challenges and increase the types and quantities of renewable carbon feedstock intermediates available for conversion.

Feedstock Supply and Logistics

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Feedstock Supply and Logistics $30,500,000	**$5,500,000**	**-$25,000,000**
• $14,000,000 to support research under the Feedstock-Conversion Interface Consortium (FCIC) at the National Labs to improve operational reliability of biomass feedstock handling, preprocessing and conversion, includes competitive selections with industry and academia.	• $3,500,000 to support research under the FCIC at the National Labs to improve operational reliability of biomass feedstock handling, preprocessing. Includes $500,000 for competitive selections with industry and academia.	• FCIC research will focus on the highest priority challenges associated with feedstock handling and preprocessing, specifically feedstock variability. Research will be conducted primarily at the National Laboratories with fewer, smaller selections to involve industry and academic partners.
• New competitive selections on biomass feedstock research beyond the efforts of the FCIC to reduce the costs of feedstocks logistics.	• No funds are requested for competitive selections on biomass feedstock research beyond efforts of the FCIC.	• No funds are requested for competitive selections on biomass feedstock research beyond efforts of the FCIC
• $6,000,000 is to support ongoing National Laboratory research on harvest logistics and quality assurance, biomass densification, and biomass analytics tools.	• $2,000,000 to support targeted ongoing National Laboratory research associated with harvest logistics and quality assurance, biomass densification, and biomass analytics tools.	• National Laboratory R&D will focus on harvest logistics and biomass densification of model woody and herbaceous feedstocks, not dedicated energy crops, or other renewable carbon sources.
• $5,000,000 is for facility upgrades at the Biomass Feedstock National User Facility at Idaho National Laboratory.	• No funds are requested for facility upgrades at the Biomass Feedstock National User Facility.	• No funds are requested for facility upgrades at the Biomass Feedstock National User Facility.
• Competitively-selected projects under the Biomass Research and Development Initiative will continue with prior year funds.	• Competitively-selected projects under the Biomass Research and Development Initiative will continue with prior year funds. No funds are requested to support new competitive selections.	• No change.

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 co-product precursors. Algal biofuels could potentially contribute up to 5 billion gallons of advanced biofuels per year by 2030, or about 25 percent of the current jet fuel market.[2] In recent years, research by the subprogram has improved capabilities to predict, breed, and select the best-performing algal strains; developed better tools to monitor and control system dynamics; improved methods to harvest algae at high-throughputs; and improved processes to extract and convert more algal biomass components into fuels and high-value co-products.[3]

In FY 2019, as a result of ongoing, competitively selected projects with prior year funding, the subprogram met its milestone to increase the value of cultivated algal biomass by 30 percent through the co-production of high-value products. Through the ongoing work of the "Development of Integrated Screening, Cultivar Optimization, and Validation Research" (DISCOVR) multi-lab consortium project, the Advanced Algal Systems subprogram met its FY 2019 GPRA subprogram milestone of 15.9 grams of algae biomass grown per square meter of open pond raceway cultivation area per day. This represents a 20 percent improvement over the FY 2016 baseline of 13 grams per square meter per day.[4]

While accomplishing this yield goal was a major achievement, the modeled minimum fuel selling price (MFSP) of algae biofuel remains too high (FY 2018 state of technology (SOT) with fully-lined open ponds: $10-16/gge)[5] to be commercially viable in the near-term. Algal productivity, the composition of the harvested algal biomass, and the frequency of crop failures continue to have the highest impact on algae MFSP. Therefore, with FY 2020 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-produced bioproducts development from promising cultivation species by continuing quantitative analyses of algal biomass productivity, composition, and energy content.

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 support businesses to successfully pursue larger-scale integration and demonstration. Specifically the following initiatives will be pursued:

Development of Integrated Screening, Cultivar Optimization, and Validation Research (DISCOVR) Project ($1,200,000): The program will prioritize support for DISCOVR — a project consortium of four DOE National Laboratories with unique and complementary capabilities to support algae R&D. In FY 2020, 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

[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 Program. Available at: https://www.energy.gov/eere/bioenergy/downloads/2016-national-algal-biofuels-technology-review.

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

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

with competitive projects awarded with prior year funds, to provide valuable field and modeled data into the techno-economic analysis.

Laboratory Algae Research ($2,300,000): FY 2020 funds will focus on functional characterization of algal strains, strain composition, and crop protection through targeted research at the DOE National Laboratories. These focus areas contribute significantly to the goal of increasing algal productivity on a fundamental level. Key breakthroughs anticipated in these targeted research areas will complement ongoing competitive efforts awarded in FY 2018 from the Enhanced Carbon Utilization in Algal Systems funding opportunity. Work will also continue in the Algae Technology Education Consortium to help provide online education material for community colleges and technical schools.

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, such as fortified foods and dietary supplements sold as capsules, tablets, or powders. The success of these activities will support industry to increase scale of production and begin accessing energy markets when the technology uncertainty and cost are reduced.

Productivity Enhanced Algal Toolkits competitively-selected projects ($500,000): Building upon an FY 2017 program, FY 2020 funds will support competitive selections to increase algal areal productivity and biofuel productivity through strain biology developments and enhanced management of ecological or abiotic contributions to cultivation biology. This work will produce measurable improvements in process performance as well as the development of knowledge and tools to accelerate innovation.

Advanced Algal Systems

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Advanced Algal Systems $32,000,000	**$4,000,000**	**$-28,000,000**
• $2,700,000 to support early stage and precompetitive applied research under the DISCOVR project National Laboratory consortium to increase algal productivity, composition, and crop protection, including data collection, analysis and modeling to assess the state-of-technology and support techno-economic analyses to inform research strategies.	• $1,200,000 support early stage and precompetitive applied research under the DISCOVR project National Laboratory consortium to increase algal productivity, composition, and crop protection with minimal experimental data collection, analysis and modeling for state-of-technology and techno-economic analyses.	• DISCOVR activities will focus on known high productivity, robust strains for operational and cultivation parameterization, and reduced data collection (maximum 6 week experiments per quarter) to support state-of-technology modeling and techno-economic analyses.
• $8,300,000 to support early-stage National Laboratory research on strain characterization, composition and crop protection to improve algal productivity.	• $2,300,000 to support early-stage ongoing National Laboratory research on strain characterization, composition and crop protection to improve algal productivity.	• National Lab research will continue on existing algae strains and crop protection strategies with no new projects for novel strains or new strategies to improve algal productivity.
• $2,000,000 for a competitive award on economical capture of CO_2 directly from the atmosphere.	• No funding requested	• No funds are requested for new competitive awards on economical capture of CO_2 directly from the air.
• New competitive selections on advanced algal research to increase algae yield, reliability, and quality.	• $500,000 will support competitive selections to drive improvements in increased algal areal productivity through strain biology developments and enhanced management of cultivation biology.	• Fewer and smaller competitive selections will focus on the development of biological tools to improve algal productivity.

Bioenergy Technologies
Conversion Technologies

Description

The Conversion Technologies subprogram pursues early-stage applied R&D to generate knowledge that supports industry efforts to demonstrate and deploy technologies for converting biomass feedstocks into transportation fuels and co-produced bioproducts. 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, crosscutting 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 applied research on a portfolio of technical challenges that support promising feedstock-flexible conversion technologies that can meet the primary goal of cost-competitive fuels (less than $3.0/gge). This research lowers technology uncertainty and establishes a knowledge base that supports industry to demonstrate 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-products.

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 efforts to increase organizational efficiency. The subprogram established these consortia 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, while reducing the potential for duplication. These three consortia, the Chemical Catalysis for Bioenergy Consortium, the Agile BioFoundry, and Bioprocessing Separations Consortium are described in greater detail below.

Agile BioFoundry (ABF, $3,200,000)[1]: The development of an Agile BioFoundry (ABF) continues to be a key activity in FY 2020. 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. This work supports predictable-design by establishing a robust set of biomanufacturing 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 Bioenergy Technologies Program.

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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.
- 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 that 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. This produces large quantities of data that are fed to the Learn team, which uses machine learning and data visualization tools to inform the next round of Design.
- Integrated Analysis: The Integrated Analysis team examines the techno-economic 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 in production-scale fermenters. 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 2019, funds were used to continue development of 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 included completion of multiple 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.

In FY 2020, competitive selections for the Agile Biofoundry will support additional industrial and academic partner collaboration with the consortium. These will continue to build on previous success by improving titers, rates and yields on the FY 2017 – FY 2019 target molecules. This will be accomplished by completing additional DBTL cycles on up to three target host pairs leading to a further 100 percent improvement for at least one target-host pair. BioFoundry throughput will also be expanded through several new industrial partnerships with ten partnerships expected to be active during FY 2020.

Chemical Catalysis for Bioenergy (ChemCatBio or CCB, $3,200,000)[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 (four catalytic tasks and two enabling tasks) and is managed by a leadership team that works together to coordinate reporting, articulate strategic direction, establish CCB-led cooperative research and development partnerships with industry, and manage interactions with stakeholders, including an industry advisory board. In FY 2020, CCB will focus on the following six tasks (four 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 inside (*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.
- Catalytic Upgrading of Carbon Dioxide: Across the country, CO_2 is generated during fermentation processes in concentrated streams. This task is developing new electrocatalytic and thermocatalytic processes for converting CO_2 into a processable intermediate chemical and then upgrading it into a product or fuel blendstock.
- 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 support CCB teams to optimize yield and fuel properties. In 2019, the subprogram demonstrated the kinetics-based methodology, and in 2020, the approach will be utilized in collaboration with industry to translate research to industry-relevant scales.

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 over 100 peer-reviewed manuscripts since its inception in FY 2017.

In FY 2019, ChemCatBio realized technology advances across several conversion pathways. For Catalytic Fast Pyrolysis, ChemCatBio increased carbon efficiency (from 33 percent to 40 percent) resulting in a $0.5/gge reduction in MFSP to a projected $3.46/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 converted 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.

In FY 2020, ChemCatBio will pursue technology advances across multiple conversion pathways. In FY 2020, ChemCatBio will attempt a $0.20 reduction in MFSP compared to the FY 2017 State of technology (SOT) by developing processes that divert 20 percent of the Catalytic Fast Pyrolysis oil to a mixed phenolics co-product. For Catalytic Upgrading of Carbon Dioxide, ChemCatBio will develop and analyze low temperature electrolyzers for CO_2 reduction and show the potential for CO_2 utilization to increase the economic viability of existing biorefineries through techno-economic analysis.

Bioprocessing Separations Consortium ($1,000,000)[2]: The Bioprocessing Separations Consortium involves seven National Laboratories and is dedicated to advancing efficient and cost-effective separation technologies that make optimal biogenic carbon. The consortium 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. The consortium 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 co-products processes. A limited amount of resources will be directed toward lignin valorization. In FY 2020, there will be three technical tasks:

[1] CCPC brings together materials scientists, biologists, and reactor/process engineers across the DOE National Laboratories to understand the fundamental mechanisms underlying catalyst, feedstock, enzyme, and reactor behavior/performance. 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. https://www.cpcbiomass.org/.

[2] The Bioprocessing Separations Consortium brings together teams from the U.S. Department of Energy's (DOE's) national laboratories to move cost-effective, high-performing separations technologies to market faster through coordinated separations research that targets challenges relevant to industry. http://www.bioesep.org/.

- 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.

In FY 2020, the consortium will develop computational and predictive methods for assessing separations needs for bioenergy processes. The goal of this work is to develop a tool for bioenergy practioners to streamline the evaluation of separations 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 ($2,100,000): 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 co-products or “valorizing” (creating higher value from) lignin is essential to improve the economics of biofuel production. In FY 2019, two initial target processes were 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. Also, in FY 2019, oxidative processes showed >40 percent yields of upgradable compounds from real lignin streams and reductive processes showed >50 percent yields. Specifically, in FY 2020, the lignin area will focus on R&D to improve the carbon efficiency of lignin to high-value co-products. This will include R&D on the hybrid strategy of using a catalytic approach to break lignin into a complex mixture of compounds which are capable of being biologically upgraded into targeted products of interest at high conversion efficiency.

Performance-advantaged co-products R&D ($700,000): In the context of a biorefinery, value-added co-products can support biofuel production by improving the overall financial viability of the biorefinery much the same as occurs in petroleum refineries. In addition, much of the co-product research is investigating conversion of process streams that are either currently put to low-value use or entirely treated as waste streams from biorefineries. Lastly, lignocellulosic-based biofuel and co-product production processes share half or more of “upstream” processes in common (feedstock supply, feeding, deconstruction to sugar or syngas intermediates, cleanup, separation, etc.). High-value co-products present the industry with 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 co-products research, in particular, is targeted at products that can be made from biofuel production process waste streams that may offer superior performance compared to conventional petrochemical-derived 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 2020 the project will predict at least three properties of a performance differentiated polymer and release a web-based tool for polymer prediction. 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 ($2,900,000): In FY 2019, 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, in FY 2019, the subprogram furthered 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. In addition, using a novel pertractive fermentation system, research achieved extracted titers of >150 g/L of butyric acid, a precursor to jet and diesel fuel. In FY 2020, the subprogram will continue to pursue R&D to raise the titers, rates, and yields of fuel-precursor production from biological fermentations for use in catalytic upgrading strategies. The subprogram will aim to increase butanediol concentrations by an additional 25 percent over FY 2019 levels (to 125 g/L) at 85 percent of theoretical yield through further genetic engineering of the organism and fermentation optimization.

Analytical Method Development and Process Control ($1,900,000): In FY 2018, the subprogram developed protocols for more precise characterization and quantification of lignin, hydrolysates, and other biochemical species. 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 was 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. In FY 2020, the system will be further automated such that the control system automatically adjusts key process parameters (e.g. pH, oxygen level, hydrolysate concentration, etc.) to maintain high organism growth and productivity for up to two weeks without human intervention.

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 2020, the work will build on the foundation of the fast pyrolysis characterization done in previous years to develop and disseminate analytical methods for bio-derived or co-processed liquids that quantify functional groups or individual chemical compounds as well as evaluation of their impact on materials. The focus will be on identifying functional groups found in next-generation bio-oils such as through Hydrothermal Liquefaction or Catalytic Fast Pyrolysis.

Waste to energy ($1,000,000): R&D on waste to energy focuses on innovative strategies to convert wet and gaseous waste streams into biofuels and co-products. No funding was requested for these R&D activities in FY 2019. In FY 2020, funding ($500,000) will be used to make competitive selections to convert waste streams, including municipal solid waste, wet waste, and gaseous waste streams to biofuels, biopower, and co-products. Lab-based R&D ($500,000) will continue to focus on transforming anaerobic digestion on a variety of waste streams to produce and separate intermediates (volatile fatty acids) that can be upgraded into fuels and co-products via catalytic routes developed under the ChemCatBio Consortium. A bench-scale system for recovery of these volatile acids will be operated to recover more than 50 percent of these compounds in a continuous system. The subprogram will continue techno-economic analysis on biological, thermochemical, and electrochemical routes for carbon dioxide conversion to higher value products.

Plastics up-cycling ($1,000,000): Significant quantities of un-recycled plastics are part of the organic portion of the waste stream in the U.S. and worldwide. Further, even plastics that are recycled are most often converted into lower-value products. New enzyme discoveries offer the possibility to break current plastics down into building blocks that can be re-used for high-value applications, such as fuels. To address these opportunities, research will continue to develop new and more efficient enzymes for breaking down existing plastics to ease recycling and conversion to fuels.

Conversion Technologies

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Conversion Technologies $96,000,000	**$17,500,000**	**-$78,500,000**
• $20,000,000 for the Agile BioFoundry consortium to accelerate the R&D of new biologically-derived molecules through the completion of ≥ 3 cycles of DBTL on ≥ three target host pairs with at least 100 percent improvement in baseline titer, rate, and yield. Includes two to three competitive selections for industry and academic partners.	• $3,700,000 for the Agile BioFoundry consortium to accelerate the R&D of new biologically-derived molecules through the completion at least two cycles of DBTL on up to three target host pairs with a further 100 percent improvement in baseline titer, rate, and yield over FY 2019 accomplishments. Includes $500,000 for competitive selections for industry and/or academic partners.	• Funds for Agile Biofoundry lab-led activities will be reduced in the areas of host on-boarding and additional design-build-test-learn cycles and support the most meritorious project proposed by industry and academic partners to complement the lab consortium research.
• $12,500,000 for National Laboratory research under the ChemCatBio consortium on catalytic upgrading of indirect liquefaction intermediates, biochemical intermediates, CO_2, catalytic fast pyrolysis, catalyst synthesis and characterization, and computational physics and chemistry for faster, less-expensive scale-up of catalytic processes.	• $3,200,000 for National Laboratory research under the ChemCatBio consortium on catalytic upgrading of indirect liquefaction intermediates, biochemical intermediates, CO_2, catalytic fast pyrolysis, and catalyst synthesis.	• ChemCatBio activities will prioritize research on upgrading bio-oil to high-value co-produced bioproducts and CO_2 utilization and reduce catalytic work to identify and mitigate catalyst deactivation mechanisms and computational chemistry.
• $2,300,000 for Bioproducts R&D with National Laboratories to synthesize, characterize and test at least 25 new bio-derived performance-advantaged materials that will support biofuels across a range of polymer applications that verify the predictive model developed in FY 2018.	• $700,000 for Performance-Advanced Bioproducts research at the National Laboratories to predict at least three properties of a performance differentiated bioproduct and release a web-based tool for polymer prediction.	• National Laboratory efforts will prioritize development of a web-based tool for bio-based polymer property prediction over production of novel bio-polymers for testing and developing new molecules
• $3,000,000 for analytical method development and applied materials issues to support ongoing projects, includes the development of a single process control scheme.	• $1,900,000 for Analytical method development and process control to support critical analytical requirements of the R&D portfolio and implement real-time automation systems for bioconversion of lignocellulosic materials.	• Analytical method research will prioritize the development and optimization of an automated bioreactor for a single process. Materials compatibility testing will be deprioritized.
• $4,500,000 for lignin valorization research at the National Laboratories that will focus on a single potential pathway to convert at least 50 percent lignin stream to upgradeable intermediates.	• $2,100,000 for lignin valorization research at the National Laboratories to improve the carbon efficiency of lignin to high-value co-products, maintaining 50 percent yields of upgradable compounds from lignin.	• Research will prioritize cost reductions and forgo strategies to further increase yield.

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
• Competitive selections for renewable energy from urban and suburban waste, biopower from municipal solid waste and advanced economic small-scale anaerobic digestion research.	• $500,000 is requested for a competitive selections for waste feedstock utilization research, such as municipal solid waste, wet waste streams and/or carbon dioxide.	• Funding for competitive selections will support early-stage research to lower the cost of biofuel, bioproduct, and biopower production from waste feedstocks.
• $4,000,000 for research at the National Laboratories to develop technologies for the conversion of wet wastes to high value intermediates and renewable natural gas, and on conversion of CO_2-derived intermediates to fuels and chemicals	• $500,000 for research at the National Laboratories to develop technologies for the conversion of wet waste to liquid fuels and products, and analysis of potential strategies to convert CO_2 to products.	• Lab research will focus strategies to produce liquid fuels and coproduced bioproducts from wet waste. No funding is requested for lab research on strategies that produce gaseous fuels or power from wastes.
• $3,000,000 to continue development of biochemical fermentation for one to two biochemical processes for the conversion of lignocellulosic biomass to hydrocarbon biofuels.	• $2,900,000 to continue development of biochemical fermentation for one to two biochemical processes for the conversion of lignocellulosic biomass to hydrocarbon biofuels, including cellulase development to support further cost reductions in biochemical pathways.	• Funds will support research for cellulase enzyme development specific to pretreatment methods that facilitate lignin utilization and a reduced set of fermentation organisms for the production of fuels and chemicals.
• $1,500,000 for the Feedstock Conversion Interface Consortium (FCIC) to quantify, understand, and manage variability in biomass from field through downstream conversion and to understand how biomass composition, structure, and behavior impacts system performance.	• Feedstock Conversion Interface Consortium (FCIC) research at the National Laboratories will continue using prior year funds.	• No funds for FCIC are requested from the Conversion subprogram.
• $3,400,000 is for laboratory research under the Bioprocessing Separations Consortium to reduce cost and increase efficiency of separations for thermochemical and biochemical processes through experimentation and modeling.	• $1,000,000 is for laboratory research under the Bioprocessing Separations Consortium to develop computational and predictive methods for assessing separations needs for bioenergy processes.	• The Bioprocessing Separations Consortium will focus on computation and predictive modeling rather than laboratory experiments on novel separation techniques.
• $1,000,000 is for National Laboratory research on plastic up-cycling and design for recyclability, including enzyme development, and designing new bio-derived plastics that have equal or better performance than existing materials and are more easily broken down and recycled.	• $1,000,000 is to continue National Laboratory research on plastic up-cycling and design for recyclability, including enzyme development, and designing new bio-derived plastics that have equal or better performance than existing materials and are more easily broken down and recycled.	• No change.
• New competitive selections for Conversion research with industry and academia to drive	• No funding requested	• No funding is requested for additional competitive selections.

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
advanced conversion technology processing that reduces capital costs and increases throughput.		

Bioenergy Technologies
Advanced Development and Optimization
(Formerly Demonstration and Market Transformation)

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 2020 to strengthen the knowledgebase 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 support 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 and university partners, 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 support higher engine efficiency.

Accomplishments in FY 2018 and FY 2019 include the completion of the evaluation of novel bio-based fuel molecules and mixtures that provide properties that maximize the efficiency and performance of advanced spark ignition engines for light duty and advanced mixing controlled compression ignition (MCCI) engines for heavy duty vehicles. Additionally, in FY 2019, BETO and VTO initiated seven new industry and university projects from a competitive Funding Opportunity Announcement (FOA) to support Co-Optima project goals. In FY 2020, the R&D focus will shift towards completing the evaluation of fuels for multi-mode engines for light duty vehicles and evaluating fuels for medium and heavy-duty vehicles. This research will result in a list of high-potential fuel candidates that provide desirable fuel properties for advanced compression ignition engines.

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 demonstration projects will be solicited or selected in FY 2020 except through active management and application of funds from prior years.

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 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 2020 through the ADO subprogram, as Bioenergy Technologies Program will leverage previous investments in integrated process development and pilot-scale systems research capabilities at the DOE National Laboratories including the Integrated Biorefinery Research Facility and Thermochemical User Facility at the National Renewable Energy Laboratory; the Biomass Feedstock National User Facility at Idaho National Laboratory; the Advanced Biofuels Process Development Unit at Lawrence Berkeley National Laboratory; and the HydroThermal Liquefaction (HTL) skid at Pacific Northwest National Laboratory (PNNL). National Laboratory projects will also evaluate alternate routes to produce jet fuels from biomass, assess performance of co-processing bio-intermediates with fossil derived intermediates to leverage existing petroleum refinery infrastructure, and investigate bio-derived fuels (including bio-intermediates and bio-blends) for marine engine uses. Other efforts at the National

Laboratories will ensure that related technologies, such as catalyst engineering, materials science, and reactor design, are correspondingly developed to support progress of the entire technology pathway.

In FY 2018 BETO competitively awarded ten projects which, through outlay of prior year obligations, will continue in FY 2020 focused on Process Development for Advanced Biofuels and Biopower. The ten projects are addressing critical R&D barriers in three different process development areas: 1) Drop-in Renewable Jet Fuel Blendstocks; 2) Drop-in Renewable Diesel Fuel Blendstocks; and 3) Biomass, Biosolids, and Municipal Solid Waste to Energy.

In FY 2017 BETO began investments in several pilot- and demonstration-scale projects for the manufacture of Advanced or Cellulosic Biofuels, bio-products, refinery compatible intermediates, or bio-power which will complete phase one activities in FY 2019. Under this FOA, the two pilot projects developing biofuels and the two pilot projects developing waste-to-energy technologies were down-selected in FY 2018 to one project in each of these areas to move into phase two using prior year funds after fully completing the phase one scope of work. Work on these projects continues in FY 2020 through outlay of prior year obligations carried forward. BETO will also continue its best practice of using an independent engineer to help with oversight and verification of engineering-scale system testing.

In FY 2017 BETO competitively awarded eight projects which, through outlay of prior year obligations, will continue in FY 2020 focused on R&D challenges within existing integrated biorefineries (IBRs) that need to be addressed to support 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 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Advanced Development and Optimization $57,500,000	**$8,000,000**	**-$49,500,000**
• $14,500,000 for the Co-Optimization of Fuels and Engines (Co-Optima) initiative in collaboration with the Vehicle Technologies Program for National Laboratory Consortium research for R&D to identify and evaluate the most promising biofuel candidates to support efficiency for advanced mixing controlled compression ignition (MCCI) engines for heavy duty and multi-mode spark and compression ignition engines for light duty. Includes one competitive award for bioblendstocks for use in MCCI engines.	• $5,500,000 for the Co-Optima initiative to conduct early stage R&D and related analysis by the National Laboratory Consortium to evaluate the most promising biofuel candidates to support fuel economy and efficiency targets for advanced compression ignition (ACI) engines.	• Research under the Co-Optima initiative will prioritize biofuel candidates for advanced compression ignition engines conducted by the National Laboratories. Research on fuels for multi-mode spark ignition engines for light-duty vehicles will be deprioritized. No funding is requested for competitive selections.
• Competitive selections for research and testing of innovative efficient wood heaters.	• No funds are requested for wood heater research.	• No funds are requested for wood heater research.
• Competitive selections for research and education to support increased renewable energy production from urban and suburban wastes.	• No funds are requested for research and education to support increased renewable energy production from urban and suburban wastes.	• No funds are requested for research and education to support increased renewable energy production from urban and suburban wastes.
• $14,000,000 to support systems R&D, including co-processing and materials research, and continue the integrated testing and pilot-scale research at the National Laboratories.	• $2,000,000 to continue the integrated testing and pilot-scale research, leveraging previous investments at the National Laboratories.	• No funding is requested to support materials research or strategies for co-processing of biofuel intermediates in petroleum refineries.
• Competitive selections for Advanced Development and Optimization with industry and academia on R&D of scaling systems, and integration in to reliable processes.	• $500,000 for competitive selections to address challenges to scale-up and integration of biofuels, bioproducts or biopower systems.	• New competitive selection(s) will leverage existing process development units at National Laboratories to address systems research needs with industry and academia.

Bioenergy Technologies
Strategic Analysis and Crosscutting 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.

Crosscutting Sustainability activities are conducted by National Laboratories, industry, and academic partners to improve understanding of and focus the research portfolio. This includes research targeting underproductive aspects of agricultural and forestry systems and leveraging the ability of biomass to improve degraded soil and water resources. Crosscutting 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 Crosscutting 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. In FY 2019, the subprogram developed a regional water availability index module that is capable of simulating rainwater and surface and groundwater use in bioenergy feedstock production. The model was then used to demonstrate modeled water quality benefits of bioenergy production based on landscape design in two watersheds in Iowa. 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 Bioproduct Transition Systems Dynamics Model, the Landscape Environmental Assessment Framework (LEAF), and the Feedstock Production Emissions to Air Model (FPEAM).

In FY 2020, funding from Crosscutting 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. The subprogram will focus on making necessary updates to high-priority models and tools for use by the program, industry and academia. For example, the subprogram will augment the water availability index module in the WATER model to include reclaimed municipal wastewater in addition to rain water, surface and ground water. The subprogram will apply these tools to conduct high-priority analyses focused on understanding the potential economic and environmental effects of novel bioenergy technologies and processes derived from biomass and waste streams. The subprogram will conduct analysis to identify innovative strategies for synergistic cost reduction and environmental benefit associated with bio-based fuel, power, and product development.

Strategic Analysis and Crosscutting Sustainability

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Strategic Analysis and Crosscutting Sustainability $10,000,000	**$5,000,000**	**-$5,000,000**
• $4,000,000 to update models and tools (including GREET, WATER, JEDI and LEAF) and apply them to conduct high-priority analyses that are expected to result in at least 10 peer reviewed publications and technical reports.	• $3,500,000 to update to models and tools (including GREET, WATER, JEDI and LEAF) and apply them to conduct high-priority analyses that are expected to result in at least 7 peer reviewed publications and technical reports.	• No Change.
• $1,500,000 to fund National Laboratory analysis of the potential for integrated landscape management strategies to reduce the cost of biofuels.	• $1,500,000 to fund National Laboratory analysis of the potential for integrated landscape management strategies to reduce the cost of biofuels.	• No Change.
• $2,500,000 to fund bioenergy sustainability research by the National Laboratories to identify and fill knowledge gaps related to food security, air, land, and water resources.	• No funds are requested for bioenergy sustainability research related to food security, air, land, and water resources.	• No funds are requested for bioenergy sustainability research related to food security, air, land, and water resources.
• Competitive selections on Strategic Analysis and Crosscutting Sustainability with industry and academia.	• No funds are requested for a new competitive selections.	• No funds are requested for a new competitive selections

Hydrogen and Fuel Cell Technologies

Overview

Hydrogen can be produced from diverse domestic resources – either directly from natural gas, oil, coal, and biomass, or through water splitting using electricity from any source including renewables and nuclear power. It can be used to store energy or as a fuel or feedstock in multiple applications across sectors. In the transportation sector, commercially available fuel cell electric vehicles (FCEVs) using hydrogen can achieve significantly higher efficiencies than combustion engines without compromising driving range or fueling times, albeit at higher levelized cost of driving. In addition to transportation, hydrogen and fuel cell technologies can serve stationary applications improving energy security and reliability by providing responsive back-up power, combined heat and power, and other electric and fuel distribution services.

The generation, storage and use of hydrogen can improve energy sector flexibility by avoiding curtailment of variable renewable sources like solar and wind, enabling more optimal capacity utilization of baseload nuclear, coal, and natural gas plants and can increase integration across transportation, industrial, and energy sectors. Thus, fuel cell and hydrogen technologies can support 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 R&D that can ultimately contribute to successful market impact. Therefore, DOE's role under the Hydrogen and Fuel Cell Technologies Program is to focus on early-stage R&D that supports industry efforts 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 support 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 cost approximately 27 cents per mile and consume 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 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 an automotive fuel cell system needs to be $30/kW with a life of 150,000 miles. While the program's 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.

The request provides $15,000,000 in support of the Advanced Energy Storage Initiative, which coordinates R&D across the DOE applied energy offices to advance energy storage and other technologies that create more flexible generation and more flexible load, thereby increasing the reliability and resilience of the U.S. electric grid. Energy storage is critical to realizing both a flexible, resilient electrical grid and a modern, affordable transportation system powered by a diverse suite of energy resources – and energy storage for the grid is complemented by a portfolio of generation and load technologies that provide flexibility, essential reliability services, and system resilience. The Advanced Energy Storage Initiative will enhance coordination across EERE and DOE and establish aggressive, achievable, and comparable goals for cost-competitive energy storage services and applications.

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[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.

Highlights of the FY 2020 Budget Request

- **Fuel Cell R&D** will focus on early-stage fuel cell component R&D with potential for transportation and crosscutting applications. Increased emphasis will be on R&D for transportation applications beyond light duty vehicles, such as medium and heavy duty vehicles, marine, rail, and air. Early-stage research includes catalysts, membranes, electrodes, and fuel cell performance and durability. 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.
- **Hydrogen Fuel R&D** will emphasize applied materials research and early-stage component and process development to support industry to develop and deploy novel hydrogen production and storage technologies capable of utilizing diverse domestic energy resources. Hydrogen production efforts will emphasize longer-term renewable options that can completely revolutionize the energy sector, such as advanced water splitting. Additional concepts include biological production of hydrogen and direct conversion of natural gas to hydrogen plus valuable carbon-based co-products, rather than conventional reforming which produces hydrogen plus carbon dioxide. Hydrogen storage efforts will continue to focus on early-stage applied R&D for advanced storage technologies offering high-energy density at lower pressures and higher round-trip efficiencies compared to today's systems. These materials-based technologies may also be applicable to natural gas storage such as for medium and heavy duty applications.
- **Hydrogen Infrastructure R&D** will include early-stage R&D activities to support the H2@Scale concept, which supports innovations to generate hydrogen as an energy carrier across multiple sectors. By producing hydrogen when power generation exceeds load, electrolyzers can prevent curtailment of renewables and support 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. The program will focus on modular, scalable concepts for dispatchable hydrogen production, delivery and storage, liquefaction, materials development, and integration with diverse generation sources. R&D will also continue to enable safety and address regulatory barriers, codes and standards.
- In FY 2020, the subprogram will continue using the consortium approach and will invest in fundamental and transformational materials R&D to support industry efforts to develop and deploy viable and safe technologies. Focus areas include: R&D on high-throughput fueling concepts to support affordable hydrogen for heavy-duty transportation sectors, such as marine, rail, and trucks; advanced characterization of hydrogen release behavior and materials compatibility R&D to address regulatory barriers; and advanced concepts for affordable and reliable infrastructure component technologies.

Highlights include competitively selected projects that also leverage National Laboratory state-of-the-art capabilities, such as advanced computational and experimental tools, to 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;
- HyMARC for hydrogen storage materials research; and
- H-Mat for hydrogen materials compatibility R&D.

Hydrogen and Fuel Cell Technologies
Funding ($K)

	FY 2018 Enacted	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
Hydrogen and Fuel Cell Technologies				
Fuel Cell R&D	32,000	30,000	8,000	-22,000
Hydrogen Fuel R&D	54,000	39,000	20,000	-19,000
Hydrogen Infrastructure R&D	0	21,000	15,000	-6,000
Systems Analysis	3,000	2,000	1,000	-1,000
Safety, Codes and Standards	7,000	7,000	0	-7,000
Technology Acceleration	19,000	21,000	0	-21,000
Total, Hydrogen and Fuel Cell Technologies	**115,000**	**120,000**	**44,000**	**-76,000**

SBIR/STTR:

- FY 2018 Transferred: SBIR $3,680,000; STTR $518,000
- FY 2019 Projected: SBIR $3,840,000; STTR $540,000
- FY 2020 Request: SBIR: $1,408,000; STTR: $198,000

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

	FY 2020 Request vs FY 2019 Enacted
Hydrogen and Fuel Cell Technologies	
Fuel Cell R&D: In FY 2020, the subprogram will focus on early stage innovations, including medium/heavy duty and other applications while continuing work on light duty vehicle requirements. The subprogram will reduce funding for the Fuel Cell Performance and Durability (FC-PAD) consortium and will increase reliance on the private sector for this work. The subprogram will also reduce R&D efforts on reversible fuel cells that store energy and generate power until feedback from innovative projects initiated in FY 2019 can inform the direction of future R&D.	**-22,000**
Hydrogen Fuel R&D: In FY 2020, the subprogram will focus on early-stage applied materials R&D for hydrogen production and storage. The program will reduce efforts within the HydroGEN consortium in order to explore innovative concepts such as biological hydrogen production and natural gas to hydrogen and valuable carbon-based co-products. As part of the Advanced Energy Storage Initiative, the FY 2020 focus will expand beyond onboard vehicular storage to include innovative concepts to reduce electrolyzer cost and hydrogen as a form of energy storage that can improve flexibility and resiliency within and across the energy, transportation, and industrial sectors.	**-19,000**
Hydrogen Infrastructure R&D: In FY 2020, the subprogram will develop 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 and electrolyzer systems integration R&D (in support of the Advanced Energy Storage Initiative), materials compatibility R&D, infrastructure related component technologies, and innovative hydrogen carriers contributing to a strong domestic economy and energy independence, security & resilience. This R&D includes activities to address safety, codes, standards, and regulatory issues.	**-6,000**
Systems Analysis: In FY 2020, the program will focus on providing analysis to identify key areas in which to strategically prioritize R&D efforts.	**-1,000**
Safety, Codes and Standards: No funding requested in FY 2020.	**-7,000**
Technology Acceleration: No funding requested in FY 2020.	**-21,000**
Total, Hydrogen and Fuel Cell Technologies	**-76,000**

Hydrogen and Fuel Cell Technologies
Fuel Cell R&D

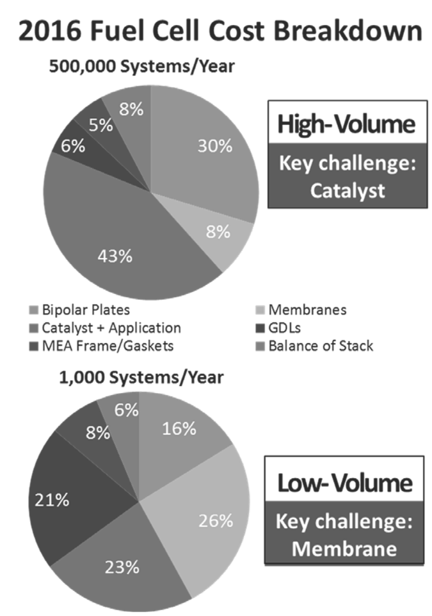
Description

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 achieving 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 $50/kW (the low-volume cost, associated with current production levels, is estimated at roughly between $180/kW and $230/kW based on input from OEMs). Similarly, the subprogram has supported a four-fold increase in durability in the last decade, now at over 4,200 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.

The planned early-stage R&D, conducted through competitively selected projects, will focus on automotive and medium/heavy duty applications with high potential for knowledge spillover benefits relevant to other uses such as distributed power for resiliency (primary and backup), auxiliary power units (APUs), and marine and rail applications. The program will ensure continued industry engagement through the US DRIVE partnership which will provide feedback on the program's 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 2020, 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, ionomers, bipolar plates, and gas diffusion layers (GDLs).[1]

Figure 1: R&D Focuses on High Cost Areas



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 platinum group metal (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 ($4,000,000). Through Lab AOP funding of

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

ElectroCat, the subprogram will include advanced high-performance computing, unique synthesis and characterization tools, and high-throughput combinatorial approaches focused on the development, 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. Activities will leverage the unique capabilities existing at the National Laboratories, including fuel cell modeling, proof of concept testing, and cost analysis to guide R&D prioritization.

The subprogram will also focus on stack and balance of plant components, including low PGM catalysts, for medium and heavy duty applications which require much more aggressive durability targets – more than five-fold higher than automotive durability targets ($2,000,000). These efforts will also support stationary applications for power generation and energy storage which require meeting long-term targets of less than $1,250/kW capital cost and a cycle life of 5,000 cycles.[1]

In addition, the subprogram will fund low-technology readiness level (TRL)[2] component and component integration R&D through competitively selected projects ($2,000,000) to enable a domestically manufactured fuel cell stack and/or balance of plant system.

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, prize competitions, 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://www.energy.gov/sites/prod/files/2017/03/f34/qtr-2015-chapter3.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 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Fuel Cell R&D $30,000,000	**Fuel Cell R&D $8,000,000**	**-$22,000,000**
• Approximately $6,000,000 to fund projects through ElectroCat consortium, including core experimental, computational, and machine learning capabilities at National Laboratories to support development of PGM-free catalysts to meet 29 mA/cm2 target (80 percent improvement over 2016 baseline).	• Approximately $4,000,000 to fund and maintain core experimental, computational, and machine learning capabilities at four National Laboratories to support development of PGM-free catalysts through the ElectroCat consortium	• Maintain critical mass of activities in support of ElectroCat while enabling prioritization of early-stage R&D in other subprogram areas to meet durability goals for medium and heavy duty vehicles.
• Approximately $14,000,000 to support projects which include National Laboratories, on promising early-stage component R&D, such as reversible fuel cells, innovative concepts, and fuel cell performance and durability R&D to meet performance and durability targets (e.g. $40/kW and 5,000 hour durability).	• No funding requested.	• Pending outcomes from prior year projects to inform future R&D direction.
	• Approximately $2,000,000 to competitively select projects on component/ integration R&D to enable domestically manufactured fuel cell stack and/or balance of plant/system, with potential to achieve the fuel cell system cost target of $40/kW.	• The program plans to fund competitively selected projects.
• Approximately $10,000,000 to competitively select approximately three to six industry/university projects on R&D for components such as catalysts and electrodes, and fuel cell performance/durability for applications requiring high durability (e.g., medium/heavy duty vehicles), and two industry/university projects for reversible fuel cell R&D for energy storage applications.	• Approximately $2,000,000 to competitively select industry/university projects on R&D for components such as catalysts and electrodes for applications requiring high durability (e.g., medium/heavy duty vehicles).	• Reduce number of new projects to allow sufficient time for prior year projects to deliver results and lead to downselects. No new funding for reversible fuel cell R&D. Projects selected in FY 2018 and FY 2019 will continue through outlay of prior year obligations.

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 support industry efforts to develop and deploy novel hydrogen production and storage technologies capable of utilizing a diversity of domestic energy resources. The overarching goal of the Hydrogen Fuel R&D subprogram is to advance viable options for hydrogen production and storage which could ultimately lead to industry development and commercialization, thereby enhancing 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 hydrogen fuel.

The hydrogen production component of the Hydrogen Fuel R&D subprogram includes the HydroGEN consortium ($6,000,000) and will address early-stage R&D 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 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. The FY 2020 activities will include a competitive solicitation, and at least six direct funded National Laboratory projects focused on advanced water splitting and leverage the HydroGEN EMN Consortium.

Additional subprogram focus areas ($4,000,000) will include early-stage foundational research in technologies for widespread domestic hydrogen production outside the water-splitting pathways covered in HydroGEN. Topics include innovative biological approaches, and hybrid systems efficiently leveraging fossil, nuclear and renewable resources, such as natural gas to hydrogen and valuable carbon co-products instead of conventional steam methane reforming. FY 2020 activities in these areas will include competitive solicitations to select at least four high-impact research projects that may include industry, university and National Laboratory partners.

To enable efficient and low-cost energy storage to increase grid resiliency and flexibility, activities ($6,000,000) will include early-stage R&D on grid-capable electrolyzers, including materials optimization and innovative concepts for advanced electrode fabrication and optimizing catalyst-electrode interfaces. Efforts will include early-stage concepts such as lower catalyst loadings and thinner but more durable membranes that can also be manufactured at scale. These efforts are part of the Advanced Energy Storage Initiative and have potential to reduce the cost and improve the performance of grid-connected electrolyzers.

The Hydrogen Fuel R&D subprogram is also developing advanced technologies to enable efficient and cost-effective hydrogen storage systems ($4,000,000), contributing to the Advanced Energy Storage Initiative. Examples include materials-based storage, with potential for significantly improved energy density and performance through the HyMARC EMN Consortium and techno-economic analysis and modeling at the National Laboratories to guide early stage R&D activities. The program's hydrogen storage activities will be coordinated with the Vehicle Technologies Office's on-board natural gas storage research.

The overarching goal of the program's hydrogen storage efforts has focused on on-board vehicle storage 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 hydrogen. However, at 700 bar, the energy density of hydrogen is only about 15 percent 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 on-board 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. The work in this subprogram may also be applicable to natural gas storage for medium or heavy duty vehicles.

In FY 2020, the subprogram will focus on unique National Laboratory 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. Aligned with the Hydrogen Infrastructure and H2@Scale efforts, analysis of advanced technologies for bulk hydrogen storage and transport will be performed to guide early-stage R&D efforts. To address grid stability and resiliency, this subprogram will develop advanced bulk hydrogen storage technologies with high round-trip efficiency capable of providing long-duration storage at low-pressure. These technologies will include materials-based technologies, such as hydrogen carriers.

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). These capabilities, which are supported by DOE, 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 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Hydrogen Fuel R&D $39,000,000	**Hydrogen Fuel R&D $20,000,000**	**-$19,000,000**
• Approximately $4,000,000 to competitively select early-stage university/industry seedling projects to collaborate with the HydroGEN Consortium to achieve hydrogen production at $2/gge.	• $2,000,000 to fund advanced water splitting early-stage university/industry seedling projects to collaborate with the HydroGEN Consortium to achieve hydrogen production at $2/gge.	• Focus on downselects of prior year seedlings work on advanced splitting projects.
• Approximately $9,000,000 for core capabilities and early-stage advanced water splitting projects at National Laboratories as part of the HydroGEN consortium.	• Approximately $4,000,000 to maintain the most critical core capabilities at relevant National Laboratories in support of HydroGEN consortium.	• Maintain critical mass of activities in support of HydroGEN through prioritization of the most utilized consortium capabilities at the National Laboratories.
• Approximately $4,000,000 to competitively select university/industry early-stage R&D projects on production of hydrogen from biomass and production of value-added co-products.	• Approximately $4,000,000 to competitively select university/industry projects to investigate early-stage concepts such as biological and direct conversion of natural gas to hydrogen and solid/chemical carbon co-products.	• Sustain efforts on innovative concepts for biological production and natural gas to hydrogen and solid/chemical carbon co-products initiated in FY 2019 and not currently pursued by industry or commercially viable.
• Approximately $6,000,000 to competitively select university/industry early-stage seedling projects, and to support National Laboratory efforts within HyMARC. Use computational materials design to prioritize research strategies that will identify materials relevant for use on board medium and heavy-duty truck applications.	• Approximately $3,000,000 to support National Laboratory projects within HyMARC that provide core capabilities.	• No new university/industry projects will be competitively selected. Sustain funding on National Laboratories projects within HyMARC that provide core capabilities.
	• Approximately $6,000,000 to competitively select projects on R&D to enable low-cost and efficient grid-connected electrolyzers for low-cost energy storage.	• Increase focus on innovative materials targeted for use in electrolyzers for grid-connection for low-cost energy storage applications.
	• Approximately $1,000,000 to support National Laboratory projects to determine the baseline performance of bulk hydrogen storage and transport technologies aligned with H2@Scale efforts and explore innovative concepts on hydrogen carrier and bulk storage technologies.	• Increase focus on hydrogen energy storage beyond automotive on-board storage.

Hydrogen and Fuel Cell Technologies
Hydrogen Infrastructure R&D

Description

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. The subprogram includes R&D for H2@Scale across multiple sectors to increase the security and resilience of the Nation's critical infrastructure, including opportunities for hydrogen energy storage, grid services, and enabling a domestic supply chain.

The cost and reliability of technologies at hydrogen fueling stations, such as liquid pumps, compressors, storage, chillers, and dispensers, are driven by numerous technical challenges, including materials compatibility, materials durability under cryogenic and high-pressure conditions, and inefficiencies of conventional mechanical processes. The subprogram is pursuing advances in innovative technologies for hydrogen delivery and station components that can enable industry to reduce delivery costs to $5/gge by 2025 with an ultimate target of $2/gge (at high volumes). R&D includes scalable technologies capable of high-throughput dispensing and storage to enable affordable hydrogen for a range of applications including medium/heavy-duty, maritime, or rail transportation. This includes activities to address safety, codes and standards issues for various components and applications.

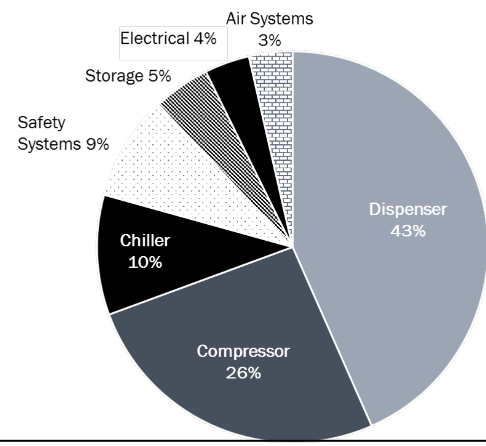


Figure 2: Hydrogen Fueling Infrastructure Maintenance by Technology

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 hydrogen fueling station components that most commonly result in downtime at the stations, based on data collected from fueling stations since 2011. Early-stage R&D will focus on improving the performance and availability of these technologies. Examples include improving the durability of materials used in dispensing hoses, compressor seals, and hydrogen storage vessels. In support of the H2@Scale initiative, the subprogram will leverage National Laboratory and industry capabilities to continue R&D of innovative materials systems for viable, highly efficient hydrogen liquefaction; and integrate computational models of hydrogen diffusion with advanced quantitative risk analysis to address safety, codes and standards, and enable reductions in station footprint.

The H2@Scale activity ($8,000,000) 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 three focus areas: 1) Innovative concepts for low-cost, safe, bulk storage of hydrogen (e.g. carriers); 2) Systems integration R&D to enable the use of hydrogen production technologies in diverse applications, including grid resiliency; and 3) R&D on high-throughput fueling concepts to enable safe and affordable hydrogen supply to heavy-duty transportation sectors, such as marine, rail, and trucks. Electrolysis technologies have potential to facilitate grid resiliency and energy storage through dynamic integration, given their ability to respond to grid signals within sub seconds. Emerging electrolysis technologies also have potential to use electricity and heat from baseload power generators, such as nuclear power plants, which cannot turn up and down quickly in response to variable generation and curtailments from renewables.

The integration of hydrogen technologies with existing electricity infrastructure will be explored through industry-led R&D projects in collaboration with National Laboratories, in support of the DOE's Advanced Energy Storage Initiative ($5,000,000 of the $8,000,000 H2@Scale activity). Projects may include evaluation of novel materials and electrolyzer stack concepts, along with early-stage simulations, including systems integration R&D, such as integrating nuclear and renewables with hydrogen production and utilization. H2@Scale activities will be coordinated with relevant programs on end-use of hydrogen such as synthetic fuels production.

Other focus areas of the Infrastructure program include advanced characterization of hydrogen release behavior, safety, and materials compatibility R&D to address regulatory barriers ($3,000,000) and the Hydrogen Materials (H-Mat) Consortium ($4,000,000). Launched in FY 2019, H-Mat will assess compatibility of both metallic and non-metallic materials with hydrogen service. Focus areas will include materials concepts for safe and affordable bulk storage and hydrogen dispensing. Foundational R&D within H-Mat will 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, components, selection criteria, test methods, and failure mitigation strategies.

Another 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, Department of Transportation, and Department of Defense. The subprogram will also continue to support peer reviews, safety R&D relevant to hydrogen production, delivery and storage, 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. Activities will also include at least $100,000 for STEM and workforce development. 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 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Hydrogen Infrastructure R&D $21,000,000	**Hydrogen Infrastructure $15,000,000**	**-$6,000,000**
• Approximately $4,000,000 to fund National Laboratory projects that address R&D needs identified in H2@Scale roadmap, including liquefaction efficiency, advanced compression, and pre-cooling. Complete technical report detailing one viable metal hydride compression concept.	• Approximately $3,000,000 to fund National Laboratory projects that address R&D needs identified in H2@Scale roadmap. Focus areas include hydrogen release behavior and advanced sensors.	• Fund fewer R&D projects, but with more funding per project, to focus on addressing the most critical regulatory barriers.
	• Approximately $5,000,000 to competitively select industry and National Laboratory projects on electrolyzer integration R&D to support Advanced Energy Storage Initiative.	• Increase efforts in support of DOE's Advanced Energy Storage Initiative.
• Approximately $3,000,000 to competitively select projects that initiate early-stage R&D on dispensing technologies for heavy-duty applications (e.g. nozzles in collaboration with Technology Acceleration subprogram.	• Approximately $1,000,000 to fund R&D project on dispensing technologies for heavy-duty applications.	• Discontinue collaboration with Technology Acceleration subprogram and refocus efforts on most impactful earlier-stage concepts.
• Approximately $10,000,000 to competitively select and fund industry/university-led and National Laboratories work on foundational R&D that increases materials service life 2X by 2022, through H-Mat.	• Approximately $4,000,000 to fund industry/university-led and National Laboratory projects on the advancement of materials used in fueling technologies through H-Mat with a focus on R&D for heavy-duty fueling applications and energy storage.	• Refocus H-Mat materials R&D on heavy duty fueling applications and on activities supporting DOE's Advanced Energy Storage Initiative.
• Approximately $4,000,000 to competitively select and fund industry/university-led and National Laboratory projects that explore chemical carriers with potential to achieve a 2X increase in storage capacity versus high pressure tanks by 2022..	• Approximately $2,000,000 for continued support of National Laboratory projects to develop chemical carriers with potential to achieve a 2X increase in storage capacity versus high pressure tanks by 2022.	• Focus R&D efforts on most promising chemical carrier activities identified through prior year activities. No new competitively selected projects will be funded.

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 ($1,000,000) 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 with increased emphasis on hydrogen 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 with industry and university participation.

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 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Systems Analysis $2,000,000	**$1,000,000**	**-$1,000,000**
• Approximately $300,000 for National Laboratory project to assess impact of fuel cell performance, including on the life cycle cost for hydrogen and fuel cell technologies.	• Approximately $200,000 for National Laboratory project to assess life cycle cost for hydrogen and fuel cell technologies in novel transportation applications (e.g. rail, marine).	• Shift focus from analysis of the costs of driving heavy duty vehicles, to other emerging applications in transportation.
• Approximately $600,000 for National Laboratory project to identify early R&D that can maximize energy independence and increase fuel diversity, including regional impacts. Complete report assessing diverse regional opportunities for hydrogen production and demand.	• Approximately $200,000 for National Laboratory project to identify early-stage R&D that can maximize energy independence and increase fuel diversity, including evaluating bulk storage technology requirements regionally.	• Reduce efforts on resource analysis, and prioritize R&D evaluating bulk storage opportunities.
• Approximately $100,000 for National Laboratory project to assess program milestones and technology readiness goals. Analysis will be used to prioritize FCTO R&D activities and inform updates to multi-year plans.	• Approximately $100,000 for National Laboratory project to continue assess program milestones and technology readiness goals. Analysis will be used to inform target-setting and priorities.	• No change.
• Approximately $1,000,000 for National Laboratory project to support analysis with the Office of Nuclear Energy on the potential for hydrogen generation through nuclear baseload sources, including hydrogen hybrid energy systems and novel nuclear power generation technologies.	• Approximately $500,000 for continued support of National Laboratory project in coordination with the Office of Nuclear Energy, to analyze the potential for hydrogen generation through nuclear baseload sources including hydrogen hybrid energy systems and novel nuclear power generation technologies.	• Reduced budget and scope to focus on hydrogen hybrid energy systems and novel nuclear power generation technologies in collaboration with the Office of Nuclear Energy at reduced funding level.

Hydrogen and Fuel Cell Technologies
Safety, Codes and Standards

Description
Reflecting the priorities for critical mass in hydrogen infrastructure R&D, no funding is requested for the Safety, Codes and Standards subprogram in FY 2019 and FY 2020. Safety considerations will continue to be an important parameter and integrated into early-stage R&D projects and activities funded through the Hydrogen Fuel, Fuel Cell and Infrastructure R&D subprograms, including best practices and procedures to ensure safety in the operation, handling, and use of hydrogen and fuel cell technologies in program-funded projects. 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 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Safety, Codes and Standards $7,000,000	**Safety, Codes and Standards $0**	**-$7,000,000**
• Approximately $2,000,000 to fund National Laboratory projects that support development of codes and standards by industry through H-Mat Consortium. R&D activities include generation of data on metallic and polymeric materials of interest to reduce costs of hydrogen infrastructure applications.	• No funding is requested for this activity in FY 2020. Some management activities related to the execution of prior year appropriations will continue until completion.	• To ensure safety R&D is incorporated throughout the program, no separate subprogram funding is requested for Safety Codes and Standards activities. Safety considerations will continue to be an important parameter integrated into early-stage R&D projects and activities funded through the Hydrogen Fuel, Fuel Cell and Infrastructure R&D subprograms. The Hydrogen Fuel, Fuel Cell and Infrastructure R&D subprograms will promote best practices and procedures to ensure safety in the operation, handling, and use of hydrogen and fuel cell technologies in program-funded projects.
• Approximately $2,000,000 to fund National Laboratory projects that support the reduction of bulk liquid hydrogen storage separation distances as required by hydrogen technology safety codes. R&D will continue to validate cryogenic hydrogen behavior models at laboratory scale, and inform improvements to existing quantitative risk assessment models. • Approximately $3,000,000 to fund National Laboratory projects that address critical technical gaps for key safety-related hydrogen infrastructure components (e.g. contaminant detectors, and sensors). Complete study of hydrogen behavior in enclosed spaces to inform hydrogen sensor technology development.		

Hydrogen and Fuel Cell Technologies
Technology Acceleration

Description

The Technology Acceleration subprogram is focused on accelerating the transition from R&D to commercial viability and market acceptance. Reflecting the shift in focus to early-stage research and development, no funding is requested for the Technology Acceleration subprogram in FY 2020. 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 data to predict whether FCEVs and hydrogen refueling stations can meet program targets through use of prior year funding. Some management activities related to the execution of prior year appropriations will continue until completion.

Technology Acceleration

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Technology Acceleration $21,00,000	**$0**	**-$21,000,000**
• Approximately $7,000,000 to competitively select projects for first-of-a-kind industry-led efforts to demonstrate a hydrogen-focused integrated renewable energy production, storage, and transportation fuel distribution/retailing system. • Approximately $7,000,000 to fund National Laboratory projects advancing R&D in support of H2@Scale and hybrid energy systems. Complete experimental evaluation of hybrid energy system technologies with potential to reduce energy consumption of hydrogen production by 30 percent. • Approximately $3,000,000 to competitive select projects that advance R&D on fueling technologies for heavy-duty applications, in collaboration with Hydrogen Infrastructure R&D subprogram. • Approximately $2,000,000 to select industry-led project to reduce the cost of electrolyzer manufacturing technologies. • Approximately $2,000,000 to fund National Laboratory projects to support first-of-a-kind industry-led efforts to demonstrate a hydrogen-focused integrated renewable energy production, storage, and transportation fuel distribution/retailing systems.	• No funding is requested for this activity in FY 2020. Some management activities related to the execution of prior year appropriations will continue until completion.	• The Hydrogen and Fuel Cell Technologies Program is refocusing efforts on early-stage R&D and no funding is requested for Technology Acceleration activities.

Solar Energy

Overview

EERE's Solar Energy Program funds early-stage research and development (R&D) to improve the affordability of solar technologies while supporting the reliability and resilience of the U.S. electric grid. Reflecting the recent and projected future growth in photovoltaic (PV) deployment, the program is increasing its emphasis on addressing the challenges and opportunities related to integrating increasing penetrations of solar onto the electric grid. 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. These objectives will invigorate American technological leadership in solar energy, diversify the Nation's electricity supply, enhance grid resilience and reliability, and catalyze domestic economic growth including job creation.

The program works to achieve the 2030 cost targets of $0.03/kWh without subsidies for utility-scale PV systems[1], which use semiconductors to convert solar photons directly to electricity, and $0.05/kWh for baseload concentrating solar power (CSP) systems, which convert light to thermal energy that can be stored before being 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 40-70 percent from 2018 benchmarks for utility-scale, commercial and residential PV as well as CSP.[2] The program has a history of success in enabling solar energy cost reduction: the original 2020 goal for unsubsidized, utility-scale solar PV electricity of $0.06/kWh was achieved in 2017, three years ahead of schedule.

Deployment of solar across the U.S. has been growing at a rapid rate, reaching a cumulative 53 GW installed at the end of 2017 — a more than 20-fold increase from the 2010 level.[3,4] Presently, solar is supplying two percent of U.S. electricity[4], and several times more during peak sunlight hours. The solar industry has also seen significant job growth[5]. 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 to realize solar's potential to support the reliability and resilience of the grid, solar energy is capable of providing supply that meets a significant portion of the Nation's electricity demand in the coming decades.

Highlights of the FY 2020 Budget Request

The Solar Energy Program will support focused activities in FY 2020:

- With solar contributing two percent of U.S. electricity supply today and projected to increase to seven percent by 2030 — over 30 percent by 2030 in some regions of the U.S. — the challenges of integrating even higher levels of solar generation onto the grid need to be researched today to support industry efforts to develop cost-effective solutions that will 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 control the impacts of solar generation on the future grid as well as opportunities for distributed solar power to support grid resilience through integration with energy storage and other distributed energy resources (DERs). FY 2020 activities include an emphasis on developing test capabilities needed to investigate the challenges of increasing amount of power electronics-based generation resources such as solar PV on the grid. National Laboratory research also supports industry's development of test and evaluation standards.
- The Solar Energy Program will contribute $20,000,000 to the Advanced Energy Storage Initiative, which coordinates R&D across DOE to advance energy storage and other technologies that create more flexible generation and more flexible load, thereby increasing the reliability and resilience of the U.S. electric grid. Energy storage is critical to advance a flexible, resilient electrical grid and expand affordable mobility options from a diverse suite of energy resources – and energy storage for the grid is complemented by a portfolio of generation and load technologies that

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[1] The goal for residential PV is $0.05/kWh and the goal for commercial PV is $0.04/kWh.
[2] R. Fu et al., "U.S. Solar Photovoltaic System Cost Benchmark: Q1 2018," NREL Technical Report, November 2018. 2018 benchmarks for utility-scale, commercial and residential PV are 5, 11 and 15 cents/kWh, respectively. The 2018 CSP benchmark was 10 cents/kWh.
[3] "2017 U.S. Solar Market Insight Report," GTM Research and SEIA, March 2018.
[4] EIA, Electric Power Monthly, Table 1.1 (July 2018).
[5] "National Solar Jobs Census 2018," The Solar Foundation. https://www.thesolarfoundation.org/national/

provide flexibility, essential reliability services, and system resilience. The Advanced Energy Storage Initiative will enhance coordination across EERE and DOE and establish aggressive, achievable, and comparable goals for cost-competitive energy storage services and applications.

- FY 2020 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 2020 will also investigate integration of CSP-relevant power cycles and advanced, efficient solar collector technologies that can utilize and provide the 700 °C heat for third generation CSP thermal transport and storage systems. Testing and validation of thermal energy storage integrated with advanced power cycles (particularly using supercritical-carbon dioxide as a working fluid) will be a priority. SETO will coordinate with AMO, FE, and NE, through HEMI, as appropriate, particularly on development of advanced, high temperature heat exchangers.
- PV Research at the National Laboratories will center on improving the reliability of PV devices and large-area production of new PV structures with the potential to achieve the 2030 cost targets. FY 2020 funding maintains a subset of the core work at the National Laboratories directed toward understanding reliability physics and materials science to better predict and increase durability. These topics will continue to support U.S. leadership in PV innovation, which has led to nearly half of the world records in solar power conversion efficiency.
- To accelerate the commercialization of the Solar Energy Program's early stage R&D portfolio, the American-Made Challenges: Solar Prize will launch additional rounds in FY 2020. The FY 2020 Solar Prize work will build on the prior two rounds which began in FY 2018 and is planned to continue in FY 2019. The Prize incentivizes the rapid transformation of research and development results into new products and services with an urgency directed to catalyzing domestic manufacturing of cells and modules.

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

Solar Energy
Funding ($K)

	FY 2018 Enacted	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
Solar Energy				
Concentrating Solar Power	55,000	55,000	11,500	-43,500
Photovoltaic R&D	70,000	72,000	16,000	-56,000
Systems Integration	71,200	54,500	35,000	-19,500
Balance of Systems Soft Cost Reduction	11,000	35,000	0	-35,000
Innovations in Manufacturing Competitiveness	34,400	30,000	4,500	-25,500
Total, Solar Energy	**241,600**	**246,500**	**67,000**	**-179,500**

SBIR/STTR:

- FY 2018 Transferred: SBIR $7,667,000; STTR $1,078,000
- FY 2019 Projected: SBIR $7,554,000; STTR $1,062,000
- FY 2020 Request: SBIR $2,144,000; STTR $302,000

Solar Energy
Explanation of Major Changes ($K)

	FY 2020 Request vs FY 2019 Enacted
Concentrating Solar Power: Funding continues efforts at the National Laboratories on developing high temperature components for next generation CSP systems with thermal energy storage. Relative to FY 2019, CSP efforts in the FY 2020 request will support a significantly more limited funding opportunity for non-National Laboratory researchers focused on coupling thermal energy storage with advanced power cycles, as a part of the Advanced Energy Storage Initiative.	**-43,500**
Photovoltaic R&D: Funding prioritizes limited efforts at the National Laboratories to improve PV reliability and pursue research on large-area production of new PV structures, as well as fund the final year of a ten-year university research consortium. Non-National Laboratory competitive programs will not be supported in FY 2020.	**-56,000**
Systems Integration: Funding maintains core efforts at the National Laboratories to advance grid integration models and technologies. Funding builds on the FY 2019 competitive funding opportunity with a more targeted $9,000,000 funding opportunity to improve cybersecurity and, as a part of the Advanced Energy Storage Initiative, improve grid reliability, flexibility, and resilience through the integration of solar energy technology with energy storage and other distributed energy resources.	**-19,500**
Balance of Systems Soft Cost Reduction: No funding is requested for this subprogram due to shift in focus to early stage R&D.	**-35,000**
Innovations in Manufacturing Competitiveness: Funding focuses on the continuation of the Solar Prize, begun in FY 2018, to incentivize the transformation of research and development results into domestic manufacturing of cells and modules. Relative to FY 2019, research and development to support inherently scalable production methods and the Incubator program will not be supported.	**-25,500**
Total, Solar Energy	**-179,500**

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 supplying affordable and reliable solar power on demand.

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 2018, 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 supports industry to drive down costs toward this goal, which could make CSP electricity cost competitive with electricity from other sources.

The CSP subprogram funds the DOE National Laboratories, in partnership with academia, research institutes, and industry, in advanced R&D topics including solar field design, high-temperature receiver and heat transfer fluids, thermal energy storage, advanced power cycles, and CSP systems integration. This funding is distributed by soliciting research proposals for both multi-year and single-year projects in topics relevant to CSP components and sub-systems from all of DOE's National Laboratories. The FY 2020 request for CSP includes $7,000,000 to continue the efforts at the National Laboratories with attention to seeding long-range, transformative ideas in high-temperature thermal engineering and optical design as well as advancing CSP-relevant power cycles and solar collector technologies energy-intensive chemicals and fuels that can be used for long-term energy storage. Included in the National Laboratory funding is approximately $1,000,000 to support the National Solar Thermal Test Facility (NSTTF) at Sandia National Laboratories (SNL). Funding will emphasize early-stage research on CSP components that are able to integrate with high-temperature thermal systems; increase the flexibility of CSP on the grid with novel thermal energy storage concepts; and develop novel concepts to increase the annualized efficiency of both solar collectors, specifically, and overall plant performance, generally.

The FY 2020 request for CSP includes a $4,500,000 funding opportunity to couple thermal energy storage with advanced power cycles, the most promising of which use supercritical carbon dioxide as a working fluid. This work will have the aim of developing and validating energy storage technologies that are highly flexible and responsive to the challenges of maintaining grid reliability, as a part of the Advanced Energy Storage Initiative. This work will be coordinated with the DOE Fossil and Nuclear Energy Offices.

The Solar Energy fellowship program funds ($200,000) 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, technical assistance, and technology to market activities.

Concentrating Solar Power

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Concentrating Solar Power $55,000,000	**$11,500,000**	**-$43,500,000**
• $8,000,000 to fund approximately 10 merit-reviewed R&D projects at the National Laboratories, through the AOP, targeting early-stage concepts in high temperature thermal engineering and optical design, as well as advancing CSP-relevant power cycles and solar collector technologies, and the use of CSP to produce energy-intensive chemicals and fuels for long-term energy storage.	• $7,000,000 to continue reviewed R&D projects.	• Reduced number of projects funded. Support limited to National Laboratories.
• $1,000,000 to support the operations and maintenance of the National Solar Thermal Test Facility (NSTTF) at Sandia National Laboratories to enable testing of CSP collectors and high-temperature CSP components and systems.	• $1,000,000 support the operations and maintenance of the National Solar Thermal Test Facility (NSTTF) at Sandia National Laboratories to enable testing of CSP collectors and high-temperature CSP components and systems.	• No significant change.
• Initiate a prize competition on solar thermal desalination.	• No funding requested for FY 2020.	• Awaiting results from existing projects to inform future research direction in this area.
• $5,000,000 to initiate 10 to 20 competitively selected projects focused on long-term thermal energy storage concepts, new materials and manufacturing techniques, and autonomous solar field operation.	• Planned funding opportunity to award competitively selected projects developing and validating thermal energy storage coupled to advanced power cycles.	• Limit new projects to support a very targeted focus on energy storage and power cycle integration as part of the Advanced Energy Storage Initiative. Projects awarded in FY 2019 will continue to completion through outlay of prior year obligations.
• Fund one to two emerging leaders that will pursue breakthrough solar energy technologies at universities, National Laboratories, and other research facilities as well as at DOE.	• Fund emerging leaders that will pursue breakthrough solar energy technologies at universities, National Laboratories, and other research facilities as well as at DOE	• No significant change.

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 emphasis is placed on generating the scientific and technological knowledge necessary to achieve the 2030 target of $0.03/kWh 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 for increasing efficiency and durability while simultaneously reducing cost, enabling U.S. industry to develop and deploy new PV innovations needed to reach the 2030 goals from the current utility-scale PV benchmark of $0.05/kWh[1].

The PV R&D subprogram advances state-of-the-art PV technologies with National Laboratory, industry, and academic partners. FY 2020 projects will build upon the state of knowledge in the areas of fundamental solar cell performance limits, advanced materials science, models for multicrystalline and tandem devices, and the impacts of outdoor soiling, temperature cycling, ultra-violet light, humidity and oxygen on PV panel performance and reliability.

In FY 2020, the PV R&D subprogram will support the second year of a three-year program of merit-reviewed research activities at the National Laboratories, performed in partnership with academia and industry. A prioritized subset of the work initiated in FY 2019 will be supported focusing on 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 used to inform best practices. Lab projects are structured with input from industry participants and reviewers to ensure relevance and impact of PV technologies that have the commercial potential. The subprogram funds R&D at the Regional Test Centers (RTCs) 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. During FY 2020, the Nevada, Vermont and Florida sites will continue the transition begun in FY 2018 to a self-sustaining business model that is not reliant on Federal funding. The National Laboratory-based RTCs will continue to receive support. DOE funding for operations and maintenance of the Nevada, Vermont, and Florida RTC sites will not be provided.

The Solar Energy fellowship program funds ($200,000) 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, technical assistance, and technology to market activities. The remainder of the funds will support the final year of a ten-year university PV R&D center (Quantum Energy and Sustainable Solar Technologies Engineering Research Center) in collaboration with the National Science Foundation at Arizona State University.

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[1] R. Fu et al., "U.S. Solar Photovoltaic System Cost Benchmark: Q1 2018," NREL Technical Report, November 2018. 2018 benchmarks for utility-scale, commercial and residential PV are 5, 11 and 15 cents/kWh, respectively. SETO 2030 goals for utility-scale, commercial and residential PV are 3, 4, and 5 cents/kWh, respectively.

Photovoltaic R&D

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Photovoltaic R&D $72,000,000	**$16,000,000**	**-$56,000,000**
• Initiate approximately 20 merit-reviewed R&D projects at the National Laboratories, academia and industry, to improve the performance and reliability of PV technologies and perform foundational analytical research.	• $14,000,000 to continue the second year of a targeted subset of National Laboratory work initiated in FY 2019.	• Funding will focus on PV reliability efforts and research on large-area production of new PV structures. Funding for new PV materials and to increase PV efficiency will end.
• Continue the collaboration (year nine of ten) 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 supports obligations in the existing agreement with NSF and is an effective method for the Solar Energy Program to leverage fundamental research.	• $1,000,000 to support the final year of the Engineering Research Center on next generation PV that is co-funded with the National Science Foundation.	• No significant change.
• DuraMat is the National Laboratory Consortium that models and measures durable coatings and packaging materials for PV modules including advanced encapsulants and flexible packaging concepts.	• $800,000 to maintain the DuraMat shared data hub.	• Funding focuses on increasing the impact of the data hub capabilities.
• Support approximately 15 competitively selected projects targeting priority PV research areas such as new low cost materials and advanced reliability research.	• No funding is requested in support of the FY 2020 SETO Funding Opportunity Announcement.	• No new funding opportunity is planned for FY 2020. FY 2019 funded projects will continue to completion through outlay of prior year obligations.
• Fund one to two emerging leaders that will pursue breakthrough solar energy technologies at universities, National Laboratories, and other research facilities as well as at DOE.	• Fund emerging leaders that will pursue breakthrough solar energy technologies at universities, National Laboratories, and other research facilities as well as at DOE.	• No significant change.

Description

The Systems Integration (SI) subprogram, in coordination with the DOE Grid Modernization Initiative (GMI), funds early-stage research and development in support of grid reliability and resilience. The FY 2020 SI request includes activities contributing to the Advanced Energy Storage Initiative, which coordinates EERE R&D with other DOE applied energy offices to advance energy storage and technologies with similar capabilities that improve flexibility during the conversion of energy resources into useful energy services. The SI subprogram focuses on generating the scientific and technological knowledge necessary to support industry efforts to more effectively integrate solar onto the electric grid. 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 and accelerate targeted innovation. Key technical challenges related to the grid integration of solar 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 support industry and regulatory agencies to develop 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 including new strategies for resilience. The SI subprogram will address these challenges by supporting early-stage R&D and field validation of solar integration models and technologies and will develop solutions for solar energy to enhance grid reliability, resilience, 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 innovative technologies.

As part of the DOE's Grid Modernization Initiative (GMI) 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. 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. 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 2020 will support early-stage R&D activities at the National Laboratories through the GMLC, 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. 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.

A competitive funding opportunity is planned to fund projects to improve cybersecurity, and to improve grid reliability, flexibility, and resilience through the integration of solar energy technology with energy storage and other distributed energy resources as a part of the Advanced Energy Storage Initiative, which coordinates energy storage activities to advance technologies that create more flexible generation and more flexible load. The solicitation will focus on early-stage research and development of system models and hardware and software prototypes. As there are nearly two million solar energy systems interfacing with the distribution grid, research will include methods for securing and hardening solar generation devices to address vulnerability to cybersecurity attacks and enhance resilience after disruptive events, in coordination with the Office of Cybersecurity, Energy Security and Emergency Response. This early-stage research is beyond the scope of utilities and regulatory agencies and provides a critical knowledge base for industry in addressing grid integration challenges.

The Solar Energy fellowship program ($200,000) 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 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Systems Integration $54,500,000	**$35,000,000**	**-$19,500,000**
• Initiate approximately 20 merit-reviewed R&D projects with the National Laboratories, through the GMLC, to address foundational analysis and evaluation of solar integration challenges, solar impacts to 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.	• Continue a subset of R&D projects with the National Laboratories started in FY 2019 through the GMLC. $6,000,000 to support developing lab and field test capabilities for power electronics on the grid.	• Funding supports a new emphasis on investigating the challenges related to the increase in power electronics-based PV generation on the grid.
• Fund ten to 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 is requested to issue a funding opportunity and award projects working to integrate solar energy with other technologies to better match energy supply and demand.	• Funding focuses on the Advanced Energy Storage Initiative. FY 2019 projects continue to completion through outlay of prior year obligations.
• Fund one to two emerging leaders that will pursue breakthrough solar energy technologies at universities, National Laboratories, and other research facilities as well as at DOE.	• Fund emerging leaders that will pursue breakthrough solar energy technologies at universities, National Laboratories, and other research facilities as well as at DOE.	• No significant change

Solar Energy
Balance of Systems Soft Cost Reduction

Description

The Balance of Systems Soft Cost Reduction (BOS) subprogram focuses on reducing soft costs, which includes financing, customer acquisition, permitting, inspection and interconnection, installation labor, 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 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, expand access to solar energy to residences and businesses in low-income communities, 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 solar installations. Between 2008 and 2017, the U.S. saw a rapid increase in renewable energy generation from solar. The solar sector of the economy now employs over 250,000 people representing a 168 percent increase since 2010, growing nine times faster than the national job growth rate. 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.

Reflecting the shift in focus to early-stage research and development, no funding is requested for the BOS subprogram in FY 2020. 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 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Balance of Systems Soft Cost Reduction $35,000,000	**$0**	**-$35,000,000**
• Initiate approximately 15 merit-reviewed R&D projects at the National Laboratories to address soft cost challenges and analyze solar market data.	• No funding requested in FY 2020.	• Reflects shift in focus to early stage R&D. FY 2019 projects continue to completion.
• Through the Grid Modernization Laboratory Consortium, provide support to institutions tackling grid modernization issues related to increasing solar energy on the grid.	• No funding requested for FY 2020	• Reflects shift in focus to early stage R&D. FY 2019 projects continue to completion.
• Fund ten to 20 competitively selected projects to tackle reduce soft costs related to solar energy across the U.S.	• No funding requested for FY 2020	• Reflects shift in focus to early stage R&D. FY 2019 projects continue to completion.

Solar Energy
Innovation in Manufacturing Competitiveness

Description

The Innovations in Manufacturing Competitiveness (IM) subprogram was established to increase U.S. competitiveness in solar 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.

Funding requested for FY 2020 ($4,500,000) will be used to run an additional round of the American-Made Challenges: Solar Prize, designed to revitalize domestic solar manufacturing of cells and modules. The FY 2020 work on the Solar Prize will concentrate on building the nationwide network (American-Made Network) associated with the prize competition to continue the momentum established with the initial competition. The American-Made Network is comprised of organizations and individuals that can provide resources and expertise to prize competitors to develop and facilitate the future transfer of solutions to the private sector for late-stage research and ultimate commercialization. The Prize incentivizes the rapid conversion of research and development innovations into new solar products with an emphasis on expanding domestic manufacturing. The Prize leverages National Laboratory research and development capacity in the generation and prototyping of new technologies. Most importantly, the Prize will continue to integrate the private sector into the competition to ensure it is the private sector which brings highest impact products to market.

Innovations in Manufacturing Competitiveness

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Innovations in Manufacturing Competitiveness $30,000,000	**$4,500,000**	**-$25,500,000**
• 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, with an emphasis on cell and module manufacturing.	• $4,500,000 to launch subsequent rounds of the Solar Prize which was started in FY 2018.	• This third year of funding continues to catalyze domestic solar energy manufacturing commercialization using the Prize model.
• Fund ten to 15 competitively selected Incubator projects to support small businesses in developing innovative solar energy technology.	• No funding requested in FY 2020	• Funding reduction is requested in this area to focus on the third year of the Solar Prize.
• $10,000,000 funding is directed to research and development to support inherently scalable production methods such as solution processing, roll-to-roll manufacturing, the science of inherent material stability, and ultrahigh efficiency through tandem manufacturing.	• No funding requested in FY 2020	• Funding reduction is requested in this area to focus on the third year of the Solar Prize.

Wind Energy

Overview

DOE's Wind Energy Program funds early-stage research and development (R&D) and related testing of advanced wind energy technologies while supporting the reliability and resilience of the U.S. electric grid. The program works to achieve breakthroughs in reducing the levelized cost of energy (LCOE) for land-based wind by 50 percent from today's LCOE, to $.023/kWh without subsidies by 2030 and achieving a 50 percent reduction in offshore wind and distributed wind by 2030 from a 2015 benchmark. Achieving these 2030 goals would make wind electricity one of the most affordable forms of electricity in the U.S. Reflecting the recent and projected future growth in wind energy deployment, the program is emphasizing three objectives:

- Wind energy cost reduction for all wind energy applications (offshore, land-based utility scale, and distributed);
- Reliable and seamless integration of high penetrations of wind energy into the electric grid;
- Market barrier reduction, elimination, or mitigation.

Taken together, these objectives will invigorate American technological leadership in wind energy, diversify the Nation's electricity supply, enhance grid resilience and reliability, and catalyze domestic economic growth including job creation.

Presently, wind energy technology is an important part of the diverse energy mix in the U.S. There are roughly 90 gigawatts (GW) of land-based, utility-scale wind deployed across 41 states,[1] supplying over six percent of U.S. electricity.[2] The U.S. has been a global leader in small wind turbine (turbines up through 100 kW capacity) sales, and has over 81,000 small wind turbines deployed across all 50 states.[3] An offshore wind industry is just beginning to develop in the U.S., driven by falling offshore wind turbine prices, accelerated Federal offshore wind lease auctions, and state policies. The majority of utility-scale wind technologies deployed are in high wind areas, where a combination of strong resource and Federal and state incentives have supported lower risk and financing rates for the industry. With the phasing out of the Production Tax Credit (PTC), significant work remains before wind energy realizes its full potential where it can be cost effectively deployed in all regions of the Nation without subsidies. Program research addresses high-risk, early-stage R&D that industry does not have the technical resources or capabilities to address on its own. With continued research and technology innovation to drive down wind energy costs and overcome grid integration and other market barriers, wind energy has the potential to further diversify our electricity mix thereby reducing price volatility for consumers and businesses.

Highlights of the FY 2020 Budget Request

- Next Generation Wind Plants: the program, through its A2e applied R&D initiative, will 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 for offshore, land-based and distributed wind applications.
- Manufacturing R&D: the program will focus on fundamental R&D in the areas of controls, sensors, algorithms, materials, and manufacturing specific to wind energy applications to lower costs and improve operational performance.
- Offshore Wind R&D: the program will accelerate fundamental R&D targeted at U.S.-specific offshore wind technology barriers, including advanced substructure technology, reduction of installation cost and risks, technology that supports less on-site O&M intervention, and design standards development for the diverse marine conditions of U.S. waters.
- Distributed Wind R&D: the program will focus on several distributed wind activities, including R&D and manufacturing improvements that directly reduce distributed wind LCOE and facilitate turbine certification goals, development of tools that increase the accuracy of distributed wind performance assessments, and maximizing the value and resiliency of microgrids utilizing wind energy and other distributed energy resources.

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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] Orrell, A., and N. Foster. 2017 Distributed Wind Market Report. Pacific Northwest National Laboratory. DOE/EE-1799. August 2018. https://www.energy.gov/eere/wind/downloads/2017-distributed-wind-market-report.

- Mitigation of Market Barriers: the program will conduct several activities to address market barriers for land-based, offshore, and distributed wind, including R&D of wind turbine/radar challenges; development of technical solutions to improve environmental performance; and STEM activities to support educating and training a wind energy workforce for the 21st century economy; and research to evaluate and address regulatory and market barriers associated with community impacts.
- Grid: as part of DOE's Grid Modernization Initiative (GMI) efforts, the program will continue activities funded as part of the Grid Modernization Initiative including analytical tools that improve grid reliability through increased flexibility and grid services. The program will evaluate R&D needs identified from an FY 2019 roadmap process for better integration of wind generation through co-optimized wind plant operation, integrating multiple technologies, flexible transmission utilization, and wind plant cybersecurity.

Wind Energy
Funding ($K)

	FY 2018 Enacted	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
Wind Energy				
Technology Research, Development & Testing and Resource Characterization (Land, Offshore, Distributed)	64,000	59,000	18,000	-41,000
Technology Validation and Market Transformation	0	10,000	0	-10,000
Mitigate Market Barriers	20,000	16,000	4,500	-11,500
Modeling and Analysis	8,000	7,000	1,200	-5,800
Total, Wind Energy	**92,000**	**92,000**	**23,700**	**-68,300**

SBIR/STTR:

- FY 2018 Transferred: SBIR $2,811,000; STTR $395,000
- FY 2019 Projected: SBIR $2,624,000; STTR $369,000
- FY 2020 Request: SBIR $726,000; STTR $102,000

Wind Energy
Explanation of Major Changes ($K)

	FY 2020 Request vs FY 2019 Enacted
Wind Energy	
Technology Research, Development & Testing and Resource Characterization (Land, Offshore, Distributed): The Budget prioritizes early-stage R&D focused on achieving scientific and technical breakthroughs in reducing the levelized cost of energy (LCOE) for land-based wind by 50 percent from today's LCOE, to $.023/kWh without subsidies by 2030 and achieving a 50 percent reduction in offshore wind and distributed wind by 2030 from a 2015 benchmark. Offshore wind facilities upgrades work is fully funded through a competitive opportunity in FY 2019. The decrease is driven by focusing on critical path research necessary to achieve the LCOE goal. As a result, the scope of ongoing research related to atmospheric wind science, wind plant reliability and optimization, tall wind, and advanced manufacturing methodologies and materials for wind energy will be narrowed. The FY 2020 Budget funds R&D at National Laboratories and requests no funding for new FOAs. Finally, the decrease is the result of maintenance and operations activities for the National Wind Technology Center (NWTC) that will be transitioned to the EERE Facilities and Infrastructure (F&I) budget ($3,300,000).	**-41,000**
Technology Validation and Market Transformation: Decrease reflects completion of the FY 2019 FOA for additional project development for offshore wind demonstration projects.	**-10,000**
Mitigate Market Barriers: The budget prioritizes early stage R&D activities to strengthen the body of knowledge necessary to inform key grid integration, regulatory, and siting decisions associated with the deployment of offshore, land-based, and distributed wind energy. The FY 2020 Budget funds R&D at National Laboratories and requests no funding for new FOAs.	**-11,500**
Modeling and Analysis: The budget prioritizes early stage R&D activities. Objective analysis using state-of-the art systems engineering, cost and deployment models, and tools is used to evaluate and prioritize early-stage R&D wind energy technology innovation opportunities for land-based, offshore, and distributed applications, as well as to prioritize activities within the portfolio.	**-5,800**
Total, Wind Energy	**-68,300**

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

Description

The Technology Research, Development and Testing and Resource Characterization subprogram focuses on achieving breakthroughs in reducing the levelized cost of energy (LCOE) for land-based wind by 50 percent from today's LCOE, to $.023/kWh without subsidies by 2030 and achieving a 50 percent reduction in offshore wind and distributed wind by 2030 from a 2015 benchmark. Achieving these 2030 goals would make wind electricity one of the most affordable forms of electricity in the U.S. To accomplish this, the program invests in understanding the fundamental science at the heart of extracting energy from the wind, which, in turn, drives the technology innovation necessary to improve wind plant performance, operation, and maintenance.

Based on research and in-depth analysis, the subprogram has identified the next big opportunity for LCOE reduction as moving beyond a focus on individual wind turbines to considering innovations that optimize the performance of large, multi-turbine wind power plants as a whole. Through its National Laboratories and other resources, DOE is strategically positioned to better understand the behavior of the atmosphere, which in turn helps predict the wind resource at the wind power plant. The complexity of the wind flow not only affects wind turbine performance, but also affects turbine reliability and lifetime. Advanced wind turbine controls are needed to minimize the structural loads on the wind turbine caused by these complex air flows. The subprogram continues to support work to tie the high-fidelity modeling and experimental efforts under the Atmosphere to Electrons (A2e) initiative to a completely new systems approach to the design and analysis of wind plants for both land-based and offshore applications. In FY 2020 efforts will fund improvement of 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, continue to develop high fidelity modeling simulation capability and demonstrate the current state of the art through benchmarking in conjunction with the Big Adaptive Rotor development program. Funds will support development and validation of multi-fidelity toolsets in order to identify pathways to improve overall performance, and reduce costs, including O&M and balance of systems costs. In FY 2020, the program will continue to maintain and operate the Scaled Wind Farm Technology (SWiFT) facility to ensure mission readiness for use by DOE wind researchers and industry partners for all wind applications. The program will transition the maintenance and operation activities for the National Wind Technology Center (NWTC) to EERE's Facilities and Infrastructure (F&I) budget, indicating the support EERE has for stewardship of the facility as an EERE-wide asset focused on energy systems integration of multiple generators, loads, and storage technologies with the grid.

The subprogram's shift to an R&D focus on the entire wind power plant is particularly important for offshore wind. Reliable performance of new generations of extremely large offshore wind turbines will present new challenges in engineering, materials science, manufacturing, controls, and maintenance. Critical data are lacking on offshore wind characteristics, including extreme weather events such as hurricanes, which need to be better understood for design engineering, energy projections, and controls development to optimize wind plant performance. In FY 2020, the subprogram will accelerate fundamental R&D targeted at U.S.-specific offshore wind technology barriers through collaboration with commercial offshore wind plant developers to collect pre- and post-installation structural and performance data. Additionally, this effort will help to develop recommended design practices, standards, and technical innovations to reduce cost and risk of offshore wind plants within U.S. waters.

For utility-scale, land-based wind, the subprogram focuses on "Tall Wind" turbine technology innovations–including those that enable higher hub heights, larger rotors, lighter weight components, and improved energy capture that have the potential to reduce today's utility-scale land-based wind LCOE by almost 30 percent and provide options for significant expansion of U.S. wind power deployment. Activities focus on developing new control methods to manage large rotor loads; materials and manufacturing innovations to facilitate transportation and installation of very large towers, rotors, drivetrains, and generators; and integrated design of the whole wind plant that includes support for grid reliability and resiliency. In FY 2020, the subprogram will fund early-stage R&D in the areas of controls, sensors, algorithms, materials, and manufacturing to lower land-based, utility-scale wind energy costs and improve operational performance. One of these efforts is the program's Big Adaptive Rotor (BAR) initiative, which focuses on development of innovative large rotor designs with longer blades to capture substantially more energy both through a greater swept area and accessing increased wind speeds higher than conventional technology does. Larger rotors also allow for higher capacity factor wind plants, which creates less variability in power production. The BAR initiative will address R&D challenges required to facilitate the next generation of rotors for tall wind applications, including large blade manufacturing and transportation, rotor controls, aerodynamics, advanced blade materials, and blade structural design.

For distributed wind energy, the subprogram focuses on reducing capital costs through standardization of project assessment, permitting, interconnection, system design, and installation. As a result of increased stakeholder engagement, in FY 2020, the subprogram will fund several newly established distributed wind activities, including R&D that directly reduces distributed wind LCOE; development of tools that enhance accuracy of distributed wind performance assessments, inform siting and system design, and reduce project development risk; efforts to maximize the value and resiliency of microgrids utilizing wind energy and other distributed energy resources; and stakeholder engagement to develop innovative solutions to market barriers.

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

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Technology RD&T and Resource Characterization $59,000,000	**$18,000,000**	**-$41,000,000**
• FY 2019 activities tie the high-fidelity modeling and experimental efforts under the Atmosphere to Electrons (A2e) initiative to a completely new systems approach to the design and analysis of wind plants for both land-based and offshore applications.	• Approximately $3,600,000 for continued collaboration with the Office of Science Exascale Computing Project and support research that continues a systems approach to the design and analysis of wind plants for both land-based and offshore applications. This effort will improve the performance and reliability of next-generation wind plants and support cost reduction goal of $.023/kWh by 2030.	• Funds reduced to focus on continued development of exascale computing wind simulation model and offshore floating wind foundation design tool set.
• 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 A2e.	• Approximately $3,000,000 for activities that will continue experimental data collection and validation of high-fidelity modeling tools supporting improved performance and reliability of next generation wind plants.	• Continue validation efforts of high-fidelity modeling tools using data collected in prior years and prepare for future field validation at a full-scale wind facility.
• Conduct wake steering experiments using the new National Rotor Testbed (NRT) blades specifically designed to replicate the wake characteristics of full-scale turbines.	• Approximately $1,000,000 for activities that support utilization of wake steering computational simulations, and an experimental field campaign of active wind plant control strategies that will provide additional validation of high-fidelity modeling and simulation tools. Supports whole plant optimization efforts and reduction in LCOE.	• Funding level reduced in order to emphasize the incorporation of improved physics modeling in FLORIS based on observations from field campaigns and high-fidelity modeling.
• Using the Weather Research and Forecast model, the program will initiate a new activity to create the Energy Research and Forecasting (ERF) simulation framework. Funds will support resource characterization effort, high fidelity meteorological modeling to improve forecasting of resource and understanding of wind flow through the plant The program will address issues associated with moving from large-scale weather forecasting	• Approximately $2,000,000 for activities to support collaborations with NCAR and NOAA, and research in atmospheric science, verification and validation of the Energy Research and Forecasting (ERF) model, and addressing issues associated with moving from large-scale weather forecasting models to smaller scales applicable to land-based and offshore wind applications.	• Funds reduced to focus on analysis of WFIP 2 data, validation of ERF, and addressing meso- to micro-scaling challenges.

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
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.		
• FY 2019 A2e Performance, Risk Uncertainty and Finance (PRUF) projects include expanded benchmark to leverage international experience and evaluating machine learning and other advanced statistical approaches to improving plant performance prediction.	• Continue benchmarking activities for wind plant performance to include offshore wind projects internationally, and demonstration of advanced statistical approaches to improving plant performance predictions.	• Shift benchmarking activity to include offshore wind plants.
• FY 2019 reliability activities include assessment of failure mitigation strategies for main bearing and high-speed shaft bearing through material and lubrication innovations.	• Approximately $1,400,000 to continued research into a more defined set of failure mitigation strategies.	• Scope of failure mitigation methods reduced to those with highest potential.
• 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.	• Approximately $1,000,000 for continued R&D on advanced manufacturing methodologies and materials benefiting land-based and offshore wind applications at three National Laboratories.	• Reduced scope to focus on the National Laboratory work and not engage with the DOE Advanced Manufacturing Office in FY 2020.
• The program will evaluate the potential to support additional R&D on wind-specific optimized carbon fiber composites.	• No funding requested for this activity.	• This project will be fully funded with FY 2019 funds.
• 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.	• Approximately $1,600,000 for continuation R&D within the Big Adaptive Rotor project addressing R&D challenges. This will enable tall wind initiative and cost reductions of 50% by 2020.	• No change in scope.
• Funding in FY 2019 will support tall tower R&D, including competitively awarded work to design, build, test, and validate a wind turbine tower with a height of at least 140 meters. The selected project(s) will develop an engineering design and cost analysis, with a go/no-go review to precede fabrication and testing.	• Continue addressing R&D challenges associated with the design and manufacturing of towers for tall wind applications. National laboratory support for techno-economic analysis of awarded project(s) will begin ($100,000).	• Funds reduced because large effort from FY 2019 will be newly initiated. This reduction will shift focus to techno-economic analyses and emphasis on gap areas not funded in the FY 2019.
• FY 2019 offshore wind resource assessment activities will include developing partnerships to deploy wind and met-ocean science buoys in areas	• Approximately $2,400,000 for efforts to collect data in collaboration with commercial offshore wind plant developers, and BOEM, to develop	• Funds reduced to allow for leveraging past efforts to develop recommended design practices and standards for offshore wind.

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
identified for offshore wind development. Analysis of prior year meteorological and oceanographic data from offshore buoys will be performed.	recommended design practices, standards, and technical innovations to reduce cost and risk of offshore wind plants within U.S. waters.	
• FY 2019 distributed wind efforts focus on analysis, research, development and manufacturing improvements that directly reduce LCOE and facilitate turbine certification goals, while increasing the ability of distributed wind systems to integrate into distribution systems and microgrids with other distributed energy resources, with a particular focus on rural utility applications.	• $800,000 to continue work to improve distributed wind integration on distribution systems and microgrids, manage existing Competitiveness Improvement Projects and other national lab work, and support collection and analysis of distributed wind technology data to identify key R&D opportunities as documented by the Distributed Wind Market Report.	• Projects awarded with FY 2018 and FY 2019 funds will continue to be managed, but no new projects will be awarded. Reduced FY 2020 funding will support microgrid integration work, and reduced data collection and analysis to identify core R&D opportunities and measure progress towards goals.
• Select 1-3 competitively awarded research projects to conduct innovative offshore wind R&D at National-level facilities.	• No funding requested for this activity.	• This project will be fully funded with FY 2019 funds and management activities will continue.
• Maintenance and operation of NWTC and SWIFT facilities including funds for upgrades at the NWTC to enable distributed wind integration with PV and micro grids and a second controllable Grid Interface	• Approximately $1,200,000 to continue to maintain and operate the SWiFT facility to ensure mission readiness for use by DOE wind researchers and industry partners engaged in fundamental technology research, development, experimentation, testing, and validation.	• Funding reduced by transitioning funding for operations and maintenance for the NWTC to EERE's F&I budget.

Wind Energy
Technology Validation and Market Transformation

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.

Two offshore wind advanced technology demonstration projects continue development activities. The Lake Erie Energy Development Corporation's Icebreaker Project plans to install six 3.45-MW, direct-drive turbines on mono bucket foundations eight miles off the coast of Cleveland, Ohio, becoming the first freshwater offshore wind project in North America. The New England Aqua Ventus I project, led by the University of Maine, Is a planned floating offshore wind farm with two 6-MW direct-drive turbines on concrete, semisubmersible foundations in deep waters off Monhegan Island, Maine, where bottom-fixed foundations are not feasible. Both projects are working toward completing project design, state and federal permitting, installation and operations plans, and offtake and grid interconnection plans.

In FY 2020, no funding is requested for this subprogram. Current projects are fully funded and outlays of prior year obligations will fund ongoing activities through project completion.

Technology Validation and Market Transformation

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Technology Validation and Market Transformation $10,000,000	**$0**	**-$10,000,000**
• Competitively awarded solicitation for additional project development for offshore wind demonstration projects.	• No funding requested for this	• Competitively selected project will continue to be managed but no funds are requested.

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, regulatory, and siting decisions associated with the deployment of offshore, land-based, and distributed wind energy. The subprogram determines research needs and evaluates technology solutions to address regulatory and siting restrictions for radar interference, wildlife impacts, and community impacts associated with domestic wind energy development, in support of 2030 cost goals. The subprogram also supports STEM and workforce programs that support a domestic wind workforce for the 21st century. The subprogram's work is critical to enabling wind deployment, since these market barriers can prevent the successful siting and development of wind projects in areas where wind is otherwise cost-competitive.

The subprogram invests in R&D to ensure cost-effective, reliable, cyber secure, and resilient operation of the power grid with increasing levels of wind energy for all wind technology applications. Its wind energy grid integration R&D aims to generate the knowledge that electric grid operators, utilities, regulators, and industry need to develop and deploy novel technologies that support reliable incorporation of wind energy into the power system. This work is conducted as part of coordinated grid modernization efforts across the Department through the National Laboratories and the Grid Modernization Initiative (GMI). Additionally, early-stage research can help identify opportunities to address power grid reliability and resilience concerns as increasing amounts of wind energy are added to the grid.

In FY 2020, the subprogram will complete development of a cybersecurity roadmap aligned with DOE cybersecurity efforts and in coordination with the Office of Cybersecurity, Energy Security, and Emergency Response. Funding will continue for research coordinated through the Grid Modernization Initiative to develop 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 frequency, voltage, and ramping support to the grid. The program will continue its work selected in a competitive lab call in FY 2019, focused on developing new technologies and analytical tools that improve grid reliability through increased flexibility and grid services. The program will evaluate R&D needs identified from an FY 2019 roadmap process for better integration of wind generation through co-optimized wind plant operation, integrating multiple technologies, flexible transmission utilization, and wind plant cybersecurity.

In FY 2020, collaboration will continue with the Department of Defense (DOD), Department of Homeland Security (DHS), Department of Transportation (DOT), Department of Interior (DOI) and Department of Commerce (DOC), and other agencies through the interagency Wind Turbine Radar Interference Mitigation memorandum of understanding (MOU) to address the impacts of wind development on critical radar missions. The objectives include development of technology solutions to evaluate the impacts of existing and planned wind energy installations on sensitive radar systems; development of mitigation measures to increase the resilience of existing radar systems to wind turbines; and encouraging the development of next-generation radar systems that are resistant to wind turbine radar interference.

In FY 2020, the subprogram will evaluate the environmental performance of offshore and land-based wind projects, including avian and bat species interactions with wind turbines, and conduct research to inform the development of technical mitigation solutions. Solutions will be developed to reduce wind impacts on wildlife through research on instrumentation, advanced components, and operational strategies. The subprogram's work in this area will inform regulatory and siting processes and facilitate wind industry deployment through the development of technical solutions.

In addition, in FY 2020 the subprogram will continue STEM activities, support for the National Wind Turbine database, research on community impacts, provision of informational resources to ensure decision-makers are using the best available science to support wind energy decisions, and support for development of a robust domestic wind energy workforce.

Mitigate Market Barriers

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Mitigate Market Barriers $16,000,000	**$4,500,000**	**-$11,500,000**
• Select three to five merit reviewed R&D projects at the National Laboratories through the GMLC that will focus on foundational and wind specific technologies such as hybrid energy systems coupling wind with other renewables and advanced storage technologies, and evaluating essential reliability services including inertia, frequency response, and voltage control.	• Continued management of projects selected in GMLC lab call in FY 2019 and complete wind specific roadmap identifying opportunities for wind in this space ($1,000,000).	• Funds are reduced to enable grid integration activities to be consolidated. Reduction in scope related to activities centered to the development of hybrid energy systems to maintain efforts to further the development of providing essential reliability services from wind.
• 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 ($1,000,000).	• Continue efforts on wind-based transmission line routing tool development, and dynamic line rating forecasting capability development in partnership with NOAA ($500,000).	• Reduction in scope related to the development in wind based dynamic line rating forecasting.
• Initiate wind cybersecurity roadmap development ($1,000,000).	• Continued efforts to develop and implement a wind cybersecurity roadmap, helping drive future investment ($500,000).	• Reduced effort related to the implementation of cybersecurity roadmap activities.
• 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.	• Continue collaboration with DOD, DHS, DOT, DOI, and DOC on research, development and implementation of technology solutions applicable to offshore ($500,000).	• Funds are reduced to enable emphasis characterizing the unique impacts of wind energy on radar in the offshore environment, and applying that knowledge to offshore specific mitigations as needed.
• Support comprehensive research on the environmental performance of offshore and land-based wind projects, including research on avian and bat species interactions with wind plants, research on instrumentation, advanced components, and operational strategies to reduce impacts and lower costs, and make publicly available information on wind wildlife research through the Tethys database and through research collaborations ($4,400,000).	• Support National Laboratory research on the environmental performance of offshore and land-based wind projects, including avian and bat species interactions with wind plants and conduct research on instrumentation, advanced components, and operational strategies to lower cost and make publicly available information on wind wildlife research through the Tethys database and through research collaborations ($1,250,000).	• Funding reduced to support an emphasis on research to reduce costs associated with environmental mitigation efforts.

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
• Continue support for the National Wind Turbine database and research on community impacts. ($500,000).	• Continue support for the National Wind Turbine database and research on community impacts ($150,000).	• Funding will narrow focus to incremental improvements and necessary maintenance of the database, as well as limited follow on community impacts research.
• Continue provision of WINDExchange informational resources to ensure decision-makers are using the best available science to support wind energy policy and deployment decisions ($1,000,000).	• Continue provision of WINDExchange informational resources to ensure decision-makers are using the best available science to support wind energy policy and deployment decisions. ($200,000).	• Funding will be narrowed to focused on web based tools and resources.
• Continue Wind for Schools for development of a robust domestic wind energy workforce ($1,000,000).	• Continue Wind for Schools for development of a robust domestic wind energy workforce ($200,000).	• Will focus on allowing for continuation of a scaled-down program. A private project partner will take on more of the management of and fundraising efforts for the existing Wind Application Centers.
• Continue the Collegiate Wind Competition funded primarily with FY 2018 funds and supplemented with FY 2019 funds, for development of a robust domestic wind energy workforce ($400,000).	• Initiate new funding cycle for Collegiate Wind Competition for development of a robust domestic wind energy workforce ($200,000).	• Funds narrowed to focus reduced size of competition.

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-based, 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. These analyses are used to identify early-stage R&D needs as well as to prioritize activities within the portfolio.

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 2020, subprogram funding will evaluate the potential impact of innovations in land-based (including community and distributed) wind and offshore wind, with a focus on identifying opportunities to increase the value of wind to the electricity system. Where possible, key modeling and analysis tools will be converted to open source software to support greater transparency.

Modeling and Analysis

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Modeling and Analysis $7,000,000	**$1,200,000**	**-$5,800,000**
• 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. Analysis supporting characterizing the electricity systems cost and benefits of wind on the grid will be conducted including ability of wind to provide ancillary services.	• $1,200,000 to engage National Laboratories and industry partners and other stakeholders to focus on core data collection and reporting, and evaluation of potential impact of innovations, with a focus on identifying opportunities to increase the value of wind to the electricity system. Where possible, key modeling and analysis tools will be converted to open source software to support greater transparency.	• Focus with reduced FY 2020 funds limited to collecting core data and measuring progress towards goals, and identifying 1-3 innovation pathways that could enhance wind's value to the electricity system.
• 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.	• No funds requested for this activity	• Project completed with FY 2019 funds

Water Power

Overview

Hydropower and marine and hydrokinetic (MHK) energy generates renewable electricity that supports domestic economic prosperity and energy security while enhancing the reliability and resiliency of the U.S. electric 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 supporting industry efforts to develop new technologies that increase U.S. hydropower and MHK generation. To accomplish its objectives, the program supports the National Laboratories, industry, and academia to conduct R&D though contracts, cooperative agreements, and other innovative partnerships and approaches.

Hydropower has provided the U.S. with sustainable, reliable, and affordable power for over 100 years. In 2017, hydropower supplied 7.5 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 powering the equivalent of 21 million homes.[3] 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. 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, the hydropower fleet requires significant innovation to realize its potential contribution to the clean energy supply and adapt to the rapidly evolving power system. In 2016, DOE's Hydropower Vision found a substantial opportunity for new hydropower and pumped storage in the U.S., with an additional 50-65 GW of generation and long-duration energy storage possible 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. At the same time, the increasing value of hydropower's ability to provide flexibility and balancing services at scale means that the operation of existing plants is changing rapidly and the current fleet faces significant uncertainty around future costs, operations, and technology needs. Realizing the potential for new hydropower and optimizing the operations of existing plants, however, will not happen without focused research and development to reduce costs and construction timelines, continued improvement of environmental performance, and comprehensive understanding and improvement in hydropower's ability to operate flexibly and provide reliability and resilience services to the grid.

To support new hydropower, 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 standardized, modular hydropower designs. Currently the vast majority of hydropower plants and turbines are custom-designed for every site, leading to high capital costs. For small hydropower, significant levelized cost of energy (LCOE) reductions are possible by standardizing design and manufacturing. In addition, the 2016 Vision found that much of the development of new small hydropower facilities – as opposed to non-powered dams – requires new technologies with improved environmental characteristics. Program R&D on standardized, modular hydropower 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 supports industry efforts to develop novel technologies and operational strategies that can increase hydropower's capability to provide generation, essential grid services, and environmental performance at existing facilities while meeting

[1] U.S. Energy Information Administration. Table 7.2A Electricity Net Generation: Total (All Sectors). Accessed August 13th, 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] "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.

multiple use demands of energy generation, irrigation, and recreation.

The program also invests in research and development that enhances the ability of hydropower and PSH to provide increased flexibility and grid-reliability services, and investigates new PSH technologies that can dramatically reduce the capital costs and barriers to new large-scale long-duration storage facilities critical to maintaining a reliable and resilient grid. Program efforts also include analysis to evaluate the specific contribution of different reliability services provided by hydropower, the ability and costs for different types of hydropower facilities to provide those services, and the technologies and operational shifts required to optimize the value of hydropower's flexibility, as well as the development of new technologies that improve facilities' abilities to operate flexibly and responsively.

The request provides $15,000,000 in support of the Advanced Energy Storage Initiative, which coordinates EERE R&D across DOE to advance energy storage and other technologies that create more flexible generation and more flexible load, thereby increasing the reliability and resilience of the U.S. electric grid. Energy storage is critical to advance a flexible, resilient electrical grid and expand affordable mobility options from a diverse suite of energy resources – and energy storage for the grid is complemented by a portfolio of generation and load technologies that provide flexibility, essential reliability services, and system resilience. The Advanced Energy Storage Initiative will enhance coordination across EERE and DOE and establish aggressive, achievable, and comparable goals for cost-competitive energy storage services and applications.

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 strategies that can increase both power generation and environmental performance at existing facilities. Whereas existing industry tools are designed to optimize for water 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 support 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 executed 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 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 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 military, commercial and scientific applications, such as ocean-based sensors, monitoring equipment and autonomous vehicle recharging at sea, as well as reducing desalination costs by avoiding the costs and efficiency losses in generating electricity to power desalination systems.

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 currents 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 the development and utilization of testing infrastructure to facilitate systematic technology development and validation 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 facilitate 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 2020 Budget Request

The Water Power Program will pursue the following major activities in FY 2020:

- In support of DOE's Advanced Energy Storage Initiative, the program continues its focus on hydropower and PSH's roles in grid reliability and resiliency by supporting innovative PSH technologies and conducting new research to characterize and improve hydropower's flexibility and responsiveness.
- In support of the Water Security Grand Challenge, the program will investigate competitive opportunities, including prizes and other innovative approaches, to advance energy-water security.
- The program will support R&D to increase improvements in controls and power take-offs for early-stage marine technologies, as well as alternative applications of the technologies for remote communities, ultimately leading to reduced costs and increased competitiveness of marine energy devices.
- Investments in R&D for innovative standardized and modular hydropower technologies using advanced manufacturing techniques to lower overall project costs and improve environmental performance versus traditional projects at new stream reaches and non-powered dams.
- Through its partnerships with the Navy and with university-National Laboratory collaborations, the program will validate reliability of marine energy technologies and assess the integration of power from MHK devices, in particular the oscillatory fluctuations from wave energy, into the electric grid.
- The program will support innovative environmental mitigation technologies and new research to inform licensing requirements and processes facilitating reduced time, cost, and uncertainty in hydropower licensing.
- In marine energy, the program will continue to analyze and disseminate the results of open water tests in order to reduce perceived environmental risk and the time associated with device permitting.

Water Power
Funding ($K)

	FY 2018 Enacted	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
Water Power				
Hydropower Technologies	35,000	35,000	25,000	-10,000
Marine and Hydrokinetic Technologies	70,000	70,000	20,000	-50,000
Total, Water Power	**105,000**	**105,000**	**45,000**	**-60,000**

SBIR/STTR:

- FY 2018 Transferred: SBIR $3,093,000; STTR $435,000
- FY 2019 Projected: SBIR $3,134,000; STTR $441,000
- FY 2020 Request: SBIR $1,431,000; STTR $201,000

Explanation of Major Changes ($K)

	FY 2020 Request vs FY 2019 Enacted
Water Power	
Hydropower Technologies: In FY 2020, no funding is provided for implementation of Section 242 of the Energy Policy Act of 2005. 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 the Clean Energy Research Center as the funding commitment was satisfied in FY 2019. Funding is provided to support the Advanced Energy Storage Initiative, to include activities in support of increasing the flexibility of hydropower to the grid and advanced storage capabilities, like pumped storage hydropower.	**-10,000**
Marine and Hydrokinetic Technologies: The FY 2020 Request eliminates funding for advanced materials, MHK device components, and current system design and validation. It does not include funding for infrastructure upgrades at marine industry testing sites operated by the National Marine Renewable Energy Centers (NMRECs), but provides funding to support collaborations between the NMRECs and the National Laboratories. The request maintains core funding for development and testing of specific marine energy systems and components, such as power take-off, controls or structural designs, for testing at the open water test facility once it becomes operational. It also reduces. It also maintains funding necessary for FY 2020 scope of work for advanced wave energy converter controls, wave, tidal and current resource classification, and sharing of environmental and regulatory data among researchers, developers and regulators. The Request includes funds for initial scoping of a funding opportunity to prove the feasibility of tidal devices in remote communities.	**-50,000**
Total, Water Power	**-60,000**

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. Consistent with the 2016 Hydropower Vision Report, the program's hydropower strategy is focused on strengthening the body of knowledge that support industry efforts 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.

The hydropower subprogram 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 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; developing models that more effectively characterize how hydropower can be operated to maximize its flexibility and contribute to grid reliability and resilience, and the corresponding implications for cost and performance; turbine designs that simultaneously optimize both generation and environmental performance; evaluating technologies that allow multiple run-of-river small (<10MW) hydropower facilities and energy storage systems to operate as a single, dispatchable system while providing essential grid services; and PSH technology configurations that reduce siting limitations, construction timelines, and environmental impacts. In support of the Water Security Grand Challenge, the subprogram will investigate competitive opportunities, including prizes and other innovative approaches, where small, modular hydropower systems could complement other water-related objectives, like irrigation systems modernization or groundwater recharge.

The subprogram's 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 subprogram partners with the private sector through competitive mechanisms to perform early-stage research. This research focuses on innovative approaches to hydropower, including design, configurations, and advanced manufacturing, 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 resources, 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. PSH provides many of these same services, in addition to the ability to absorb excess generation during the pumping mode and provide long-term power storage 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. As part of the Advanced Energy Storage Initiative, the hydropower subprogram 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. This research includes understanding the value of hydropower under future electric system conditions, quantifying the effect of flexibility constraints on plant capabilities and performance (e.g. from variations in water flows, plant designs, or license conditions), addressing critical technical barriers to effective operation of hydropower resources for reliability and economic dispatch, and identifying technology solutions that will preserve or enhance hydropower capabilities to deliver services or system benefits competitively. In addition, the subprogram 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 subprogram continues to develop turbine design and evaluation tools based on new biological research that support the efforts of 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 subprogram also engages with stakeholders and partner agencies to provide unbiased scientific data to facilitate targeted improvements to regulatory processes.

In FY 2020, the hydropower subprogram will contribute $15,000,000 to the Advanced Energy Storage Initiative to continue research and development to increase the flexibility of hydropower's generation and pumped storage, and the ability of those technologies to provide critical grid services. The subprogram will continue to assess and drive innovation in hydropower flexibility, as well as new PSH configurations that reduce geographic siting limitations, construction costs and timelines, and environmental impacts. 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. The subprogram will also conduct research to compare cost, performance, deployment timelines, and capabilities of new and existing PSH technologies, including those competitively selected through funding opportunities in FY 2016 and FY 2018. In addition, the subprogram will build off prior years' work to develop 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 that could also provide essential grid services to maintain system reliability.

In FY 2020, the subprogram will continue National Laboratory and industry R&D efforts to develop standard, modular hydropower components and site designs. While prior years' efforts have focused on conducting the foundational research for standard, modular approaches and competitively selecting hydropower developers to apply existing technologies for site design pertaining to new stream reach development, in FY 2020 subprogram focus will shift towards standard, modular approaches at existing non-powered dams. Similar to FY 2018, the subprogram will utilize competitive mechanisms to work with developers to develop new hydropower designs for non-powered dams, including innovative generation, foundation, and passage modules. New module development will leverage results from the prior year's analysis to identify opportunities for advanced manufacturing hydropower applications.

In FY 2020, the subprogram will continue its work to develop turbine design and evaluation tools that improve fish passage and turbine efficiency (the third year of the four-year Phase II of a multi-lab project). The subprogram will also begin updating the Department's 2016 Hydropower Vision Roadmap to ensure it fulfils its intention to be a living document that reflects past progress. In addition, the subprogram will build off efforts in prior years to develop a scientific framework for identifying the key factors that contribute to environmental impacts of hydropower. The FY 2020 effort will apply the framework in a regulatory setting to minimize the time and costs for scientific studies needed for regulatory permitting. Funding also supports the third and final Report to Congress under the SECURE Water Act Section 9505, due in 2021.

Hydropower Technologies

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Hydropower Technologies $35,000,000	**$25,000,000**	**-$10,000,000**
• $11,300,000, in support of Beyond Batteries for projects that explore: 1) opportunities for run-of-river hydropower facilities to be operated together as a single, dispatchable system; and 2) the ability of existing hydropower facilities to operate flexibly and provide essential grid services. This effort also includes technology and analytical research at National Laboratories to evaluate hydropower's contributions to grid resiliency.	• $15,000,000, in support of the Advanced Energy Storage Initiative to design and evaluate new PSH technology configurations and analytical research at five National Laboratories to evaluate: 1) opportunities for run-of-river hydropower facilities to be operated together as a single, dispatchable system; and 2) the ability of existing hydropower facilities to operate flexibly and provide essential grid services.	• No change from FY 2019.
• $5,000,000 to leverage advanced manufacturing techniques for standard, modular hydropower components for new stream reaches.	• $2,000,000 for projects that employ standard modular hydropower at existing non-powered dams.	• FY 2020 Request will build on past research and lessons learned from previously-funded projects to develop new hydropower designs for non-powered dams, including innovative generation, foundation, and passage modules.
• $1,500,000 to continue National Laboratory efforts to develop design specifications and computer modeling tools for standardized, modular hydropower technologies.	• $1,800,000 to continue National Laboratory efforts to develop design specifications and computer modeling tools for standardized, modular hydropower technologies.	• No change from FY 2019.
• $6,600,000 for implementation of section 242 of the Energy Policy Act of 2005 (P.L. 109-58).	• No funding requested	• Funding incentive payments for deployment is inconsistent with the focus on early-stage R&D.
• $400,000 to fund the final year of the Clean Energy Research Center (CERC).	• No funding requested	• FY 2019 represents the final year of a multi-year commitment to provide funding for the CERC.

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 non-utility scale 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 support the efforts of 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 supports the domestic MHK industry to advance toward achieving cost competitiveness with local hurdle rates in near-term markets, while working toward long-term cost-competitiveness at the utility scale. This will be focused on design concepts that have the potential to increase energy capture and annual energy production, improve reliability and availability, and reduce capital and operating costs if further developed and deployed by industry. R&D activities will include a focus on design concepts that have the potential to serve existing or emerging ocean-based technologies that can advance the nation's military, commercial and scientific capabilities. These 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. Many of these markets and applications contribute to the development of the "Blue Economy," a multi-sector effort to advance our understanding of the ocean and drive technology innovation to unlock the scientific and commercial opportunities it holds. The Blue Economy is an Administration priority, and will require new sources of energy available at sea which marine energy may be particularly well-suited to provide.[2]

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

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[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 U.S. 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 U.S." (https://energy.gov/sites/prod/files/2013/12/f5/1023527.pdf), and "Assessment of Energy Production Potential from Ocean Currents along the U.S. Coastline" (https://energy.gov/sites/prod/files/2013/12/f5/energy_production_ocean_currents_us_0.pdf).

[2] Understanding new opportunities for innovation and growth in the Blue Economy has been a focus of the Administration articulated in the following: "Science and Technology for America's Oceans: A Decadal Vision." White House National Science and Technology Council. November, 2018. Accessed December 20, 2018. https://www.whitehouse.gov/wp-content/uploads/2018/11/Science-and-Technology-for-Americas-Oceans-A-Decadal-Vision.pdf; "Water Security Grand Challenge." U.S. Department of Energy. Accessed December 20, 2018. https://www.energy.gov/water-security-grand-challenge; and Executive Order 13840, Ocean Policy to Advance the Economic, Security, and Environmental Interests of the U.S. June 16, 2018. Accessed December 20, 2018. https://www.whitehouse.gov/presidential-actions/executive-order-regarding-ocean-policy-advance-economic-security-environmental-interests-united-states/.

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.

The subprogram makes strategic investments to support fundamental technology innovations and reduce barriers to testing and validation. Testing of wave energy systems is essential to understanding device-ocean interactions and improving early-stage designs. Many device developers struggle to raise the capital needed to conduct tank testing, and this challenge slows the pace of design iterations required to reduce LCOE. By providing access to testing facilities and expertise on how to perform experiments and numerical modeling in operational and extreme conditions, the subprogram is able to reduce testing costs, facilitate more robust testing at smaller scales; increase credibility and comparability of performance test data; enable use of common metrics and testing standards, and provide world-class research and testing expertise to improve MHK technologies.

For industry to move MHK technologies beyond small-scale prototypes, in-water validation of performance, efficiency and reliability across a wide range of sea states including extreme conditions, is essential. 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 to support the development and testing of early-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 supports industry efforts to develop new technologies that more accurately monitor in-water devices. 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 continuing development of the first-ever national wave classification metrics and site-specific wave energy characterization. This work is similar to what DOE has provided historically for the wind and solar industries including national level maps and dynamic resource predictions. The subprogram's efforts will refine and expand on the high-resolution wave and tidal resource data that assists in identifying project sites, informs design requirements, maximizes energy capture, reduces project uncertainty and risk, and thereby reduces LCOE. This type of national level, unbiased information is essential both to help industry make informed project siting decisions and also to inform 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 under development in FY 2019, incorporating feedback and input on the draft strategy published previously. The strategy will highlight and prioritize pathways through strategic investments in early-stage R&D that support industry efforts to effectively drive down the cost of energy and overcome market barriers.

In FY 2020, the subprogram will competitively select industry-led projects to test and validate performance of wave devices at PacWave (formerly known as the Pacific Marine Energy Center – South Energy Test Site), and as part of these projects, support the commissioning of PacWave and validate its ability to meet all international standards required to achieve certification as an accredited wave energy test facility. The subprogram will also support further development of promising novel concept R&D paths within the marine energy research community as well as continue to work with the international community on universally accepted and consistent performance metrics for marine energy.

In FY 2020, the subprogram will continue activities for supporting assistance to private industry to test early stage subscale marine energy systems, in collaboration with U.S. universities and National Laboratories. Funding also supports effort by the National Laboratories to collaborate with industry to collect high-quality loads and site environmental conditions data, stakeholder engagement and initial scoping of funding opportunities to prove the feasibility of tidal devices in remote communities. The subprogram will continue work on improvements to hydrodynamic and acoustic models for environmental prediction as well as instrumentation guidance and open source processing software tools for MHK Laboratory and Field Scale Testing.

In FY 2020, the subprogram will support continued R&D in advanced controls working with industry to validate the most promising systems. The subprogram will commence follow-on to previous work in non-utility scale markets by scoping and analyzing the viability of expanding to other markets (which will be done in coordination with other relevant Federal agencies and the National Oceanographic Partnership Program); and continue efforts to characterize and classify marine energy resources, including developing a user tool for resource classification.

Marine and Hydrokinetic Technologies

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Marine and Hydrokinetic Technologies $70,000,000	**$20,000,000**	**-$50,000,000**
• $7,200,000 for technology-specific system design and validation of marine hydrokinetic technologies, including the design of wave energy capture systems and prototyping in-river energy conversion components and systems.	• $5,720,000 to test and validate performance of wave devices at PacWave (formerly known as the Pacific Marine Energy Center – South Energy Test Site).	• Funding prioritizes wave energy devices at a scale and design appropriate for testing at the PacWave facility in Oregon. Projects begun in FY20 will be ready for testing when the facility begins operation in 2021.
• $2,000,000 to support continued research and development at National Laboratories into 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 funding requested.	• The program will evaluate the results of the applying advanced materials at the sub-component level prior to committing funding for additional research.
• $335,000 to support continued research and development at National Laboratories for performance validation of industry-developed monitoring instrumentation systems. Develop instrumentation capabilities identified as a gap during the 2017 workshop.	• No funding requested.	• FY 2019 represents the final year of funding for this activity.
• $8,000,000 to direct a rolling test campaign to provide developers access to marine testing facilities and expertise on how to perform experiments and numerical modeling in operational and extreme conditions for MHK technologies developers.	• $2,000,000 to support activities begun in FY 2018 and continuing in FY 2019 for supporting industry-led testing in collaboration with U.S. universities and National Laboratories for early stage subscale marine energy systems.	• Funding in FY20 will be focused on addressing specific gaps in the rolling test program identified in its first year of operation

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
• $5,000,000 for 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.	• $500,000 for National Laboratory efforts to analyze the results from prior year work in oceanic military, commercial and scientific applications and begin development of new R&D efforts in other markets.	• Focus on analyzing results of prior years' funding opportunities for viability of technologies to serve other markets.
• $1,230,000 to continue DOE's commitment to a joint DOE/Navy project targeting advanced controls. The same control strategies and WEC used in FY 2017 will be tested operating in 3-degrees of freedom.	• $1,230,000 to continue DOE's commitment to a joint DOE/Navy project targeting advanced controls in the FY 2020 Request.	• No change from FY 2019.
• $2,175,000 to continue National Laboratory work begun in FY 2017 on large-scale field study to evaluate strike-risk to fish from tidal turbines.	• $1,000,000 to complete National Laboratory work to examine fish interactions with tidal turbines in a natural environment.	• No change from FY 2019. — Builds upon other studies over several years and has the potential to dramatically reduce regulatory concerns over this high-profile issue.

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 to support industry efforts to accelerate the development and deployment of innovative geothermal energy technologies.

The program's technology portfolio prioritizes early-stage R&D in three closely related geothermal categories: Hydrothermal, EGS, and Low Temperature.[3] This research addresses the high risk in early-stage R&D that industry may 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 to support efforts of the geothermal sector to develop innovative technologies that will help harness American energy resources safely and efficiently.

Highlights of the FY 2020 Budget Request

The Geothermal Technologies Program will pursue the following major activities in FY 2020:

- The Geothermal Technologies Program will continue implementation of the Frontier Observatory for Research in Geothermal Energy (FORGE) to advance Phase 3 field operations at the FORGE site in FY 2020. The $5,000,000 requested, is the last funding increment needed for the multi-year FORGE commitment. It supports site decommissioning at the end of Phase 3 in FY 2024. Activities will include demobilization of any equipment and facilities, shut-in of wells, remedial activities, and transfer of land and subsurface ownership, as necessary.
- FORGE Wells of Opportunity: This new effort will facilitate high-risk tests of wellbore stimulation, zonal isolation, and subsurface interrogation technologies in available unused geothermal wells across the U.S., prior to testing in the high-value main injection production pair sites at the FORGE site in Milford, UT.
- Subsurface Imaging: In FY 2020, GTO will expand research in exploration topics, starting with research in subsurface imaging, particularly for current and pre-existing subsurface volcanic terrain.
- Machine Learning for Geothermal: In support of American leadership in artificial intelligence and strategic computing, in FY 2020, the program will focus on early stage R&D applications in machine learning (ML) that could have a significant impact on interpreting subsurface data and drilling operations. Building off previous work in ML and following a down select of projects awarded under the FY 2018 Machine Learning funding opportunity announcement, GTO will scale up the most promising applications of ML technology with the launch of several new data acquisition campaigns. Extensive training data are required for advanced algorithms such as deep reinforcement learning, and FY 2020 work will focus on building those datasets to the scale required for success in this area.
- Advanced Energy Storage Initiative: The request provides $6,500,000 in support of the Advanced Energy Storage Initiative. GTO will competitively select projects for Reservoir Thermal Energy Storage (RTES) R&D including deep direct use (DDU) engineering, design and systems research; this R&D is critical for modernizing the nation's electrical grid and minimizing impacts from variable energy sources, as RTES provides an on-demand "earth battery," holding hot water in storage.

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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 2018 Enacted	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
Geothermal Technologies				
Enhanced Geothermal Systems	50,790	53,000	12,000	-41,000
Hydrothermal	18,415	15,000	6,250	-8,750
Low Temperature and Coproduced Resources	8,000	10,000	6,500	-3,500
Systems Analysis	3,701	6,000	3,250	-2,750
Total, Geothermal Technologies	**80,906**	**84,000**	**28,000**	**-56,000**

SBIR/STTR:

- FY 2018 Transferred: SBIR $2,589,000; STTR $364,000
- FY 2019 Projected: SBIR $2,688,000; STTR $378,000
- FY 2020 Request: SBIR: $896,000; STTR: $126,000

Geothermal Technologies
Explanation of Major Changes ($K)

	FY 2020 Request vs FY 2019 Enacted
Geothermal Technologies	
Enhanced Geothermal Systems: The reduction in funding is attributed in large part to the decreased request for FORGE (a decrease of $25,000,000 from FY 2019 Enacted). The $5,000,000 requested in FY 2020 funds the remaining balance of the final year of Phase 3 at the FORGE site in Milford, UT, for activities that will occur in FY 2024. Further, a decrease of $16,000,000 reflects fully funded efforts in FY 2019 including EGS Collab, Efficient Drilling for Geothermal Energy (EDGE) funding opportunity announcement (FOA) alternates, and the Enhanced Geothermal Systems Early Stage R&D Open Laboratory Call. In support of efforts at the FORGE site, the FY 2020 Request provides up to $6,700,000 in funding for a new effort titled FORGE Wells of Opportunity to facilitate high-risk tests of wellbore stimulation, zonal isolation, and subsurface interrogation technologies in available unused geothermal wells across the U.S., prior to testing at the FORGE site.	**-41,000**
Hydrothermal: Funding in FY 2020 is not requested for activities focused on Subsurface Stress ($7,000,000). A shift of $2,700,000 will support exploration R&D; in FY 2020, GTO will expand research in exploration topics, starting with research in subsurface imaging, particularly for current and pre-existing subsurface volcanic terrain. Additionally, $3,500,000 is requested to support the priority of Artificial Intelligence through Machine Learning (ML) in FY 2020. Efforts will focus on scaling up the most promising applications of ML technology with the launch of several new data acquisition campaigns. Reflecting a decrease of $8,000,000 from FY 2019, no funding is requested for fully funded efforts in FY 2019 including the Efficient Drilling for Geothermal Energy (EDGE) awards, and the Hydrothermal Early Stage R&D Open Laboratory Call.	**-8,750**
Low Temperature and Coproduced Resources: The FY 2020 Request supports the Energy Department's Advanced Energy Storage Initiative providing $6,500,000 for Reservoir Thermal Energy Storage (RTES) R&D including deep direct-use (DDU) engineering, design and systems research that may also include innovative ground source heating and cooling applications. The Request also reflects a decrease of $3,500,000 of fully funded efforts in FY 2019 including a gap analysis of Critical Materials in Geothermal Brines and the Low Temperature & Coproduced Resources Early Stage R&D Open Laboratory Call.	**-3,500**
Systems Analysis: The change in the Systems Analysis subprogram is largely attributed to the decrease of $3,600,000 to the Systems Analysis Early Stage R&D Open Laboratory Call in FY 2019. The Request shifts $850,000 to support new and ongoing efforts including a scoping study that will identify actionable areas where the program could develop future work to address barriers in geothermal market penetration across geothermal sectors. Funding will also continue to support program technical monitoring teams, and analysis tools & data systems including the Geothermal Electricity Technology Evaluation Model (GETEM) and Geothermal Data Repository (GDR).	**-2,750**
Total, Geothermal Technologies	**-56,000**

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 support the development of replicable, sustainable, man-made heat exchangers. In the long term, strengthening the body of EGS knowledge through early-stage R&D will support industry to develop a baseload energy resource estimated at over 100 GW[1]. The research supported by the EGS subprogram will address the goal of meeting $0.06/kWh by 2050 from newly developed enhanced geothermal systems.

EGS research is in a relatively early stage, yet it shares common challenges with other subsurface industries. 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 two of the EGS subprogram's initiatives, the Frontier Observatory for Research in Geothermal Energy (FORGE) and EGS Collab, discussed below.

In FY 2018, the final FORGE site was selected at Milford, Utah. 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. FORGE 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. Furthermore, testing of new technologies and methodologies in the deep rock environment accessed at FORGE will facilitate a fundamental understanding of the key mechanisms controlling processes at depth at full operational scale.

In FY 2019, the FORGE initiative will enter into year one of Phase 3, fully funded with $35,000,000 of prior appropriations. Phase 3 involves full implementation of FORGE and tasks specific to the solicitation, selection, testing and evaluation of new and innovative EGS tools, techniques, and supporting science. It is anticipated that the first of two highly-deviated wells optimized to the in-situ stress field will be drilled in this initial year of Phase 3. In addition, the lower portion of the highly deviated well will be stimulated, leaving the remaining portion of the well open. The FORGE team, led by the University of Utah, will also issue the first of five annual competitive R&D solicitations focused on advanced monitoring technologies, new technologies and approaches for implementing multi-zone stimulations, and dynamic reservoir modeling that incorporates high-fidelity characterization data collected to date. The program will select up to twenty proposals submitted by the broader scientific and technical community to conduct R&D at the Milford site.

FORGE will move into year two of Phase 3 in FY 2020. Prior year appropriated funding in the amount of $35,000,000 will facilitate drilling of the second full-sized wellbore, stimulation of both wells, long-term monitoring of microseismic activity and other geophysical and geochemical signatures to further characterize the subsurface. The FORGE team will also issue the second competitive R&D solicitation focused on reservoir creation, permeability enhancement, and monitoring the evolution of permeability in the reservoir.

In the final three years of Phase 3, from FY 2021 through FY 2024, the FORGE team will continue stimulation experiments, test a variety of completions for ideal flow conditions, and perform long-term flow testing, along with continuous site characterization and monitoring. The team will issue competitive solicitations on an annual basis in technical areas deemed appropriate by the DOE.

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

In FY 2020, funding in the amount of $5,000,000 is requested to support final site decommissioning in FY 2024. These closeout activities will include demobilization of any equipment and facilities, shut-in of wells, remedial activities, and transfer of land and subsurface ownership.

In addition, the subprogram will invest $6,700,000 in a parallel effort to FORGE called "Wells of Opportunity". Intended to complement and build on the research at the FORGE site, the effort will facilitate high-risk tests of wellbore stimulation, zonal isolation, and subsurface interrogation technologies in available unused geothermal wells across the U.S., prior to testing in the high-value wells at Milford, UT. Progress in these areas of R&D will help reduce the LCOE of energy captured through EGS. GTO will target wells previously funded by GTO that may be sub-economic from a commercial perspective or out of commission; with knowledge gained from FORGE, these wells can provide opportunities to test high-risk technologies at a variety of in-situ conditions prior to validation in state of the art FORGE wells. As a result, this will reduce the risk of irreparable damage to the valuable assets at the Utah FORGE site.

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Enhanced Geothermal Systems $53,000,000	**$12,000,000**	**-$41,000,000**
• FORGE: $30,000,000 of FY 2019 funding supports (Phase 3 Years 4 & 5) 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.	• FORGE: $5,000,000 requested in FY 2020 will fund the remaining balance of Phase 3 Year 5 in FY 2024, the final year of the FORGE initiative. Funding will support site decommissioning activities including demobilization of any equipment and facilities, shut-in of wells, remedial activities, and transfer of land and subsurface ownership, as necessary.	• FORGE: Decrease of $25,000,000 requested in FY 2020 for remaining Phase 3 FORGE field operations in FY 2024. The FY 2020 request of $5,000,000 will support site decommissioning activities in FY 2024.
• EGS Collab: Up to $12,000,000 of FY 2019 funding supports laboratory funding for 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: No funding requested.	• EGS Collab: Decrease of $12,000,000 in FY 2020 to reflect effort was fully funded in FY 2019. Work will continue into FY 2020 through outlay of prior year obligations. Experimentation conducted in previous fiscal years (on hydraulic fracturing) will validate modeling assumptions, leading to more complex and focused experiments in FY 2020 that involve mixed mode fracturing experiments, which represent most realistic scenarios for reservoir creation in geothermal environments.
• Additive Manufacturing Prize: Up to $7,000,000 of FY 2019 funding supports, in coordination with Oak Ridge National Laboratory, scoping and analysis for a potential prize focused on using additive manufacturing techniques to develop new bits, bit components, assemblies, and casings to facilitate lower cost drilling in geothermal environments. Funding supports the administration of the Prize, support at Oak Ridge National Laboratory's 3-D printing facility, and the $2,000,000 prize purse.	• Additive Manufacturing Prize: No funding requested.	• Additive Manufacturing Prize: Decrease of $7,000,000 million in FY 2020 to reflect effort was fully funded in FY 2019. No additional funding is requested in FY 2020.
• Enhanced Geothermal Systems Early Stage R&D Open Laboratory Call: Up to $3,000,000 of FY 2019 funding supports National Laboratory capabilities in novel and high impact early stage R&D related to enhanced geothermal systems.	• Enhanced Geothermal Systems Early Stage R&D Open Laboratory Call: No funding requested.	• Enhanced Geothermal Systems Early Stage R&D Open Laboratory Call: Decrease of $3,000,000 in FY 2020. No funding is requested in FY 2020.

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
• Efficient Drilling for Geothermal Energy (EDGE): $700,000 in FY 2019 to fund one alternate under the FY 2018 funding opportunity focused on reducing the costs of geothermal drilling.	• Efficient Drilling for Geothermal Energy (EDGE): No funding requested.	• Decrease of $700,000 in FY 2020 reflects effort fully funded in the previous fiscal year. No funding is requested in FY 2020.
	• FORGE Wells of Opportunity: $6,700,000 requested to facilitate high-risk tests of wellbore stimulation, zonal isolation, and subsurface interrogation technologies in available unused geothermal wells across the U.S., prior to testing in the high-value main injection production pair sites at the FORGE site in Milford, Utah.	• FORGE Wells of Opportunity: Increase of $6,700,000 in FY 2020 for new effort to facilitate high-risk tests of wellbore stimulation, zonal isolation, and subsurface interrogation technologies in available unused geothermal wells across the U.S.

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). Hydrothermal resources can be categorized as either "identified" or "undiscovered." Identified hydrothermal resources are known to exist through the application of conventional exploration technologies and methods. Identified hydrothermal systems typically have at least some surface expression, such as a geyser, hot spring, fumarole, or other indication that a hydrothermal resource may exist at depth. Conversely, undiscovered hydrothermal resources are difficult to identify with existing exploration technologies and methods, largely because these resources lack traditional surface manifestations that indicate subsurface resource potential. In FY 2020, the Hydrothermal subprogram will focus on both developing new exploration tools and technologies needed to capture the resource potential of these undiscovered, "hidden" resources and assessing the feasibility of advanced drilling technologies.

In FY 2020, the Hydrothermal subprogram will focus on early-stage R&D applications in machine learning (ML) to advance the state of the art in power plant operations as well as in interpreting subsurface data. Technology improvements in geothermal exploration, subsurface characterization, and drilling will reduce overall deployment costs significantly. Research will focus on scaling up the most promising applications of ML technology with the launch of several new data acquisition campaigns. Extensive training data are required for advanced algorithms such as deep reinforcement learning, and FY 2020 work will focus on building those datasets to the scale required for success in this area.

The program will also initiate new efforts in Subsurface R&D in FY 2020. GTO will expand research in exploration topics, starting with laboratory research in subsurface imaging, particularly for current and pre-existing subsurface volcanic terrain. Subsurface volcanic terrain is challenging to image, and this work is critical for hydrothermal exploration, supercritical resource identification, and fracture characterization. Volcanic terrains are generally associated with current or recent episodes of heat but are comprised of complex lithologic sequences that hamper the resolution of traditional subsurface imaging techniques. Improved imaging technology would allow for precise targeting in these areas, de-risking many new geothermal development opportunities. Potential R&D paths include downhole sources and sensing (cross-well methods) as well as alternative, non-acoustic signals such as muons.

Hydrothermal early-stage research investments can support industry to reduce the upfront cost of exploration and resource evaluation as well as the drilling costs to facilitate the production of affordable, clean, renewable baseload energy. Geothermal power production derives from a reliable, secure fuel source that supports domestic energy security. The research supported by the Hydrothermal subprogram 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 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Hydrothermal $15,000,000	**$6,250,000**	**-$8,750,000**
• Subsurface R&D: Up to $7,000,000 to develop technologies that advance our ability to characterize, monitor, predict, and adapt to subsurface stress.	• Subsurface Imaging: $2,700,000 to fund research at the National Laboratories to develop technologies that advance our ability to address the challenge of imaging subsurface volcanic terrain.	• Subsurface Imaging: GTO will pivot $2,700,000 funding from R&D in subsurface stress in FY 2019 to subsurface imaging in FY 2020.
• Hydrothermal Early Stage R&D Open Laboratory Call: Up to $6,700,000 of FY 2019 funding supports National Laboratory capabilities in novel and high impact early stage R&D related to hydrothermal.	• Hydrothermal Early Stage R&D Open Laboratory Call: No funding requested.	• Hydrothermal Early Stage R&D Open Laboratory Call: Decrease of $6,700,000 in FY 2020. No funding is requested in FY 2020.
• Efficient Drilling for Geothermal Energy (EDGE): Up to $1,300,000 in FY 2019 to fund two to three alternates under the FY 2018 funding opportunity focused on reducing the costs of geothermal drilling.	• Efficient Drilling for Geothermal Energy (EDGE): No funding requested.	• Decrease of $1,300,000 million in FY 2020 reflects effort fully funded in the previous fiscal year. No funding is requested in FY 2020.
• Machine Learning (ML): No new funding allocated to FY 2018 awardees pending completion of Phase 1.	• Machine Learning (ML): $3,500,000 to fund projects down selected from FY 2018 awardees focused on scale up the most promising applications of ML technology with the launch of several new data acquisition campaigns.	• Machine Learning (ML): Increase of $3,500,000 in Machine Learning to support continued R&D from work previously funded in FY 2018. The increase reflects the high prioritization of this research area by the subprogram in support of the Artificial Intelligence priority.

Geothermal Technologies
Low Temperature and Coproduced Resources

Description

The Low Temperature and Coproduced Resources subprogram supports targeted R&D on technologies applicable to geothermal resources below a temperature of 300°F (150°C) as well as geothermal resources, including 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, these resources are abundant, and using tools developed to exploit EGS resources can make low-temperature resources across the U.S. economically feasible. Low-temperature resources used for district heating and cooling may have much of the necessary infrastructure already in place, lowering the effective levelized cost of electricity or heat. Improving the efficiency of low-temperature geothermal systems, and expanding their utility through value-added commercial opportunities (i.e., cascaded borehole thermal energy storage, geothermal heat pumps, and distributed low-temperature power production) can facilitate near-term development of innovative geothermal technologies in geographically diverse areas of the U.S.

The Low Temperature and Coproduced Resources subprogram also supports R&D including the direct use of thermal resources for process and space heating applications. These technologies 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 could be extracted from geothermal resources below 90°C in the U.S. using currently available technologies.[1]

GTO will contribute to the Advanced Energy Storage Initiative, which coordinates R&D across DOE to advance energy storage and other technologies that create more flexible generation and more flexible load, thereby increasing the reliability and resilience of the U.S. electric grid. Energy storage is critical to advance a flexible, resilient electrical grid and expand affordable mobility options from a diverse suite of energy resources – and energy storage for the grid is complemented by a portfolio of generation and load technologies that provide flexibility, essential reliability services, and system resilience. The Advanced Energy Storage Initiative will enhance coordination across EERE and DOE and establish aggressive, achievable, and comparable goals for cost-competitive energy storage services and applications.

In FY 2020, as part of the Advanced Energy Storage Initiative, GTO will continue Reservoir Thermal Energy Storage (RTES) R&D including DDU engineering, design and systems research that may also include innovative ground source heating and cooling applications. This R&D is critical for modernizing the nation’s electrical grid and minimizing impacts from variable energy sources, as RTES provides an on-demand “earth battery,” holding hot water in storage. New industry-deployable, low-temperature geothermal technologies will include electric grid load-shifting approaches. In FY 2019, GTO partnered with the U.S. Geological Survey to develop quantitative models for pre-assessment of RTES. In FY 2020, this national-scale comparative analysis across a diverse range of conditions and geography will help determine a baseline set of metrics for potential offsets of traditional grid-based heating and cooling and be utilized by the FY 2020 RTES R&D projects.

[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 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Low Temperature and Coproduced Resources $10,000,000	**$6,500,000**	**-$3,500,000**
• Geothermal Energy Applications for Storage Alternatives: Following a down select from the FY 2018 Beyond Batteries Laboratory Call, up to $6,000,000 is for Phase 2 of the effort. Projects will assess the potential for geothermal energy to provide flexible generation, controllable loads, and new approaches to the broader concept of energy storage to effectively mimic many of the benefits of large-scale batteries and to increase the reliability and resilience of the U.S. energy systems.	• Advanced Energy Storage Initiative – $6,500,000 for RTES R&D, including direct use applications. In FY 2020, GTO will leverage a U.S. Geological Survey national-scale comparative analysis across a diverse range of conditions and geography to determine a baseline set of metrics for potential offsets of traditional grid-based heating and cooling and be utilized by the FY 2020 RTES R&D projects. These efforts are aimed at increasing the ability to provide low-cost renewable energy long-term for university campuses, industrial parks, and military installations.	• Advanced Energy Storage Initiative – Thermal energy storage work will be coordinated with the Advanced Energy Storage Initiative, incorporating prior year projects and a new funding for R&D in this space, comparable in size to the FY 2017 Deep Direct Use effort.
• Low Temperature & Coproduced Resources Early Stage R&D Open Laboratory Call: Up to $3,000,000 of FY 2019 funding supports National Laboratory capabilities in novel and high impact early stage R&D related to low temperature & coproduced resources.	• Low Temperature & Coproduced Resources Early Stage R&D Open Laboratory Call: No funding requested.	• Low Temperature & Coproduced Resources Early Stage R&D Open Laboratory Call: Decrease of $3,000,000 in FY 2020. No funding is requested in FY 2020.
• Critical Materials in Geothermal Brines: In FY 2019, up to $500,000 to fund a gap analysis on critical materials in geothermal brines. This research project is in response to Executive Order 13817 on Critical Materials and follows-on from previous mineral recovery research supported by the Low Temperature and Coproduced Resources subprogram.	• Critical Materials in Geothermal Brines: No funding requested.	• Critical Materials in Geothermal Brines: Decrease of $500,000 reflects effort fully funded in the previous fiscal year. No funding is requested in FY 2020.

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, undertake geothermal resource assessments, 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 Laboratories, Federal agencies, academic institutions, and industry stakeholders to maximize interagency coordination to provide greater impact than that of individual agency activities.

In FY 2019, GTO released the GeoVision Report, Harnessing the Heat Beneath Our Feet. Based on rigorous modeling and simulation, the GeoVision analysis addresses gaps in understanding the potential of geothermal resources and provides a case for geothermal energy to have a sizable role in meeting the nation's 21st-century energy demands. By evaluating various geothermal deployment scenarios, the GeoVision provides a foundation to maintain and advance the Nation as a leader in geothermal energy applications and technology innovation. Leveraging the results from the GeoVision analysis, in FY 2019, GTO initiated development of a Multi-Year Program Plan, slated to be completed in FY 2020. The Multi-Year Program Plan will provide additional baseline metrics and R&D activities for achieving the outcomes identified in the GeoVision analysis.

In FY 2020, the program will continue support for data collection and dissemination across all Geothermal Technologies subprograms. This includes continuing input into the 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 catalog used by industry to leverage existing data to evaluate a geothermal prospect reducing the need to capture duplicate and costly data. A node on the NGDS, the DOE Geothermal Data Repository (GDR) contains more than 1,000 public facing data submissions from GTO funded R&D. The Systems Analysis subprogram will deploy integrated datasets from Hydrothermal efforts into the GDR 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, building from lessons learned from the recent GeoVision analysis and the innovative partnerships awards from the FY 2018 Efficient Drilling in Geothermal Energy (EDGE) funding opportunity announcement, the Systems Analysis subprogram will fund a geothermal non-technical barriers analysis. This scoping study will identify actionable areas where the Geothermal Technologies Program could develop future work to address non-technical barriers in geothermal market penetration across geothermal sector.

Systems Analysis

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Systems Analysis $6,000,000	**$3,250,000**	**-$2,750,000**
• Techno-Economic Analyses, Tools and Data: Up to $2,400,000 in FY 2019 supports continued maintenance of Geothermal Electricity Technology Evaluation Model (GETEM) and assisting the FORGE teams in deploying a node on the National Geothermal Data System (NGDS), as well as the Geothermal Data repository (GDR). In addition, Technical Monitoring Teams will continue to provide independent expert consultation to DOE on major GTO projects.	• Techno-Economic Analyses, Tools and Data: $2,600,000 in FY 2020 supports continued maintenance of GETEM and assisting the FORGE teams in deploying a node on the NGDS, as well as the GDR and development of the GTO Multi-Year Program Plan. In addition, Technical Monitoring Teams will continue to provide independent expert consultation to DOE on major GTO projects.	• Techno-Economic Analyses, Tools and Data: Increase of $200,000 in FY 2020 to support additional GDR data storage needs of GTO funded projects.
• Systems Analysis Early Stage R&D Open Laboratory Call: Up to $3,600,000 of FY 2019 funding supports National Laboratory capabilities in novel and high impact early stage R&D related to Systems Analysis.	• Systems Analysis Early Stage R&D Open Laboratory Call: No funding requested.	• Systems Analysis Early Stage R&D Open Laboratory Call: Decrease of $3,600,000 in FY 2020. No funding is requested in FY 2020.
	• Geothermal Non-Technical Barriers Analysis: This $650,000 National Laboratory scoping study will identify actionable areas where the Geothermal Technologies Program could develop future work to address non-technical barriers in geothermal market penetration across geothermal sectors.	• Geothermal Non-Technical Barriers Analysis: Increase of $650,000 for this scoping study in FY 2020 builds from the results of the GeoVision analysis.

Advanced Manufacturing

Overview

Manufacturing generates 11 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 support manufacturers of all kinds to be more competitive in the global marketplace. The program accomplishes this by focusing on early-stage research and development (R&D) in cross-cutting, platform technologies to both reduce energy intensity by 17.5 percent within existing manufacturing processes by 2022, 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.

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 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.

Unlike other EERE technology programs structured around technical focus areas, AMO subprograms are structured around modes of program implementation: individual R&D projects, collaborative R&D consortia, and technology partnerships. Through each mode, AMO supports research of manufacturing processes, 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.

Within each mode, AMO focuses on technical areas with high potential for impact. The AMO technical focus areas are developed through engagement with stakeholders and targeted toward knowledge gaps that, if addressed through early stage R&D, can be further developed by industry to improve productivity through manufacturing process, information, and materials technologies.

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 (e.g., rare-earth materials) essential to energy for which there is potential for supply chain disruption;
- 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;

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[1] "GDP by Industry / VA, GO, II, EMP," 2017, Bureau of Economic Analysis; available from: https://apps.bea.gov/iTable/iTable.cfm?ReqID=51&step=1

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

- 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;
- Automation, Novel Sensors and Process Controls: Technologies that leverage advanced sensors, controls, platforms, and models to facilitate real-time, cybersecure, 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: Cybersecure 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 2020 Budget Request

FY 2020 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. The focus of this early-stage R&D is the discovery of new technical knowledge and investigation of new technical ideas.
- R&D projects ($45,500,000): 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. The request provides $5,000,000 in support of the Advanced Energy Storage Initiative focused on energy storage to support flexible manufacturing plants with increased electricity dispatchablity for enhanced grid stability and resiliency as well as $10,000,000 for the Harsh Environment Materials initiative to exploit synergies in materials and component manufacturing R&D for advanced thermoelectric modular power plants.
- R&D consortia ($25,000,000): Focus on coordinated early-stage R&D in high-priority areas essential to energy in manufacturing, including foundational knowledge in rare-earth materials, additive processes, power semiconductors, innovative process controls, new materials, and water security. Executed through competitive merit-reviewed consortia led 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 ($10,000,000): Focus on research and validation of early-stage research through partnerships 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 2020, EERE will fund only early-stage R&D projects that utilize the MDF and CFTF facilities.

Advanced Manufacturing
Funding ($K)

	FY 2018 Enacted	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
Advanced Manufacturing				
Advanced Manufacturing R&D Projects	120,800	113,100	45,500	-67,600
Advanced Manufacturing R&D Consortia	153,000	166,900	25,000	-141,900
Advanced Manufacturing Technical Partnerships	31,200	40,000	10,000	-30,000
Total, Advanced Manufacturing	305,000	320,000	80,500	-239,500

SBIR/STTR:
- FY 2018 Transferred: SBIR $8,762,000; STTR $1,232,000
- FY 2019 Projected: SBIR $8,960,000; STTR $1,260,000
- FY 2020 Request: SBIR: $2,256,000; STTR: $317,000

Advanced Manufacturing
Explanation of Major Changes ($K)

	FY 2020 Request vs FY 2019 Enacted
Advanced Manufacturing R&D Projects: In FY 2020, AMO will prioritize early-stage advanced manufacturing technology R&D focused on novel materials and process technologies relevant to manufacturing advanced thermoelectric generation system components capable of withstanding high-temperature, harsh environments and new energy storage technologies capable of improving supply and demand flexibility. Specifically, AMO will issue a funding opportunity focused on manufacturing challenges relevant to the two intradepartmental initiatives: Advanced Energy Storage Initiative (AESI) and Harsh Environment Materials Initiative (HEMI). AMO will fund a new round of high-performance computing for manufacturing (HPC4MFG) projects that align industry proposals with challenges in computer science. Research on roll-to-roll manufacturing processes and efficient drying technologies will be deemphasized until results from project awards made in FY 2019 can be assessed to inform future R&D direction.	-67,600
Advanced Manufacturing R&D Consortia (formerly R&D Facilities): In FY 2020 AMO 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. Emphasis will be placed on developing National Laboratory-based consortia focused on manufacturing challenges including rare-earth materials and water security. In addition, funding will support solicitations for new consortia for power semiconductors, innovative cybersecure process controls and new materials. No funds are requested for the Critical Materials Institute, the Energy-Water Desalination Hub, or the existing Manufacturing USA institutes. Balances from prior year appropriations will be used to conduct an orderly wind-down and termination of these R&D Consortia. Funding for the MDF and CFTF will be focused on the highest priority projects focused on early-stage R&D.	-141,900
Advanced Manufacturing Technical Partnerships (formerly Industrial Technical Assistance): Reflecting the shift in focus to early-stage R&D, no funds are requested for the Industrial Assessment Centers (IACs) or Combined Heat and Power Technical Assistance Partnerships (CHP TAPs), which primarily provided technical assistance support for small and medium manufacturers. Some existing partnership programs are designed to validate research results with the private sector and maintain the bi-directional flow of information between partners with respect to the efficacy of current applied R&D activities.	-30,000
Total, Advanced Manufacturing	**-239,500**

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 support 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 2020, the subprogram will support R&D projects totaling $45,500,000. There will be $6,500,000 dedicated to supporting 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 facilitate research that leverages the unique High-Performance Computing resources of the National Laboratories on manufacturing relevant, first of kind early-stage R&D projects, $5,200,000 will support the High-Performance Computing for Manufacturing (HPC4MFG) program, funding new competitively selected projects to advance new knowledge in research impacting both computer science and manufacturing science.

AMO will provide $10,000,000 for a crosscutting effort coordinated with Fossil Energy and Nuclear Energy, also known as the Harsh Environment Materials (HEM) initiative, to exploit synergies in materials and component manufacturing R&D for advanced thermoelectric power plants with a specific focus on reactor technologies for high efficiency nuclear and fossil-based, modular, power plants. AMO efforts will focus on advanced materials to facilitate innovative configurations not currently possible including novel component geometries, materials that vary in composition and structure gradually over volume, sensing capabilities integrated into materials, and materials for harsh service conditions. In addition, AMO will contribute $5,000,000 to the Advanced Energy Storage Initiative, which coordinates R&D across DOE to advance energy storage and other technologies that create more flexible generation and more flexible load, thereby increasing the reliability and resilience of the U.S. electric grid. Energy storage is a critical component to realizing both a flexible, resilient electrical grid and a modern, affordable transportation system powered by a diverse suite of energy resources. The Advanced Energy Storage Initiative will enhance coordination across EERE and DOE and establish aggressive, achievable, and comparable goals for cost-competitive energy storage services and applications. AMO Advanced Energy Storage Initiative research R&D will specifically focus on the integration of advanced process controls, modular processing, combined heat and power, and chemical and thermal energy storage to support flexible manufacturing plants with increased control of electricity demand for enhanced grid stability and resiliency.

Advanced Manufacturing R&D Projects

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Advanced Manufacturing R&D Projects $113,100,000	**$45,500,000**	**-$67,600,000**
• During FY 2019, 77,900,000 will support new competitively selected, merit-based, early-stage applied R&D projects at National Laboratories, universities, and companies focused on advanced materials and manufacturing topics including $5,500,000 for lab-based activities affecting secure and reliable hybrid power system.	• During FY 2020, $23,800,000 will support new competitively selected, merit-based, early-stage applied R&D projects at National Laboratories, universities, and companies focused on advanced materials and manufacturing topics including $5,000,000 to support the Advanced Energy Storage Initiative through projects focused on flexible combined heat and power systems.	• During FY 2020, a $54,100,000 reduction is due to funding only the highest quality competitively selected, merit-based, at National Laboratories, universities, and companies including a $500,000 reduction in advanced energy storage.
• $20,000,000 will support competitively selected, merit-based, early-stage applied R&D projects at National Laboratories, universities, and companies focused on materials operating in harsh environments.	• $10,000,000 will support the Harsh Environment Materials initiative to exploit synergies in materials and component manufacturing.	• A $10,000,000 reduction in early stage R&D to focus on the most promising materials operating in harsh environments.
• $5,200,000 will support the HPC4MFG program.	• $5,200,000 will support the HPC4MFG program.	• No change.
• $10,000,000 will be dedicated to supporting new projects led by early-career post-doctoral researchers through competitive solicitations.	• $6,500,000 will be dedicated to supporting new projects led by early-career post-doctoral researchers through competitive solicitations.	• A $3,500,000 reduction to fund only the most meritorious new projects led by new early-career post-doctoral researchers through competitive solicitations.

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 support 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 2020 funding of $16,500,000 will support up to four advanced manufacturing consortia in the priority areas listed below:

- Scientific research into the foundational knowledge related to critical and rare-earth materials;
- New approaches to sensors, modeling, communications, cybersecurity and controls in manufacturing;
- Next generation materials, structures and processes; and
- Discovery of new composite materials and structures.

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. No funds are requested for the existing or new 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. No funds are requested for the Critical Materials Institute or the Energy-Water Desalination 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. 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.

Additionally, in FY 2020, $8,500,000 is requested for early-stage R&D activities at the MDF and the 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.

Advanced Manufacturing R&D Consortia

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Advanced Manufacturing R&D Consortia $166,900,000	**$25,000,000**	**-$141,900,000**
• During FY 2019, $25,000,000 to continue MDF/CFTF, including $5,000,000 for systems with potential to deposit multiple materials.	• During FY 2020, $8,500,000 to continue high priority projects at the MDF/CFTF, a model for public-private partnership on early-stage applied R&D related to additive manufacturing and carbon fiber materials research related to energy.	• During FY 2020, the $16,500,000 decrease in funding for the MDF/CFTF reflects an emphasis on early stage R&D activities related to additive manufacturing and carbon fiber materials research related to energy.
• $54,900,000 will support competitively selected, merit-based, early-stage applied R&D consortia to address scientific and technical challenges relevant to U.S. manufacturing including $5,000,000 for wide-bandgap power electronics that incorporate controls to improve storage system reliability and $20,000,000 to develop additive manufacturing of nanocellulosic feedstock materials.	• $16,500,000 will support competitively selected, merit-based, early-stage applied R&D consortia at National Laboratories, universities, and companies with a focus on early stage applied R&D.	• The $38,400,000 decrease is due to the transition from the R&D institute/hub approach to a set of smaller and more directly managed, early-stage, R&D consortia activities at National Laboratories and universities to address important scientific and technical challenges relevant to U.S. manufacturing.
• $42,000,000 to support three CEMI institutes.	• No funding to continue the three CEMI institutes.	• The $42,000,000 decrease is due to no funds requested to continue CEMI institutes. Prior year funds will be used for the orderly closeout activities.
• $45,000,000 to support the Energy-Water Desalination Hub and the Critical Materials Institute.	• No funding to continue the Energy-Water Desalination Hub and the Critical Materials Institute.	• The $45,000,000 decrease is due to no funds requested for the Critical Materials Institute or the Energy-Water Desalination Hub. Prior year funds will be used for the orderly closeout activities.

Advanced Manufacturing
Advanced Manufacturing Technical Partnerships

Description

The advanced manufacturing technical partnerships subprogram provides engagement with the private sector to validate the results from existing and well-established early-stage R&D activities related to advanced manufacturing and energy for further development or commercialization by the private sector. Additionally, technical partnerships will foster feedback from the private sector on the science and technology challenges that might be addressed through follow-on early-stage applied R&D.

In FY 2020, the Advanced Manufacturing technical Partnerships sub-program is requesting $10,000,000. Reflecting the shift in focus to early-stage R&D, no funding is requested for the IACs or CHP TAPs, which primarily supported technical assistance for small and medium manufacturers. Closeout costs for the IAC and CHP TAPs programs will include collection and public dissemination of scientific and technical data from prior IAC and CHP TAP field verification studies to inform new research.

Within the available resources, $2,000,000 will support lab-based analysis and research designed to validate existing combined heat and power, waste heat to power, and district energy R&D and identify emerging technological opportunities. $6,000,000 is requested for partnerships between National Laboratories, universities and the private sector to develop information and energy management tools and technologies intended to validate research results and inform future research direction in energy productivity. The request also includes $2,000,000 for student-led research projects at National Laboratories in areas relevant to energy management for advanced manufacturing technologies.

Advanced Manufacturing Technical Partnerships

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Advanced Manufacturing Technical Partnerships $40,000,000	**$10,000,000**	**-$30,000,000**
• During FY 2019, $24,000,000 will support the CHP TAPS; CHP and district energy research and development; and the IACs including water-related activities.	• During FYY 2020, no funding is requested for CHP TAPs and the IACs.	• During FY 2020, the $24,000,000 decrease is due to elimination of the CHP TAPs and the IACs.
• Funding of $16,000,000 supports partnerships between National Laboratories, universities, and the private sector related to energy management including field validation, tool development and student led research projects.	• Funding of $10,000,000 supports partnerships between National Laboratories, universities, and the private sector related to energy management including field validation, tool development and student led research projects.	• The $6,000,000 decrease is due reduced focus on the partnerships between National Laboratories, universities and the private sector with the greatest potential for impactful field validation, priority tool development and successful student led research projects.

Federal Energy Management Program

Overview

The Federal Government is the single largest U.S. energy consumer with more than 350,000 buildings and 600,000 vehicles. As such, the Federal Government carries significant opportunity and responsibility to take the lead in cutting energy costs and advancing America's progress toward energy independence, resilience, and security. The Federal Energy Management Program (FEMP) supports all Federal agencies to reduce their $15.6 billion annual energy bill, meet energy-related goals, and identify affordable solutions. FEMP achieves its mission by supporting Federal agencies in meeting Executive Order and statutory energy and water management-related goals through identifying government best practices, providing technical assistance, tracking progress, and helping train both the Federal workforce and other stakeholders.

In FY 2020, FEMP will help agencies leverage Federal investment in support of other Federal 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 helps other agencies support the Administration's goal of energy dominance and implement Executive Order (EO) 13834, Efficient Federal Operations, by providing opportunities for more efficient, cost effective and secure energy usage and management in Government facilities. FEMP's efforts 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 2017, the Federal Government used 1.3 quads of primary energy at a cost of $15.6 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] Substantial opportunities exist for further energy cost reduction and conservation. Agencies estimated and report $9 billion[3] of potential cost effective investment for energy savings exist in Federal buildings. In a 2017 study Lawrence Berkley National Laboratory (LBNL) estimates up to $15 billion of potential investment.[4] Approximately $150 billion would be required to bring Government owned property, plant and equipment to an acceptable condition.[5] FEMP works with all Federal agencies to improve the U.S. Federal Government's energy management and energy and water security by sharing resources, training, technical assistance, data coordination, and best practices to improve and monitor overall Federal energy management.

Highlights of the FY 2020 Budget Request

The FEMP FY 2020 Budget Request of $8,400,000 supports Federal agencies efforts to enhance energy and water resilience and meet statutory energy and water management related goals and requirements.[6] With FEMP-provided assistance and initiatives, as of FY2017 the Federal Government has reduced its facility energy intensity by 50.1 percent since 1975 and 26.7 percent since 2003 and a cumulative avoided cost of approximately $50,000,000. By way of comparison with commercial facilities, General Services Administration facilities, which are mainly office buildings, have an energy intensity

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[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] https://www.fiscal.treasury.gov/reports-statements/

[6] 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/.

of 56,328 Btu per gross square foot[1] which is approximately 28 percent lower than the average energy intensity of all U.S. office buildings at 77,800 Btu per gross square foot.[2] Similarly, Veterans Affairs facilities, which are mainly hospitals, have an energy intensity of 132,012 Btu per gross square foot which is approximately 24 percent lower than the average hospital in the U.S. which has an energy intensity of 172,700 Btu per gross square foot.[3] 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; and to improve water management in water use intensive facilities.

FEMP, in conjunction with its partnership with the National Laboratories, is the primary Federal entity that provides energy management technical assistance for agencies. In 2020, FEMP will share existing performance contracting models and business case methodologies that optimize facilities and increase energy efficiency, which leads to enhanced energy and water resilience and security and reduces the operating cost of Federal facilities. FEMP will provide technical project development assistance for energy savings performance contracts (ESPCs), utility energy service contracts (UESCs), and other contract structures in pursuit of energy and water efficiency improvements, distributed energy projects, and demand reduction strategies. 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, the Department of Veterans Affairs, and the General Services Administration to provide a consistent and standardized approach for Federal agencies and to drive contracting costs down.

As part of technical assistance, FEMP will share best practices for portfolio planning and facility optimization resources with Federal agencies that include the strategic integration of advanced technologies into power supply and master facility planning. Additionally, FEMP will share best practices to help DOE as a whole meet its goals to 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 sharing resources focused on improvements for metering, auditing, operations and maintenance, and water use.

To increase the agility and skills of the Federal workforce, FEMP will lead the annual Energy Exchange training workshop and provide other internationally accredited training. Energy Exchange will provide technical training and successful, affordable, replicable models while enhancing opportunities for veterans, collaboration among agencies, and sharing of best practices.

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

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[1] FY 2016 Energy Intensity of GSA goal subject buildings adjusted for source savings http://ctsedwweb.ee.doe.gov/Annual/Report/GoalSubjectBuildingSiteDeliveredEnergyUseperGrossSquareFoot.aspx.

[2] 2012 Energy Intensity of all U.S. office buildings https://www.eia.gov/consumption/commercial/data/2012/.

[3] 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 2018 Enacted	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
Federal Energy Management Program				
Federal Energy Management Program	27,000	27,000	8,400	-18,600
Federal Energy Efficiency Fund	0	3,000	0	-3,000
Total, Federal Energy Management Program	**27,000**	**30,000**	**8,400**	**-21,600**

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

	FY 2020 Request vs FY 2019 Enacted
Federal Energy Management Program: In FY 2020, FEMP will monitor and track agencies' energy management performance and identification, design, and completion of energy and water efficient projects through ESPCs, utility energy service contracts (UESCs), and other contract structures. At the FY 2020 Request level, FEMP will concentrate its activities to focus on a limited number of agencies whose scorecards reflect challenges meeting goals and assisting one agency with energy and water resilience and security to produce replicable solutions for agencies at large. As part of the technical assistance available to agencies, FEMP will share resources for facility optimization, resilient portfolio planning and security, and consistent best practices to assure energy management process quality. FEMP will focus on sustaining existing tools for evaluation, optimization and strategic management of energy resources rather than developing new tools. FEMP programming will also focus specifically on disseminating existing training resources that enhance the skills and agility of the existing Federal workforce rather than developing new on demand courses.	**-18,600**
Federal Energy Efficiency Fun: FEMP will not fund the Federal Energy Efficiency Fund Program in FY 2020 but will continue to manage prior year awards.	**-3,000**
Total, Federal Energy Management Program	**-21,600**

Federal Energy Management Program

Description

The Federal Energy Management Program (FEMP) assists all Federal agencies by providing technical resources and best practices to support agencies' compliance with applicable statutory and executive order goals and the objectives of Executive Order 13834, Efficient Federal Operations.

The Federal Government is the largest U.S. energy consumer. As such, the Federal Government carries significant responsibility to improve energy efficiency and reducing energy costs. The authority provided by National Energy Conservation Policy Act, as amended,[1] mandates that DOE, through FEMP, promotes 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 manage 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.

FEMP 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 best practices that leverage performance contracting and power purchase agreements to ensure 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 efforts 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 2020, FEMP will work with agencies to provide resources and best practice guidance to overcome barriers and design affordable, replicable energy and water savings projects that optimize facilities and enhance energy and water resilience. Technical assistance will share best practices to assist agencies' targeted facility, site, mission, and agency needs and use all obtainable technologies to identify barriers and capture lessons learned with a focus on continuous improvement. FEMP will provide documented resources for agencies as they apply business case methodology for affordable, reliable facility energy that provides edge of grid benefits behind the meter at the installation-grid interface and leverages performance contracting. FEMP will evaluate focused performance contracting solutions that include specific cybersecurity and resilience portfolio components such as 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 2020, FEMP will share existing best practices for implementing energy management projects and documenting results. FEMP, working directly through experts at the DOE National Laboratories, will implement its designated responsibilities as outlined in E.O. 13834 to:

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[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.

- Continue Federal Agency Data Collection, analysis and reporting and identify mechanisms to further streamline data collection;
- Maintain current tools and methodologies to assist agencies in developing internal milestones and projections;
- Share replicable case studies for distributed energy resources, water management, metering, ESPCs, e-Project Builder, and facility evaluations;
- Establish energy efficiency and sustainable design criteria for new Federal buildings;
- Promote agency's effective utilization of performance contracting to achieve energy, water, building; modernization, and infrastructure goals; and
- Maintain FleetDASH reporting for the Section 701 waiver process.

In 2020, FEMP will continue support of performance contracting which facilitated agencies' record investment of $809,000,000 in FY 2018 through the DOE ESPC indefinite delivery, indefinite quantity (IDIQ) contract. This one year investment alone will result in a guaranteed energy reduction of 2.3 million BTU annually which is equivalent to the energy used in 25,000 average US households annually. FEMP will cultivate its publicly accessible training and educational resources to develop a resilient Federal workforce and leverage lessons learned. FEMP will leverage use cases for performance contracting energy and water savings while strengthening resilience and security.

Since 1992, Congress has authorized Federal agency use of performance contracts to help 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 or serving utility to invest in needed energy projects and pay for the investment through the energy, water, and operations and maintenance savings achieved over the life of the contract. Aging Federal buildings can be improved and updated and obsolete equipment still in operation from the 1940s, 50s, or 60s, can be replaced. Approximately $150 billion would be 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 estimates that Government-wide, since the programs began in the 1990s, over 600 ESPC projects and over 2,000 UESC projects have been implemented with energy infrastructure improvements of $12.5[2] billion and with expected value of cumulative energy savings over the life of these projects of $27.5[3] billion.

Over the life of the contract, the 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 and UESC database system – a secure, online tool developed and managed on behalf of FEMP by the University of California/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 and aggregated project data across Government and the private sector to improve analysis of performance contracting. The DOE ESPC IDIQ contract awarded in April 2017 requires the use of ePB. The continued maintenance of the

[1] https://www.fiscal.treasury.gov/reports-statements/

[2] Investment represents dollars at the time of award and is cumulative from the 1990's until FY 2018. The total represents performance contracts for DOE IDIQ, Army MATOC, ENABLE, ESPC site specific, and UESC.

[3] Savings are based on the DOE ESPC IDIQ and ENABLE contractual guarantees and estimates for UESC, the Army ESPC MATOC, and site specific contracts. These are the savings expected over the life of the contract. Measurement and verification is performed for ESPCs to verify if the contractually defined saving guarantee was achieved. Performance assurance is performed for UESC projects.

ePB system and Federal access to the data will provide valuable benchmarking information to improve the performance and cost of all Federal contracts.

FEMP also tracks energy management performance, provides engagement and collaboration with stakeholders, and enhances 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, 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 2020, 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)).

FEMP will continue to enhance Federal workforce competencies and strengthen performance through internationally accredited training programs and by leveraging public-private partnerships, such as the Energy Exchange event. In FY 2018, FEMP offered a total of 315 training sessions including courses, workshops, webinars, and Energy Exchange sessions. Through these venues, FEMP provided over 30,693 training hours, including awarding 5,339 International Association of Continuing Education and Training Continuing Education Units. 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.

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

- Develop analytical reports to Office of Management and Budget 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;
- Track each Executive agency requirement to establish and maintain a program to ensure that facility energy managers are trained energy managers. Every agency is to report to DOE on their progress in meeting this requirement. DOE 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));
- Develop, in consultation with the Secretary of Defense and the Administrator of General Services, 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));
- Establish the technical performance requirements for applicable technologies (42 U.S.C. § 8259b(b)). 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. DOE's requirement is to establish the technical performance requirements for the applicable technologies; and promote procurement practices which facilitate the purchase of energy efficient products (42 U.S.C. § 8259b(b)).
- 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.).

Federal Energy Management Program

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Federal Energy Management Program $27,000,000	**$8,400,000**	**-$18,600,000**
• Engage in no less than 3 strategic partnerships with agencies to develop resilience and security solution sets that will yield application benefits across the country. • Provide training content through the Energy Exchange. Develop 3-5 on-demand training courses. • Update eProject builder to include additional high-priority features required by federal agencies, including tracking UESC projects and actual savings. • Provide focused support and technical assistance for development of UESC acquisition strategy. • Share best practices and validate actionable resources, in collaboration with agency partners, for a systems approach to facilitate prioritized mission driven energy management at the agency and installation level utilizing best practices and available optimization technologies. • Validate 50001 Ready, in collaboration with agency partners, as a standardized energy management system for federal facilities to further reduce energy intensity and to streamline energy savings reporting • Provide statutorily-required reporting and technical guidance.	• Maintain resources to help agencies leverage performance contracting to meet mission and energy management mandates and goals. • Continue to track the Government's progress in energy goal achievement. • Continue to provide technical assistance, training and accountability. • Host/Facilitate the Energy Exchange training workshop.	• Concentrate activities to focus on technical assistance leveraging performance contracting and power purchase agreements for limited agencies, assisting 1 selected agency with energy and water resilience and security. • Focus on maintaining and updating current sources of workforce development rather than creating new on demand courses. • Evaluate implementation of ESPC models in order to better concentrate ESPC support. Limited enhancements to tools and resources such as eProject builder. • Sustain existing tools for evaluation, optimization and strategic management of energy resources.

Federal Energy Management Program
Federal Energy Efficiency Fund
AFFECT

Description

In 2019, the FEEF or AFFECT Program provided direct funding to Federal agencies for the development of energy, water and resiliency projects and processes to initiate, supplement, improve or otherwise increase the viability and adoption of energy efficiency at U.S. Federal government-owned facilities through use of a privately financed performance contract such as an Energy Savings Performance Contract (ESPC) or Utility Energy Service Contract (UESC), etc., or an enterprise-wide approach. AFFECT provided greater opportunities for agencies to develop and implement projects that may not otherwise get off the ground. AFFECT supported the best available agency projects, enabled implementation of projects, and leveraged cost sharing at other Federal agencies for capital improvement projects and other initiatives to increase energy efficiency, conserve water, advance resiliency and increase renewable energy investments at Federal facilities. In FY 2020, FEMP will not fund the FEEF program.

Federal Energy Management Program

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Federal Energy Efficiency Fund $3,000,000	**$0**	**-$3,000,000**
• Using the Federal Energy Efficiency Fund (FEEF) authority, competitively select agency programs that establish a process to systematically prioritize mission-critical sites and implement projects that leverage performance contracting at least 15:1 to enhance efficiency, resiliency, safety and security, as well as address the issue of aging infrastructure and deferred maintenance and repairs.	No funding requested.	• FEMP will not fund the FEEF Program in FY 2020 but will continue to manage prior year awards.

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, 80 percent or more of peak power demand 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 relative to a 2010 baseline through the application of cost-effective efficiency technologies. To help meet the long term goal, BTO has established a goal of reducing building energy use intensity (EUI) 30 percent by 2030. In 2017, the EUI was 9 percent lower than the EUI of the building sector in 2010.[3]

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 funding of early-stage research and development (R&D) supports the efforts of the building sector to develop and deploy technologies that can improve energy efficiency and affordability without sacrificing the comfort of people inside buildings and the performance of labor-saving devices, appliances, and equipment.

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.

Through pre-competitive, early-stage R&D supported by EERE's BTO, a fundamental understanding of physical properties and phenomena relevant to buildings, building materials, and building equipment support 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 support industry to develop and deploy grid-interactive buildings capable of connecting with the power grid in new and increasingly adaptive manners to

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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] Using micro datasets from AEO, BTO was able to calculate that the EUI was 9% lower than the EUI of the building sector in 2010. Data accessed from EIA.

[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://www.energy.gov/sites/prod/files/2017/01/f34/Appliance%20and%20Equipment%20Standards%20Fact%20Sheet-011917_0.pdf.

help with overall energy system efficiency, resiliency, and energy affordability. As a result, BTO not only acts as a catalyst for innovation, but spurs U.S. economic competiveness through scientific and engineering leadership.

BTO will contribute to the Advanced Energy Storage Initiative ($13,000,000), which coordinates R&D across DOE to advance energy storage and other technologies that create more flexible generation and more flexible load, thereby increasing the reliability and resilience of the U.S. electric grid. Energy storage supports a more flexible, resilient electrical grid and expands affordable mobility options from a diverse suite of energy resources – and energy storage for the grid is complemented by a portfolio of generation and load technologies that provide flexibility, essential reliability services, and system resilience. The Advanced Energy Storage Initiative will enhance coordination across EERE and DOE and establish aggressive, achievable, and comparable goals for cost-competitive energy storage services and applications.

BTO's contribution to the Advanced Energy Storage Initiative is closely related to BTO's grid-interactive buildings activities and 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 sides 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. Too often, however, the view of energy storage is limited to electrochemical batteries, when the same capabilities can be achieved in other ways, and with additional benefits. For example, in the case of buildings, there is a unique and very large opportunity in thermal storage that is often overlooked. Importantly, it is possible to store cold and/or heat through the existing capacity of building equipment (e.g. water heaters and heating, ventilation & air conditioning [HVAC]) and/or the thermal mass of building envelope in combination with advanced controls. BTO's Advanced Energy Storage Initiative efforts will focus on a range of early stage R&D into innovative, non-traditional energy storage approaches in two key areas: controllable building loads ($8,000,000); and, thermal energy storage technologies ($5,000,000) for resilience, efficiency, and energy affordability needs at the building and campus/district scales.

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 a wide range of 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, affordable, 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. 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 2020 Budget Request

FY 2020 activities support Administration, departmental, and programmatic goals. Highlights include:

- Buildings-to-Grid R&D ($11,000,000): Focus early-stage R&D on cyberphysical 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 more sophisticated control of building energy loads 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 and helping develop buildings which are more interactive with the electric grid.
- Advanced Energy Storage Initiative ($13,000,000): Early-stage R&D on advancing opportunities to use thermal energy storage and controllable building loads to enhance grid reliability by making building loads more flexible while meeting the needs of building occupants and maintaining the performance of labor-saving devices, appliances, and equipment.

- Building Equipment and Envelope R&D ($5,000,000): Early-stage research on 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 ($4,000,000): 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 crosscutting scientific investigations into fundamental research into lighting utilization, such as application specific lighting efficiency and glare metrics.
- Buildings Integration Challenge ($4,000,000): Launch a new challenge designed to seed industry investment in energy efficient, flexible, and interoperable envelope products and HVAC sensors and controls for both commercial and residential buildings integration to meet cost, energy, and technical performance targets laid out through engagement with technical subject-matter experts, purchasing entities and manufacturers.
- Equipment and Building Standards ($19,000,000): Meet statutory obligations for test procedures, energy and water conservation standards, and building codes.

BTO activities are implemented through partnerships with National Laboratories and competitively-selected, cost-shared projects. Equipment and Building Standards activities will be carried out with technical assistance from established contracts and National Laboratories.

In addition, FY 2020 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.

Building Technologies
Funding ($K)

	FY 2018 Enacted	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
Building Technologies				
Building Energy Research & Development				
Lighting R&D	30,000	25,000	3,510	-21,490
HVAC and Refrigeration R&D	21,623	24,000	3,940	-20,060
Buildings-to-Grid R&D[1]	49,140	36,000	10,920	-25,080
Building Envelope R&D	6,228	16,800	880	-15,920
Building Energy Modeling R&D	8,736	7,200	1,750	-5,450
Advanced Energy Storage Initiative	0	0	7,000	+7,000
Total, Building Energy Research & Development	**115,727**	**109,000**	**28,000**	**-81,000**
Commercial Buildings Integration				
Advanced Energy Storage Initiative	0	0	3,000	3,000
Buildings Integration Challenge	0	0	2,000	2,000
Total, Commercial Buildings Integration	**32,000**	**39,000**	**5,000**	**-34,000**
Residential Buildings Integration				
Advanced Energy Storage Initiative	0	0	3,000	3,000
Buildings Integration Challenge	0	0	2,000	2,000
Total, Residential Buildings Integration	**23,000**	**28,000**	**5,000**	**-23,000**
Equipment and Buildings Standards	**50,000**	**50,000**	**19,000**	**-31,000**
Total, Building Technologies	**220,727**	**226,000**	**57,000**	**-169,000**

SBIR/STTR:

- FY 2018 Transferred: SBIR $5,198,000; STTR $731,000
- FY 2019 Projected: SBIR $5,309,000; STTR $747,000
- FY 2020 Request: SBIR $1,216,000; STTR $171,000

[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 2020 Request vs FY 2019 Enacted
Building Energy Research and Development: The FY 2020 Budget Request supports early stage R&D in solid-state lighting, heating, ventilation, air conditioning, and refrigeration equipment (HVAC&R), building envelope, and buildings-to-grid. This includes the Department of Energy's Advanced Energy Storage Initiative to enhance grid resiliency and reliability. No further funding is being requested for technology application R&D for solid-state lighting, CRADAs with industry for HVAC&R, demonstration and deployment of transactive controls at the campus- and neighborhood-level, as well as significant reduction in the annual Buildings Energy Efficiency Frontiers & Innovation Technologies (BENEFIT) FOA. Previously competitively-selected work will continue to outlay prior year obligations carried forward to conduct close-out activities.	**-81,000**
Commercial Buildings Integration: The FY 2020 Budget Request supports the Department of Energy's Advanced Energy Storage Initiative providing $3,000,000 for applied research into integrated storage solutions and their interaction with, and impact on, existing dynamic building systems. In addition, CBI will contribute $2,000,000 to the Buildings Integration Challenge to drive industry development of affordable energy management and information systems that can produce 20-40 percent energy savings in homes and commercial building. No funding requested for later-stage development and commercialization activities, such as the High Impact Technology early adoption efforts. Previously competitively-selected work will continue to outlay prior year obligations carried forward to conduct close-out activities.	**-34,000**
Residential Buildings Integration: The FY 2020 Budget Request supports the Department of Energy's Advanced Energy Storage Initiative providing $3,000,000 to support early-stage R&D advancing opportunities to use thermal energy storage and controllable building loads to enhance grid reliability. In addition, RBI will contribute $2,000,000 to the Buildings Integration Challenge to drive industry development of affordable energy management and information systems that can produce 20-40 percent energy savings in homes and commercial buildings. No funding is requested for later-stage development and commercialization activities such as Home Performance with ENERGY STAR, Better Buildings Residential, and demonstration efforts with industry partners. Previously competitively-selected work will continue to outlay prior year obligations carried forward to conduct close-out activities.	**-23,000**
Equipment and Buildings Standards: 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.	**-31,000**
Total, Building Technologies	**-169,000**

Building Technologies
Building Energy Research and Development

Description

The Building Energy Research and Development (BERD) subprogram 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 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 technologies that help building owners and homeowners reduce energy intensity. This early-stage research portfolio leverages the National Laboratories' researchers, computing capabilities, and other unique facilities that are critical for BTO to support industry efforts 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).

The innovations supported through BTO's early-stage R&D portfolio define new research opportunities in the private and public sectors. 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. 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 complexities. For a building to operate efficiently and securely while still meeting the needs of the occupants, all of the technologies must be integrated into a full building system. 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 supports industries' ability 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 also generates knowledge spillover benefits for other industries, such as defense, computing and manufacturing.

Two annual funding opportunity announcements (FOA) are envisioned in FY 2020 that includes one for solid-state lighting and the one for other building energy R&D topics (as part of the BENEFIT FOA).

The FY 2020 SSL FOA topics ($3,000,000) 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 and OLEDs. This research will support BTO's goal to increase power conversion efficiency of amber light to 30 percent by 2025 compared to the baseline of 10 percent and will assist industry on the path to a 2030 LED package efficacy goal of 255 lumens/Watt (lm/W) and a 2030 OLED panel efficacy goal of 190 lm/W. The priority research areas for the FY 2020 SSL FOA include:
- LEDs: Emitter materials to address green gap and improve the efficiency of green and amber emitters, down-conversion materials, and application level efficiency; and
- OLEDs: Novel materials for stable, efficient white devices and designs for efficient light extraction and utilization.

Other BENEFIT FOA topics ($5,000,000) 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 previous FOAs and builds upon buildings-to-grid R&D.

Research areas of interest for the FY 2020 BENEFIT FOA include:
- Thermal storage integration and controls with building equipment; and
- Research to incorporate time-of-use energy consumption into core building energy modeling tools.

In addition to the annual BENEFIT and SSL 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 mechanisms such as Cooperative Research and Development Agreements (CRADAs) for early-stage R&D efforts.

The direct laboratory funding is divided into the four following technology categories. R&D will focus on basic principles, communications and physical phenomena for next-generation technologies to facilitate secure, energy efficient, grid-interactive buildings.

Buildings-to-Grid (B2G)
BTO's early-stage B2G R&D will help strengthen the body of knowledge to support industry efforts to develop and deploy grid-interactive buildings capable of connecting with the power grid in new and increasingly adaptive manners to help with overall energy system efficiency, resiliency, and energy affordability. The R&D will focus on cyberphysical 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 more sophisticated control of building energy loads as well as improvements in building operation and maintenance, which are key strategies to meeting BTO's overall goals for reducing the energy intensity of buildings and helping develop grid-interactive buildings.

R&D will also focus on foundational cyberphysical 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 typically 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 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 supports 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 intensity in buildings. 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 2020 activities will be a continuation of the B2G R&D supported in FY 2019:

- Multi-functional wireless sensor networks that are automated, plug-and-play, and capable of monitoring multiple parameters through effective power management. This will support a low-cost approach to accurately detect and diagnose failures and resulting inefficiencies in building equipment as well as increased, effective building-to-grid integration;
- Integrated building control schemes at the whole-building level with multi-variate optimization across consuming and generating devices using predictive analytics to respond to external and building conditions to reduce energy intensity and support secure building-to-grid integration over longer-temporal periods;
- Integration of detection and diagnostics for whole-building level faults (both software and hardware) with analytics for other complementary distributed energy resources at the grid edge; this will improve building performance for energy efficiency and grid integration;
- 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; and

- Data models and analytics to intelligently shut down devices or place devices in sleep mode to improve efficiency and provide demand response services.

BTO's B2G strategy has been developed in coordination with partners like the National Institute of Science and Technology and DOE's offices through the Grid Modernization Initiative (GMI) to fully address cyberphysical security and resilience and to avoid duplication. 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. 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. 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.

Advanced Energy Storage Initiative
BTO's Advanced Energy Storage Initiative effort will focus on a range of early stage R&D into innovative, non-traditional energy storage approaches in two key areas: controllable building loads ($2,000,000); and, thermal energy storage technologies such as building energy storage ($5,000,000) for resilience, efficiency, and affordability needs at the building and campus/district scales.

Controllable Building Loads
As new energy technologies are installed, energy systems consist of an increasingly diverse mix of loads, generation sources, and storage, installed at all scales (individual homes, commercial buildings, and utility installations) across the country. These component technologies must be controlled to provide needed energy resources and maintain a reliable and resilient electricity grid. These activities include R&D for advanced controls technologies that are need for the optimization and integration of these building loads with electric vehicles, on-site photovoltaics and energy storage, both electricity and thermal. This work will be coordinated with the Advanced Energy Storage Initiative activities in the Commercial and Residential Buildings Integration subprograms as well as related activities in DOE's Grid Modernization Initiative. Research areas of interest include:
- Research into predictive analytics and autonomous controls at the building level to enhance the coordination of building loads with the grid, energy storage on on-site generation; and
- Control of generation and storage with thermal loads (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.

Thermal Energy Storage
Building thermal energy storage, either dedicated or inherent to the building equipment or envelope, is often overlooked in favor of electrochemical storage technologies at the grid or transportation scale. However, nearly 40 percent of electricity is used for thermal demands (space conditioning and water heating) of residential and commercial buildings and there is an increasing penetration of non-dispatchable electricity generation. As a result, thermal energy storage at the building and/or district scale becomes a compelling solution to manage variable resources and improve the reliability of energy systems. These activities will focus on developing advanced materials and systems needed to store thermal energy from building technologies. Research areas of interest include:
- R&D into materials capable of storing, directing, and controlling thermal energy (both heat and cold) for buildings applications; and
- R&D to enhance the thermal storage capabilities of existing building components – water heaters, HVAC, building envelope.

Solid State Lighting
Direct National Laboratory funding supports crosscutting 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:
- The energy reporting accuracy, system-level energy performance, interoperability and system integration, cybersecurity vulnerability, and grid integration of connected lighting systems;
- Quantitative analysis of the potential for lighting to provide grid services; and
- The development of non-visual and system level metrics for emerging lighting applications.

Building Equipment (HVAC&R) & Envelope
R&D targets fundamental research that supports performance advances and cost reductions in HVAC&R and envelope technologies. This research will contribute to BTO's goal to support 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. FY 2020 R&D activities 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 diodes). This work will support thermal storage, variable speed drives, and more sophisticated interactions between building equipment, such as water heaters, HVAC and appliances, with the electricity grid.

The following FY 2020 activities will be a continuation of the R&D supported in FY 2019:
- 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;
- Transformational heat pumping and non-vapor compression technologies for water heating and space conditioning applications;
- Self-healing and multi-property materials for non-linear thermal transport in order to reclaim and dissipate heat;
- Materials that can independently modulate near infrared and visible light;
- High part-load efficiency building equipment needed to facilitate building-to-grid integration; 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 support 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 and symbolic algebra.

BTO's BEM research portfolio has been developed to 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. 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. 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. This includes the transition of the static energy modeling capabilities, primarily used for building design, into a transformational building energy modeling platform, based on the equation-based modeling language, Modelica. This next-generation tool will support building energy modeling to be utilized for building and community operation, as well as design. The following FY 2020 activities will be a continuation of the R&D supported in FY 2019:
- 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.

Building Energy Research and Development

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Building Energy Research and Development $109,000,000	**$28,000,000**	**-$81,000,000**
Lighting R&D $25,000,000	$3,510,000	-$21,490,000
• $15,000,000 for competitively-selected projects in which success will be measured based on progress in achieving an LED phosphor-converted package efficacy goal of 255 lumens/watt (lm/W), an LED color-mixed package efficacy of 330 lm/W, and organic LED (OLED) panel efficacy of 190 lm/W beyond 2030.	• $3,000,000 for competitively-selected projects focused on emitter materials, down-conversion materials, and encapsulation. Award one OLED project focused on novel materials for stable, efficient white devices and designs for efficient light extraction and utilization.	Work will continue to support BTO's goal to increase power conversion efficiency of amber light to 30 percent by 2025 compared to the baseline of 10 percent and will assist industry on the path to a 2030 LED package efficacy goal of 255 lumens/Watt (lm/W) and a 2030 OLED panel efficacy goal of 190 lm/W.
• Direct funded laboratory AOP projects that focus on connected lighting systems, lighting technology systems, and emerging lighting science.	• Direct funded lab AOP projects that focuses on crosscutting early-stage research topics.	• Focus the scope of AOP projects on connected lighting systems.
HVAC & Refrigeration R&D $24,000,000	$3,940,000	-$20,060,000
• Support direct laboratory funding for research in HVAC, water heating, and appliances with an increased emphasis on heat transfer and materials science. This included scoping studies to inform future research directions.	Support direct laboratory funding for research in HVAC with an increased emphasis on heat transfer and materials science. This includes a scoping study to inform future research directions.	• Maintain core laboratory capability in HVAC R&D. Projects funded with prior year appropriations will continue until funding has been fully costed.
• Award competitively-selected projects on HVAC and natural gas technologies.	• No funding requested for new competitively-selected projects.	• No funding requested. Projects previously funded will continue to outlay prior year obligations carried forward to conduct close-out activities.
Buildings-to-Grid (B2G) R&D $36,000,000	$10,920,000	-$25,080,000
• Support laboratory projects in solid-state physics research for advanced sensor development as well as three to five projects focused on autonomous control and pattern matching and integrated multi-scale data analytics. • Conduct =laboratory scoping studies of the building envelope contribution to a building's virtual storage capacity, transactive & smart transformers R&D and	• Support laboratory projects in solid-state physics research for advanced sensor development as well as three to five projects focused on advanced control and data analytics. • Support competitively-selected projects building on FY 2019 scoping studies of the building envelope contribution to a building's virtual storage capacity, transactive & smart transformers R&D and	• No change. • Initiate new competitively-selected projects that support BTO in goal of reducing the energy intensity of buildings and helping develop grid-interactive buildings.

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
analytics needed to intelligently shut down devices or place devices in sleep mode. • Support flexible building technologies, including adaptive building controls for cybersecurity, advanced actuators, and Beyond Batteries, including thermal storage materials.	analytics needed to intelligently shut down devices or place devices in sleep mode. • Support 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.	• Beyond Batteries work moved to separate activity, Advanced Energy Storage Initiative.
Building Envelope R&D $16,800,000	$880,000	-$15,920,000
• Focus on advanced envelope retrofit technologies, particularly those that can be mass produced and applied to existing facades and robotics. • Direct funded lab AOP projects that focus on thermal and optical characterization of materials for advanced envelope technologies, including windows, and thermal measurement science for building envelope materials.	• No funding requested for a new competitively-selected awards. • Direct funded lab AOP projects that focus on thermal and optical characterization of materials for advanced envelope technologies, including windows, and thermal measurement science for building envelope materials.	• No funding requested. Projects previously funded will continue to outlay prior year obligations carried forward to conduct close-out activities. • Reduction in the number of lab funded projects. Projects that are funded with prior year appropriations will continue until funding has been fully costed.
Building Energy Modeling Research $7,200,000	$1,750,000	-$5,450,000
• Support laboratory projects focused on treatment of uncertain and stochastic inputs, such as occupancy and infiltration, activities to incorporate building controls and grid-integration.	• Support laboratory projects focused on treatment of uncertain and stochastic inputs, such as occupancy and infiltration, activities to incorporate building controls and grid-integration.	• No change to the number of projects, but elimination of focus on the evolution of the EnergyPlus package towards a modular framework and descoping of OpenStudio expansion efforts.
Advanced Energy Storage Initiative $0	$7,000,000	+$7,000,000
	• Support development of materials and systems for controllable, thermal storage technologies for use in building equipment or building envelope. • Support early-stage R&D to develop controls for building loads that can provide flexibility needed to incorporate energy storage and PV behind-the-meter and improve grid reliability.	• Rebranding of Beyond Batteries work. Beyond Batteries was formerly conducted under Buildings-to-Grid activity. Effort now referred to as Advanced Energy Storage Initiative and is its own distinct activity. Efforts will be done in close coordination with DOE's Grid Modernization Initiative and with Advanced Energy Storage Initiative activities in CBI and RBI subprograms.

Building Technologies
Commercial Buildings Integration

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 and accounts for 36 percent of all U.S. electricity consumption.[1] This costs consumers nearly $175 billion 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 support 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. BTO's Commercial Buildings Integration (CBI) 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 cost-effectively use 50-70 percent less energy than typical buildings, with an emphasis on solutions that do not sacrifice the comfort of building occupants or the performance of labor-saving devices, appliances, and equipment.

Buildings Integration Challenge

BTO's Commercial and Residential Buildings Integration subprograms will launch a new challenge designed to drive industry development of affordable, plug-and-play energy management and information systems, which can produce 20-40 percent energy savings in homes and commercial buildings. These energy management and information systems provide simplified user interfaces that prioritize energy and cost savings opportunities without sacrificing the comfort of building occupants or the performance of labor-saving devices, appliances, and equipment. Solutions will also support automated commissioning and control of homes and buildings to produce and maintain energy savings, and access time-of-use and load management strategies at the whole building system and equipment level.[5]

CBI's component of the Buildings Integration Challenge will leverage private sector investment in R&D by identifying and sharing with manufacturers the significant technical requirements that allow building owners and operators to access more than 2 quads of achievable energy savings in commercial buildings.[6] These technical requirements facilitate focused investment by private-sector manufacturers capable of developing the products that meet those needs, with an emphasis on solutions that do not sacrifice comfort and performance. CBI will support objective verification that products meet

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[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.

[5] In *Sensitivity Analysis of Installation Faults on Heat Pump Performance,* NIST concluded that 30% of the energy wasted in homes is largely attributed to problems that can be remedied through better energy management and control. In *Impacts of Commercial Building Controls on Energy Savings and Peak Load Reduction*, PNNL concluded that 23-40% of energy wasted in the commercial stock is primarily attributed to control-based measures that can be identified, and often fixed, through better energy management and control. Additionally BTO recently published technical reviews documenting savings opportunities available through the use energy management and controls-based measures and tools that identify design, installation, operations and maintenance faults. *Residential*: https://www.energy.gov/sites/prod/files/2018/06/f53/bto-ResidentialHVACLitReview-06-2018.pdf, Commercial: https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/EMIS_Top_Opportunities-May_2017.pdf.

[6] *Energy Information Systems: Technology Costs, Benefits, and Best Practice Uses*, Jessica Granderson et al., Lawrence Berkeley National Laboratory, 2013. Available at: http://eis.lbl.gov/pubs/lbnl-6476e.pdf.

challenge criteria and recognize winning products through existing networks of potential purchasers such as the Better Buildings Initiative.

BTO will streamline voluntary engagement with industry through cross-program collaboration. The Integration subprograms will work with builders, building owners/operators, consumers, electric and natural gas utilities, states, local governments, and other building sector stakeholders to document key technology gaps standing in the way of significant energy efficiency savings for each subprogram component. Based on technical requirements and identified interest for specific efficiency technologies among building owners, the Integration subprograms will develop product performance and cost criteria to support development of and/or validation of targeted technologies. RBI and CBI will facilitate technical evaluation of product submissions through phased reviews by the DOE National Laboratories. Products that are compliant will be included in third-party laboratory and field testing activities to verify that compliance and to validate that the products deliver anticipated energy-saving performance.

Advanced Energy Storage Initiative

This effort will focus on controllable building loads ($3,000,000). Specifically, CBI will conduct applied research into integrated storage solutions and their interaction with, and impact on, existing dynamic building systems. Demand response and related programs enable commercial utility customers to access utility cost reductions leveraging flexible load controls and other storage solutions that can cut whole building peak electric consumption by 30 percent.[1] However, of more than 5 million U.S. commercial utility customers, only 1 million subscribe to these programs. CBI will work with industry and National Laboratories to study and validate the costs, energy savings, impact on occupants and operators, and infrastructure dependencies associated with integrated storage solutions as they are applied in existing commercial buildings. This work will be coordinated with the Advanced Energy Storage Initiative activities in the BERD and Residential Buildings Integration subprograms as well as related DOE Advanced Energy Storage Initiative and Grid Modernization Initiative activities. Research areas of interest include:

- Testing of integrated thermal and electric storage solutions when integrated with connected, flexible building technologies in existing commercial buildings; and
- Control and optimization of behind-the-meter energy storage, DC-powered building loads, and on-site photovoltaics.

[1] https://www.mge.com/saving-energy/business/bea/article_detail.htm (30% whole building). Also, http://lightingcontrolsassociation.org/2014/05/20/lighting-control-and-demand-response (lighting controls reduce peak by 14-23% without impacting occupants), and https://www.nrc.gov/docs/ML1123/ML11231A756.pdf (HVAC control in small buildings in Texas can enable 30% peak reduction).

Commercial Buildings Integration

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Commercial Buildings Integration $39,000,000	**$5,000,000**	**-$34,000,000**
• Contribute $14,000,000 towards projects that will focus on air conditioning and ventilation, natural gas, next generation retrofits and workforce development.	• No funding requested for new competitively-selected projects.	• No funding requested. Projects previously funded will continue to outlay prior year obligations carried forward to conduct close-out activities.
• Focus direct funded lab AOP projects on field validation and verification and data and modeling.	• No funding requested for direct funded lab AOP projects on field validation and verification and data and modeling. • Implement the Buildings Integration Challenge. With support from the National Laboratories, the Commercial Buildings Integration subprogram will convene stakeholders, including potential purchasers/end-users and researchers/developers/ manufacturers to document and share technical requirements; accept participants; review and verify that products meet technical criteria and then recognize successful products. • One to two National Laboratory led projects focusing on the integration of high potential system-level solutions that produce energy optimization across building systems, and for whole buildings and multi-building cohorts.	• Laboratory projects previously funded will continue to outlay prior year obligations carried forward to conduct close-out activities. • Efforts will focus on the Buildings Integration Challenge.
Advanced Energy Storage Initiative $0	$3,000,000	+$3,000,000
	• Fund projects for technical analysis to set thresholds and metrics and focus on integrated solutions that will conduct applied research into integrated storage solutions and their interaction with, and impact on, existing dynamic building systems.	• Rebranding of Beyond Batteries work. Beyond Batteries was formerly conducted under Buildings-to-Grid activity. Effort now referred to as Advanced Energy Storage Initiative and is its own distinct activity. Efforts will be coordinated with DOE's Grid Modernization Initiative and with AESI activities in BERD and RBI subprograms.

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 to add more than 4 million new housing units over the next four years.[5]

BTO's Residential Buildings Integration (RBI) activities have a goal of supporting industry efforts 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).

Buildings Integration Challenge
BTO's Commercial and Residential Buildings Integration subprograms will launch a new challenge designed to drive industry development of affordable energy management and information systems that can produce 20-40 percent energy savings in homes and commercial buildings. These energy management and information systems provide simplified user interfaces that prioritize energy and cost-saving opportunities. This will enable automated commissioning and control of homes and buildings to produce and maintain energy savings, and be able to use time-of-use and/or load management strategies.

The Residential component of the Buildings Integration Challenge will focus on spurring development of technologies that dramatically improve the efficiency and the long term performance of home energy systems through integration of automated fault detection or other quality assurance features such as simplified installation requirements. RBI will work with builders, building owners/operators, consumers, electric and natural gas utilities, states, local governments, and other building sector stakeholders to document key technology gaps standing in the way of significant energy efficiency savings for each subprogram component. Based on technical requirements and identified interest for specific efficiency technologies among building owners, RBI, in coordination with CBI, will develop product performance and cost criteria to support development and validation of these targeted technologies. RBI and CBI will facilitate technical evaluation of product submissions through phased reviews by the DOE National Laboratories. Submitted technologies that meet the established criteria will undergo third-party laboratory and field testing to validate that the products deliver anticipated energy savings and performance objectives. DOE will widely recognize qualifying products and link manufacturers to potential high volume purchasers (e.g., housing developments).

Advanced Energy Storage Initiative
This effort will focus on controllable building loads ($3,000,000). Residential air conditioning is estimated to be at least 17 percent of peak demand nationwide, but is significantly more than that in some areas of the country. For example, according to the Electric Reliability Council of Texas' analysis, in 2017 the residential sector in Texas accounted for approximately 50 percent of both summer and winter peak demand electricity consumption. The Advanced Energy Storage

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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/.

Initiative activities in RBI will focus on research and testing to help meet residential air conditioning needs of a building through integrated management of HVAC systems, thermal and other energy storage, and onsite distributed energy resources. This work will build upon BTO's FY 2017-2019 utility-led residential Connected Communities R&D to advance smart grid systems and will include National Laboratories, equipment manufacturers and builders. This work will be coordinated with the Advanced Energy Storage Initiative activities in the Building Energy Research and Development and Commercial Buildings Integration subprograms as well as related activities in DOE's Grid Modernization Initiative.

Research areas of interest include:

- Field validation of connected, controllable air conditioning with energy storage to provide grid services and improve reliability during peak demand times;
- Integration of storage systems as a part of common retrofit and renovation practices and within advanced manufacturing of efficient and modular construction; and
- Field validation and modeled analysis of heat pump water heaters' storage capabilities and ability to respond to grid, envelope capabilities for thermal coasting, among other promising technologies.

Residential Buildings Integration

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Residential Buildings Integration $28,000,000	**$5,000,000**	**-$23,000,000**
• Contribute $14,000,000 to projects that will focus on next generation retrofits that can be delivered quickly and with little disruption to existing occupants, advanced building construction and automation, natural gas technologies, next generation high efficiency air conditioning and ventilation, and workforce development.	• No funding requested for new competitively-selected projects.	• No funding requested, projects previously funded will continue to outlay prior year obligations carried forward to conduct close-out activities.
• Ongoing National Laboratory led work on field validation and verification, data and modeling, Home Energy Score, among other technical priorities.	• No funding requested for direct funded lab AOP projects on field validation and verification and data and modeling and Home Energy Score.	• Lab projects previously funded will continue to outlay prior year obligations carried forward to conduct close-out activities.
• Solar Decathlon spans 2019 and 2020 and focuses on two challenges: the Design Challenge and the Build Challenge.	• No funding requested for Solar Decathlon.	• No funding requested for Solar Decathlon, previously funded activities will continue to outlay prior year obligations carried forward to conduct close-out activities.
	• Issue the Buildings Integration Challenge for a specific, identified new technology. One or more National Laboratories will run the challenge.	• Focus on Buildings Integration Challenge.
Advanced Energy Storage Initiative $0	$3,000,000	+$3,000,000
• This activity did not exist in FY 2019 under RBI.	• Projects that will focus on meeting residential air conditioning needs of a building through integrated management of HVAC systems, thermal and other energy storage, and onsite distributed energy resources.	• Rebranding of Beyond Batteries work. Beyond Batteries was formerly conducted under Buildings-to-Grid activity. Effort now referred to as Advanced Energy Storage Initiative and is its own distinct activity. Efforts will be done in close coordination with DOE's Grid Modernization Initiative and with Advanced Energy Storage Initiative activities in BERD and CBI subprograms

Buildings Technologies
Equipment and Buildings Standards

Description

The Equipment and Buildings Standards subprogram develops national appliance and equipment standards and test procedures, as required by statute. The subprogram 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 technologically feasible and economically justified.

The Appliance and Equipment Standards subprogram regulates the energy or water use (or efficiency) of labor-saving 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 subprogram's test procedure and standards rulemaking activities. The rulemaking schedule, and thus the level of subprogram activity, is determined by existing statute.

In FY 2020, funds made available to the Appliance and Equipment Standards subprogram will be used 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 2020, Appliance and Equipment Standards activities plan to:

- Issue 2 energy conservation standards final rules or determinations;
- Issue 4 test procedure final rules or determinations; and
- Enforce standards violations to the extent possible.

This subprogram includes Building Energy Codes activities which fulfill the 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 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Equipment and Buildings Standards $50,000,000	**$19,000,000**	**-$31,000,000**
• The subprogram 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.	• The subprogram plans to 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: Four test procedure final rules or determinations and two energy conservation standards final rules or determinations.	• Funds made available to the Appliance and Equipment Standards subprogram will be used 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.
• 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.	• 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 2020 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. Additionally, supporting promising early-stage, innovative technologies will expand American energy resources safely and efficiently. WIP's mission is to facilitate strategic investments in the deployment of energy efficiency and renewable energy technologies and innovative practices across the U.S. by a wide range of government, community and business stakeholders, in partnership with state and local organizations.

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 2020 Budget Request

WIP's FY 2020 Budget Request includes no funding for WAP and SEP. These programs are not aligned with EERE's focus on early-stage applied research and development for sustainable transportation, renewable energy, and energy efficiency technologies. WIP activities 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 2018 Enacted	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
Weatherization and Intergovernmental Programs				
Weatherization				
Weatherization Assistance Grants	248,000	254,000	0	-254,000
Training and Technical Assistance	3,000	3,000	0	-3,000
Total, Weatherization	**251,000**	**257,000**	**0**	**-257,000**
State Energy Program	55,000	55,000	0	-55,000
Total, Weatherization and Intergovernmental Programs	**306,000**	**312,000**	**0**	**-312,000**

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

	FY 2020 Request vs FY 2019 Enacted
Weatherization Assistance Program: The FY 2020 Budget Request does not include funding for weatherization technical assistance and formula grants. This will allow DOE to focus limited resources on early-stage applied energy research and development activities.	**-257,000**
State Energy Program: The FY 2020 Budget Request does not include funding for State Energy Program formula grants, technical and policy assistance, and competitive awards. This will allow DOE to focus limited resources on early-stage applied energy research and development activities.	**-55,000**
Total, Weatherization and Intergovernmental Programs	**-312,000**

Weatherization and Intergovernmental Programs
Weatherization Assistance Program

Description

The Weatherization Assistance Program (WAP) allocates funds on a statutory formula basis and makes 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, have 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.

In FY 2020, 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 2019 and prior year funding.

In FY 2020, Weatherization's Training and Technical Assistance (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.

Weatherization

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Weatherization $257,000,000	$0	**-$257,000,000**
Weatherization Assistance Grants $254,000,000	$0	-$254,000,000
• Award and actively manage 57 weatherization formula grantees, which will support over 38,000 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	$0	-$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. 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.	• No funding is requested.	• Existing balances will be used to conduct close-out activities.

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
• 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.		

Weatherization and Intergovernmental Programs
State Energy Program

Description
State Energy Program (SEP) assisted states in establishing and implementing energy plans, policies, and programs. SEP provided states with financial assistance, technical assistance, and best practice sharing networks to facilitate the adoption of plans, policies, and programs. 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.

In FY 2020, 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 $60,000,000 to $80,000,000 in combined formula funds from prior years and continue to manage competitive awards made in previous years.

State Energy Program

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
State Energy Program $55,000,000	**$0**	**-$55,000,000**
• Award and actively manage 56 formula grants supporting $49,000,000 in state energy projects. • 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. • 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, providing technical resources developed by DOE labs and other experts, and delivering replicable models and solutions through the State and Local Solution Center. SEP's activities and strategic partnerships with state energy offices include the public sector Better Buildings Challenge and technical assistance projects with national state associations.	• No funding is requested.	• Existing balances will be used to conduct close-out activities.

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 transportation, renewable power, and energy efficiency to address our Nation's energy and environmental challenges. The FY 2020 Program Direction Budget Request provides essential resources for program and project management, oversight activities, contract administration, workforce management, IT support, and Headquarters (HQ) and field site non-laboratory facilities and infrastructure.

EERE will reduce Full-Time Equivalents (FTEs) by approximately 26 percent from its FY 2019 planned level of 625 FTEs 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 2020. 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.

Highlights of the FY 2020 Budget Request

The FY 2020 EERE Program Direction Budget Request will:

- Support 461 FTEs at HQ and the GFO;
- Fund the last year of funding for 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;
- 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 2018 Enacted	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
Program Direction				
Washington Headquarters				
Salaries and Benefits	78,006	77,500	58,000	-19,500
Travel	3,693	3,695	2,150	-1,545
Support Services	7,278	8,206	7,400	-806
Other Related Expenses	40,181	39,268	33,680	-5,588
Total, Washington Headquarters	**129,158**	**128,669**	**101,230**	**-27,439**
Golden Field Office				
Salaries and Benefits	19,262	20,299	18,600	-1,699
Travel	188	236	150	-86
Support Services	867	1,138	700	-438
Other Related Expenses	1,575	1,456	1,320	-136
Total, Golden Field Office	**21,892**	**23,129**	**20,770**	**-2,359**
National Energy Technology Laboratory				
Salaries and Benefits	6,470	5,882	0	-5,882
Travel	210	220	0	-220
Support Services	300	300	0	-300
Other Related Expenses	4,470	4,300	0	-4,300
Total, National Energy Technology Laboratory	**11,450**	**10,702**	**0**	**-10,702**
Total Program Direction				
Salaries and Benefits	103,738	103,681	76,600	-27,081
Travel	4,091	4,151	2,300	-1,851
Support Services	8,445	9,644	8,100	-1,544
Other Related Expenses	46,226	45,024	35,000	-10,024
Total, Program Direction	**162,500**	**162,500**	**122,000**	**-40,500**

	FY 2018 Enacted	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
Federal FTEs	566	585	461	-124
Additional Office of Fossil Energy's (FE) FTEs at NETL [1]	40	40	0	-40
Total EERE-funded FTEs	**605**	**625**	**461**	**-164**

	FY 2018 Enacted	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
Support Services				
Technical Support	6,248	7,808	6,364	-1,444
Management Support	2,197	1,836	1,736	-100
Total, Support Services	**8,445**	**9,644**	**8,100**	**-1,544**
Other Related Expenses				
Other Services	21,026	19,824	9,800	-10,024
Working Capital Fund (WCF)	25,200	25,200	25,200	0
Total, Other Related Expenses	**46,226**	**45,024**	**35,000**	**-10,024**

[1] EERE funded 40 FTEs at NETL through a reimbursable agreement who supported EERE activities. These 40 FTEs were not included in the EERE FTE totals shown in the table.

Program Direction

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Program Direction $162,500,000	**$122,000,000**	**-$40,0,000**
Salaries and Benefits $103,681,000	**$76,600,000**	**-$27,081,000**
• Funding levels provide resources for program and project management, administrative support, contract administration, and human capital management.	• Funding levels provide resources for program and project management, administrative support, contract administration, and human capital management.	• Funding will support a Federal workforce of 461 FTEs, a decrease of 164 Federal FTEs (26 percent) from the planned FTE level for FY 2019.
Travel $4,151,000	**$2,300,000**	**-$1,851,000**
• EERE's FY 2019 travel budget supports management of projects and close-outs, providing essential oversight of EERE-funded projects.	• EERE's FY 2020 travel budget supports management of projects and close-outs, providing essential oversight of EERE-funded projects.	• The 45 percent reduction reflects the decrease in anticipated site-visits and other travel related to managing a lower number of projects and supporting a smaller workforce.
Support Services $9,644,000	**$8,100,000**	**-$1,544,000**
• 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 16 percent reduction is a reduction of non-IT support contractors in HQ and Golden.
Other Related Expenses $45,024,000	**$35,000,000**	**-$10,024,000**
• Other Related Expenses provides funds for overhead at DOE Headquarters, the National Energy Technology Laboratory and the Golden Field Office through EERE's contribution to the WCF and through direct payments in the field. Expenses covered include building operations, telecommunications, network connectivity, supplies/equipment, printing/graphics, mail, contract closeout, purchase card surveillance, computer equipment, utilities, postage, administrative expenses, security, and publications. Also includes funding for EERE's IT modernization project (i.e., EPIC).	• Other Related Expenses provides funds for overhead at DOE Headquarters and the Golden Field Office through EERE's contribution to the WCF and through direct payments in the field. Expenses covered include building operations, telecommunications, network connectivity, supplies/equipment, printing/graphics, mail, contract closeout, purchase card surveillance, computer equipment, utilities, postage, administrative expenses, security, and publications. Also includes funding for EERE's IT modernization project (i.e., EPIC).	• The decrease is due to a reduced investment in EERE's IT modernization project (i.e., EPIC) to support the last year of funding for the multi-year development effort and reduced requirements in support of a smaller workforce.

Strategic Programs

Overview

Strategic Programs funds high-impact, crosscutting, integrative activities most efficiently executed by a single cross-cutting organization in coordination with EERE technology programs and other DOE offices.

Strategic Programs consists of three principal subprograms:

- **Technology-to-Market (T2M)** – supports efforts under the Energy Transitions Initiative (ETI) to address high energy costs, reliability, and inadequate infrastructure challenges faced by islands and remote communities. Further, ETI engages a cross-sector set of organizations pursuing similar efforts to address energy challenges, build capacity, and accelerate the sharing of best practices and innovations to leverage specialized expertise into commercial opportunity and support long-term recovery efforts.
- **Strategic Priorities and Impact Analysis (SPIA)** – provides a portfolio-based analytical foundation to perform impact assessments of EERE's portfolio. Informs R&D strategic planning and decision-making, enabling continuous improvement of EERE's approach. Analyzes crosscutting issues that affect EERE technologies, such as integration of EERE technologies into the energy system, changing demand for energy, competitiveness implications of clean energy technologies, and potential energy system transformations.
- **Communications and Outreach** – provides key stakeholders and the public with the latest and most accurate information regarding advances, impacts, and issues on clean energy technology development and deployment, in addition to resources available through EERE, communicated objectively and transparently across a range of traditional and online media.

Highlights of the FY 2020 Budget Request

To eliminate redundancies and increase efficiencies across the department, staff and functions will be centralized within corporate offices, including DOE's Office of Public Affairs (PA). Therefore, no funds are requested for Strategic Programs within the EERE program in FY 2020.

In FY 2020, Strategic Programs will transition the following activities as indicated:

- Strategic Priorities and Impact Analysis (SPIA) subprogram activities will be funded, as appropriate, by relevant EERE programs.
- Internal communications activities, such as EERE-specific graphics and informational materials, will be funded, as appropriate, by relevant EERE programs.
- Technology-to-Market (T2M) activities would be discontinued. Some management activities related to the execution of prior year appropriations will continue until completion.

Strategic Programs
Funding ($K)

	FY 2018 Enacted	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
Strategic Programs				
Technology-to-Market	2,475	2,500	0	-2,500
Strategic Priorities and Impact Analysis	6,800	7,000	0	-7,000
International	225	0	0	0
Communications and Outreach	5,500	4,500	0	-4,500
Total, Strategic Programs	**15,000**	**14,000**	**0**	**-14,000**

Strategic Programs
Explanation of Major Changes ($K)

	FY 2020 Request vs FY 2019 Enacted
Strategic Programs	
Technology-to-Market: No funds are requested for the T2M subprogram in FY 2020.	**-2,500**
Strategic Priorities and Impact Analysis: No funds are requested for the SPIA subprogram in FY 2020. Analysis activities will be funded, as appropriate, by relevant EERE technology programs.	**-7,000**
International: No change. Internation activities were transferred to the Office of International Affairs in FY 2018.	**0**
Communications and Outreach: No funds are requested for the Communications and Outreach subprogram in FY 2020. Communication activities associated with external outreach were transferred to the Office of Public Affairs in FY 2019. Internal communications activities will be funded, as appropriate, by relevant EERE technology programs.	**-4,500**
Total, Strategic Programs	**-14,000**

Strategic Programs
Technology-to-Market

Description

The T2M subprogram supported efforts under the Energy Transitions Initiative (ETI) to address high energy costs, reliability, and inadequate infrastructure challenges faced by islands and remote communities. Further, ETI engages a cross-sector set of organizations pursuing similar efforts to address energy challenges, build capacity, and accelerate the sharing of best practices and innovations to leverage specialized expertise into commercial opportunity and support long-term recovery efforts in jurisdictions impacted by natural disasters.

No funds are requested for the T2M subprogram in FY 2020. Some management activities related to the execution of prior year appropriations will continue until completion.

Technology-to-Market

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Technology-to-Market $2,500,000	**Technology-to-Market $0**	**-$2,500,000**
• Activities focused on the ongoing work of the Energy Transition Initiative (ETI). • Non-ETI activities were transferred to the Office of Technology Transitions in FY 2018	• No funding is requested.	• Some management activities related to the execution of prior year appropriations will continue until completion.

Strategic Programs
Strategic Priorities and Impact Analysis

Description

The Strategic Priorities and Impact Analysis (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 crosscutting, 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 2020. Analysis activities will be funded, as appropriate, by relevant EERE technology programs.

Strategic Priorities and Impact Analysis

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Strategic Priorities and Impact Analysis $7,000,000	**$0**	**-$7,000,000**
• Complete retrospective evaluation studies that quantify the impact of EERE investments and guide future EERE program implementation. • Continue the Electrification Futures Study exploring the impacts of widespread electrification across the economy. Publish reports focusing on the potential evolution and operation of U.S. electricity supply, as well as the implications for distribution systems and utility business models. • Continue project examining the economic; operational; grid stability; and land, water and materials use challenges of achieving 100 percent renewable energy electric grids. • Support the Beyond LCOE and Beyond Batteries initiatives. • Analyze competitiveness opportunities for clean energy technologies, including an examination of international trade flows, and opportunities for EERE technologies in new industries and sectors. • Provide consistent and transparent cost and performance assumptions for renewable energy and sustainable transportation technologies.	• 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
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 2020. Communication activities associated with external outreach were transferred to DOE's Office of Public Affairs in FY 2019. 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 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Communications and Outreach $4,500,000	**$0**	**-$4,500,000**
• Maintains content for EERE web and social media presence. • Provides modest support for analysis of communications data. • Continues support to EERE senior leaders in developing presentation materials and messages for frequent speaking engagements. • Majority of external communications activities will be transferred to DOE's Office of Public Affairs.	• 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 2020 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 2020 Budget Request

To posture NREL's capabilities to support emerging technologies and future requirements, the FY 2020 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 third 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 transforming energy technologies. However, demand for computing from R&D efforts has saturated the current HPC capabilities. In FY 2018, HPC cycle demand was double current capacity resulting in rationing. The improved capacity provided by the refresh/upgrade enables the HPC to continue to provide enhanced computational capability for increasingly complex, specific energy technology issues across the portfolio of research topics that EERE programs address.

EERE's budget request also includes an expansion of the diverse capabilities of the National Wind Technology Center (NWTC) campus at the National Renewable Energy Laboratory. The mission of the NWTC will expand to support a fully integrated, large-scale experimental research platform, which includes building an Enhanced Grid/Energy Systems Control Center and a High-Speed Data Link that connects the NWTC campus to the Energy Systems Integration Facility (ESIF) at NREL's main campus and to other National Laboratories. Funding also supports a Beyond Megawatt Scale Extreme Fast Charging Station to research, integrate, and evaluate fast charging station impacts on the grid. These investments support research for DOE's Grid Modernization Initiative, which includes reliably integrating an increasing amount of variable generation into the electric grid. These expanded capabilities will allow DOE to test a suite of technologies supported under the Advanced Energy Storage Initiative and leverage the NWTC's future power capacity of 19.9MW with the capabilities of the ESIF.

This request realigns NREL Site-Wide Facility Support within the Operations and Maintenance (O&M) subprogram. This consolidates all O&M activities at NREL into one F&I subprogram, mirroring other DOE laboratory budgets.

Facilities and Infrastructure (NREL)
Funding ($K)

	FY 2018 Enacted	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
Facilities and Infrastructure (NREL)				
Operations and Maintenance	26,000	31,500	69,500	+38,000
Facility Management	36,000	37,500	37,500	0
NREL Site-Wide Facility Support	30,000	28,000	0	-28,000
Total, Facilities and Infrastructure (NREL)	**92,000**	**97,000**	**107,000**	**+10,000**

Energy Efficiency and Renewable Energy
Proposed Budget Structure Change
Budget Structure Crosswalk ($K)

FY 2019 Budget Structure	**Proposed FY 2020 Budget Structure**		
Facilities and Infrastructure	**Operations and Maintenance**	**Facility Management**	**Total**
Operations and Maintenance	41,500	0	**41,500**
Facility Management	0	37,500	**37,500**
NREL Site-Wide Facility Support	28,000	0	**28,000**
Total, Program Name	**69,500**	**37,500**	**107,000**

This request realigns NREL Site-Wide Facility Support within Operations and Maintenance.

Explanation of Major Changes ($K)

	FY 2020 Request vs FY 2019 Enacted
Facilities and Infrastructure (NREL)	
Operations and Maintenance: Investments at the NWTC, prioritizes Maintenance and Repair, Cyber Security, and realigns NREL Site-Wide Facility Support within Operations and Maintenance.	**+38,000**
Facility Management: Continuation of resources to address HPC upgrade and operations of the ESIF facility.	**0**
NREL Site-Wide Facility Support: Realigns NREL Site-Wide Facility Support within Operations and Maintenance.	**-28,000**
Total, Facilities and Infrastructure (NREL)	**+10,000**

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), Safeguards and Security (S&S) and Site-Wide (SW).

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:

- An Enhanced Grid/Energy Systems Control Center at the NWTC site, with computing and data visualization capabilities, for gathering, analyzing, and visualizing remote field research data during integrated, real-time experiments across multiple sites while conducting grid integration research.
- A High-Speed Data Link that connects the NWTC with the ESIF and other National Laboratories. Network upgrades will improve data transfer from field-based research projects and provide deterministic data communication and dynamic, closed-loop experimentation between NWTC, ESIF, and other National Laboratories to enable advanced micro-grid and grid integration research.

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

Major GPE activities:

- A Beyond Megawatt Scale Extreme Fast Charging Station at the NWTC campus for researching fast charging station design that accommodates multiple vehicles simultaneously. Research includes integration and evaluation with the power grid using NWTC's multi-megawatt systems, large-scale energy storage, and thermal management systems research environment.

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. The FY 2020 request aligns additional resources to M&R funding for the NWTC campus. NREL will continue to remain 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 2020 funding aligns additional resources to cyber needs due to the increasing and evolving cybersecurity risk environment.

SW funding provides for site management of both campuses which includes fire and emergency services, environment, safety and health compliance, hazardous waste management, health programs, medical services, safety programs including electrical safety, energy intelligent campus, utilities (electricity, natural gas, water & sewer, desk phones, internet, cable, PV power purchase agreements, Renewable Fuels Heating Plant), shipping/receiving, facility and space planning, facility condition assessment inspections, and database management of DOE's Facilities Information Management System.

Operations and Maintenance

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Operations and Maintenance $31,500,000	**$69,500,000**	**+$38,000,000**
• Increases GPP level of investments from FY 2018. • Maintains operational readiness for M&R activities and keeps funding within the DOE control standard of two to four percent of RPV. • Increases operational readiness for S&S activities, above FY 2018 levels, with an increased focus on cybersecurity.	• GPP and GPE Investments in an expanded NWTC Campus. • Increases operational readiness for M&R activities including the NWTC campus, and keeps funding within the DOE control standard of two to four percent of RPV. • Maintains operational readiness for S&S activities, with increased focus on cybersecurity. • Realigns NREL Site-Wide Facility Support within Operations and Maintenance.	• Emphasizes NWTC Campus GPP and GPE investments. • Increases M&R to ensure suitable condition, as facilities and equipment age, for research activities at NREL. Consolidates M&R funding for the NWTC previously funded through the Wind Energy budget. • Realigns NREL Site-Wide Facility Support and Operations and Maintenance.

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 2020 request provides funding for the third year of the four-year refresh/upgrade.

Requirements for advanced modeling and simulation capabilities continue to trend upward as the variety of energy sources grows and integrated energy systems become more complex.

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

Major ESIF Costs
ESIF Administration, Facility Management & Research Operations ($13,300K): 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). ESIF-dedicated technical staff supports users in designing, setting up and conducting experiments in the 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 ($19,200K): 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 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Facility Management $37,500,000	**$37,500,000**	**$0**
• 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.	• Provides for the third year of a four-year refresh/upgrade of the HPC. • 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 2019.

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

Description

The NREL Site-Wide Facility Support subprogram funding provides for site management for both campuses which includes fire and emergency services, environment, safety and health compliance, hazardous waste management, health programs, medical services, safety programs including electrical safety, energy intelligent campus, utilities (electricity, natural gas, water & sewer, desk phones, internet, cable, PV power purchase agreements, Renewable Fuels Heating Plant), shipping/receiving, facility and space planning, facility condition assessment inspections, and database management of DOE's Facilities Information Management System.

This request realigns NREL Site-Wide Facility Support within Operations and Maintenance.

NREL Site-Wide Facility Support

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
NREL Site-Wide Facility Support $28,000,000	**$0**	**-$28,000,000**
• Provides funding for building maintenance, facility operations, project management and engineering, utilities, intelligent campus, facility managers, and site services.	• No funding requested.	• This request realigns NREL Site-Wide Facility Support within Operations and Maintenance.

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

	Total	Prior Years	FY 2018 Enacted	FY 2018 Actuals	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
Capital Operating Expenses Summary (including Major Items of Equipment (MIE))							
Capital Equipment > $500K (including MIE)	n/a	n/a	5,100	5,100	7,468	7,700	+232
Accelerator Improvement Projects (AIP) (<$5M)	n/a	n/a	0,000	0,000	0,000	0,000	+0,000
Minor Construction	0,000	0,000	7,800	7,800	9,300	14,300	+5,000
Total, Capital Operating Expenses	**n/a**	**n/a**	**12,900**	**12,900**	**16,768**	**22,000**	**+5,232**
Capital Equipment > $500K (including MIE)							
Total Non-MIE Capital Equipment	n/a	n/a	5,100	5,100	2,468	0,000	-2,468
HPC Eagle E-Cell	n/a	n/a	0,000	0,000	5,000	0,000	-5,000
Beyond Megawatt-Scale Fast Charging Station	0,000	0,000	0,000	0,000	0,000	7,700	+7,700
Total, Capital Equipment (including MIE)	**n/a**	**n/a**	**5,100**	**5,100**	**7,468**	**7,700**	**+232**
Minor Construction Projects							
Total Direct Funded Minor Construction Projects (TEC <$5M)	n/a	n/a	7,300	7,300	9,300	3,900	-5,400
Total Indirect Funded Minor Construction Projects (TEC <$5M)	n/a	n/a	0,000	0,000	0,000	0,000	+0,000
NWTC Electrical Upgrade Project	11,800	11,300	500	500	0,000	0,000	+0,000
Enhanced Grid/Energy Systems Control Center	10,400	0,000	0,000	0,000	0,000	10,400	+10,400
Total, Minor Construction Projects	**n/a**	**n/a**	**7,800**	**7,800**	**9,300**	**14,300**	**+5,000**
Total, Capital Summary	**n/a**	**n/a**	**12,900**	**12,900**	**16,768**	**22,000**	**+5,232**

Minor Construction Projects

Facilities & Infrastructure Operations & Maintenance	
Enhanced Grid/Energy Systems Control Center NREL National Wind Technology Center Campus:	
Type: Total Estimated Cost: Construction Design: Project Start: Design Complete: Construction Complete:	Minor Construction (Direct-funded) $10,400 $800 FY 2020 FY 2020 FY 2022
Project Description:	A central control center at the NWTC campus serves a dual function for enabling remote data collection and analysis involving diverse research portfolios while also conducting grid integration research. The center would accommodate space to allow for multiple parallel project field campaigns; a visualization room capable of providing state of the art, high-resolution visual imagery that will illustrate research findings to stakeholders; a conference room and offices. This Control Center will serve as the hub for all grid/energy research at the site and coordinate multiple level energy integration and cybersecurity experiments with both local and remote facilities. The visualization room will be connected to the Energy Systems Integration facility and other National Laboratories through a high-speed data connection.
Prior Year Accomplishments:	N/A
Planned Activities:	• Design (Preparing and finalizing drawings, specifications, and other documents describing the work to allow construction of the project) • Construction (Construction of the project up to final payment as defined in the construction subcontract; construction administration by the design team) • Project Management, Laboratory Services, and Government Furnished Equipment (Project management; independent testing/inspection, commissioning, and other third-party services; technical oversight during design and construction; IT and other laboratory provided services; procurement and installation of Government Furnished Equipment
Significant Changes from original plan:	N/A.

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. This excludes maintenance of excess facilities (including high-risk excess facilities) necessary to minimize the risk posed by those facilities prior to disposition.

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

	FY 2018 Actual Cost	FY 2018 Planned Cost	FY 2019 Planned Cost	FY 2020 Planned Cost
National Renewable Energy Laboratory	14,907	12,462	11,272	11,283
Total, Direct-Funded Maintenance and Repair	**14,907**	**12,462**	**11,272**	**11,283**

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

	FY 2018 Actual Cost	FY 2018 Planned Cost	FY 2019 Planned Cost	FY 2020 Planned Cost
National Renewable Energy Laboratory	0	0	0	0
Total, Indirect-Funded Maintenance and Repair	**0**	0	**0**	**0**

Report on FY 2018 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 2018 to the amount planned for FY 2018, including Congressionally-directed changes.

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

	FY 2018 Actual Cost	FY 2018 Planned Cost
National Renewable Energy Laboratory	14,907	12,462
Total, Maintenance and Repair	**14,907**	**12,462**

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

	FY 2018 Enacted	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
Protective Forces	3,100	3,100	2,080	-1,020
Physical Security Systems	750	750	750	0
Information Security	500	500	500	0
Cybersecurity	3,680	4,180	5,200	1,020
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**	**9,700**	**9,700**	**0**

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

	FY 2018 Enacted	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
Basic	0	0	0	0
Applied	1,317,000	1,407,000	472,000	-935,000
Development	440,000	435,000	164,000	-271,000
Subtotal, R&D	1,757,000	1,842,000	636,000	-1,206,000
Equipment[2]	0	0	0	0
Construction[3]	0	0	0	0
Total, R&D	**1,757,000**	**1,842,000**	**636,000**	**-1,206,000**

[1] The data in this column is based on the programmatic funding level of $696 million as opposed to the net appropriation of $343 million.
[2] Funding for major R&D equipment was inadvertently prorated to conduct of R&D. Amounts that should have been reported separately are: FY 2018 $5.1 million; FY 2019 $7.5 million, and FY 2020 $7.7 million. Future updates of Schedule C will be reported on line 1312.
[3] Funding for construction of R&D facilities was inadvertently prorated to conduct of R&D. Amounts that should have been reported separately are: FY 2018 $7.8 million; FY 2019 $9.3 million, and FY 2020 $14.3 million. Future updates of Schedule C will be reported on line 1322.

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

	FY 2018 Enacted	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
Vehicles Technologies				
SBIR	10,102	9,990	2,285	-7,705
STTR	1,421	1,405	321	-1,084
Bioenergy Technologies				
SBIR	7,089	7,232	1,280	-5,952
STTR	997	1,017	180	-837
Hydrogen and Fuel Cell Technologies				
SBIR	3,680	3,840	1,408	-2,432
STTR	518	540	198	-342
Solar Energy				
SBIR	7,667	7,554	2,144	-5,410
STTR	1,078	1,062	302	-760
Wind Energy				
SBIR	2,811	2,624	726	-1,898
STTR	395	369	102	-267
Water Power				
SBIR	3,093	3,134	1,431	-1,703
STTR	435	441	201	-240
Geothermal Technologies				
SBIR	2,589	2,688	896	-1,792
STTR	364	378	126	-252
Advanced Manufacturing				
SBIR	8,762	8,960	2,256	-6,704
STTR	1,232	1,260	317	-943
Building Technologies				
SBIR	5,198	5,309	1,216	-4,093
STTR	731	747	171	-576
Total, SBIR	50,991	51,331	13,642	-37,689
Total, STTR	7,171	7,219	1,918	-5,301

Department Of Energy

FY 2020 Congressional Budget

Funding by Appropriation by Site

($K)

Energy Efficiency and Renewable Energy	**FY 2018 Total Enacted**	**FY 2019 Enacted**	**FY 2020 Request**
Ames Laboratory			
Energy Efficiency and Renewable Energy			
Hydrogen & Fuel Cell Technologies	263	686	0
Vehicle Technologies	800	650	0
Advanced Manufacturing	33,160	25,000	0
Total, Energy Efficiency and Renewable Energy	**34,223**	**26,336**	**0**
Total, Ames Laboratory	**34,223**	**26,336**	**0**
Argonne National Laboratory			
Energy Efficiency and Renewable Energy			
Wind Energy	1,198	1,052	703
Hydrogen & Fuel Cell Technologies	7,169	5,399	2,000
Water Power	1,398	153	583
Solar Energy	1,641	2,637	1,469
Vehicle Technologies	62,026	58,000	15,500
Building Technologies	1,320	1,320	245
Advanced Manufacturing	12,840	3,120	2,000
Bioenergy Technologies	8,435	5,457	2,650
Total, Energy Efficiency and Renewable Energy	**96,027**	**77,138**	**25,150**
Total, Argonne National Laboratory	**96,027**	**77,138**	**25,150**
Brookhaven National Laboratory			
Energy Efficiency and Renewable Energy			
Geothermal Technologies	425	0	0
Hydrogen & Fuel Cell Technologies	500	996	0
Solar Energy	20	0	0
Vehicle Technologies	3,085	2,500	2,000
Total, Energy Efficiency and Renewable Energy	**4,030**	**3,496**	**2,000**
Total, Brookhaven National Laboratory	**4,030**	**3,496**	**2,000**

Department Of Energy

FY 2020 Congressional Budget

Funding by Appropriation by Site

($K)

Energy Efficiency and Renewable Energy	**FY 2018 Total Enacted**	**FY 2019 Enacted**	**FY 2020 Request**
Golden Field Office			
Energy Efficiency and Renewable Energy			
Wind Energy	6,432	20,845	225
Program Direction	21,091	23,129	20,770
Geothermal Technologies	23,224	6,986	15,000
Hydrogen & Fuel Cell Technologies	37,743	53,007	25,000
Water Power	52,338	49,965	18,720
Solar Energy	120,662	139,759	11,000
Vehicle Technologies	3,440	2,800	1,000
Building Technologies	18,276	54,885	19,440
Federal Energy Management Program	1,721	650	600
Weatherization	470	811	0
State Energy Program Grants	1,485	1,495	0
Advanced Manufacturing	130,362	77,000	0
Bioenergy Technologies	68,919	88,578	0
Total, Energy Efficiency and Renewable Energy	**486,163**	**519,910**	**111,755**
Total, Golden Field Office	**486,163**	**519,910**	**111,755**
Idaho National Laboratory			
Energy Efficiency and Renewable Energy			
Wind Energy	869	159	524
Geothermal Technologies	556	744	25
Hydrogen & Fuel Cell Technologies	3,575	5,442	1,200
Water Power	2,640	877	583
Solar Energy	185	0	0
Vehicle Technologies	12,932	10,500	4,900
Federal Energy Management Program	400	135	200
Advanced Manufacturing	5,000	0	0
Bioenergy Technologies	14,806	11,350	3,600
Total, Energy Efficiency and Renewable Energy	**40,963**	**29,207**	**11,032**
Total, Idaho National Laboratory	**40,963**	**29,207**	**11,032**

Department Of Energy

FY 2020 Congressional Budget

Funding by Appropriation by Site

($K)

Energy Efficiency and Renewable Energy	**FY 2018 Total Enacted**	**FY 2019 Enacted**	**FY 2020 Request**
Lawrence Berkeley National Laboratory			
Energy Efficiency and Renewable Energy			
Wind Energy	2,626	1,675	1,152
Geothermal Technologies	4,132	4,070	75
Hydrogen & Fuel Cell Technologies	6,324	5,479	1,950
Solar Energy	2,575	126	0
Vehicle Technologies	17,238	14,500	4,250
Building Technologies	38,017	31,718	8,395
Federal Energy Management Program	3,803	4,187	809
Weatherization	0	170	0
State Energy Program Grants	760	605	0
Advanced Manufacturing	9,325	12,200	2,000
Strategic Programs	680	2,750	0
Bioenergy Technologies	10,640	6,935	3,350
Total, Energy Efficiency and Renewable Energy	**96,120**	**84,415**	**21,981**
Total, Lawrence Berkeley National Laboratory	**96,120**	**84,415**	**21,981**
Lawrence Livermore National Laboratory			
Energy Efficiency and Renewable Energy			
Wind Energy	874	771	592
Geothermal Technologies	2,523	1,183	25
Hydrogen & Fuel Cell Technologies	3,630	2,833	1,000
Solar Energy	300	434	836
Vehicle Technologies	4,959	3,800	1,000
Building Technologies	107	774	25
Advanced Manufacturing	7,293	5,200	5,200
Bioenergy Technologies	1,384	400	0
Total, Energy Efficiency and Renewable Energy	**21,070**	**15,395**	**8,678**
Total, Lawrence Livermore National Laboratory	**21,070**	**15,395**	**8,678**
Los Alamos National Laboratory			
Energy Efficiency and Renewable Energy			
Wind Energy	345	212	0
Geothermal Technologies	576	570	25
Hydrogen & Fuel Cell Technologies	5,552	5,741	1,000
Solar Energy	5,248	0	0
Vehicle Technologies	388	350	0
Building Technologies	291	291	50
Advanced Manufacturing	250	0	0
Bioenergy Technologies	6,138	5,719	2,250
Total, Energy Efficiency and Renewable Energy	**18,788**	**12,883**	**3,325**
Total, Los Alamos National Laboratory	**18,788**	**12,883**	**3,325**

Department Of Energy

FY 2020 Congressional Budget

Funding by Appropriation by Site

($K)

Energy Efficiency and Renewable Energy	**FY 2018 Total Enacted**	**FY 2019 Enacted**	**FY 2020 Request**
National Energy Technology Lab			
Energy Efficiency and Renewable Energy			
Program Direction	15,646	10,702	0
Geothermal Technologies	30,140	30,000	5,000
Vehicle Technologies	93,371	128,000	6,500
Building Technologies	13,729	17,750	45
Strategic Programs	1,000	0	0
Bioenergy Technologies	6,855	333	200
Total, Energy Efficiency and Renewable Energy	**160,741**	**186,785**	**11,745**
Total, National Energy Technology Lab	**160,741**	**186,785**	**11,745**
National Renewable Energy Laboratory			
Energy Efficiency and Renewable Energy			
Wind Energy	45,396	33,694	11,858
Facilities and Infrastructure (NREL)	92,000	97,000	107,000
Geothermal Technologies	1,765	758	200
Hydrogen & Fuel Cell Technologies	19,467	14,493	3,800
Water Power	14,099	9,657	4,090
Solar Energy	39,199	45,479	27,478
Vehicle Technologies	42,923	38,000	9,200
Building Technologies	19,507	15,764	1,250
Federal Energy Management Program	6,563	10,600	2,270
Weatherization	1,656	0	0
State Energy Program Grants	1,250	795	0
Advanced Manufacturing	10,552	1,825	1,000
Strategic Programs	6,011	5,250	0
Bioenergy Technologies	62,314	41,961	14,300
Total, Energy Efficiency and Renewable Energy	**362,702**	**315,276**	**182,446**
Total, National Renewable Energy Laboratory	**362,702**	**315,276**	**182,446**
Oak Ridge Institute for Science & Education			
Energy Efficiency and Renewable Energy			
Geothermal Technologies	497	500	500
Solar Energy	1,347	0	0
Vehicle Technologies	1,996	900	0
Building Technologies	2,034	2,150	0
Federal Energy Management Program	204	0	0
Weatherization	150	450	0
State Energy Program Grants	500	800	0
Advanced Manufacturing	5,817	5,700	5,000
Bioenergy Technologies	1,241	0	0
Total, Energy Efficiency and Renewable Energy	**13,786**	**10,500**	**5,500**
Total, Oak Ridge Institute for Science & Education	**13,786**	**10,500**	**5,500**

Department Of Energy

FY 2020 Congressional Budget

Funding by Appropriation by Site

($K)

Energy Efficiency and Renewable Energy	**FY 2018 Total Enacted**	**FY 2019 Enacted**	**FY 2020 Request**
Oak Ridge National Laboratory			
Energy Efficiency and Renewable Energy			
Wind Energy	4,234	925	215
Geothermal Technologies	2,276	320	25
Hydrogen & Fuel Cell Technologies	3,073	2,609	500
Water Power	6,829	5,749	5,118
Solar Energy	5,248	2,581	289
Vehicle Technologies	55,330	52,000	12,300
Building Technologies	25,559	15,316	5,550
Federal Energy Management Program	4,159	3,829	1,145
Weatherization	837	1,025	0
State Energy Program Grants	30	30	0
Advanced Manufacturing	48,610	32,025	10,500
Bioenergy Technologies	10,515	7,894	4,350
Total, Energy Efficiency and Renewable Energy	**166,700**	**124,303**	**39,992**
Total, Oak Ridge National Laboratory	**166,700**	**124,303**	**39,992**
Oak Ridge Office			
Energy Efficiency and Renewable Energy			
Hydrogen & Fuel Cell Technologies	1,954	721	500
Total, Oak Ridge Office	**1,954**	**721**	**500**
Pacific Northwest National Laboratory			
Energy Efficiency and Renewable Energy			
Wind Energy	8,613	6,501	1,810
Geothermal Technologies	1,970	1,228	25
Hydrogen & Fuel Cell Technologies	8,304	4,904	1,500
Water Power	10,312	11,233	4,159
Solar Energy	1,055	48	0
Vehicle Technologies	17,851	14,500	7,250
Building Technologies	33,947	22,898	4,325
Federal Energy Management Program	2,797	1,815	1,145
State Energy Program Grants	35	0	0
Advanced Manufacturing	405	300	300
Strategic Programs	190	250	0
Bioenergy Technologies	17,920	13,877	3,900
Total, Energy Efficiency and Renewable Energy	**103,399**	**77,554**	**24,414**
Total, Pacific Northwest National Laboratory	**103,399**	**77,554**	**24,414**

Department Of Energy

FY 2020 Congressional Budget

Funding by Appropriation by Site

($K)

Energy Efficiency and Renewable Energy	FY 2018 Total Enacted	FY 2019 Enacted	FY 2020 Request
Sandia National Laboratories			
Energy Efficiency and Renewable Energy			
Wind Energy	6,963	7,254	3,951
Geothermal Technologies	4,792	2,635	910
Hydrogen & Fuel Cell Technologies	8,880	7,542	3,000
Water Power	8,043	6,706	2,073
Solar Energy	13,659	10,918	6,797
Vehicle Technologies	15,561	13,000	4,000
Building Technologies	272	272	75
Advanced Manufacturing	3,000	0	0
Strategic Programs	699	750	0
Bioenergy Technologies	6,730	5,920	2,900
Total, Energy Efficiency and Renewable Energy	**68,599**	**54,997**	**23,706**
Total, Sandia National Laboratories	**68,599**	**54,997**	**23,706**
Savannah River National Laboratory			
Energy Efficiency and Renewable Energy			
Hydrogen & Fuel Cell Technologies	1,128	1,344	500
Solar Energy	100	0	0
Advanced Manufacturing	2,005	0	0
Bioenergy Technologies	290	0	0
Total, Energy Efficiency and Renewable Energy	**3,523**	**1,344**	**500**
Total, Savannah River National Laboratory	**3,523**	**1,344**	**500**
SLAC National Accelerator Laboratory			
Energy Efficiency and Renewable Energy			
Hydrogen & Fuel Cell Technologies	50	50	50
Solar Energy	1,713	2,445	591
Vehicle Technologies	5,600	4,500	1,500
Building Technologies	397	397	115
Advanced Manufacturing	8,395	0	0
Total, Energy Efficiency and Renewable Energy	**16,155**	**7,392**	**2,256**
Total, SLAC National Accelerator Laboratory	**16,155**	**7,392**	**2,256**

Department Of Energy

FY 2020 Congressional Budget

Funding by Appropriation by Site

($K)

Energy Efficiency and Renewable Energy	**FY 2018 Total Enacted**	**FY 2019 Enacted**	**FY 2020 Request**
Washington Headquarters			
Energy Efficiency and Renewable Energy			
Wind Energy	14,450	18,912	2,670
Program Direction	125,763	128,669	101,230
Geothermal Technologies	8,030	35,006	6,190
Hydrogen & Fuel Cell Technologies	7,388	8,754	2,000
Water Power	9,341	20,660	9,674
Solar Energy	48,648	42,073	18,540
Vehicle Technologies	0	0	4,000
Building Technologies	67,271	62,465	17,485
Federal Energy Management Program	7,353	8,784	2,231
Weatherization	247,887	254,544	0
State Energy Program Grants	50,940	51,275	0
Advanced Manufacturing	27,986	157,630	54,500
Strategic Programs	6,420	5,000	0
Bioenergy Technologies	5,358	37,576	2,500
Total, Energy Efficiency and Renewable Energy	**626,835**	**831,348**	**221,020**
Total, Washington Headquarters	**626,835**	**831,348**	**221,020**
Total, Energy Efficiency and Renewable Energy	**2,321,778**	**2,379,000**	**696,000**

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, **[**$1,326,090,000,**]** $824,000,000, to remain available until expended: Provided, That of such amount, **[**$80,000,000**]** $64,350,000 shall be available until September 30, **[**2020**]** 2021, for program direction. *(Energy and Water Development and Related Agencies Appropriations Act, 2019.)*

Nuclear Energy
($K)

FY 2018 Enacted[1,2]	FY 2019 Enacted[1,2]	FY 2020 Request
1,205,056	1,326,090	824,000

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 approximately 60 percent of the nation's annual clean electricity production, and generates about 20 percent of U.S. electricity from a fleet of 98 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) 2020 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.

In FY 2020, the Department is collaborating on two new activities crosscutting the applied energy programs – an Advanced Energy Storage Initiative to coordinate efforts to advance energy storage R&D and the Harsh Environment Materials Initiative that will exploit synergies in materials and component manufacturing process research for advanced thermoelectric power plants.

Highlights and Major Changes in the FY 2020 Budget Request

- Within Reactor Concepts Research, Development and Demonstration (RC RD&D), the Versatile Advanced Test Reactor subprogram sees a major ramp us as the Department proceeds to conceptual design and other activities necessary for approval of Critical Decision-1 (CD-1), Alternative Selection and Cost Range, which is anticipated in the first quarter of FY 2021.
- The FY 2020 Budget includes funds for the second year of a three-year effort to demonstrate the ability to produce high-assay low enriched uranium (HALEU) to support the anticipated fuel requirements for new advanced reactor

[1] Funding does not reflect the transfer of SBIR/STTR to the Office of Science.
[2] Funding does not reflect the transfer of $85.5M from Naval Reactors for maintenance and operation of the Advanced Test Reactor.

designs. Funding for this effort is included in a new subprogram within the Fuel Cycle R&D program, "Civil Nuclear Enrichment."

- Another new subprogram, "Transformational Challenge Reactor", within the Nuclear Energy Enabling Technologies program (NEET), applies new advanced additive manufacturing and modeling methods to specific materials, parts, and systems required for new advanced reactor designs.
- Also within NEET, the Nuclear Energy Advanced Modeling and Simulation subprogram incorporates the completed work scope of the Energy Innovation Hub for Modeling and Simulation (Hub). The Hub was a 10 year effort, completed in 2019, to develop computational tools for the simulation of light water reactors.
- 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 regarding the scaling up and commercialization of the technology.
- The FY 2020 Budget provides that International Nuclear Energy Cooperation (INEC), and associated federal staff, will be transferred to DOE's Office of International Affairs (IA). This transfer from NE to IA is part of a larger effort to consolidate international cooperation efforts throughout the Department.
- In FY 2020, activities associated with resuming regulatory activities concerning Yucca Mountain and initiating a robust interim storage program are included in a new program, Yucca Mountain and Interim Storage (YMISP). Consistent with this, the Integrated Waste Management System subprogram is discontinued; interim storage and transportation planning scope is being moved to YMISP. 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 YMISP.
- 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 2018 Enacted[1,2]	FY 2019 Enacted[1,2]	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
Integrated University Program	**5,000**	**5,000**	**0**	**-5,000**
STEP R&D	**5,000**	**5,000**	**0**	**-5,000**
Reactor Concepts Research, Development and Demonstration	**237,000**	**323,500**	**215,150**	**-108,350**
Fuel Cycle Research and Development	**260,056**	**263,915**	**90,000**	**-173,915**
Nuclear Energy Enabling Technologies	**159,000**	**152,585**	**98,450**	**-54,135**
Radiological Facilities Management	**29,000**	**29,000**	**9,000**	**-20,000**
Idaho Facilities Management				
Operations & Maintenance	288,000	288,000	204,000	-84,000
16-E-200, Sample Preparation Laboratory	6,000	30,000	5,242	-24,758
Total, Idaho Facilities Management	**294,000**	**318,000**	**209,242**	**-108,758**
Idaho Sitewide Safeguards and Security	**133,000**	**146,090**	**137,808**	**-8,282**
International Nuclear Energy Cooperation	**3,000**	**3,000**	**0**	**-3,000**
Program Direction	**80,000**	**80,000**	**64,350**	**-15,650**
Total, Nuclear Energy	**1,205,056**	**1,326,090**	**824,000**	**-502,090**
Federal FTEs	289	291	256	-35

SBIR/STTR:
- FY 2018 Transferred: SBIR $20,434; STTR $2,873
- FY 2019 Projected: SBIR $23,120; STTR $3,251
- FY 2020 Request: SBIR $9,715; STTR $1,366

[1] Funding does not reflect the transfer of SBIR/STTR to the Office of Science.
[2] Funding does not reflect the transfer of $85.5M from Naval Reactors for maintenance and operation of the Advanced Test Reactor.

Integrated University Program

Overview

No funding is requested in the FY 2020 Budget 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 2018 Enacted	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
Integrated University Program				
Integrated University Program	5,000	5,000	0	-5,000
Total, Integrated University Program	**5,000**	**5,000**	**0**	**-5,000**

Integrated University Program
Explanation of Major Changes
($K)

	FY 2020 Request vs FY 2019 Enacted
Integrated University Program:	
No funding is requested to continue this program in FY 2020.	**-5,000**
Total, Integrated University Program	**-5,000**

Integrated University Program

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Integrated University Program $5,000,000	**$0**	**-$5,000,000**
• Support 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 2020.	• No funding is requested to continue this program in FY 2020.

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 Demonstration (RD&D) program.

Highlights of the FY 2020 Budget Request
No funding is requested for the STEP R&D 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 2018 Enacted	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
Supercritical Transformational Electric Power Research and Development				
Supercritical Transformational Electric Power Research and Development	5,000	5,000	0	-5,000
Total, Supercritical Transformational Electric Power Research and Development	**5,000**	**5,000**	**0**	**-5,000**

SBIR/STTR:

- FY 2018 Enacted: SBIR $160; STTR $22
- FY 2019 Enacted: SBIR $160; STTR $22
- FY 2020 Request: SBIR $0; STTR $0

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

	FY 2020 Request vs FY 2019 Enacted
Supercritical Transformational Electric Power Research and Development:	
No funding is requested in the FY 2020 Budget.	**-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 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Supercritical Transformational Electric Power Research and Development $5,000,000	**$0**	**-$5,000,000**
• Identify/validate materials to satisfy the performance requirements for components in a commercial scale system. • Finalize build for seals test rig and test mechanical lift of seals in super critical Carbon Dioxide (sCO_2) at 4400 psi and 700C in order to support the commercialization of a 10 Mega Watt sCO_2 Re-compression Closed Brayton Cycle. • Upgrade and maintain the Development Platform with new subsystems and upgraded infrastructure. • Identification and support of sCO_2 program variables; systems and concurrent engineering, systems modeling, requirements test plans and validation plans, Technology Readiness Level management, system metrics, technology roadmapping, communities of practice management, research and development planning. • Perform Lowest Cost of Electricity optimization of the sCO_2 Brayton cycle to inform design parameters while considering cross-cutting heat sources. • Complete design guidelines for Printed Circuit Heat Exchanger including a materials tradeoff analysis. • Demonstrate the viability for sCO_2 Power System qualification for grid connection by scoping the work needed to support the new on-the-grid Kirtland First initiative.	• No funding is requested.	• No funding is requested in the FY 2020 Budget.

Reactor Concepts Research, Development and Demonstration

Overview

The Reactor Concepts Research, Development and Demonstration (RD&D) program supports the conduct of early stage research and development (R&D) on existing and advanced reactor designs and technologies to enable industry to address technical challenges while 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, high temperature reactors using gas or liquid salt coolants, and micro-reactors.

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 the industry to reverse the downward trajectory of our nation's nuclear energy sector and regaining a leadership role.

The Reactor Concepts RD&D program will continue to support R&D efforts focused on SMRs in FY 2020. The Advanced SMR R&D subprogram was initiated in FY 2019 and supports cost-shared, early stage design-related R&D, the results of which are intended to be widely applicable to many advanced reactor designs, including micro-reactors, and adopted by nuclear technology development vendors for the purpose of accelerating the development of their technologies into the market. 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, related technical assistance and direct-funded cross-cutting early stage 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 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 micro-reactors, 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 diverse 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 supports conceptual design activities in the Versatile Advanced Test Reactor R&D subprogram. 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. Activities in FY 2020 will focus on work that must be performed prior to CD-1, Approval of Alternative Selection and Cost Range.

Highlights of the FY 2020 Budget Request

The Versatile Advanced Test Reactor R&D subprogram sees a major ramp up as the Department proceeds to conceptual design and other activities necessary for approval of Critical Decision-1 (CD-1), Alternative Selection and Cost Range. Following approval of CD-1, anticipated in the 1st quarter of FY 2021, activities will be initiated to develop preliminary design.

In FY 2019, Congress provided $30 million for the Transformational Challenge Reactor (TCR) activity. Funding for the TCR in the FY 2020 Budget Request is located within the Nuclear Energy Enabling Technologies program, aligning it with other Nuclear Energy advanced manufacturing R&D efforts.

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

	FY 2018 Enacted	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
Reactor Concepts Research, Development and Demonstration				
Advanced Small Modular Reactor R&D	0	100,000	10,000	-90,000
Light Water Reactor Sustainability	47,000	47,000	30,150	-16,850
Advanced Reactor Technologies	155,000	111,500	75,000	-36,500
Versatile Advanced Test Reactor R&D	35,000	65,000	100,000	+35,000
Total, Reactor Concepts Research, Development and Demonstration	**237,000**	**323,500**	**215,150**	**-108,350**

SBIR/STTR:
- FY 2018 Transferred: SBIR $7,584; STTR $1,067
- FY 2019 Projected: SBIR $10,352; STTR $1,456
- FY 2020 Request: SBIR $6,885; STTR $968

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

	FY 2020 Request vs FY 2019 Enacted
Advanced Small Modular Reactor R&D: The decrease from $100,000,000 to $10,000,000 focuses efforts supporting cost-shared early-stage design-related research and development (R&D) relevant to a broad spectrum of advanced small modular and micro-reactor designs. The reduction also reflects a transition of the Transformational Challenge Reactor (TCR) in FY 2020 to the Nuclear Energy Enabling Technologies (NEET) program to better align it with other Nuclear Energy advanced manufacturing research and development (R&D) efforts.	**-90,000**
Light Water Reactor Sustainability: The decrease from $47,000,000 to $30,150,000 represents successfully addressing industry's highest priority materials aging issues necessary to submit subsequent license renewal applications. Materials R&D will continue within the LWRS program at a reduced scale to resolve lower priority materials aging issues and mitigating techniques.	**-16,850**
Advanced Reactor Technologies: The decrease from $111,500,000 to $75,000,000 focuses the program on the highest priority industry-identified advanced reactor R&D needs and provides the final funds to the ARC 15 industry cost-shared awards. The reduction also reflects a transition of the TCR in FY 2020 to the NEET program to better align it with other Nuclear Energy advanced manufacturing R&D efforts. Tristructural-isotropic (TRISO)-coated particle fuel qualification activities for high-temperature advanced reactors will focus on continued irradiation testing and only conducting the highest priority post irradiation examinations.	**-36,500**
Versatile Advanced Test Reactor R&D: The increase from $65,000,000 to $100,000,000 supports development of information necessary to achieve Critical Decision-1, Approve Alternative Selection and Cost Range.	**+35,000**
Total, Reactor Concepts Research, Development & Demonstration	**-108,350**

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 to reestablish dominance in the nuclear technology development arena. Significant risk remains in developing advanced SMR and micro-reactor designs. By continuing this Advanced SMR R&D effort, the Department intends to continue to leverage its appropriate federal role and notable R&D expertise to facilitate industry's development of advanced SMR and micro-reactor 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 effort is essential to regaining a dominant position in the global market.

The Advanced SMR R&D subprogram will support early stage, design-related R&D, the results of which are intended to be widely applicable and adopted by domestic nuclear reactor vendors for the purpose of accelerating the development of their technologies. Specifically, Advanced SMR R&D will support only early-stage R&D that results in broad benefits to the U.S. nuclear energy sector that can serve as the basis for later stage advanced SMR or micro-reactor R&D that the private sector chooses to fund. 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. 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. This subprogram does not pick winners, but instead produces widely available results.

In FY 2020 the program funding will focus on efforts to support early stage, R&D on advanced small modular and micro-reactor designs.

Funding for the Transformational Challenge Reactor in the FY 2020 Budget Request is located within the Nuclear Energy Enabling Technologies program, aligning it with other Nuclear Energy advanced manufacturing R&D efforts.

Advanced Small Modular Reactor R&D

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Advanced Small Modular Reactor R&D $100,000,000	**$10,000,000**	**-$90,000,000**
• Supports a broad scope of cost-shared 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 generic plant structural design; conducting emergency core cooling system and component research; and design and development of prototype components. • In the 1st quarter of FY 2019, one project was selected for award under the Industry Funding Opportunity Announcement and two projects were incrementally funded to support the development of small modular reactors. • Transformational Challenge Reactor (TCR) - Identify source of TCR project-related nuclear material for the test specimen and nuclear demonstration core to be tested in the Transient Reactor Test Facility (TREAT); develop TREAT test plan; develop regulatory framework documents for demonstration authorization; and procure, install, and calibrate in-situ data collection for the additive machines for the Surrogate Core, Digital Twin and Sensor suites.	• Support early stage R&D to further advance small modular and micro reactors.	• The decrease reflects funding early stage R&D activities to support the development of small modular and micro-reactor designs and having fully funded seismic analysis work in FY 2019 and transferring the TCR activity to Nuclear Energy Enabling Technologies.

Description

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 nuclear industry achieved an important and planned milestone in FY 2018 with the submittal of two Subsequent License Renewal (SLR) applications and more are planned in the near-term. The LWRS program will work with owner-operators to provide the technical basis for second license renewal specifically, as well as to address current and future material issues needed to ensure a long-term viable source of nuclear power generation.

With the initial success of the lead plants' SLR submittals, the sustainability of the existing fleet has shifted from extending their operational license to addressing the economic challenges. LWRS will continue to collaborate with nuclear power plant owner-operators, vendors, suppliers, industry support organizations, other research organizations, and the Nuclear Regulatory Commission to closely coordinate early-stage research that addresses industry needs.

Currently, the LWRS program consists of the following primary technical areas of research and development (R&D):

- Materials Research: R&D to develop the scientific basis for understanding and predicting long-term environmental degradation behavior of materials in nuclear power plants. The R&D products will be used to define operation limits and aging mitigation approaches for materials in nuclear power plant systems, structures and components (SSCs) subject to long-term operating conditions, providing key input to both regulators and industry.
- Risk-Informed Systems Analysis: R&D to support decision-making related to economics, reliability, and safety by providing integrated plant systems analysis solutions to enhance economic competitiveness of the operating fleet. The R&D products in this area will be used to optimize plant economic performance and safety by incorporating plant impacts, physical aging, and degradation processes.
- Plant Modernization: R&D to address nuclear power plant economic viability in current and future energy markets through innovation, efficiency gains, and business model transformation through digital technologies. The R&D products will enable modernization of plant systems and process while building a technology-centric business model platform, which supports improved performance at a lower cost.
- Flexible Plant Operations and Generation: R&D to establish the technical feasibility, economic potential, and license considerations for dispatching thermal and electrical energy to diversify and increase revenue of light water reactors in the U.S. The R&D products will allow the existing fleet of nuclear reactors to more readily respond to increasing renewable energy production and demonstrate the ability to repurpose nuclear power reactors into a flexible energy source for low-carbon industrial commodity production.

In FY 2020, the LWRS program will continue to leverage cost-shared, private-public partnerships and our national laboratory system 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 bases for managing the aging of structures, systems and components (SSCs) so nuclear power plants can continue to operate safely and cost effectively and providing science and technology-based solutions to improve the current business model and associated practices.

Light Water Reactor Sustainability

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Light Water Reactor Sustainability $47,000,000	**$30,150,000**	**-$16,850,000**
• 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 research and development (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. • Flexible Plant Operations and Generation - Evaluate the non-electric market options, including energy storage in response to peak renewable energy production, hydrogen generation, and desalination, for a light water reactor in the Midwest. Award a competitively-	• Materials Research – Integrate embrittlement model for high fluence conditions into Grizzly, a simulation tool, to provide a more accurate prediction of the age induced degradation of mechanical properties in the reactor pressure vessel. Optimize the welding process for nickel-based alloys, which could allow industry to avoid costly in core internal replacements. • Risk-Informed Systems Analysis – Develop component maintenance and testing optimization models to enable a risk-and-cost based decision-making process. Working with industry, apply methods and tools to enhance plant resiliency through new technologies to improve plant performance, operational flexibility in future energy markets, and reduce costs. • Plant Modernization – Conduct research on an online monitoring system at a commercial nuclear power plant and develop performance insights for their use by industry. Develop advanced automation concepts for control room operators using digital technologies to enhance system performance and reliability. • Flexible Plant Operations and Generation – Continue R&D to support the integration of a hydrogen generation capability at an existing nuclear power plant in order to enable the plant's diversification. Begin to examine a second competitively-awarded pilot project to demonstrate the technology necessary to allow nuclear power plants to move flexibly between	• The decrease in funding represents successfully addressing industry's highest priority materials aging issues necessary to submit subsequent license renewal applications. Materials R&D will continue within the Light Water Reactor Sustainability (LWRS) program at a reduced scale to resolve lower priority materials aging issues and mitigating techniques. The LWRS program will also transition funds applied to the industry Funding Opportunity Announcement in previous years to begin monitoring the status of awarded projects that support industry's highest concerns and providing support where necessary.

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
selected pilot project to support plant modifications and licensing requirements necessary to demonstrate nuclear plant integration with an integrated energy system.	electricity and hydrogen generation during periods of peak renewable energy production.	

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 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 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, including small modular reactors and micro-reactors, and stimulation of new ideas for transformational future concepts.

Early stage R&D efforts support innovative reactor concepts, including high temperature gas-cooled reactors (HTGRs), and molten salt reactors (MSRs) using liquid salt coolants and/or fuels. The ART subprogram focuses on early-stage R&D priorities identified by industry that could provide wide benefits across many different advanced reactor concepts 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, fuel development and graphite material qualification for high-temperature reactors, cross-cutting areas of support in 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 that yield benefits to the U.S. advanced reactor pipeline. Industry-led innovative early-stage cost-shared R&D activities are supported through competitive industry awards, including R&D that reduces regulatory risk in support of NRC's development of a streamlined regulatory process for advanced reactor technologies. 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.

Funding for the Transformational Challenge Reactor in the FY 2020 Budget Request is located within the Nuclear Energy Enabling Technologies program, aligning it with other Nuclear Energy advanced manufacturing R&D efforts.

Advanced Reactor Technologies

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Advanced Reactor Technologies $111,500,000	**$75,000,000**	**-$36,500,000**
• Fast Reactor Technologies - Initiate in-sodium testing of gear test assembly in the Mechanisms Engineering Test Laboratory (METL) facility and develop next industry-prioritized experimental assemblies. Continue to modernize and validate fast reactor safety codes for use in normal operation and transient analyses. Lead International Atomic Energy Agency (IAEA) Coordinated Research Project on Fast Flux Test Facility Historical Safety Test Benchmark; continue American Society of Mechanical Engineers (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 tristructural-isotropic (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	• Fast Reactor Technologies - Any ART work involving in-sodium testing of industry-identified fast reactor component experiments in METL will have broadly-available results that can be useful to multiple reactor developers • 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 and resolve issues necessary to achieve endorsement by NRC. Continue high-priority irradiation testing and examination of TRISO fuels. • Molten Salt Reactor Technologies - Continue development of chemical monitoring requirements, methods, and instrumentation. Establish modeling framework for salt characterization. Continue to collect fundamental data to understand fission product behavior in chloride salt-fueled systems. Develop advanced instrumentation for monitoring fissile material inventory. Investigate chemical control strategies for controlled plating techniques and filtering methods. • Cross-Cutting Technologies - Continue cross-cutting R&D for special purpose applications, as described in technology roadmap. 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 early-stage R&D.	• The decrease reflects funding the highest priority industry-identified advanced reactor early state R&D needs, and having provided the final funding to the ARC 15 industry cost-shared awards, and transferring the Transformational Challenge Reactor activity to Nuclear Energy Enabling Technologies.

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
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 Supercritical Carbon Dioxide Power Cycle. Continue work on printed circuit heat exchangers, intermediate heat exchanger alloys and Brayton cycle plant analysis codes. • Micro-Reactors - Issue a micro-reactor technology deployment report based on high-priority Department of Defense and Department of Energy stakeholder needs and continue cross-cutting research and development (R&D) applicable to multiple micro-reactor concepts. • Advanced Reactor Regulatory Framework - The Department will continue to engage with the 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. • Transformational Challenge Reactor - Procure and install additive machines for cladding development and production at the Manufacturing Demonstration Facility (MDF); select the optimal alloy for the core application; and establish manufacturing process parameters, post heat treatment methodologies, and possible geometries with materials and technologies.	• Advanced Reactor Regulatory Framework - The Department will continue to engage with the 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

For the United States to regain a global leadership role in the development of the next generation of advanced reactors, a fast spectrum test reactor will 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 environments, 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 can 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.

The Versatile Advanced Test Reactor (VATR) is one of the Department's highest priorities, and the VATR subprogram serves as a cornerstone to the Administration's focus on reviving and expanding the nuclear sector in the United States. Specifically, the VATR will support the modernization of United States infrastructure for early stage R&D. It also aligns with the prioritization of investment in infrastructure and test beds in DOE's FY 2020 Budget, in order to maintain the world-class nature of national laboratory facilities and better enable private sector demonstration and deployment of energy technologies. Advancements in nuclear energy, particularly in the area of testing of advanced materials and fuels in extreme environments, is necessary for the advanced reactor community in the United States to achieve its goals. The VATR would help allow the U.S. to regain its global technical leadership role in the field of nuclear energy, contribute to the creation of high-paying jobs and economic prosperity, and train the next generation of scientists and engineers needed for the future viability of our nuclear sector.

The VATR Research and Development (R&D) subprogram has conducted R&D, evaluated options, and developed pre-conceptual design details for fast test reactor needs and concepts. In FY 2019, the R&D activities include pre-conceptual design development to support the development of highly credible cost estimates for the facility. An independent alternatives analysis began in FY 2018 and will be completed in FY 2019.

In FY 2020, activities will focus on development of conceptual design and other information necessary for approval of CD-1, Alternative Selection and Cost Range. The process of completing a conceptual design will include conducting a design review of the conceptual design with reviewers external to the project, and completing a conceptual design report. DOE also will conduct a Technology Readiness Assessment and develop a Technology Maturation Plan, as appropriate. A safety basis compliance strategy will be developed and a cost estimate for fuel source, fuel fabrication and assembly will be completed. National Environmental Policy Act required activities will continue with the goal of achieving a Record of Decision in FY 2021. FY 2020 work also will include formulation and approval of an Acquisition Strategy and approval of a Project Execution Plan. DOE also will develop a Risk Management Plan and a Design Management Plan.

Versatile Advanced Test Reactor R&D

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Versatile Advanced Test Reactor $65,000,000	**$100,000,000**	**+$35,000,000**
• 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. • Initiate development of a Virtual Design and Construction 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. • Make awards to industry and universities to support pre-conceptual and conceptual design development and experiment concept development. • Obtain Departmental Approval of Critical Decision (CD)-0, Mission Need. • Begin conceptual design development.	• Develop and approve an Acquisition Strategy. • Develop and approve a preliminary Project Execution Plan. • Complete the safety basis compliance strategy. • Complete draft reactor sizing study. • Complete information to support approval of CD-1 including identification of a preferred alternative. • Complete a conceptual design and associated cost and schedule estimates. • Complete cost estimate for fuel source, fuel fabrication and assembly. • Conduct National Environmental Policy Act required activities with the goal of achieving a Record of Decision in FY 2021.	• The increase in funding supports development of information necessary to achieve CD-1. This effort will be managed in accordance with DOE Order 413.3B, Program and Project Management for the Acquisition of Capital Assets.

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 (U.S.), 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 R&D 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 2020 Budget Request

The Advanced Fuels subprogram will 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.

Many of the U.S. advanced reactors developers have identified high-assay low enriched uranium (HALEU) (uranium enriched in u-235 to >5% and <20%) as a fuel requirement. Currently, the U.S. lacks a sustainable domestic supply of HALEU. The Office of Nuclear Energy (NE) is investigating technologies for providing HALEU. For example, NE aims to explore the feasibility of reprocessing highly-enriched uranium to produce HALEU via the ZIRCEX process. In addition, the Civil Nuclear Enrichment subprogram, initiated in FY 2019, is aimed at demonstrating the capability to produce HALEU utilizing U.S. centrifuge technology. These activities support high priority research and development related to advanced fuels that in turn supports industry's demonstration of advanced reactors, including micro reactors.

In FY 2020, the Used Nuclear Fuel Disposition R&D subprogram supports the highest priority research including the study of the performance of the high burnup used nuclear fuel demonstration, and the continued support of international collaborations.

Fuel Cycle Research and Development
Funding
($K)

	FY 2018 Enacted	FY 2019 Enacted	FY 2019 Current[1]	FY 2020 Request	FY 2020 Request vs FY 2019 Current[1]
Fuel Cycle Research and Development					
Material Recovery and Waste Form Development	30,000	38,000	36,700	6,000	-30,700
Civil Nuclear Enrichment	0	0	30,200	40,000	+9,800
Advanced Fuels	125,000	125,000	112,708	36,000	-76,708
System Analysis and Integration	8,641	8,500	6,376	0	-6,376
Materials Protection, Accounting and Control Technology	10,000	6,000	4,716	3,000	-1,716
Used Nuclear Fuel Disposition R&D	63,915	63,915	50,715	5,000	-45,715
Integrated Waste Management System	22,500	22,500	22,500	0	-22,500
Total, Fuel Cycle Research and Development	**260,056**	**263,915**	**263,915**	**90,000**	**-173,915**

SBIR/STTR:
- FY 2018 Enacted: SBIR $7,602; STTR $1,069
- FY 2019 Enacted: SBIR $7,725; STTR $1,086
- FY 2020 Request: SBIR $2,880; STTR $405

[1] FY 2019 Current column reflects alignment of FY 2019 Fuel Cycle Research and Development appropriations to initiate the Civil Nuclear Enrichment subprogram.

Fuel Cycle Research and Development
Explanation of Major Changes
($K)

	FY 2020 Request vs FY 2019 Current[1]
Material Recovery and Waste Form Development: The decrease from $36,700,000 to $6,000,000 reflects the realignment of existing research and development (R&D) programs and a refocusing of the subprogram priorities on critical R&D efforts important to nonproliferation needs and objectives and leveraging R&D efforts with critical elements identified in recovery of HALEU from spent naval fuel.	**-30,700**
Civil Nuclear Enrichment: The increase from $30,200,000 to $40,000,000 is aimed at demonstrating the capability to produce HALEU using U.S.-origin centrifuge technology. This demonstration is intended to show that a U.S.-owned and U.S.-origin centrifuge technology will be available to the private sector as the HALEU market emerges. Demonstration of this capability is critical to U.S. leadership in this emerging market sector and to advance vital strategic interests.	**+9,800**
Advanced Fuels: The decrease from $112,708,000 to $36,000,000 reflects the refocusing of the program to fund only early-stage, high-risk/high-reward accident tolerant fuel concepts. Other advanced reactor fuel R&D will be conducted as needed within the advanced reactor programs that they support.	**-76,708**
Systems Analysis and Integration: The decrease from $6,376,000 to $0 represents a realignment of activities within Fuel Cycle Research and Development (FCR&D). The essential crosscutting activities of the Systems Analysis and Integration subprogram will continue with contributions from the R&D programs managed by FCR&D.	**-6,376**
Materials Protection, Accounting and Control Technology: The decrease from $4,716,000 to $3,000,000 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 and advanced processing and safeguard by design continue to be priorities of this subprogram.	**-1,716**
Used Nuclear Fuel Disposition R&D: The decrease from $50,715,000 to $5,000,000 is a result of focusing funding 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.	**-45,715**

[1] FY 2019 Current column reflects alignment of FY 2019 Fuel Cycle Research and Development appropriations to initiate the Civil Nuclear Enrichment subprogram.

	FY 2020 Request vs FY 2019 Current[1]
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 Yucca Mountain and Interim Storage program.	**-22,500**
Total, Fuel Cycle R&D	**-173,915**

Fuel Cycle Research and Development
Material Recovery and Waste Form Development

Description

The Material Recovery and Waste Form Development (MRWFD) subprogram 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. The subprogram is being re-scoped to focus on critical R&D efforts important to nonproliferation needs and objectives. The subprogram conducts targeted R&D activities related to the improvement of the 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 subprogram employs a long-term, science-based approach to foster innovative and transformational technology solutions to achieve this objective.

Highly enriched uranium (HEU) can be recovered from spent fuel that contains HEU by using the ZIRCEX process, which is a dry head-end process to remove cladding (zirconium or aluminum) from nuclear fuel. This subprogram funds the ¼ scale ZIRCEX pilot plant, using unirradiated materials (cold tests), at the Idaho National Laboratory to conduct research on the feasibility of reprocessing Navy spent fuel for high-assay low-enriched uranium (HALEU) production.

In addition, this subprogram funds research to support advanced reactor technologies based on the use of molten salts as fuel and/or coolants. It also funds research on integrated advanced technologies encompassing R&D on off gas capture, waste form development, and co-conversion using innovative process control capabilities to support the back end of the nuclear fuel cycle strengthens 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 2019 Current[1]	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Current[1]
Material Recovery and Waste Form Development **$36,700,000**	**$6,000,000**	**-$30,700,000**
• Continue 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. • Support continued processing of light water reactor (LWR) fuel and metallic fuel fabrication in the U.S./Republic of Korea (ROK) Joint Fuel Cycle Study. • Support other bilateral collaborations on waste forms and noble gas capture. • Support design, construction, installation and scoping tests of the ZIRCEX process in the Material Recovery Pilot Plant (MRPP).	• Complete CoDCon studies using simulated effluent. • Continue fission products gas and noble gas capture and immobilization focusing on head end process and developing new sorbent. • Continue to develop advanced waste forms and associated processes. • Conduct cold, lab scale test at the ¼ pilot plant using the ZIRCEX process.	• No funding for the U.S. /ROK Joint Fuel Cycle Study. • Initial efforts using ZIRCEX process to provide HALEU supply.

[1] FY 2019 Current column reflects alignment of FY 2019 Fuel Cycle Research and Development appropriations to initiate the Civil Nuclear Enrichment subprogram.

Fuel Cycle Research and Development
Civil Nuclear Enrichment

Description

Natural uranium consists almost exclusively of two types of uranium isotopes, mostly uranium-238 (99.3 percent) and a smaller fraction (0.7 percent) of the fissionable isotope uranium-235 (U-235). Many advanced reactor concepts are anticipated to require high-assay low enrichment uranium (HALEU), which contains a uranium concentrated or enriched to levels between 5 and 20% in the U-235 isotope. Currently, there is no enrichment facility in the United States (U.S.) to produce HALEU for industry's advanced reactor demonstration and deployment.

A HALEU production capability utilizing U.S.-origin enrichment technology will enhance U.S. energy security as well as provide fuel to support development and deployment of advanced reactors, including the global use of U.S. designs. Demonstration of the capability of U.S.-origin enrichment technology to produce HALEU is an initial step towards establishing a sustainable U.S.-owned and U.S.-origin HALEU production capability. This demonstration is intended to show that a U.S. technology option is available to the private sector as the market for HALEU emerges, making it critical to promoting U.S. leadership in this emerging market sector and to advancing vital strategic interests.

In FY 2020, the Civil Nuclear Enrichment subprogram will procure material, equipment, and services to execute a cost-shared project with industry to complete one lead cascade of centrifuges to produce domestic HALEU by FY 2021. This is a three-year effort. The Federal Government's cumulative cost share contribution for this project, during the entire life of this project, will not exceed $115 million. The lead cascade will include only a small number of centrifuges for demonstration purposes only. The private sector is responsible for funding any expansion or commercialization of the technology to produce HALEU after this project concludes in FY 2021. Work under this Civil Nuclear Enrichment subprogram will take place during three fiscal years, FY 2019 through FY 2021. Early production of HALEU will permit vendors to ensure that reactor developers will have sufficient time to test new advanced fuels containing HALEU prior to seeking qualification of these fuels from the U.S. Nuclear Regulatory Commission. This effort is complimentary to National Nuclear Security Administration's Domestic Uranium Enrichment program, which is exploring options to meet certain long-term Departmental uranium enrichment needs.

Civil Nuclear Enrichment

Activities and Explanation of Changes

FY 2019 Current[1]	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Current[1]
Civil Nuclear Enrichment $30,200,000	**$40,000,000**	**+$9,800,000**
• Initiate engineering, procurement and construction of centrifuge facilities and equipment, including initiating long-lead procurement, design engineering, physical security modifications, and refurbishment of assembly facility. • Initiate manufacturing activities including centrifuge components. • Initiate regulatory support to enable demonstration of high-assay low-enriched uranium (HALEU) production.	• Procure materials, components and services to complete one lead cascade of centrifuges with the goal to produce HALEU by FY 2021. • Continue regulatory support related to demonstrating the production of HALEU in FY 2021, including maintain the existing NRC license and amending it to allow demonstration at 19.75%. No funding will be used to pay NRC licensing fees or for regulatory support or licensing activities that support commercialization.	• The increase from $30,200,000 to $40,000,000 reflects initial steps to support the demonstration of HALEU production capability in support of advanced reactor development and deployment and for the Department's research and development needs.

[1] FY 2019 Current column reflects alignment of FY 2019 Fuel Cycle Research and Development appropriations to initiate the Civil Nuclear Enrichment subprogram.

Fuel Cycle Research and Development
Advanced Fuels

Description
The subprogram mission is enabling industry's development of one or more light water reactor (LWR) fuel concepts with significantly enhanced accident tolerance through early-stage cost shared research and development (R&D).

Following the accident at Fukushima, Advanced Fuels initiated a program to explore advanced LWR 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 2020, the program will continue to focus its support on 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 its investment in supporting fuel development capabilities of the national laboratories.

Advanced Fuels

Activities and Explanation of Changes

FY 2019 Current[1]	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Current[1]
Advanced Fuels $112,708,000	**$36,000,000**	**-$76,708,000**
• Award follow on contracts to the three fuel vendors developing accident tolerant fuel (ATF) concepts. • Install lead test assemblies of accident tolerant fuel concepts in commercial U.S. reactor: – Westinghouse's chromium-coated zirconium cladding loaded with uranium silicide pellets in Byron-2. – Framatome's chromium-coated zirconium cladding loaded with chromia doped pellets in Vogtle-2. – GE's iron cladding and coated cladding in Clinton. – Framatome's chromium-coated zirconium cladding in Arkansas Nuclear One-1 (ANO-1). • Continue irradiation testing of fuel rodlets in the central water loop of the Advanced Test Reactor (ATR). • Upgrade the central water loop to add boiling water reactor rodlets and increase the power and capacity of the loop. • In the Transient Reactor Test Facility (TREAT), 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. • Develop innovative miniature irradiation test vehicles to greatly expand the capability to test advanced fuels and cladding.	• Prepare for the installation of high-risk, high-reward lead test assemblies in commercial reactors in the FY 2022 time frame. • Develop topical reports to support licensing and ramp up development of first batch reloads of accident tolerant fuel concepts for the mid-2020s. • Continue irradiations of fuel rodlets in the central water loop of the ATR. • In the TREAT Facility, progress to conducting dry capsule tests on irradiated ATF samples. • Continue limited investment in fuel development capabilities at the national laboratories that are critical for accident tolerant fuel development.	• The decrease from $112,708,000 to $36,000,000 reflects the refocusing of the program to fund early-stage R&D on the high-risk/high-reward accident tolerant fuel concepts. Other advanced reactor fuel research and development (R&D) will be conducted as needed within the advanced reactor programs that they support.

[1] FY 2019 Current column reflects alignment of FY 2019 Fuel Cycle Research and Development appropriations to initiate the Civil Nuclear Enrichment subprogram.

FY 2019 Current[1]	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Current
• Begin to expand the capability for fuels and material testing in the U.S. to compensate for the loss of the Halden test reactor in Norway. • Expand advanced reactor fuels R&D to support once-through and high-temperature fast spectrum reactors under development by private industry.		

Fuel Cycle Research and Development
Systems Analysis and Integration

Description

In FY 2020, the Systems Analysis and Integration subprogram will be discontinued. 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 provided 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 2019 Current[1]	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Current[1]
Systems Analysis and Integration $6,376,000	**$0**	**-$6,376,000**
• Analyze nuclear energy systems to improve the understanding of how technology options function as a system. • Develop technical insights on newly proposed nuclear energy systems by collecting and analyzing information on those systems under development by private industry. • Develop new algorithms or update existing algorithms for estimating costs of new facilities for which existing data does not exist. • Conduct analyses related to the transition from the current U.S. nuclear energy system to alternative systems considering various deployment and implementation scenarios. • Develop a technology development roadmap for a continuous recycle system with fast reactors using the technology and system readiness process. • Document high-level information on the key lessons learned from past transition analysis studies. • Analyze the long-term scale, timing, and value of nuclear energy within the context of a comprehensive U.S. and global energy system, focusing on the potential impact to baseload power demand and nuclear energy use from renewable energy.	• No funding is requested in FY 2020.	• The decrease from $6,376,000 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.

[1] FY 2019 Current column reflects alignment of FY 2019 Fuel Cycle Research and Development appropriations to initiate the Civil Nuclear Enrichment subprogram.

Fuel Cycle Research and Development
Materials Protection, Accounting and Control Technology

Description

The Materials Protection, Accounting and Control Technology (MPACT) subprogram develops the technologies and analysis tools needed to support next generation nuclear materials management and safeguards for emerging U.S. nuclear fuel cycles. It also includes assessing vulnerabilities in current nuclear systems while minimizing proliferation and terrorism risks. Addressing the energy security needs of the country requires innovative approaches to material 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 U.S. Department of State, and the U.S. Nuclear Regulatory Commission on issues related to nuclear nonproliferation. NNSA has broad responsibilities in international nonproliferation and nuclear security while MPACT is focused on research and development (R&D) for future potential U.S. fuel cycle facilities.

MPACT R&D addresses multiple challenges facing nuclear materials accountancy including:

- Limitations on accuracy and timeliness of detection, especially in high radiation fields,
- Aggregation and integration of process data from large information streams,
- Assessment of new reactor designs and fuel cycle concepts which require new nuclear material management approaches such as molten salt reactors (MSRs), electrochemical processing, and aqueous co-decontamination (CoDCon), and
- Traditional material control and accountability challenges such as uncertainty in large throughput facilities.

Materials Protection, Accounting and Control Technology

Activities and Explanation of Changes

FY 2019 Current[1]	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Current[1]
Materials Protection, Accounting and Control Technology $4,716,000	**$3,000,000**	**-$1,716,000**
• Complete a virtual facility definition for both an electrochemical processing facility as well as an integrated CoDeContamination (CoDCon) facility including operational parameters and nuclear material accountancy (NMA)/safeguards and security target values in preparation for an FY 2020 lab-scale demonstration. • Develop, test, and deploy sensors, instrumentation, and tools in U.S. domestic electrochemical processing systems in order to address electrochemical safeguards and security challenges. • Explore new sensor technologies, develop proof-of-concept and prototype hardware, demonstrate advanced instrumentation systems, conduct field tests and generate datasets for NMA/safeguards and security applications. • Complete an initial evaluation and assessment of NMA/safeguards and security needs for an integrated CoDCon facility as well as a Molten Salt Reactor (MSR).	• Complete a lab-scale testing of an advanced safeguards and security system relevant to an electrochemical processing facility as well as an integrated electrochemical & Integrated CoDCon facility. • Develop, test, and deploy sensors, instrumentation, and tools in U.S. domestic electrochemical processing systems at minimal sustainable levels for existing projects.	• Focus funding on highest priority research and development related to sensors, instrumentation, and tools relevant to U.S. domestic electrochemical processing systems to ensure best use of taxpayer dollars.

[1] FY 2019 Current column reflects alignment of FY 2019 Fuel Cycle Research and Development appropriations to initiate the Civil Nuclear Enrichment subprogram.

Fuel Cycle Research and Development
Used Nuclear Fuel Disposition R&D

Description

The Used Nuclear Fuel Disposition Research and Development (R&D) subprogram conducts scientific research and technology development to enable long term storage, transportation, and disposal of spent nuclear fuel and wastes. The primary focus of this subprogram supports 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, has initiated 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.

Disposal R&D – Priority 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 only as related to international collaborations, which 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.

Used Nuclear Fuel Disposition Research & Development (R&D)

Activities and Explanation of Changes

FY 2019 Current[1]	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Current[1]
Used Nuclear Fuel Disposition R&D $50,715,000	**$5,000,000**	**-$45,715,000**
• Develop 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. • Evaluate 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. • 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. • Continue science and engineering technical basis for the disposal of heat generating waste in salt. • Continue to support standardized canister work and the development of cask transloading capability of used fuel currently stored at the Idaho National Laboratory.	• Study of the performance of the high burnup used nuclear fuel demonstration. • Continue destructive testing on the 25 rods that will be used to determine the performance baseline. • Continue priority research and development (R&D) activities associated with exploring potential alternative disposal options for various waste and spent nuclear fuel forms, focusing on maintaining collaborations with international partners to leverage R&D being conducted in various geologic media.	• The decrease from $50,715,000 to $5,000,000 is a result of focusing funding on targeted R&D supporting storage and disposal.

[1] FY 2019 Current column reflects alignment of FY 2019 Fuel Cycle Research and Development appropriations to initiate the Civil Nuclear Enrichment subprogram.

Fuel Cycle Research and Development
Integrated Waste Management System

Description

The Integrated Waste Management System (IWMS) subprogram will be discontinued. No funding is required in FY 2020. Interim storage and transportation planning scope is moving under the new Yucca Mountain and Interim Storage program.

Previously, this subprogram supported the development of and design of an IWMS.

Integrated Waste Management System

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Integrated Waste Management System $22,500,000	**$0**	**-$22,500,000**
• Conduct system analyses to evaluate an integrated approach to transportation, storage, and disposal in the waste management system. • Identify and evaluate 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. • Expand and maintain the Used Nuclear Fuel Storage, Transportation & Disposal Analysis Resource and Data System (UNF-ST&DARDS) database. • Continue to work with State Regional Groups and Tribes in jurisdictions where Spent Nuclear Fuel (SNF) may be transported to develop policy on how to provide funds and training for public safety officials. • Develop transportation routing analysis methodology. • Evaluate and develop options on how to transport SNF from reactor sites.	• No funding is requested in FY 2020.	• This subprogram is being discontinued. Interim storage and transportation planning scope is moving under the new Yucca Mountain and Interim Storage program.

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, 2017, 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, including topical areas such as sensors and instrumentation; cybersecurity; innovative manufacturing, fabrication and construction technologies; advanced cooling concepts; and other stakeholder-identified research areas. 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). In addition, NEET includes the Transformational Challenge Reactor (TCR) subprogram to provide a revolutionary platform to reduce the deployment costs and timelines of nuclear energy systems. 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, electricity grid resiliency, national security and clean baseload power.

Highlights of the FY 2020 Budget Request

The Transformational Challenge Reactor (TCR) subprogram continues to enhance the development of breakthrough technologies that provide the ability to manufacture small/micro advanced reactor components using additive manufacturing techniques. A central goal of the TCR subprogram is to exploit advanced manufacturing techniques and digital predictive analysis capabilities to deliver a new approach to nuclear design and qualification for advanced reactor technologies. Successful execution of the TCR subprogram will result in the establishment of a demonstrated digital platform for coupling data analytics with nuclear core design, manufacturing and testing data to certify component performance. In support of this innovative approach to manufacturing, advanced manufacturing research methods previously conducted under the CTD subprogram will now be accomplished as part of the TCR subprogram. In FY 2019, the TCR utilized funding provided for the Reactor Concepts Research, Development and Demonstration program.

The Energy Innovation Hub for Modeling and Simulation (M&S Hub) has accomplished its mission to develop computational tools for the advanced simulation of Light Water Reactors (LWRs) and demonstrated their application to industry-identified operational issues in the existing LWR fleet. Through the execution of several industry-defined challenge problems, the M&S Hub provided the insights and tools needed by industry to address these key issues. Consequently, the Department fully met its M&S Hub objectives with FY 2019 Congressional Funding and will not request FY 2020 funding. NE will integrate the products of the successful M&S Hub by expanding the applicability of NEAMS tools to a broader range of early-stage advanced reactor development and initiate several high-impact modeling and simulation activities.

Nuclear Energy Enabling Technologies
Funding
($K)

	FY 2018 Enacted	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
Nuclear Energy Enabling Technologies				
Crosscutting Technology Development	50,000	50,000	17,400	-32,600
Nuclear Energy Advanced Modeling and Simulation	28,200	31,000	30,000	-1,000
Energy Innovation Hub for Modeling and Simulation	30,000	27,585	0	-27,585
Nuclear Science User Facilities	50,800	44,000	27,600	-16,400
Transformational Challenge Reactor	0	0	23,450	+23,450
Total, Nuclear Energy Enabling Technologies	**159,000**	**152,585**	**98,450**	**-54,135**

SBIR/STTR:

- FY 2018 Enacted: SBIR $5,088; STTR $716
- FY 2019 Enacted: SBIR $4,883; STTR $687
- FY 2020 Request: SBIR $3,150; STTR $443

Nuclear Energy Enabling Technologies
Explanation of Major Changes
($K)

	FY 2020 Request vs FY 2019 Enacted
Crosscutting Technology Development (CTD):	
The decrease from $50,000,000 to $17,400,000 refocuses the advanced manufacturing research methods previously conducted under the CTD subprogram into the TCR subprogram. In FY 2020, the CTD subprogram will focus primarily on sensors and instrumentation research and cybersecurity.	**-32,600**
Nuclear Energy Advanced Modeling and Simulation (NEAMS):	
The decrease from $31,000,000 to $30,000,000 reflects a decrease of $3,000,000 due to the completion of MW-scale reactor modeling and simulation directed in FY 2019 and an increase of $2,000,000 for the incorporation of scope from the M&S Hub that must continue in order to address pressing light-water reactor industry needs.	**-1,000**
Energy Innovation Hub for Modeling and Simulation (M&S Hub)	
The decrease from $27,585,000 to $0 reflects the completion of the second and final five year performance period for the M&S Hub. Ongoing scope incorporated into NEAMS.	**-27,585**
Nuclear Science User Facilities (NSUF):	
The decrease from $44,000,000 to $27,600,000 reflects a consolidation of the competitive facility access awards and facility capability enhancement investments by the NSUF program.	**-16,400**
Transformational Challenge Reactor (TCR):	
The increase from $0 to $23,450,000 provides support for advanced manufacturing methods to manufacture components of a small/micro advanced reactor using additive manufacturing concepts.	**+23,450**
Total, Nuclear Energy Enabling Technologies	**-54,135**

Crosscutting Technology Development

Description

The Crosscutting Technology Development (CTD) subprogram competitively awards pioneering early-stage research and development (R&D) funding to U.S. industry, U.S. universities, and national laboratory partners to develop innovative solutions to crosscutting nuclear energy technology challenges. The CTD subprogram focuses on foundational research that addresses technical gaps in order to support and enable new state-of-the-art transformative technologies needed to maintain the current fleet of nuclear reactors and support the development of advanced reactors (including small modular reactors and microreactors) and advanced fuels. CTD is closely 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, early-stage R&D to improve the economics, quality, security, and efficiencies of nuclear technologies.

The focus areas for FY 2020 include advanced sensors and instrumentation and nuclear cybersecurity research.

- Advanced Sensors and Instrumentation supports R&D of unique sensor and instrumentation technologies needed to monitor and control new advanced reactors and fuel cycle facilities.
- Nuclear Cybersecurity supports innovative cybersecurity capability development to address cyber threats to the U.S nuclear power infrastructure.
- Other crosscutting areas could be considered based on industry needs and funding availability.

Crosscutting Technology Development

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Crosscutting Technology Development $50,000,000	**$17,400,000**	**-$32,600,000**
• Competitively solicit and award new fully-funded research and development (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. • Continue 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 early-stage research on integrated energy systems to support nuclear and renewables co-generation and nuclear/industrial applications.	• Competitively solicit and award new fully-funded R&D projects in the advanced sensors and instrumentation area with applicability to next generation reactor and fuel cycle technologies. • Continue advanced sensors and instrumentation and advanced methods for manufacturing research initiated in prior years. • Conduct research on nuclear cybersecurity to address cyber threats to the U.S. nuclear power infrastructure. Areas of emphasis in FY 2020 include developing standards for reducing supply chain risks and integrating nuclear safety risk management with cybersecurity risk management to better inform whole plant risk.	• The decrease in funding will maintain cyber security at the FY 2019 level, while consolidating funding for other Crosscutting Technology Development technology research with a primary focus on advanced sensors and instrumentation research and cybersecurity. • No new work will be initiated in the advanced methods for manufacturing or integrated energy systems activities in FY 2020. • Advanced methods for manufacturing research will be conducted under the Transformational Challenge Reactor subprogram element.

Nuclear Energy Advanced Modeling and Simulation

Description

Nuclear Energy Advanced Modeling and Simulation (NEAMS) develops and deploys a set of predictive analytic computer tools called the NEAMS ToolKit, which has been primarily focused on advanced reactor technologies but specifically flexible to accommodate different reactor types and designs. 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 the Office of Nuclear Energy (NE) program priorities, such as the development of fuels with enhanced accident tolerance.

The Energy Innovation Hub for Modeling &Simulation (M&S Hub) developed and deployed a reactor simulation tool set called the Virtual Environment for Reactor Applications (VERA), which is focused on light water reactor (LWR) technologies for an improved understanding of important operational and safety issues in existing commercial reactors. The 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 to analyze light-water based small modular reactor designs currently under development in the United States.

Through an enhanced NEAMS programmatic framework, NEAMS and VERA tools will be crucial in supporting NE's three priority areas: Existing Fleet, Advanced Reactor Pipeline, and the Fuel Cycle Infrastructure. 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 industry to accelerate advanced reactor development and meet otherwise cost-prohibitive data needs and will support Nuclear Regulatory Commission efforts to address its confirmatory analysis needs. For fuel cycle technologies, continued modeling and simulation tool development will provide capabilities that can support future used nuclear fuel research and development, 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

<table>
<tr><th>FY 2019 Enacted</th><th>FY 2020 Request</th><th>Explanation of Changes
FY 2020 Request vs FY 2019 Enacted</th></tr>
<tr><td>Nuclear Energy Advanced Modeling and Simulation
$31,000,000</td><td>$30,000,000</td><td>-$1,000,000</td></tr>
<tr><td>• Initiate development of an advanced modeling and simulation capability for micro-reactor concepts, including coupled models of heat pipe, metallic fuel, and mechanical response of structure and neutronics.
• Accelerate deployment and validation of the Nuclear Energy Advanced Modeling and Simulation (NEAMS) ToolKit.
− Expand engagement with industry through the Gateway for Accelerated Innovation in Nuclear (GAIN) infrastructure and new competitively awarded projects focused on industry needs in both the existing nuclear fleet and advanced reactor development.
− Apply advanced coupled capabilities to advanced thermal-fluids solutions needed by industry through the Center for Advanced Thermal-Hydraulics Simulations at the Idaho National Laboratory (INL).
− Enable acceleration of Accident Tolerant Fuel (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 tools to enable industry to accelerate development and enhance marketability of existing and advanced reactor concepts</td><td>• Continue deployment and validation of the NEAMS ToolKit.
− Engage industry through GAIN infrastructure and competitively award projects focused on industry needs in both the existing nuclear fleet and advanced reactor development.
− Apply advanced coupled capabilities to advanced thermal-fluids solutions needed by industry through the Center for Advanced Thermal-Hydraulics Simulations at the 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.
• Engage NEAMS/VERA user communities to focus on those capability enhancements that have broad application to each reactor technology area, and offer greater potential impact in accelerating implementation of new concepts.
• Collaborate with the NRC to implement necessary confirmatory analysis capabilities for ATF and advanced reactor technologies.</td><td>• The decrease in funding reflects a decrease of $3,000,000 due to the completion of MW-scale reactor modeling and simulation directed in FY 2019 and an increase of $2,000,000 for the incorporation of scope from the Modeling and Simulation Hub that must continue in order to address pressing light-water reactor industry needs.</td></tr>
</table>

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
– Release code updates across the NEAMS and Virtual Environment for Reactor Applications (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.		

Energy Innovation Hub for Modeling and Simulation

Description

The Energy Innovation Hub for Modeling and Simulation (M&S 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 M&S Hub has provided the insights and tools needed by industry to address these key issues. Consequently, the Department has fully met its M&S Hub objectives and it is being brought to closure. Hub-developed capabilities, such as the Virtual Environment for Reactor Analysis (VERA) tool suite, will be integrated into the Nuclear Energy Advanced Modeling & Simulation (NEAMS) program and deployed along with NEAMS tools to industry for commercial application to existing and advanced reactors.

Energy Innovation Hub for Modeling and Simulation

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Energy Innovation Hub for Modeling and Simulation $27,585,000	**$0**	**-27,585,000**
• Provide access of Virtual Environment for Reactor Applications (VERA) tools to industry stakeholders. • Consolidate remaining VERA research activities within the Nuclear Energy Advanced Modeling and Simulation subprogram to improve efficiencies by leveraging capabilities and resources.	• No funding is requested in the FY 2020 budget.	• The decrease in funding reflects the successful completion of the second and final five year performance period for the Modeling and Simulation Hub.

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 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Nuclear Science User Facilities $44,000,000	**$27,600,000**	**-$16,400,000**
• Provide facility access awards in three FY 2019 Rapid Turnaround Experiment solicitations, the FY 2019 Consolidated Innovative Nuclear Research (CINR) solicitation, and in support of the Funding Opportunity Announcement issued in FY 2018, which are 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.	• Provide facility access awards in three FY 2020 Rapid Turnaround Experiment solicitations and the FY 2020 CINR solicitation. All awards would be fully funded. • Invest in select domestic scientific infrastructure capabilities to better support the advancement of applied research and development in support of the Office of Nuclear Energy mission. • Continue to enhance NSUF's unique nuclear scientific capabilities that are offered at the Idaho National Laboratory and the NSUF Partner Institutions. This collaborative user facility model will allow more efficient use of the NSUF program funds by leveraging facility and capability investments. • Continue to enhance the NFML and the Nuclear Energy Infrastructure Database (NEID). Expand the tools available to NSUF researchers by offering a Combined Materials Experiment Toolkit (CoMET) that offers on-line experiment design tools and subject matter expertise integrated with the NMFL and NEID.	• The decrease in funding reflects a consolidation of the competitive facility access awards and facility capability enhancement investments by the NSUF Program.

Transformational Challenge Reactor

Description

The Transformational Challenge Reactor (TCR) subprogram provides a revolutionary platform to demonstrate the ability to reduce the deployment costs and timelines for nuclear energy systems.

The TCR subprogram enhances the development of breakthrough technologies that provide the ability to manufacture small/micro advanced reactor components using additive manufacturing techniques. A central goal of the TCR program is to demonstrate the ability to exploit advanced manufacturing techniques and digital predictive analysis capabilities to deliver a new approach to nuclear design and qualification for advanced reactor technologies. It will combine advanced manufacturing with materials and computational sciences to predict optimal performance of components to enable faster innovation and certification. Successful execution of the TCR program will result in demonstration of a digital platform for coupling data analytics with nuclear core design, manufacturing and testing data to certify component performance.

TCR subprogram goals:

- Dramatically reduce the deployment costs and timelines of nuclear energy systems while maintaining safety, simplifying operations.
- Integrate digital platforms for manufacturing, design, and qualification to enable rapid nuclear innovation.
- Fully leverage capabilities and expertise across the national laboratory complex to deliver on its goals.

Transformational Challenge Reactor

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Transformational Challenge Reactor $0	**$23,450,000**	**+$23,450,000**
• No funds requested under the Nuclear Energy Enabling Technology (NEET) program; $30 million provided under the Reactor Concepts Research, Development and Demonstration (RD&D) program.	• Continue the Transformational Challenge Reactor (TCR) subprogram initiated in FY 2019 under the Reactor Concepts RD&D program to demonstrate the ability to develop advanced additive manufacturing concepts and apply to reactor applications. • Continue non-nuclear system research and development demonstration efforts. • Continue to develop the digital manufacturing platform for the surrogate core.	• The increase in funding will initiate the TCR subprogram within the NEET program to demonstrate the ability to manufacture a small/micro advanced reactor using additive manufacturing techniques.

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 2020 Budget Request

In FY 2020, the RRI subprogram, in support of its mission and objectives, 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 select universities and 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, initiated in FY 2017, of reusing lightly-irradiated TRIGA fuel in the DOE inventory and evaluate additional alternatives to the current sole-source supply issue.

Radiological Facilities Management
Funding
($K)

	FY 2018 Enacted	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
Radiological Facilities Management				
Oak Ridge Nuclear Infrastructure	20,000	20,000	0	-20,000
Research Reactor Infrastructure	9,000	9,000	9,000	0
Total, Radiological Facilities Management	**29,000**	**29,000**	**9,000**	**-20,000**

Radiological Facilities Management
Explanation of Major Changes
($K)

	FY 2020 Request vs FY 2019 Enacted
Oak Ridge Nuclear Infrastructure: The decrease from $20,000,000 to $0 represents completion of one-time congressionally directed nuclear infrastructure activities. Infrastructure used for Office of Nuclear Energy research and development is fully funded through associated FY 2020 program budgets.	**-20,000**
Research Reactor Infrastructure: There are no changes in the FY 2020 Budget Request.	**0**
Total, Radiological Facilities Management	**-20,000**

Radiological Facilities Management
Oak Ridge Nuclear Infrastructure

Description

Consistent with congressional direction, this subprogram provided funds in FY 2019 to support Oak Ridge National Laboratory (ORNL) hot cells. In FY 2020, Office of Nuclear Energy use of these facilities is fully funded through associated program budgets.

Oak Ridge Nuclear Infrastructure

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Oak Ridge Nuclear Infrastructure $20,000,000	**$0**	**-$20,000,000**
• Install the lazy susan and the lazy susan glovebox for Building 7920. • Complete installation of the K-15l ventilation system components at the Irradiated Fuels Examination Facility and perform final testing to demonstrate operability. • Install new manipulators in Building 3525 and continue with the procurement effort for the three remote manipulators at Building 3525. • Complete the design for the replacement of the Hot Cell Support Area ventilation system and initiate procurement of HEPA housing. • Replace the air compressors at Building 7930 for the Radiochemical Engineering Development Center (REDC) facilities to improve reliability of the plant air system that supports the safety class ventilation systems. • Initiate procurement of two portable waste tanks for the Non-Reactor Nuclear Facilities Division (NNFD) manipulator shop to replace the aging tank and improve efficiency of decontamination operations. • Develop size reduction capabilities and dry decontamination capabilities in Building 3525 to allow disposition of large waste items from the 3525 hot cells.	• No funding is requested.	• Decrease represents completion of one-time congressionally directed nuclear infrastructure activities. 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 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Research Reactor Infrastructure $9,000,000	**$9,000,000**	**+$0**
• Procure 40 and deliver between 33 and 36 plate fuel elements required annually by University of Missouri (MURR) and Massachusetts Institute of Technology (MIT) as determined by need and fuel availability. • Ship up to two cask loads of lightly-irradiated 8.5 wt% standard Training, Reactor, Isotope, General Atomics (TRIGA) fuel elements from the Irradiated Fuel Storage Facility at Idaho National Laboratory (INL) to select 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 Savannah River Site (SRS) and the INL, pending resolution of moratorium on such shipments to the INL. • Continue 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 select 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 and ship fuel elements to TRIGA reactor facilities as determined by need and fuel availability. • 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.	• No change.

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 2020 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 2020, these activities include:

- Operating and maintaining the ATR Complex, the Transient Reactor Test Facility (TREAT), and key nuclear facilities at the MFC in a safe and compliant manner, including the Remote-Handled Low-Level Waste Disposal Facility following turnover to operations in FY 2019.
- Improving the reliability and availability of the ATR to meet research customer demands. This strategy, jointly developed with Naval Reactors, will increase efficiency and irradiation days through risk-based prioritization of plant, equipment, and experimental loop investments.
- Addressing infrastructure gaps identified and required to fulfill the NE Mission by initiating construction activities for the Sample Preparation Laboratory following Critical Decision 3 approval.

Idaho Facilities Management
Funding
($K)

	FY 2018 Enacted	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
Idaho Facilities Management				
INL Nuclear Research Reactor Operations and Maintenance	120,739	119,000	103,491	-15,509
INL Non-Reactor Nuclear Research Facility Operations and Maintenance	149,830	152,286	84,890	-67,396
INL Engineering and Support Facility Operations and Maintenance	7,112	7,321	6,500	-821
INL Regulatory Compliance	10,319	9,393	9,119	-274
Construction	6,000	30,000	5,242	-24,758
Total, Idaho Facilities Management[1]	**294,000**	**318,000**	**209,242**	**-108,758**

[1] Funding does not reflect the transfer of approximately $85.5M in FY 2018 and $85.5M in FY 2019 from Naval Reactors for maintenance and operation of the Advanced Test Reactor.

Idaho Facilities Management
Explanation of Major Changes
($K)

	FY 2020 Request vs FY 2019 Enacted
INL Nuclear Research Reactor Operations and Maintenance: The decrease from $119,000,000 to $103,491,000 reflects completion of strategic investments to improve Advanced Test Reactor (ATR) availability and reliability, such as nuclear instrumentation replacement, emergency coolant pump replacement, and experiment loop refurbishment, and to support the upcoming ATR Core Internals Change-out, including activities to optimize ATR canal operations. The Budget Request provides funding for operating and maintaining ATR, continued investments to improve ATR availability and reliability, and base operations at the Transient Reactor Test Facility (TREAT).	**-15,509**
INL Non-Reactor Nuclear Research Facility Operations and Maintenance: The decrease from $152,286,000 to $84,890,000 reflects completion of strategic investments at the Materials and Fuels Complex (MFC), such as hot cell window and manipulator replacement, HVAC upgrades, and roof replacements, and one time investment in FY 2019 Appropriations in the MFC Analytical Laboratory HVAC and Controls Upgrade General Plant Project. The Budget Request provides funding for operating and maintaining key nuclear facilities at the MFC and base operations at the Remote-Handled Low-Level Waste (RHLLW) Disposal Facility.	**-67,396**
INL Engineering and Support Facility Operations and Maintenance: The decrease from $7,321,000 to $6,500,000 reflects lower projected costs for federally-funded activities that support implementation of the Idaho Facilities Management (IFM) program. The Budget Request provides funding to support Federally-funded program activities, community regulatory support activities, and meeting obligations defined in crosscutting agreements and contracts.	**-821**
INL Regulatory Compliance: The decrease from $9,393,000 to $9,119,000 reflects lower projected costs for continued compliance with State and Federal environmental laws and other regulations. The Budget Request provides funding to support activities for continued compliance with State and Federal environmental laws and other regulations that are under the purview of the Office of Nuclear Energy, including efforts that support continued compliance with the 1995 Settlement Agreement with the State of Idaho.	**-274**
Construction: The decrease from $30,000,000 to $5,242,000 reflects completion of full first year award of the Sample Preparation Laboratory (SPL) construction subcontract and start of construction, following partial first year award in FY 2019.	**-24,758**
Total, Idaho Facilities Management	**-108,758**

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 reactors are both located at the Materials and Fuels Complex (MFC).

The ATR is the primary research reactor at the INL. The ATR supports the majority of Office of Nuclear Energy (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 (NSUF). R&D demand for neutron irradiation at ATRC and neutron radiography and small component test irradiation at NRAD has increased significantly over the past several years. The TREAT reactor, also supporting NE R&D and the NSUF, continues to address challenges related to nuclear-fuel performance and qualification. All programmatic work is funded by the sponsoring federal programs. The cost to other users is determined in accordance with 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 continue in FY 2019 and FY 2020 to refurbish and replace major ATR components and systems in order to improve the availability and reliability of the ATR. This strategy, jointly developed with NR, addresses a significant portion of the Top 100 Plant Heath Committee items and eliminates the majority of ATR deferred maintenance items by the completion of the next Core Internals Change-out (CIC). In FY 2018, strategic investments led the ATR to achieve 173 irradiation days of a total planned 186.3 days, resulting in a cumulative operating efficiency of 92.9%. This operating efficiency was the highest achieved since 2002, and work executed as part of this strategy reduced ATR deferred maintenance by $20M. One of the Idaho Facilities Management Performance Measures is to enable nuclear research and development activities by providing operational facilities and capabilities, as measured by availability percentages, and with ATR’s availability of 92.9%, the performance measure target of 80% availability was achieved. ATR operations and maintenance activities are jointly funded by NE and NR.

In FY 2018, TREAT completed all activities for unrestricted reactor operation 2 months ahead of schedule. Following these activities, TREAT successfully performed a Loss of Coolant Accident (LOCA) and Reactivity Insertion Accident (RIA). TREAT also performed the first two fueled experiments in the reactor since 1987 which provided the opportunity to operate the new fuel motion monitoring system with fuel in an experimental device. Transient testing activities will continue in FY 2019 in support of fuel development and testing programs.

INL Nuclear Research Reactor Operations and Maintenance

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
INL Nuclear Research Reactor Operations and Maintenance $119,000,000	**$103,491,000**	**-$15,509,000**
• Maintain an Advanced Test Reactor (ATR) operating efficiency greater than 80% with a target of 169 irradiation days. • Continue investments to improve ATR availability and reliability through refurbishments and replacements of reactor systems and components such as primary coolant system refurbishment, confinement seals and system refurbishment, and reactor data acquisition system replacement. • Continue preparatory activities for the ATR Core Internals Change-out (CIC), currently planned for 2021, such as staging all required parts, rigging, and tools, and completing a management self-assessment. • Continue transient testing base operations at the Transient Reactor Test Facility (TREAT).	• Maintain an ATR operating efficiency greater than 80% with a target of 182 irradiation days. • Continue investments to improve ATR availability and reliability through refurbishments and replacements of reactor systems and components such as primary coolant pump check valve replacement, 2400 V switchgear replacement, and ATR simulator refurbishment. • Continue preparatory activities for the ATR CIC, currently planned for 2021, such as completing all required procedures and work packages. • Continue transient testing base operations at TREAT.	• The decrease reflects completion of strategic investments to improve ATR availability and reliability, such as nuclear instrumentation replacement, emergency coolant pump replacement, and experiment loop refurbishment, and to support the upcoming ATR CIC, including activities to optimize ATR canal operations.

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 (R&D) 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 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 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 is provided to ensure facility availability and equipment reliability at MFC is as high as feasible to enable research and development activities. In FY 2018, in part due to addressing legacy equipment and facility issues, cumulative facility availability for the MFC was 81.0%, achieving the performance measure target of 80%. Plant Health investments at MFC, accomplished through the 5 year investment plan, continue to focus on improving availability and throughput in MFC mission facilities. In FY 2018, investments included hot cell manipulators and window replacements, 40 ton crane part fabrication and argon supply system installation at the Hot Fuels Examination Facility (HFEF), and scientific equipment purchases for the fuels and Applied Sciences Building. These investments resulted in the highest output at HFEF in FY 2018, a 96% mission completion rate across MFC, and enabled R&D achievements which were published in hundreds of papers and presentations at technical and scientific conferences in FY 2018, documenting the work achieved by the laboratory to the scientific community. FY 2018 also brought the completion of the Irradiated Materials Characterization Laboratory (IMCL) thermal properties cell, the last item of the IMCL equipment plan, and a key strategic asset for post-irradiation examination. In FY 2019, funding is provided for a one time investment in the MFC Analytical Laboratory HVAC and Controls Upgrade General Plant Project.

A major achievement of FY 2018, the Remote-Handled Low-Level Waste (RHLLW) Disposal Facility Project obtained approval of Critical Decision (CD)-4, *Project Completion*, 6 months ahead of schedule and approximately $4.5M under budget. The resulting RHLLW Disposal Facility provides for the continued capability to dispose of RHLLW, ensuring continuity of operations for both NE and Naval Reactors (NR) missions at the Idaho National Laboratory. The current waste disposal site, the Radioactive Waste Management Complex (RWMC), has been in operation since 1952 and will soon be unavailable due to closure. This subprogram provides funding for RHLLW Disposal Facility base operations, and waste emplacements will begin in FY 2019.

INL Non-Reactor Nuclear Research Facility Operations and Maintenance

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
INL Non-Reactor Nuclear Research Facility Operations and Maintenance $152,286,000	**$84,890,000**	**-$67,396,000**
• Operate and maintain Materials and Fuels Complex (MFC) infrastructure and facilities to support facility operations and programmatic work activities, and address emergent conditions. • Perform maintenance within the MFC nuclear facilities and infrastructure consistent with the approved safety bases. • Continue off-site disposition of surplus Nuclear Energy (NE)-owned special nuclear material (SNM) 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. Emplace initial waste shipment in 2nd quarter of FY 2019. • One time investment in the MFC Analytical Laboratory HVAC and Controls Upgrade General Plant Project from FY 2019 Appropriations. • Continue MFC infrastructure investments, such as hot cell window and manipulator replacement, HVAC upgrades, and roof replacements.	• 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 SNM consistent with programmatic needs and approved nuclear material allotment forecasts. • Operate and maintain the RHLLW Disposal Facility to provide newly-generated waste disposal capability.	• The decrease reflects completion of strategic infrastructure investments at MFC in FY 2019 such as hot cell window and manipulator replacement, HVAC upgrades, and roof replacements.

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 the 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 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
INL Engineering and Support Facility Operations and Maintenance $7,321,000	**$6,500,000**	**-$821,000**
• Continue to support 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 (PILT), and environmental monitoring to support State requirements.	• Continue to support Federally-funded activities to maintain operations at the INL such as NRC certificates for casks, PILT, and environmental monitoring to support State requirements.	• The decrease reflects lower projected costs for federally-funded activities that support implementation of the Idaho Facilities Management program.

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 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
INL Regulatory Compliance $9,393,000	**$9,119,000**	**-$274,000**
• Continue regulatory compliance program management. • Meet Idaho National Laboratory (INL) Site Treatment Plan milestones for treatment of two cubic meters of Mixed Low-Level Waste (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 Experimental Breeder Reactor II (EBR-II) used nuclear fuel.	• 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.	• The decrease reflects lower projected costs for continued compliance with State and Federal environmental laws and other regulations.

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 Office of 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 has completed final design and is developing documentation and conducting reviews necessary to support approval of Critical Decision (CD)-2, Approve Performance Baseline, and approval of CD-3, Approve Start of Construction, and initiate SPL construction by 4Q FY 2019. Congressional direction in FY 2019 provided $30M to initiate construction activities post-CD-3 through partial first year award of the construction subcontract. Capital funding in FY 2020 would provide the funding required to complete full first year award of the construction subcontract and place execution of SPL construction on the most expeditious path to completion.

In the Mission Need Statement, approved June 18, 2015, NE identified the need for an advanced Post-Irradiation Examination (PIE) capability as a limiting factor in moving towards a science-based nuclear energy research, development, and demonstration (RD&D) program in the FY 2020 – FY 2025 timeframe. The SPL will 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, world-leading 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 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Construction $30,000,000	**$5,242,000**	**-$24,758,000**
Sample Preparation Laboratory (16-E-200) ($30,000,000) • Achieve approval of Critical Decision (CD)-2, Approve Performance Baseline, achieve approval of CD-3, Approve Start of Construction, and support partial first year award of the Sample Preparation Laboratory (SPL) project construction subcontract.	*Sample Preparation Laboratory (16-E-200) ($5,242,000)* • Funding is requested to complete the full first year award of the SPL construction subcontract and begin construction activities.	*Sample Preparation Laboratory (16-E-200) (-$24,758,000)* • The decrease from $30,000,000 to $5,242,000 reflects completion of full first year award of the SPL construction subcontract and start of construction, following partial first year award in FY 2019.

Idaho Facilities Management
Capital Summary
($K)

	Total	Prior Years	FY 2018 Enacted	FY 2018 Actuals	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
Capital Operating Expenses Summary (including Major Items of Equipment)							
Capital Operating Expenses	n/a	2,475	14,182	14,182	750	0	-750
Total, Capital Operating Expenses	**n/a**	**2,475**	**14,182**	**14,182**	**750**	**0**	**-750**
Minor Construction Projects							
Total Direct Funded Minor Construction Projects (TEC <$5M)	n/a	0	1,435	1,435	0	0	0
Materials and Fuel Complex Analytical Laboratory HVAC and Controls Upgrade General Plant Project	n/a	0	0	0	10,904	0	-10,904
Total, Minor Construction Projects	**n/a**	**0**	**1,435**	**1,435**	**10,904**	**0**	**-10,904**
Total, Capital Summary	**n/a**	**2,475**	**15,617**	**15,617**	**11,654**	**0**	**-11,654**

Idaho Facilities Management
Construction Projects Summary
($K)

	Total	Prior Years	FY 2018 Enacted	FY 2018 Actuals	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
16-E-200, Sample Preparation Laboratory, INL							
Total Estimated Cost (TEC)	86,000	8,000	6,000	6,000	30,000	5,242	-24,758
Other Project Costs (OPC)	12,200	4,647	0	0	0	0	0
Total Project Cost (TPC) Project Number 16-E-200	**98,200**	**12,647**	**6,000**	**6,000**	**30,000**	**5,242**	**-24,758**
Total All Construction Projects							
Total Estimated Cost (TEC)	86,000	8,000	6,000	6,000	30,000	5,242	-24,758
Total Other Project Costs (OPC)	12,200	4,647	0	0	0	0	0
Total Project Cost (TPC) All Construction Projects	**98,200**	**12,647**	**6,000**	**6,000**	**30,000**	**5,242**	**-24,758**

16-E-200, Sample Preparation Laboratory
Idaho National Laboratory
Project is for Design and Construction

1. Summary, Significant Changes, and Schedule and Cost History

Summary

The most recent DOE Order 413.3B approved Critical Decision (CD) is for CD-1, which was approved on September 30, 2016. Approval of CD-1 established a cost range for the design and construction of the Sample Preparation Laboratory (SPL) of $72.7M to $98.2M, with a CD-4 date of 4Q FY 2022. The SPL project has completed final design and is developing documentation and conducting reviews necessary to support approval of CD-2, Approve Performance Baseline, and approval of CD-3, Approve Start of Construction, and initiate SPL construction by 4Q FY 2019. Congressional direction in FY 2019 provided $30M to initiate construction activities post-CD-3 through partial first year award of the construction subcontract. Capital funding in FY 2020 would provide the funding required to complete full first year award of the construction subcontract and place execution of SPL construction on the most expeditious path to completion. In the Mission Need Statement, approved June 18, 2015, NE identified the need for an advanced post-irradiation examination (PIE) capability as a limiting factor in moving towards a science-based nuclear energy research, development, and demonstration (RD&D) program in the FY 2020 – FY 2025 timeframe.

The SPL will 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 will, when coupled with existing facilities and recapitalization efforts, fulfill near-term capabilities necessary for conducting the advanced post-irradiation examination needed to improve understanding of nuclear fuels and material performance at the micro-, nano-, and atomic scales. In accordance with the National Environmental Policy Act (NEPA) (42 USC§ 4321 et seq.), a thorough analysis of the environmental consequences of the design, construction, and operation of the SPL was completed to support CD-1 approval.

The proposed laboratory will include capabilities that will allow high hazard materials to be routinely prepared and tested in a safe, secure, and controlled environment. In addition, this laboratory will contribute to the suite of capabilities fulfilling near-term advanced post-irradiation examination needs that will serve as a center for advanced fuels and materials characterization, as well as development of new processes, tools, and instruments to further research.

A Level 2 Federal Project Director has been assigned to this project.

Significant Changes

This Construction Project Data Sheet (CPDS) is an update of the FY 2018 CPDS and does not include a new start for FY 2020.

Critical Milestone History

(Fiscal Quarter or Date)

Fiscal Year	CD-0	Conceptual Design Complete	CD-1	CD-2	Final Design Complete	CD-3	D&D Complete	CD-4
FY 2016	1/31/2011	4Q FY2014	3Q FY2015	TBD	TBD	TBD	TBD	TBD
FY 2017	6/18/2015	1Q FY2016	1Q FY2016	TBD	TBD	TBD	N/A	TBD
FY 2018	6/18/2015	8/31/2016	9/30/2016	TBD	TBD	TBD	N/A	TBD
FY 2019	6/18/2015	8/31/2016	9/30/2016	TBD	TBD	TBD	N/A	TBD
FY 2020	6/18/2015	8/31/2016	9/30/2016	TBD	TBD	TBD	N/A	TBD

CD-0 – Approve Mission Need for a construction project with a conceptual scope and cost range
Conceptual Design Complete – Actual date the conceptual design was completed (if applicable)
CD-1 – Approve Alternative Selection and Cost Range
CD-2 – Approve Performance Baseline

Final Design Complete – Estimated/Actual date the project design will be/was complete (d)
CD-3 – Approve Start of Construction
D&D Complete – Completion of D&D work
CD-4 – Approve Start of Operations or Project Closeout

Fiscal Year	Performance Baseline Validation	CD-3A	CD-3B
FY 2016	TBD	TBD	TBD
FY 2017	TBD	TBD	TBD
FY 2018	TBD	N/A	N/A
FY 2019	TBD	TBD	TBD
FY 2020	TBD	TBD	TBD

CD-3A – Approve Long-Lead Procurements, Original Scope
CD-3B – Approve Long-Lead Procurements, Revised Scope

Project Cost History

Fiscal Year	TEC, Design	TEC, Construction	TEC, Total	OPC, Except D&D	OPC, D&D	OPC, Total	TPC
FY 2016	10,000	68,000	78,000	17,000	0	17,000	95,000
FY 2017	10,000	73,000	83,000	12,000	0	12,000	95,000
FY 2018	13,385	72,615	86,000	12,200	0	12,200	98,200
FY 2019	13,385	72,615	86,000	12,200	0	12,200	98,200
FY 2020	13,385	72,615	86,000	12,200	0	12,200	98,200

a. Project costs revised based on preliminary scoping of project based on updated Mission Need Statement approved 3Q FY 2015.
b. Project costs are preliminary pending CD-2 approval and represent the high end of the cost range.

No construction will be performed until the project performance baseline has been validated and CD-3 has been approved.

CD-3A activities will be approved by the PME outside of the CD process.

2. Project Scope and Justification

<u>Scope</u>

The Sample Preparation Laboratory (SPL) will be designed and constructed to receive irradiated materials and to prepare samples for micro-/nano-scale structural, chemical, mechanical, and thermal properties analyses. The improved sample preparation and analytical capabilities provided by SPL will enhance non-destructive examination, elemental, and radiological capabilities already present at the Materials and Fuels Complex (MFC).

SPL will provide the required capabilities to allow high hazard materials to be routinely prepared and tested in a safe, secure, and environmentally controlled environment. To meet this objective, SPL will be designed and constructed to include the following specific capabilities:

- Next generation radiation-shielded enclosures designed for regular manned access when radioactive samples are not present. The shielded enclosures will be flexible and reconfigurable to accommodate operational requirements for use with modern characterization instruments.
- The facility will be designed to meet stringent vibration, electrical and magnetic field, acoustic, and temperature fluctuation requirements for advanced analytical equipment with the ability to support development and deployment of equipment, instruments, and models to meet future nuclear fuel development R&D needs over a 40-year period.

- The facility will be designed to provide operational flexibility and streamlined workflow processes, including handling of radioactive fuels and materials.
- The facility will include enhanced material handling capabilities using robotics and vision technologies in radioactive sample, specimen, and equipment handling applications.
- The facility will include state-of-the art sample preparation technologies and equipment.
- The facility will support advanced data collection and management capabilities to enable efficient use by advanced modeling and simulation assets.
- The facility will provide interim storage for radioactive material experiments subject to examination.
- The facility will be designed to include radioactive waste management capabilities.

The initial complement of scientific instruments will be procured, remotized (as needed), and tested as part of the project prior to installation in the facility.

The SPL facility will be an alpha-limited post-irradiation examination facility and operate in conjunction with the Hot Fuel Examination Facility, Analytical Laboratory, IMCL, and offsite facilities to provide the overall capability to analyze and characterize irradiated and non-irradiated nuclear material samples. The SPL facility will not replace these facilities; it will function synergistically with them. Having most of these facilities located within a single security-protected site (i.e., MFC) supports efficient nuclear material control, security, and management.

Facility operations will include cask receipt and unloading, experiment decontamination, sample preparation (e.g., machining, grinding, and polishing), sample storage, waste packaging, and various microstructure and thermal examinations. The majority of these operations will take place within shielded cells and enclosures due to the radioactivity of the materials handled. These include the Sample Preparation Line, the Mechanical Properties Test Cell (MPTC), and the shielded instrument rooms. The facility is anticipated to be a Hazard Category 3 nuclear facility.

A wide variety of samples will be handled in the facility. Non-alpha emitting samples will include solids or contained powders. In some cases, very small quantities of non-dispersible alpha-emitting material (i.e., fuels) may be received in the form of metallurgical mounts for examination using the advanced examination capabilities deployed at SPL. Nuclear materials and samples will be received in containers ranging from the Battelle Energy Alliance, LLC (BEA) research reactor cask to shielded/non-shielded 55 gallon drums, incorporating a truck lock for cask and related container handling. The primary method of sample transfer within the SPL facility will be via a progressive pass-along process through the sample preparation line of hot cells. Once processed in the hot cells, the materials will be distributed to the MPTC, a glove box, IMCL, or to the individual shielded instrument rooms. Transfer of samples within the SPL facility will be via a pneumatic transfer system. Samples will also be transferred within the facility and to other facilities via small shielded pigs or casks that mate to the outside of the hot cells. Samples will be appropriately shielded and confined to protect workers, equipment, and the facility. Preliminary key performance parameters (KPPs) were established for the project at CD-1. KPPs are defined as a vital characteristic, function, requirement, or design basis that, if changed, would have a major impact on the facility or system performance, scope, schedule, cost, risk, or the ability of an interfacing project to meet its mission requirements. The KPPs represent the minimum acceptable scope for successful delivery of SPL. Achievement of KPPs will be a prerequisite for approval of CD-4. If project performance is sustained, management reserve and/or contingency funds can be allocated to contingent scope or infrastructure enhancements to improve facility performance. The KPPs provided herein are preliminary, pre-baseline objectives. The final KPPs will be established as part of CD-2/3.

Preliminary SPL threshold and objective KPPs.

Performance Measure	Threshold	Objective
Shielded sample preparation capability inclusive of work areas for cask receipt, material handling, gross source material sizing, and fine sample preparation	Five sample preparation workstations/windows	N/A
Shielded specimen examination/testing capability, inclusive of instrumentation/hardware and shielded enclosure	Three shielded scientific instrument enclosures Three advanced scientific instruments Mechanical Properties Test Cell with three testing stations and associated equipment/instruments	Up to one additional shielded instrument enclosure and up to four additional non-shielded instrument enclosures Up to five additional advanced scientific instruments

The proposed facility will be a Hazard Category 3 nuclear facility. Design and construction of the facility will include provisions for meeting the Guiding Principles for Federal Leadership in High Performance and Sustainable Building per Executive Order 13693 *"Planning for Federal Sustainability in the Next Decade."*

Funds appropriated under this data sheet may be used to provide independent assessments related to project planning and execution.

Justification

The behavior of fuels and materials in a nuclear reactor irradiation environment is the limiting factor in nuclear plant safety, longevity, efficiency, and economics. During the last 15 years, nano-scale (i.e., 10^{-9} meter) characterization of nonnuclear materials has become routine, with capabilities for sub-angstrom (i.e., 10^{-10}meter) investigation becoming increasingly available to researchers in other fields. An understanding of nuclear fuel and material performance in the nuclear reactor internal environment at this scale is critical to development of the innovative fuels and materials required for tomorrow's nuclear energy systems.

Existing post-irradiation examination and thermal and mechanical properties testing capabilities at U.S. Department of Energy (DOE) laboratories, universities, and in the private sector are widely dispersed. Current post-irradiation examination capabilities serve basic needs for fuel examination, material handling, and waste disposal, but are limited in their ability to function on the micro, nano, and atomic scale. Advanced characterization of radioactive samples at nano-scale to micro-scale length resolutions will support development of modern computer codes that could enable order-of-magnitude improvements in the time and cost of developing new fuels.

The SPL facility will support a variety of programs and users by receiving irradiated nuclear materials and by preparing samples for micro-/nano-scale structural, chemical, mechanical, and thermal properties analyses. This improved sample preparation capability will enhance non-destructive examination, elemental, and radiological capabilities already present at the Materials and Fuels Complex (MFC). The SPL may also provide source material and sample storage capability. The laboratory will, when coupled with existing facilities and recapitalization efforts, fulfill near-term advanced post-irradiation capabilities necessary for conducting the advanced post-irradiation examination needed to improve understanding of nuclear fuels and materials performance at the micro-, nano-, and atomic scales. This new understanding will allow for the development of innovative fuels and materials that can be used by the nuclear energy community. Irradiation-driven phenomena can only be understood through conducting a scientific program that includes experimental irradiation testing and post-irradiation examination, materials characterization, and testing coupled with modeling and simulation.

The project is being conducted in accordance with the project management requirements in DOE Order 413.3B, Program and Project Management for the Acquisition of Capital Assets.

3. Financial Schedule

(Dollars in Thousands)

	Budget Authority (Appropriations)	Obligations	Costs
Total Estimated Cost (TEC)			
Design			
Prior Years	8,000	8,000	33
FY 2018	5,385	5,385	6,484
FY 2019	0	0	TBD
FY 2020	TBD	TBD	TBD
Construction			
FY 2018	615	615	0
FY 2019	30,000	30,000	TBD
FY 2020	5,242	TBD	TBD
Total Estimated Costs (TEC)			
Prior Years	8,000	8,000	33
FY 2018	6,000	6,000	6,484
FY 2019	30,000	30,000	TBD
FY 2020	5,242	TBD	TBD
Total TEC	**TBD**	**TBD**	**TBD**
Other Project Costs			
Prior Years	4,647	4,647	2,279
FY 2018	0	0	477
FY 2019	0	0	TBD
FY 2020	0	TBD	TBD
Outyears	TBD	TBD	TBD
Total OPC	TBD	TBD	TBD
Total Project Costs (TPC)			
Prior Years	12,300	12,300	2,312
FY 2018	6,000	6,000	6,961
FY 2019	30,000	30,000	TBD
FY 2020	5,242	TBD	TBD
Outyears	TBD	TBD	TBD
Grand Total	**TBD**	**TBD**	**TBD**

4. Details of Project Cost Estimate

(Budget Authority in Thousands of Dollars)

	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
Total Estimated Cost (TEC)			
Design			
Design	10,785	8,500	N/A
Contingency	2,600	1,500	N/A
Total, Design	13,385	10,000	N/A
Construction			
Site Work	2,230	6,000	N/A
Equipment	8,545	15,000	N/A
Construction	56,840	40,500	N/A
Other, as needed	--	--	--
Contingency	5,000	11,500	N/A
Total, Construction	72,615	73,000	N/A
Other TEC (if any)			
Cold Startup	--	--	--
Contingency	--	--	--
Total, Other TEC	--	--	--
Total **Estimated Cost**	86,000	83,000	N/A
Contingency, TEC	7,600	13,000	N/A
Other Project Cost (OPC)			
OPC except D&D			
R&D	4,220	2,000	N/A
Conceptual Planning	1,310	1,930	N/A
Conceptual Design	821	4,500	N/A
Other OPC Costs	4,549	2,370	N/A
Contingency	1,300	1,200	N/A
Total, OPC	12,200	12,000	N/A
Contingency, OPC	1,300	1,200	N/A
Total Project Cost	98,200	95,000	N/A
Total Contingency (TEC+OPC)	8,900	14,200	N/A

5. Schedule of Appropriation Requests

(Dollars in Thousands)

Request Year	Type	Prior Years	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021	FY 2022	FY 2023	Total
FY 2016	TEC	0	2,000	TBD	TBD	TBD	TBD	0	0	0	78,000
	OPC	347	1,500	TBD	TBD	TBD	TBD	0	0	0	17,000
	TPC	347	3,500	TBD	TBD	TBD	TBD	0	0	0	95,000
FY 2017	TEC	0	2,000	6,000	TBD	TBD	TBD	TBD	TBD	TBD	83,000
	OPC	347	1,500	2,800	TBD	TBD	TBD	TBD	TBD	TBD	12,000
	TPC	347	3,500	8,800	TBD	TBD	TBD	TBD	TBD	TBD	95,000
FY 2018	TEC	0	2,000	6,000	6,000	TBD	TBD	TBD	TBD	TBD	86,000
	OPC	347	1,500	2,800	0	TBD	TBD	TBD	TBD	TBD	12,200
	TPC	347	3,500	8,800	6,000	TBD	TBD	TBD	TBD	TBD	98,200
FY 2019	TEC	0	2,000	6,000	6,000	TBD	TBD	TBD	TBD	TBD	86,000
	OPC	347	1,500	2,800	0	TBD	TBD	TBD	TBD	TBD	12,200
	TPC	347	3,500	8,800	6,000	TBD	TBD	TBD	TBD	TBD	98,200
FY 2020	TEC	0	2,000	6,000	6,000	30,000	5,242	TBD	TBD	TBD	86,000
	OPC	347	1,500	2,800	0	0	0	TBD	TBD	TBD	12,200
	TPC	347	3,500	8,800	6,000	30,000	5,242	TBD	TBD	TBD	98,200

6. Related Operations and Maintenance Funding Requirements

Start of Operation or Beneficial Occupancy (fiscal quarter or date)	4Q FY 2022
Expected Useful Life (number of years)	40
Expected Future Start of D&D of this capital asset (fiscal quarter)	4Q FY 2062

Related Funding Requirements
(Budget Authority in Millions of Dollars)

	Annual Costs		Life Cycle Costs	
	Previous Total Estimate	Current Total Estimate	Previous Total Estimate	Current Total Estimate
Operations and Maintenance	N/A	8,264	N/A	785,042

Life-cycle operations and maintenance costs include annual escalation.

7. D&D Information

The new area being constructed in this project is not replacing existing facilities.

	Square Feet
New area being constructed by this project at [Lab]	Up to 44,000
Area of D&D in this project at [Lab]	0
Area at [Lab] to be transferred, sold, and/or D&D outside the project, including area previously "banked"	0
Area of D&D in this project at other sites	0
Area at other sites to be transferred, sold, and/or D&D outside the project, including area previously "banked"	0
Total area eliminated	0

Site location, building name or numbers, and square footages of existing facilities to be replaced: N/A

As a new Laboratory facility, the proposed SPL is not subject to Freeze the Footprint (>50% lab space).

8. Acquisition Approach

As a Hazard Category 3 nuclear facility, design and construction of the SPL must be integrated with ongoing nuclear operations activities. Design and construction must also be coordinated/integrated with nuclear R&D programs. Therefore, a design-bid-build project delivery method managed by the INL management and operating contractor will be used for the design and construction of the SPL. A fixed price construction subcontract is anticipated for construction of the SPL.

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 2020 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 2020 Budget Request

In FY 2020, 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 2020 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 continued 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 2018 Enacted	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
Idaho Sitewide Safeguards and Security				
Protective Forces	71,802	76,881	79,450	+2,569
Security Systems	10,575	10,075	10,075	0
Security Infrastructure	7,339	16,839	5,988	-10,851
Information Security	4,674	4,674	4,674	0
Personnel Security	8,703	7,714	7,714	0
Material Control & Accountability	4,876	4,876	4,876	0
Program Management	8,175	8,175	8,175	0
Cybersecurity	16,856	16,856	16,856	0
Total, Idaho Sitewide Safeguards and Security	**133,000**	**146,090**	**137,808**	**-8,282**

Idaho Sitewide Safeguards and Security
Explanation of Major Changes
($K)

	FY 2020 Request vs FY 2019 Enacted
Protective Forces:	
The increase from $76,881,000 to $79,450,000 reflects costs for additional protective force staff to support Phase IIA Implementation Plan activities consistent with Departmental protection requirements. Funding also supports additional protective force equipment, training, facilities, and management consistent with approved protection strategy.	**+2,569**
Security Systems:	**0**
There are no changes to the budget.	
Security Infrastructure:	**-10,851**
The decrease from $16,839,000 to $5,988,000 reflects completion of Phase IIA Implementation Plan activities and the limited start of Phase IIB Implementation plan activities consistent with the approved protection strategy. The decrease also reflects the one-time congressionally funded activity to construct a protective forces facility at the ATR Complex.	
Information Security:	**0**
There are no changes to the budget.	
Personnel Security:	**0**
There are no changes to the budget.	
Material Control & Accountability:	**0**
There are no changes to the budget.	
Program Management:	**0**
There are no changes to the budget.	
Cybersecurity:	**0**
There are no changes to the budget.	
Total, Idaho Sitewide Safeguards and Security	**-8,282**

Idaho Sitewide Safeguards and Security

Description

The Idaho Sitewide Safeguards and Security (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 the 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 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Protective Forces $76,881,000	**$79,450,000**	**+$2,569,000**
• Provides funds for additional protective force staff to fully implement security infrastructure Phase I Implementation Plan activities consistent with the Site Security Plan and begin Phase IIA staff increase, approved site labor wage agreement, and Idaho National Laboratory (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.	• Provides funds for additional protective force staff to continue 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 funds for additional protective force staff to support Phase IIA Implementation Plan activities consistent with the approved protection strategy for integrating Departmental security requirements.
Security Systems $10,075,000	**$10,075,000**	**+$0**
• Provides funding for operations and maintenance of the INL security system, consisting of approximately 6,500 alarm points, 800 security card reader devices, over 450 access portals, and 144 security areas at the Limited Area level or higher.	• Provides full funding for staff and equipment to plan and conduct preventative and corrective maintenance on physical security systems across multiple security areas. • Supports the operation of INL central alarm stations, development and modification of security alarm systems and life cycle replacement of systems.	• No change.
Security Infrastructure $16,839,000	**$5,988,000**	**-$10,851,000**
• 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. • Initiation of Advanced Test Reactor (ATR) Complex Security Building (with no additional funds needed for completion in FY 2020).	• Supports planned Implementation Plan Phase IIA activities and initial Implementation of Phase IIB by performing design work, related analyses, and modifications to support a multi-year effort to enhance physical security infrastructure across several INL complexes.	• Change reflects completion of Phase IIA Implementation Plan activities and the limited start of Phase IIB Implementation Plan activities consistent with the approved protection strategy. The change also reflects that no additional funds are needed for the completion of the ATR Complex Security Building.

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Information Security $4,674,000	**$4,674,000**	**+$0**
• 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.	• 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.	• No change.
Personnel Security $7,714,000	**$7,714,000**	**+$0**
• Provides partial funding 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. • Supports personnel security services for Office of Nuclear Energy (NE) headquarters staff, including the maintenance and processing of staff security clearances.	• Provides partial funding for federal and contractor personnel security programs including processing, tracking and adjudication of security investigations, including the reduction in case backlog, 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 NE headquarters staff.	• No change.
Material Control & Accountability (MC&A) $4,876,000	**$4,876,000**	**+$0**
• Provides 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.	• Provides funds to maintain the site's SNM database and tracking systems, coordinate on-and off-site material movements, and to conduct SNM inventories.	• No change.
Program Management $8,175,000	**$8,175,000**	**+$0**
• 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	• Provides funding to improve program management functions, including develop, update, and maintain security program documentation, vulnerability/risk assessments and to conduct performance testing to assure program effectiveness in the implementation of Departmental Orders. • Provides funds to support force-on-force exercises which directly test the efficacy of the protection	• No change.

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
methodology and posture and allow for risk-informed decision making.	methodology and posture and allow for risk-informed decision making.	
Cybersecurity $16,856,000	**$16,856,000**	**+$0**
• 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. • Continues maintenance and operation of the Idaho National Laboratory (INL) Industrial Control Systems cybersecurity program. • Continues to implement the formal cloud assurance program across INL.	• Provides funding for certification and accreditation activities for classified and unclassified cybersecurity systems, a key activity in FY 2020 to maintain an effective cybersecurity program consistent with the Department's measured risk management and vulnerability and incident management strategies including staffing, training, tools, and hardware/software lifecycle replacement. • Continue to maintain and operate the INL Industrial Control Systems cybersecurity program. • Continue to improve network traffic visibility and further develop advanced forensic capabilities. • Maintain 24/7 intrusion detection and prevention monitoring, ensuring that incidents and breaches are discovered and remediated as soon as possible.	• No change.

Idaho Sitewide Safeguards and Security
Capital Summary
($K)

	Total	Prior Years	FY 2018 Enacted	FY 2018 Actuals	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
Capital Operating Expenses Summary (including Major Items of Equipment)							
Minor Construction	n/a	0	5,150	5,150	15,339	4,488	-10,851
Total, Capital Operating Expenses	**n/a**	**0**	**5,150**	**5,150**	**15,339**	**4,488**	**-10,851**
Minor Construction Projects							
ATR Complex Security Building	10,000	0	0	0	10,000	0	-10,000
Security Infrastructure Phase IIB	9,300	0	0	0	0	4,488	+4,488
Security Infrastructure Phase IIA project 1	5,700	0	3,900	3,900	1,800	0	-1,800
Security Infrastructure Phase IIA project 2	5,300	0	1,250	1,250	3,539	0	-3,539
Total, Minor Construction Projects	**30,300**	**0**	**5,150**	**5,150**	**15,339**	**4,488**	**-10,851**
Total, Capital Summary	**n/a**	**0**	**5,150**	**5,150**	**15,339**	**4,488**	**-10,851**

International Nuclear Energy Cooperation

Overview

The International Nuclear Energy Cooperation (INEC) program's mission has been 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 have contributed to international bilateral and multilateral engagement and civil nuclear energy research and development (R&D) activities with countries that are considering development of, or currently have, a civilian nuclear power sector. INEC has utilized 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 has been its support of advocacy for the U.S. commercial nuclear sector, including industry vendors and utilities, via direct engagement with foreign governments. Such support could contribute to increased nuclear exports, which in turn contribute to domestic infrastructure development and job creation.

INEC has provided 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 has engaged 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 has also leveraged 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 2020 Budget Request

In alignment with Administration reforms, this request consolidates the DOE international staffing currently within the Office of Nuclear Energy into the headquarters Office of International Affairs (IA).

International Nuclear Energy Cooperation
Funding
($K)

	FY 2018 Enacted	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
International Nuclear Energy Cooperation				
International Nuclear Energy Cooperation	3,000	3,000	0	-3,000
Total, International Nuclear Energy Cooperation	**3,000**	**3,000**	**0**	**-3,000**

International Nuclear Energy Cooperation
Explanation of Major Changes ($K)

	FY 2020 Request vs FY 2019 Enacted
International Nuclear Energy Cooperation:	
The decrease from $3,000,000 to $0 reflects the transfer of work to the Office of International Affairs (IA).	**-3,000**
Total, International Nuclear Energy Cooperation	**-3,000**

International Nuclear Energy Cooperation

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs. FY 2019 Enacted
International Nuclear Energy Cooperation $3,000,000	**$0**	**-$3,000,000**
• Provide country-specific policy and logistical support required to effectively implement NE's bilateral nuclear energy research and development (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 the Secretary and senior U.S. Department of Energy (DOE) leadership on all international nuclear matters, including numerous bilateral meetings and support for international nuclear related missions such as the International Atomic Energy Agency (IAEA). • Continue to manage International Nuclear Research Initiatives (INERI) collaborative partnerships on research and development projects with the European Atomic Energy Community (EURATOM) and Republic of Korea that focus on advanced nuclear technologies for	• Activities will be transferred to the Office of International Affairs (IA).	• Activities will be transferred to IA.

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs. FY 2019 Enacted
improving the cost, safety and proliferation-resistance of nuclear energy systems. • Continue ongoing activities with the International Framework for Nuclear Energy Cooperation (IFNEC) exploring multinational cooperation on used fuel disposal. • Continue collaboration with the United Kingdom, France, India, and Japan through mechanisms such as 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. • 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. Headquarters, Oak Ridge Operations Office, the Nevada Site Office, and the Idaho 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, business functions, and public outreach. 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: employee health and testing services, and consolidated training and recruitment initiatives; all established in previous fiscal years and supported in FY 2020.

In addition to appropriated funds, NE also manages approximately $200 million 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 FY 2020 Program Direction Budget 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 NE.

Highlights of the FY 2020 Budget Request
In alignment with Administration reforms, the FY 2020 Program Direction Budget Request consolidates the DOE international staffing currently within NE into the headquarters Office of International Affairs.

The FY 2020 Program Direction Budget Request also reflects a transfer of $13.5 million of scope from NE Research and Development Program Direction to the new Yucca Mountain and Interim Storage Program.

Program Direction
Funding
($K)

	FY 2018 Enacted	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
Program Direction				
Salaries and Benefits	50,944	52,908	42,106	-10,802
Travel	1,376	1,512	1,377	-135
Support Services	9,031	10,255	7,179	-3,076
Other Related Expenses	18,649	15,325	13,688	-1,637
Total, Program Direction	**80,000**	**80,000**	**64,350**	**-15,650**

Program Direction
Explanation of Major Changes
($K)

	FY 2020 Request vs FY 2019 Enacted
Salaries and Benefits:	
The decrease from $52,908 to $42,106 reflects the transfer of funding for personnel costs of employees to support the Yucca Mountain and Interim Storage Program, as well as the transfer of employees supporting the International Nuclear Energy Cooperation (INEC) program to International Affairs (IA).	**-10,802**
Travel:	
The decrease from $1,512 to $1,377 reflects the transfer of travel funding associated with the employees supporting the Yucca Mountain and Interim Storage Program, as well as the transfer of travel funding for the employees supporting INEC to IA.	**-135**
Support Services:	
The decrease from $10,255 to $7,179 reflects the transfer of support service funding associated with the needs of the Yucca Mountain and Interim Storage Program as well as the transfer of support service funding for the employees supporting INEC to IA.	**-3,076**
Other Related Expenses:	
The decrease from $15,325 to $13,688 reflects the transfer of funds for WCF, Training, and Rent charges to support the needs of the Yucca Mountain and Interim Storage Program, as well as the transfer of other related expenses funding for the employees supporting INEC to IA.	**-1,637**
Total, Program Direction	**-15,650**

Program Direction
Funding
($K)

	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
Program Direction Summary			
Washington Headquarters			
Salaries and Benefits	28,632	19,945	-8,687
Travel	1,080	945	-135
Support Services	8,250	5,174	-3,076
Other Related Expenses	7,445	5,935	-1,510
Total, Washington Headquarters	**45,407**	**31,999**	**-13,408**
Oak Ridge Operations Office			
Salaries and Benefits	456	456	0
Travel	7	7	0
Support Services	1,075	1,075	0
Other Related Expenses	108	108	0
Total, Oak Ridge Operations Office	**1,646**	**1,646**	**0**
Nevada Site Office			
Salaries and Benefits	2,114	0	-2,114
Travel	0	0	0
Support Services	0	0	0
Other Related Expenses	128	0	-128
Total, Nevada Site Office	**2,242**	**0**	**-2,242**
Idaho Operations Office			
Salaries and Benefits	21,706	21,706	0
Travel	425	425	0
Support Services	930	930	0
Other Related Expenses	7,645	7,645	0
Total, Idaho Operations Office	**30,706**	**30,706**	**0**

	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
Total Program Direction			
Salaries and Benefits	52,908	42,106	-10,802
Travel	1,512	1,377	-135
Support Services	10,255	7,179	-3,076
Other Related Expenses	15,325	13,688	-1,637
Total, Program Direction	**80,000**	**64,350**	**-15,650**
Federal FTEs	**291**	**256**	**-35**
Support Services			
Technical Support			
Mission Related	1,913	1,339	-574
Advisory and Assistance	2,213	1,550	-663
Total, Technical Support	4,126	2,889	-1,237
Management Support			
Administrative	3,453	2,416	-1,037
IT	2,676	1,874	-802
Total Management Support	6,129	4,290	-1,839
Total, Support Services	**10,255**	**7,179**	**-3,076**
Other Related Expenses			
Working Capital Fund	6,505	5,500	-1,005
Training	265	190	-75
Miscellaneous	6,095	5,603	-492
Rents and Utilities	2,460	2,395	-65
Total, Other Related Expenses	**15,325**	**13,688**	**-1,637**

Program Direction

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Program Direction $80,000,000	**$64,350,000**	**-$15,650,000**
Salaries and Benefits $52,907,867	**$42,106,572**	**-$10,801,295**
Provides salaries and benefits for 291 federal staff (FTEs).	Provides salaries and benefits for 256 FTEs.	The decrease of 35 FTEs reflects the transfer of funding for personnel costs of employees to support the Yucca Mountain and Interim Storage Program, as well as the transfer of employees supporting the International Nuclear Energy Cooperation (INEC) program to International Affairs (IA).
Travel $1,512,000	**$1,377,000**	**-$135,000**
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.	The decrease reflects the transfer of funding from travel to support the Yucca Mountain and Interim Storage Program, as well as the transfer of travel for supporting the INEC program to IA.
Support Services $10,255,000	**$7,178,828**	**-$3,076,172**
Provides for technical and administrative support services for the NE federal staff.	Provides for technical and administrative support services for the NE federal staff.	The decrease reflects the transfer of funding from support services to support the Yucca Mountain and Interim Storage Program, as well as the transfer of activities supporting the INEC program to IA.
Other Related Expenses $15,325,133	**$13,687,600**	**-$1,637,533**
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.	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.	The decrease reflects the transfer of funding from other related expenses to support the Yucca Mountain and Interim Storage Program, as well as the transfer of activities supporting the INEC program to IA.

Nuclear Energy
Small Business Innovative Research/Small Business Technology Transfer (SBIR/STTR)
($K)

	FY 2018 Enacted	FY 2019 Enacted	FY 2020 Request
STEP R&D			
SBIR	160	160	0
STTR	22	22	0
Reactor Concepts RD&D			
SBIR	7,584	10,352	3,685
STTR	1,066	1,456	518
Fuel Cycle R&D			
SBIR	7,602	7,725	2,880
STTR	1,069	1,086	405
Nuclear Energy Enabling Technologies			
SBIR	5,088	4,883	3,150
STTR	716	687	443
Total, SBIR	**20,434**	**23,120**	**9,715**
Total, STTR	**2,873**	**3,251**	**1,366**

Nuclear Energy
Research and Development
($K)

	FY 2018 Enacted	FY 2019 Enacted	FY 2020 Request
Basic	0	0	0
Applied	842,796	892,113	505,950
Development	329,592	401,519	205,824
Subtotal, R&D	**1,172,388**	**1,293,632**	**711,774**
Equipment	0	0	0
Construction	0	0	0
Total, R&D	**1,172,388**	**1,293,632**	**711,774**[1]

[1] FY 2020 Nuclear Energy R&D distribution reflects the final Congressional Justification modified after the closure of the President's Budget data base.

Nuclear Energy
Safeguards and Security
($K)

	FY 2018 Enacted	FY 2019 Enacted	FY 2020 Request
Idaho Sitewide Safeguards and Security			
Protective Forces	71,802	76,881	79,450
Security Systems	10,575	10,075	10,075
Security Infrastructure	7,339	16,839	5,988
Information Security	4,674	4,674	4,674
Personnel Security	8,703	7,714	7,714
Material Control & Accountability	4,876	4,876	4,876
Program Management	8,175	8,175	8,175
Cybersecurity	16,856	16,856	16,856
Total, Idaho Sitewide Safeguards and Security	**133,000**	**146,090**	**137,808**

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 and are intended to halt asset condition degradation. This excludes maintenance of excess facilities (including high-risk excess facilities) necessary to minimize the risk posed by those facilities prior to disposition.

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

	FY 2018 Actual Cost	FY 2018 Planned Cost	FY 2019 Planned Cost	FY 2020 Planned Cost
Idaho National Laboratory	67,569	30,441	25,186	22,120
Total, Direct-Funded Maintenance and Repair	67,569	30,441	25,186	22,120

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

	FY 2018 Actual Cost	FY 2018 Planned Cost	FY 2019 Planned Cost	FY 2020 Planned Cost
Idaho National Laboratory	40,073	25,393	25,362	21,082
Total, Indirect-Funded Maintenance and Repair	40,073	25,393	25,362	21,082

Report on FY 2018 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 2018 to the amount planned for FY 2018, including congressionally directed changes.

Nuclear Energy
Total Costs for Maintenance and Repair
($K)

	FY 2018 Actual Cost	FY 2018 Planned Cost
Idaho National Laboratory	107,642	55,834
Total, Maintenance and Repair	**107,642**	**55,834**

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 2018.

Nuclear Energy
Excess Facilities

Costs for Direct-Funded
($K)

	FY 2018 Actual Cost	FY 2018 Planned Cost	FY 2019 Planned Cost	FY 2020 Planned Cost
Idaho National Laboratory	2,576	3,483	1,159	0
Total, Direct-Funded Excess Facilities	2,576	3,483	1,159	0

Costs for Indirect-Funded
($K)

	FY 2018 Actual Cost	FY 2018 Planned Cost	FY 2019 Planned Cost	FY 2020 Planned Cost
Idaho National Laboratory	0	0	0	500
Total, Indirect-Funded Excess Facilities	0	0	0	500

Department Of Energy

FY 2020 Congressional Budget

Funding by Appropriation by Site

($K)

Nuclear Energy	FY 2018 Total Enacted	FY 2019 Enacted	FY 2020 Request
Argonne National Laboratory			
Fuel Cycle R & D			
Fuel Cycle R & D	8,608	6,490	1,060
Program Direction-NE			
Program Direction-NE	100	0	0
Nuclear Energy Enabling Technologies			
Nuclear Energy Enabling Technologies	7,667	6,380	5,780
Reactors Concepts RD&D			
Reactors Concepts RD&D	20,242	21,170	22,350
International Nuclear Energy Cooperation			
International Nuclear Energy Cooperation	155	195	0
Total, Argonne National Laboratory	**36,772**	**34,235**	**29,190**
Bechtel Marine Propulsion Center			
Fuel Cycle R & D			
Fuel Cycle R & D	7,000	7,000	0
Total, Bechtel Marine Propulsion Center	**7,000**	**7,000**	**0**
Brookhaven National Laboratory			
Fuel Cycle R & D			
Fuel Cycle R & D	2,406	1,444	730
Nuclear Energy Enabling Technologies			
Nuclear Energy Enabling Technologies	650	650	500
Reactors Concepts RD&D			
Reactors Concepts RD&D	102	210	150
Total, Brookhaven National Laboratory	**3,158**	**2,304**	**1,380**
Chicago Operations Office			
Nuclear Energy Enabling Technologies			
Nuclear Energy Enabling Technologies	428	234	234
Total, Chicago Operations Office	**428**	**234**	**234**

Department Of Energy

FY 2020 Congressional Budget

Funding by Appropriation by Site

($K)

Nuclear Energy	FY 2018 Total Enacted	FY 2019 Enacted	FY 2020 Request
Idaho National Laboratory			
Fuel Cycle R & D			
Fuel Cycle R & D	58,013	56,307	13,390
Radiological Facilities Management			
Radiological Facilities Management	8,948	8,949	8,948
Idaho Facilities Management			
Idaho Facilities Management	287,437	310,708	202,742
Idaho Sitewide Safeguards and Security			
Idaho Sitewide Safeguards and Security	129,183	142,191	133,909
Program Direction-NE			
Program Direction-NE	280	0	0
Nuclear Energy Enabling Technologies			
Nuclear Energy Enabling Technologies	71,846	64,354	38,675
Reactors Concepts RD&D			
Reactors Concepts RD&D	70,537	110,310	120,350
International Nuclear Energy Cooperation			
International Nuclear Energy Cooperation	838	1,415	0
Supercritical Transformational Electric Power Generation			
Supercritical Transformational Electric Power Generation	53	0	0
Total, Idaho National Laboratory	**627,135**	**694,234**	**518,014**
Idaho Operations Office			
University Research Program			
University Research	5,000	0	0
Fuel Cycle R & D			
Fuel Cycle R & D	85,822	77,515	24,211
Radiological Facilities Management			
Radiological Facilities Management	44	44	44
Idaho Facilities Management			
Idaho Facilities Management	6,072	6,072	5,500
Idaho Sitewide Safeguards and Security			
Idaho Sitewide Safeguards and Security	3,697	3,697	3,697
Program Direction-NE			
Program Direction-NE	37,486	30,706	30,706
Nuclear Energy Enabling Technologies			
Nuclear Energy Enabling Technologies	16,370	17,360	14,360
Reactors Concepts RD&D			
Reactors Concepts RD&D	97,700	94,005	40,500
International Nuclear Energy Cooperation			
International Nuclear Energy Cooperation	1,249	1,117	0
Supercritical Transformational Electric Power Generation			
Supercritical Transformational Electric Power Generation	998	0	0
Total, Idaho Operations Office	**254,438**	**230,516**	**119,018**

Department Of Energy

FY 2020 Congressional Budget

Funding by Appropriation by Site

($K)

Nuclear Energy	**FY 2018 Total Enacted**	**FY 2019 Enacted**	**FY 2020 Request**
Lawrence Berkeley National Laboratory			
Fuel Cycle R & D			
Fuel Cycle R & D	3,397	2,765	290
Nuclear Energy Enabling Technologies			
Nuclear Energy Enabling Technologies	0	200	200
Total, Lawrence Berkeley National Laboratory	**3,397**	**2,965**	**490**
Lawrence Livermore National Laboratory			
Fuel Cycle R & D			
Fuel Cycle R & D	793	791	100
Nuclear Energy Enabling Technologies			
Nuclear Energy Enabling Technologies	75	150	150
Reactors Concepts RD&D			
Reactors Concepts RD&D	0	0	50
Total, Lawrence Livermore National Laboratory	**868**	**941**	**300**
Livermore Site Office			
Reactors Concepts RD&D			
Reactors Concepts RD&D	50	50	0
Total, Livermore Site Office	**50**	**50**	**0**
Los Alamos National Laboratory			
Fuel Cycle R & D			
Fuel Cycle R & D	11,708	10,730	2,800
Nuclear Energy Enabling Technologies			
Nuclear Energy Enabling Technologies	4,563	3,293	2,650
Reactors Concepts RD&D			
Reactors Concepts RD&D	3,575	6,260	2,500
Total, Los Alamos National Laboratory	**19,846**	**20,283**	**7,950**
Nevada Field Office			
Program Direction-NE			
Program Direction-NE	2,459	2,241	0
Total, Nevada Field Office	**2,459**	**2,241**	**0**

Department Of Energy

FY 2020 Congressional Budget

Funding by Appropriation by Site

($K)

Nuclear Energy	**FY 2018 Total Enacted**	**FY 2019 Enacted**	**FY 2020 Request**
Oak Ridge National Laboratory			
Fuel Cycle R & D			
Fuel Cycle R & D	23,429	17,351	4,100
Radiological Facilities Management			
Radiological Facilities Management	19,982	19,985	0
Nuclear Energy Enabling Technologies			
Nuclear Energy Enabling Technologies	28,903	22,195	25,385
Reactors Concepts RD&D			
Reactors Concepts RD&D	19,341	17,365	12,000
International Nuclear Energy Cooperation			
International Nuclear Energy Cooperation	530	120	0
Total, Oak Ridge National Laboratory	**92,185**	**77,016**	**41,485**
Oak Ridge Office			
Fuel Cycle R & D			
Fuel Cycle R & D	0	35,000	37,040
Program Direction-NE			
Program Direction-NE	596	1,646	1,646
Total, Oak Ridge Office	**596**	**36,646**	**38,686**
Pacific Northwest National Laboratory			
Fuel Cycle R & D			
Fuel Cycle R & D	14,180	10,214	1,200
Nuclear Energy Enabling Technologies			
Nuclear Energy Enabling Technologies	644	80	80
Reactors Concepts RD&D			
Reactors Concepts RD&D	600	580	600
International Nuclear Energy Cooperation			
International Nuclear Energy Cooperation	50	0	0
Total, Pacific Northwest National Laboratory	**15,474**	**10,874**	**1,880**
Sandia National Laboratories			
Fuel Cycle R & D			
Fuel Cycle R & D	24,310	20,610	1,380
Nuclear Energy Enabling Technologies			
Nuclear Energy Enabling Technologies	2,093	2,853	2,025
Reactors Concepts RD&D			
Reactors Concepts RD&D	3,464	1,845	2,700
International Nuclear Energy Cooperation			
International Nuclear Energy Cooperation	75	15	0
Supercritical Transformational Electric Power Generation			
Supercritical Transformational Electric Power Generation	3,556	4,755	0
Total, Sandia National Laboratories	**33,498**	**30,078**	**6,105**

Department Of Energy

FY 2020 Congressional Budget

Funding by Appropriation by Site

($K)

Nuclear Energy	FY 2018 Total Enacted	FY 2019 Enacted	FY 2020 Request
Savannah River National Laboratory			
Fuel Cycle R & D			
Fuel Cycle R & D	2,750	2,420	190
Total, Savannah River National Laboratory	**2,750**	**2,420**	**190**
Washington Headquarters			
University Research Program			
University Research	0	5,000	0
Fuel Cycle R & D			
Fuel Cycle R & D	17,640	15,278	3,509
Radiological Facilities Management			
Radiological Facilities Management	26	22	8
Idaho Facilities Management			
Idaho Facilities Management	491	1,220	1,000
Idaho Sitewide Safeguards and Security			
Idaho Sitewide Safeguards and Security	120	202	202
Program Direction-NE			
Program Direction-NE	39,079	45,407	31,998
Nuclear Energy Enabling Technologies			
Nuclear Energy Enabling Technologies	25,761	34,836	8,411
Reactors Concepts RD&D			
Reactors Concepts RD&D	21,389	71,705	13,950
International Nuclear Energy Cooperation			
International Nuclear Energy Cooperation	103	138	0
Supercritical Transformational Electric Power Generation			
Supercritical Transformational Electric Power Generation	393	245	0
Total, Washington Headquarters	**105,002**	**174,053**	**59,078**
Total, Nuclear Energy	**1,205,056**	**1,326,090**	**824,000**

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 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, $26,000,000, to remain available until expended.

Yucca Mountain and Interim Storage Program
($K)

FY 2018 Enacted	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
0	0	116,000	+116,000

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
The Yucca Mountain and Interim Storage program is dedicated to resuming regulatory activities concerning Yucca Mountain and initiating a robust interim storage program. The FY 2020 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 FY 2020 Budget Request provides for essential management, subject matter expertise, and other capabilities, such as technical, scientific, and legal support, needed to support the resumption of Yucca Mountain regulatory activities and the development and implementation of a robust interim storage program.

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 2020 Budget Request
The Yucca Mountain and Interim Storage Program FY 2020 Budget Request supports the resumption of the NRC licensing process for the Yucca Mountain site and initiation of a robust interim storage program.

This Budget 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. The Office of Legacy Management (LM) will continue to maintain the official archives until such time as Yucca Mountain and Interim Storage Program is prepared to transfer the electronic records to a modern, cybersecurity compliant system.

The FY 2020 Budget Request includes funding for research, planning, and implementation of robust interim storage enabling consolidation of nuclear waste to complement the disposal system.

The Program Direction budget is structured to support both Yucca Mountain regulatory activities and interim storage. Program Direction supports 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	86,484	0	86,484
Interim Storage	0	6,516	6,516
Program Direction	19,600	3,400	23,000
Total	106,084	9,916	116,000

Financial Assistance and Payments-Equal-to-Taxes
Based on the full funding request of $116 million and consistent with the percentages identified within the Appropriation language, the following table represents a total of $9,513,000 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 2020 funding profile is as follows.

Funding Purpose	Proposed Amount ($ in thousands)
Oversight § 116(c), State of Nevada	$1,879
Oversight § 116(c), AULG	$3,376
Oversight § 118(b), Timbisha Shoshone	$186
PETT § 116(c), State of Nevada	$534
PETT § 116(c), Nye County	$3,480
PETT § 116(c), Clark County	$58
TOTAL	$9,513

Yucca Mountain and Interim Storage
Funding by Congressional Control
($K)

	FY 2018 Enacted	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
Yucca Mountain and Interim Storage				
Yucca Mountain	0	0	86,4848	+86,484
Interim Storage	0	0	6,516	+6,516
Program Direction	0	0	23,000	+23,000
Total, Yucca Mountain and Interim Storage	**0**	**0**	**116,000**	**+116,000**
Federal FTEs	0	0	83	83

Yucca Mountain and Interim Storage Program

Overview

The Yucca Mountain and Interim Storage Program supports the resumption of Nuclear Regulatory Commission regulatory activities related to the Yucca Mountain nuclear waste repository and the development of a robust interim storage program. This program 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.

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 the Yucca Mountain site, 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 review process.

Highlights of the FY 2020 Budget Request

In FY 2020, the primary focus of the Yucca Mountain and Interim Storage Program would be the continuation of Yucca Mountain-related regulatory activities and the initiation of efforts to develop a robust interim storage program.

The Program Direction budget is structured to support both Yucca Mountain-related regulatory activities and interim storage. Program Direction supports a variety of activities including the salaries of federal employees working in furtherance of the NWPA.

The FY 2020 Budget Request proposes funding from two separate appropriation accounts, Nuclear Waste Disposal ($90 million) and Defense Nuclear Waste Disposal ($26 million).

Yucca Mountain and Interim Storage Program
Funding
($K)

	FY 2018 Enacted	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
Yucca Mountain and Interim Storage Program				
Yucca Mountain	0	0	86,484	+86,484
Interim Storage	0	0	6,516	+6,516
Program Direction	0	0	23,000	+23,000
Total, Yucca Mountain and Interim Storage Program	0	0	116,000	+116,000

Yucca Mountain and Interim Storage Program
Explanation of Major Changes
($K)

	FY 2020 Request vs FY 2019 Enacted
Yucca Mountain:	
The increase from $0 to $86,484,000 reflects support for the resumption of the Yucca Mountain site licensing activities to help accelerate progress on fulfilling the Federal Government's obligations to address nuclear waste, enhance national security, and reduce future taxpayer burden.	**+86,484**
Interim Storage:	
The increase from $0 to $6,516,000 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.	**+6,516**
Program Direction:	
The increase from $0 to $23,000,000 reflects the program direction support required to resume Yucca Mountain site licensing activities and support an interim storage program.	**+23,000**
Total, Yucca Mountain and Interim Storage Program	**+116,000**

Description
The Yucca Mountain program requests $86.5 million to restart Nuclear Regulatory Commission (NRC) licensing activities for the Yucca Mountain nuclear waste repository. This subprogram includes the following activities: Licensing Support, Balance of Plant Infrastructure, Project Support, Program Management and Integration, and Litigation.

Regulatory 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; and Safety Analysis Report updates and ongoing LA-configuration control. This Budget Request also includes funding for discovery support required during the licensing proceeding.

As the license applicant to the NRC, the Department of Energy (DOE) must comply with NRC's process and schedule. 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 (GC) staff will represent DOE in the administrative litigation aspects of the licensing process. The GC also will support 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 2020, 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 2020 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, whereby the Secretary is to determine annually the adequacy of the fee charged to generators of commercial spent nuclear fuel. The FY 2020 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 2020 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 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
$0	**$86,484,000**	**+$86,484,000**
• No funding in FY 2019.	• 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 Licensing Board 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. • Continue development of 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 $86,484,000 is for activities necessary for the resumption of the Yucca Mountain site 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) 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), the Department 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 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
$0	**$6,516.000**	**+$6,516,000**
• No funding in FY 2019.	• 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 SNF and HLW shipments. • Maintain minimal support for logistical requirements and analytical capabilities.	• The increase from $0 to $6,516,000 reflects support to develop an interim storage capability for earlier acceptance of SNF to help accelerate progress.

Program Direction

Overview

Program Direction (PD) 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 program staff would be 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. PD 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 2020.

Highlights of the FY 2020 Budget Request

The Yucca Mountain and Interim Storage programs' PD Budget 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.

In FY 2020, funding in PD is allocated between Yucca Mountain site 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	86,484	0	86,484
Interim Storage	0	6,516	6,516
Program Direction	19,600	3,400	23,000
Total	106,084	9,916	116,000

Program Direction
Funding
($K)

	FY 2018 Enacted	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 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**

Program Direction
Funding
($K)

	FY 2018 Enacted	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 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**

	FY 2018 Enacted	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
Support Services				
Technical Support				
Mission Related	0	0	520	+520
Advisory and Assistance	0	0	120	+120
Total, Technical Support	0	0	640	640
Management Support				
Administrative	0	0	510	+510
IT	0	0	600	+600
Total, Management Support	0	0	1,110	+1,110
Total, Support Services	**0**	**0**	**1,750**	**1,750**

Program Direction

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY2019 Enacted
Program Direction $0	**$23,000,000**	**+$23,000,000**
Salaries and Benefits $0	**$18,840,000**	**+$18,840,000**
• No funding in FY 2019.	• Supports the salaries and benefits of 83 employees located in Washington, DC and Las Vegas, NV.	• Supports the salaries and benefits of 83 employees located in Washington, DC and Las Vegas, NV.
Travel $0	**$650,000**	**+$650,000**
• No funding in FY 2019.	• 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**
• No funding in FY 2019.	• Provides for technical and administrative support services for the NE 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 (OECD/NEA).	• Provides for technical and administrative support services for the NE federal staff including access to and participation with external and international nuclear energy organizations such as the OECD/NEA.
Other Related Expenses $0	**$1,760,000**	**+$1,760,000**
• No funding in FY 2019.	• 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.	• 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.

Department Of Energy

FY 2020 Congressional Budget

Funding by Appropriation by Site

($K)

Nuclear Waste Disposal	FY 2018 Total Enacted	FY 2019 Enacted	FY 2020 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	40,686
Total, Nevada Field Office	**0**	**0**	**40,686**
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	35,430
Total, Sandia National Laboratories	**0**	**0**	**35,430**

Department Of Energy

FY 2020 Congressional Budget

Funding by Appropriation by Site

($K)

Nuclear Waste Disposal	FY 2018 Total Enacted	FY 2019 Enacted	FY 2020 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	31,364
Total, Washington Headquarters	**0**	**0**	**31,364**
Total, Nuclear Waste Disposal	**0**	**0**	**116,000**

Advanced Research Projects Agency-Energy

Advanced Research Projects Agency-Energy

Advanced Research Projects Agency - Energy
($K)

FY 2018 Enacted	FY 2019 Enacted	FY 2020 Request
353,314	366,000	-287,000

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 requests no additional appropriation and requests the cancellation of $287,000,000 in unobligated balances. ARPA-E will utilize the remainder of its unobligated balances to execute the multi-year termination of the program, with all operations ceasing by FY 2022.

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.

ARPA-E focuses on energy technologies that can be meaningfully advanced with a targeted investment over a defined period of time. ARPA-E's rigorous program design, close coordination with other DOE offices and federal agencies, competitive project selection process, and hands-on engagement, ensure thoughtful expenditures while empowering America's energy researchers with funding, technical assistance, and market awareness.

ARPA-E was established by the America COMPETES Act of 2007 following a recommendation by the National Academies in the *Rising above the Gathering Storm* report. As of February 2018, ARPA-E has funded over 660 projects with approximately $1.8 billion through focused programs and open funding solicitations.

Highlights and Major Changes in the FY 2020 Budget Request
Under the Budget Request for FY 2020, ARPA-E requests no additional appropriation and will execute the multi-year termination of the program as described in the President's "America First – A Budget Blueprint to Make America Great Again." ARPA-E will utilize reprogrammed carryover to actively manage its $343 million[1] portfolio of forward-funded projects. ARPA-E will not invest in new R&D technologies in FY 2020 and as such will not make additional Small Business Innovation Research / Small Business Technology Transfer (SBIR/STTR) program investments. The FY 2020 Budget Request also includes the cancellation of $287 million of ARPA-E unobligated balances.

[1] "ARPA-E Projects" uncosted balance as of the November 2018

Advanced Research Projects Agency - Energy
Funding by Congressional Control ($K)

	FY 2018 Enacted	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
ARPA-E Projects	324,064	334,750	0	-334,750
Program Direction	29,250	31,250	0	-31,250
Subtotal, Advanced Research Projects Agency - Energy	**353,314**	**366,000**	**0**	**-366,000**
Rescission of Prior Year ARPA-E Project Funds	0	0	-287,000	-287,000
Total, Advanced Research Projects Agency - Energy	**353,314**	**366,000**	**-287,000**	**-653,000**
Federal FTEs	**56**	**60**	**60**	**0**

ARPA-E Projects
Funding ($K)

	FY 2018 Enacted	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
ARPA-E Projects:				
Transportation Systems	162,032	167,375	0	-167,375
Stationary Power Systems	162,032	167,375	0	-167,375
Total, ARPA-E Projects	**324,064**	**334,750**	**0**	**-334,750**

SBIR/STTR

- FY 2018 Current: $10,341 total (SBIR $9,921 / STTR $420)
- FY 2019 Enacted: $12,218 total (SBIR $10,712 / STTR $1,506)
- FY 2020 Request: $0 total (SBIR $0 / STTR $0)

ARPA-E Projects
Explanation of Major Changes ($K)

	FY 2020 Request vs FY 2019 Enacted
Transportation Systems: The Transportation Systems request for FY 2020 is $0 to execute the termination of the program.	**-167,375**
Stationary Power Systems: The Stationary Power Systems request for FY 2020 is $0 to execute the termination of the program.	**-167,375**
Total, ARPA-E Projects	**-334,750**

Department Of Energy

FY 2020 Congressional Budget

Funding by Appropriation by Site

($K)

Advanced Researched Projects Agency-Energy	**FY 2018 Total Enacted**	**FY 2019 Enacted**	**FY 2020 Request**
Washington Headquarters			
Advanced Researched Projects Agency-Energy			
Projects	324,064	334,750	0
Program Direction	29,250	31,250	0
Total, Advanced Researched Projects Agency-Energy	**353,314**	**366,000**	**0**
Total, Washington Headquarters	**353,314**	**366,000**	**0**
Total, Advanced Researched Projects Agency-Energy	**353,314**	**366,000**	**0**

Office of Indian Energy Policy and Programs

Office of Indian Energy Policy and Programs

Office of Indian Energy
Proposed Appropriation Language

For necessary expenses for Indian Energy activities in carrying out the purposes of the Department of Energy Organization Act (42 U.S.C. 7101 et seq.), **[**$18,000,000**]** *$8,000,000*, to remain available until expended: *Provided*, That, of the amount appropriated under this heading, **[**$4,800,000**]** *$3,521,000* shall be available until September 30, **[**2020**]** *2021*, for program direction. *(Energy and Water Development and Related Agencies Appropriations Act, 2019.)*

Explanation of Change

Reflects a $10,000,000 decrease in funding from FY 2019 enacted. This results in a slight decrease to program direction and will have minimal impact on financial assistance and technical assistance.

Public Law Authorizations

Public Law 109-58, “Energy Policy Act” (2005) Title V Sec 502 (a)
Public Law 115-244, FY2019 Consolidated Appropriations Act

Office of Indian Energy
($K)

FY 2018 Enacted	FY 2019 Enacted	FY 2020 Request
$18,000	$18,000	$8,000

Overview

The Office of Indian Energy Policy and Program's (IE) financial and technical assistance are critical to advancing electrification and energy development and deployment on Indian lands, reducing energy costs, and assisting economic development in tribal communities where unemployment and poverty rates far exceed national averages. This assistance is intended to overcome barriers to deploying energy generation projects (used for heat and electric power), as well as energy efficiency projects that result in reduced or stabilized energy costs.

The Financial Assistance program will support funding opportunities toward energy development and electrification in Indian Country in the form of competitive grant awards.

Since 2010, DOE's Office of Indian Energy invested more than $62.5 million in nearly 160 tribal energy projects implemented across the contiguous 48 states and in Alaska. These projects, valued at over $130 million, are leveraged by over $68 million in recipient cost share.

From 2010-2017, DOE invested $25 million in 43 deployment (hardware installation) projects valued at more than $70 million, resulted in tangible results, including:

- Installed 18.5 MW of new generation on tribal lands
- Electricity bills reduced for more than 2,500 tribal government and community buildings and more than 29,000 tribal members
- Every $1 in DOE funding will result in $7.22 savings for those tribe[1]
- Average annual savings of $10M and lifetime savings of a $500 million dollars.

In 2018, DOE announced the selection of an additional 15 projects for award negotiations valued at $25 million which will require l DOE investment of $9 million. These 15 hardware installation projects will result in an additional 10 MW of new generation for more than 900 tribal buildings and homes across the nation, saving those communities more than $1.5 million each year.

Technical Assistance overcomes barriers to project development and builds knowledge and skills necessary to implement energy projects on tribal land. It is available in the following areas: energy efficiency, energy development, electrification, resilience and cost reduction, and human capital building activities that support tribal sovereignty, tribal self-determination, self-sufficiency, and energy security.

[1] [(DOE cost share/total project cost) * total savings from all projects]/DOE cost share: [($24,924,255/$70,135,364)*($507,000,000)]/$24,924,255 (2010-2016 Data)

Office of Indian Energy
Funding by Congressional Control

($K)

	FY 2018 Enacted	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
Assistance Programs[1]				
Financial Assistance	**14,500**	**12,270**	**4,000**	**-8,270**
Technical Assistance	**1,150**	**930**	**479**	**-451**
Total, Assistance Programs	**15,650**	**13,200**	**4,479**	**-8,721**
Program Direction				
Salaries and Benefits	**1,600**	**1,986**	**1,986**	**0**
Travel	**150**	**214**	**75**	**-139**
Support Services	**315**	**1,800**	**1,100**	**-700**
Other Related Expenses	**285**	**800**	**360**	**-440**
Total, Program Direction	**2,350**	**4,800**	**3,521**	**-1,279**
Total, Office of Indian Energy	**18,000**	**18,000**	**8,000**	**-10,000**
Federal FTEs	**7**	**7**	**7**	**0**

[1] Formerly named Tribal Energy Program which was an EERE Program

Office of Indian Energy

Explanation of Major Changes ($K)

	FY 2020 Request vs FY 2019 Enacted
• **Financial Assistance:** Continue to provide competitive grants for energy development, energy cost savings, and electrification in Indian Country.	**-8,270**
• **Technical Assistance:** Continue to provide technical assistance focused on energy development, energy cost savings, and electrification in Indian Country.	**-451**
• **Program Direction:** Maintains federal staffing at current on board level of the necessary levels of FTEs.	**-1,279**
Total, Office of Indian Energy	**-10,000**

Office of Indian Energy
Assistance Programs

Overview

The Office of Indian Energy Policy and Programs (IE) serves all Federally-recognized Indian tribes including Alaska Native villages, Regional Corporations and Village, as well as tribal and intertribal organizations and associations.

Numerous factors burden Indian tribes interested in developing their vast energy resources. Energy and infrastructure development in Indian Country is limited due to inadequate financial and human capital and a complicated legal and regulatory structure governing Indian lands. As a result, more than 175 Alaska Native villages rely almost exclusively on diesel fuel for electricity and oil for heat. In some communities, electricity costs exceed $1.00/kilowatt-hour, more than eight times the national average.

In consultation with tribal and other stakeholders, IE achieves its mission by promoting Indian energy development, electrifying Indian Country, and helping to reduce/ stabilize the cost of electricity. IE achieves the mission through financial assistance, deploying technical assistance, education, and implementing policies, that benefit tribes.

Financial assistance via cooperative agreements and competitive grant awards to Indian tribes support the deployment of energy generation and energy efficiency projects, reducing the cost of energy on Indian lands and building capacity within and between tribes to foster tribal energy development and electrification in Indian Country.

IE is transitioning to become more effective and efficient through the use of local Subject Matter Experts (SME's) to assist Indian tribes and Alaska Native villages in deploying energy projects and providing support for energy planning, project development, transmission interconnection, utility formation, and intertribal coordination to (1) improve energy systems and promote electrification on tribal lands, (2) contribute to domestic energy development and export, and (3) enhance the resilience of remote, rural tribal communities.

Policy initiatives include coordination and collaboration with various sectors of government that are critical to investment, job creation, project development, and operation of energy systems throughout Indian Country, including the Indian Country Energy and Infrastructure Working Group (ICEIWG). ICEIWG advises the Secretary of Energy on behalf of Indian tribes and Alaska Natives regarding policy priorities. Policy analysts survey energy needs and energy resources on Indian lands, including available infrastructure support, and develop strategies for electrification and energy deployment and development. Policy initiatives also include coordination and collaboration through a Memorandum of Understanding with the Department of the Interior on issues including electrification and energy development in Indian Country.

Public-private partnerships encompass industry sectors including finance (lending/debt, institutional and venture capital investment, foundation and other sources of capital), fossil fuel and renewable energy sources, research and development/technology, and human capital building.

Highlights and Major Changes in the FY 2020 Budget Request

IE's FY2020 budget priorities are financial assistance, technical assistance, education & outreach.

- Continue the Financial Assistance program to support funding opportunities toward energy development and electrification in Indian Country.

- Technical Assistance: Reconfigure technical assistance by expanding the local network of service providers to improve effectiveness and efficiency and to target needs of tribes based on data collected and analyzed by IE.

Office of Indian Energy
Assistance Programs

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Office of Indian Energy $18,000,000	**$8,000,000**	**-$10,000,000**
Assistance Programs $13,200,000	**$4,479,000**	**-$8,721,000**
Financial Assistance $12,270,000	**$4,000,000**	**-$8,270,000**
• Competitive grant program supporting energy development and electrification in Indian Country, and associated support contracts.	• Competitive grant program supporting energy development and electrification in Indian Country, and associated support contracts. Financial Assistance: Maximize available funding, including existing prior year carry over balances, for financial assistance awards and expand opportunities for historically underserved populations, including those who have not received funding from IE.	• Continue to provide grants for energy development, energy cost savings, and electrification in Indian Country. The decrease will have minimal impact as existing carry over balances will continue to be executed.
Technical Assistance $930,000	**$479,000**	**$-451,000**
• Technical Assistance disseminates information to Indian Country through in-person and on-line training, internships, regional/national workshops, webinars, and printed guides and materials. • On-request assistance efforts provides high-level support for electrification and energy development in Indian Country. • Efforts will also focus on building partnerships and leveraging resources to maximize education, training, and technical assistance.	• Technical Assistance: Reconfigure technical assistance by expanding the network of local service providers to improve effectiveness and efficiency and to target needs of tribes based on data collected and analyzed by IE. • Education and Outreach: Expand education and internship programs to include K-12, vocational/technical opportunities, and non-traditional students, and increase stakeholder outreach efforts to better educate the public on tribal energy development challenges.	• Continue to provide technical assistance focused on energy development, energy cost savings, and electrification in Indian Country. The decrease will have minimal impact as existing carry over balances will continue to be executed.

Office of Indian Energy
Program Direction

Overview

Program direction provides federal staff responsible for the management and execution of IE's programs and activities, as well as the associated support contractors, rent, supplies, travel, and other related expenses. The staff is responsible for providing overall guidance and direction for DOE program offices on tribal energy activities and initiatives necessary to achieve IE's program objectives and provides day-to-day management of technical assistance, financial assistance, and education programs. Program direction also provides managerial support for the reporting, compliance, and other statutory responsibilities.

The FY 2020 Budget anticipates 7 federal staff: 3 FTEs in Washington, D.C., 2 FTEs in Anchorage, Alaska, and 2 FTEs in Golden, Colorado. The Washington, D.C. staff includes executive leadership, operations, and policy analysis. The Anchorage, Alaska staff provides education and technical assistance for the nearly 230 Alaska Native villages, over 200 Alaska Native regional and village corporations, 13 Alaska Regional Corporations, and 13 regional associations and organizations to promote IE policies and initiatives. The Golden, Colorado staff provides management and oversight for approximately 90 existing financial assistance awards throughout the nation, while delivering technical assistance within the contiguous US for nearly 340 Indian tribes and dozens of tribal and intertribal organizations.

Highlights and Major Changes in the FY 2020 Budget Request

- Education and Outreach: Expand education and internship programs to include K-12, vocational/technical opportunities, and non-traditional students, as well as increasing stakeholder outreach efforts to better educate the public on tribal energy development challenges.
- Support project management and procurement across IE's portfolio of projects, including closing out completed financial assistance awards; and
- Maximize the efficient and effective use of available resources to accomplish IE's core mission while reducing overall expenses and improving the delivery of IE's services in Indian Country.

Program Direction Funding
($K)

	FY 2018 Enacted	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
Program Direction Summary				
Washington Headquarters				
Salaries and Benefits	1,600	1,986	1,986	0
Travel	150	214	75	-139
Support Services	315	1,800	1,100	-700
Other Related Expenses	285	800	360	-440
Total, Washington Headquarters	**2,350**	**4,800**	**3,521**	**-1,279**
Total Program Direction				
Salaries and Benefits	1,600	1,986	1,986	0
Travel	150	214	75	-139
Support Services	315	1,800	1,100	-700
Other Related Expenses	285	800	360	-440
Total, Program Direction	**2,350**	**4,800**	**3,521**	**-1,279**
Federal FTEs	**7**	**7**	**7**	**0**
Support Services				
Management Support				
Administrative Support Contracts	315	1,800	1,100	-700
Total Management Support	**315**	**1,800**	**1,100**	**-700**
Total, Support Services	**315**	**1,800**	**1,100**	**-700**
Other Related Expenses				
WCF	217	650	270	-380
Other Services	68	150	90	-60
Total, Other Related Expenses	**285**	**800**	**360**	**-440**

Office of Indian Energy
Program Direction

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Program Direction $4,800,000	**$3,521,000**	**-$1,279,000**
Salaries and Benefits $1,986,000	**$1,986,000**	**$0**
• Federal Salaries and benefits to implement program activities, monitor over 200 grantee and contractor activities, and provide program management functions.	• Federal Salaries and benefits to implement program activities, monitor over 200 grantee and contractor activities, and provide program management functions.	• Maintains federal staffing at current on board level.
Travel $214,000	**$75,000**	**-$139,000**
• Travel required for Federal staff delivery of program management and Office of Indian Energy deployment activities, including outreach and education, technical assistance, and project management to support the 573 federally recognized Indian tribes throughout the nation, many of which are located in remote and rural areas.	• Travel required for Federal staff delivery of program management and Office of Indian Energy deployment activities, including outreach and education, technical assistance, and project management to support the 573 federally recognized Indian tribes throughout the nation, many of which are located in remote and rural areas.	• Anticipates less federal travel.
Support Services $1,800,000	**$1,100,000**	**-$700,000**
• Management, administrative, and operations support.	• Management, administrative, and operations support.	• No major changes.
Other Related Expenses $800,000	**$360,000**	**-$440,000**
• Computer hardware and software provided through the OCIO, Working Capital Fund, office space, registration fees, supplies, and small purchases through the micro-purchase credit card.	• Computer hardware and software provided through the OCIO, Working Capital Fund, office space, registration fees, supplies, and small purchases through the micro-purchase credit card.	• No major changes.

Department Of Energy

FY 2020 Congressional Budget

Funding by Appropriation by Site

($K)

Office of Indian Energy Policy and Programs	**FY 2018 Total Enacted**	**FY 2019 Enacted**	**FY 2020 Request**
Advanced Photon Source			
Program direction			
Program direction	0	4,800	3,521
Tribal Energy Program			
Tribal Energy Program	0	13,200	4,479
Total, Advanced Photon Source	**0**	**18,000**	**8,000**
Total, Office of Indian Energy Policy and Programs	**0**	**18,000**	**8,000**

Advanced Technology Vehicles Manufacturing Loan Program

Advanced Technology Vehicles Manufacturing Loan Program

Advanced Technology Vehicles Manufacturing Loan Program
(Including Cancellation of Funds)
Proposed Appropriation Language

[For Department of Energy administrative expenses necessary in carrying out the Advanced Technology Vehicles Manufacturing Loan Program, $5,000,000, to remain available until September 30, 2020.**]** *The unobligated balances available from amounts appropriated for the costs of direct loans in section 129 of the Consolidated Security, Disaster Assistance, and Continuing Appropriations Act, 2009 (Public Law 110–329) are hereby permanently cancelled. (Energy and Water Development and Related Agencies Appropriations Act, 2019.)*

Explanation of Changes

The President's FY 2020 Budget eliminates the Advance Technology Vehicles Manufacturing (ATVM) Loan Program and proposes to cancel all $4.3 billion in remaining appropriated credit subsidy. The Loan Programs Office (LPO) will utilize the estimated $5 million in unobligated balances carried forward from prior-year appropriations to cover loan-portfolio monitoring and administrative expenses: salaries for its full time employees as well as the cost of outside advisors for financial, legal, engineering, credit, and market analyses. The ATVM Loan Program's FY 2020 appropriations request is $0. In FY 2020, LPO will stop originating loans for the ATVM Loan Program but will continue to monitor the existing portfolio.

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 2018 Enacted	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
Administrative Expenses	5,000	5,000	0	-5,000
Loan Subsidy Cancelation[1]	0	0	-4,333,500	-4,333,500

[1] 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)

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 completely disbursed.

Organization

LPO currently utilizes five divisions to proactively monitor the portfolio: Portfolio Management Division (PMD), the Risk Management Division (RMD), Technical and Project Management Division (TPMD), Legal Division, and Management Operations Division (MOD).

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.

The Risk Management Division (RMD) conducts continuous risk assessments of the assets in the portfolio to comply with regulatory requirements such as OMB Circular No. A-129 of the Federal Credit Reform Action of 1990.

The Technical and Project Management Division (TPMD) evaluates the technical performance of assets and project management throughout the entire lifecycle of the loan to ensure meeting the technical requirements of the loan agreement. TPMD conducts site visits, provides expertise on project construction status and budget, and identifies potential technical risks inhibiting the borrower's ability to meet requirements and repay the loan.

LPO Legal Division supports 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 2020 LPO will continue to consolidate and streamline the organizational structure of monitoring activities to effectively manage the loan-portfolios while minimizing the administrative burden. In addition, LPO will explore options to reduce or mitigate the expected administrative cost of monitoring over the tenure of the remaining loans.

[1] Net of recoveries

Highlights and Major Changes in the FY 2020 Budget Request

In FY 2020, LPO will terminate ATVM direct loan activities and continue to monitor the existing portfolio.

Advanced Technology Vehicles Manufacturing Loan Program
Funding by Congressional Control ($K)

	FY 2018 Enacted	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
Advanced Technology Vehicles Manufacturing Loan Program				
Administrative Expenses	5,000	5,000	0	-5,000
Total, Advanced Technology Vehicles Manufacturing Loan Program	**5,000**	**5,000**	**0**	**-5,000**
Federal FTEs	**16**	**12**	**4**	**-8**
Loan Subsidy Cancellation [1]	0	0	-4,333,500	-4,333,500

[1] The FY 2020 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)

Advanced Technology Vehicles Manufacturing Loan Program
Administrative Expenses
Funding ($K)

	FY 2018 Enacted	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
Administrative Expenses				
Salaries & Benefits	2,400	1,800	0	-1,800
Travel	150	200	0	-200
Support Services	1,630	1,930	0	-1,930
Other Related Expenses	820	1,070	0	-1,070
Total, Administrative Expenses	**5,000**	**5,000**	**0**	**-5,000**

Administrative Expenses
Explanation of Major Changes ($K)

	FY 2020 Request vs FY 2019 Enacted
Administrative Expenses	
Salaries and Benefits: LPO will utilize approximately $1.8 million unobligated balances carried forward from prior-year appropriations to provide salaries and benefits for 4 full-time equivalent employees (FTEs).	-1,800
Travel: LPO will utilize approximately $200,000 in unobligated balances carried forward from prior-year appropriations to support the travel of staff members for site visits, training, and attending meetings and conferences.	-200
Support Services: LPO will utilize approximately $1.9 million in unobligated balances carried forward from prior-year appropriations to support outside expertise in finance, legal, engineering, technology, credit analysis, and market assessments.	-1,930
Other Related Expenses: LPO will utilize approximately $1 million in unobligated balances carried forward from prior-year appropriations to support DOE working capital, DOE IT services, and training requirements.	-1,070
Total, Administrative Expenses	**-5,000**

Administrative Expenses

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Administrative Expenses $5,000,000	**$0**	**-$5,000,000**
Salaries and Benefits $1,800,000	**$0**	**-$1,800,000**
• Provides for salaries and benefits of 12 full-time equivalent employees to administer the following functions to the office: Director, Origination, Legal, Management Operations, Environmental Compliance, Portfolio Management, Risk Management, and Technical and Project Management.	• Prior-year funds will support the salaries and benefits of 4 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.	• The program is expected to have sufficient unobligated carryover balances to fund salaries and benefits necessary to monitor the existing loan portfolio as proposed.
Travel $200,000	**$0**	**-$200,000**
• Supports the travel of staff members for site visits, as well as attending meetings and conferences.	• Prior year funds will support the travel of staff members for site visits, as well as attending meetings and conferences.	• The program is expected to have sufficient unobligated carryover balances to fund travel necessary to monitor the existing loan portfolio as proposed.
Support Services $1,930,000	**$0**	**-$1,930,000**
• Supports range of contract services including administrative support, subject matter experts, legal services, information technology, publications, credit analysis, and market assessments.	• Prior-year funds will support range of contract services including administrative support, subject matter experts, legal services, information technology, publications, credit analysis, and market assessments.	• The program is expected to have sufficient unobligated carryover balances to fund support services necessary to monitor the existing loan portfolio as proposed.
Other Related Expenses $1,070,000	**$0**	**-$1,070,000**
• Supports DOE Working Capital Fund, DOE IT Services expenses, and LPO federal staff training.	• Prior-year funds will support DOE Working Capital Fund, DOE IT Services expenses, and LPO federal staff training.	• The program is expected to have sufficient unobligated carryover balances to fund other related expenses necessary to monitor the existing loan portfolio as proposed.

Department Of Energy

FY 2020 Congressional Budget

Funding by Appropriation by Site

($K)

Advance Technology Vehicles Man Loan Program	FY 2018 Total Enacted	FY 2019 Enacted	FY 2020 Request
Washington Headquarters			
Energy Transformation Acceleration Fund			
Administrative Expenses	5,000	5,000	0
Total, Washington Headquarters	**5,000**	**5,000**	**0**
Total, Advance Technology Vehicles Man Loan Program	**5,000**	**5,000**	**0**

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

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 of the Title 17 Innovative Technology Loan Guarantee Program, as authorized, **[**$33,000,000**]** *$3,000,000* 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, **[**2020**]** *2021*: *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 purposes of no more than* **[**up to $33,000,000**]** *$3,000,000: Provided further, That* **[**of**]** fees collected **[**in fiscal year 2019**]** pursuant to *such* section 1702(h) **[**of the Energy Policy Act of 2005**]** *for fiscal year 2020* shall be credited as offsetting collections under this heading and *shall not be available until appropriated:* **[**used for necessary administrative expenses in this appropriation and shall remain available until September 30, 2020: *Provided further*, That to the extent that fees collected in fiscal year 2019 exceed $33,000,000, those excess amounts shall be credited as offsetting collections under this heading and available in future fiscal years only to the extent provided in advance in appropriations Acts: *Provided further*, That the sum herein appropriated from the general fund shall be reduced (1) as such fees are received during fiscal year 2019 (estimated at $15,000,000) and (2) to the extent that any remaining general fund appropriations can be derived from fees collected in previous fiscal years that are not otherwise appropriated, so as to result in a final fiscal year 2019 appropriation from the general fund estimated at $0:**]** *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, 2019, is hereby permanently cancelled: Provided further, That the unobligated balances from prior year appropriations Acts, including amounts available under this heading in the American Recovery and Reinvestment Act of 2009 (Public Law 111–5), for the cost to guarantee loans are hereby permanently cancelled*. *(Energy and Water Development and Related Agencies Appropriations Act, 2019.)*

Explanation of Changes

The FY 2020 Budget cancels all remaining Title 17 Innovative Technology (Title 17) Loan Guarantee Program loan volume authority. In addition to $3,000,000 in appropriation offset by $3,000,000 in collections, the Loan Programs Office (LPO) will utilize approximately $26 million in unobligated balances carried forward from prior-year appropriations to cover loan portfolio monitoring and administrative expenses: salaries for its full time employees as well as the cost of outside advisors for financial, legal, engineering, credit, and market analyses. In FY 2020, LPO will stop originating loans for the Title 17 Loan Guarantee Program but will continue to monitor the existing portfolio. It is assumed that the recently-issued conditional commitment for $3.7 billion in loan guarantees to the owners of the Plant Vogtle Expansion Project will reach financial close in FY 2019. No other projects are assumed to reach financial close prior to FY 2020.

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

Title 17 Innovative Technology Loan Guarantee Program
($K)

	FY 2018 Enacted	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
Administrative Expenses	33,000	33,000	3,000	-30,000
Offsetting Collections[a]	-2,108	-20,000	-3,000	17,000
Total	30,892	13,000	0	-13,000
FY 2011 Loan Subsidy Cancellation [b]	0	0	-160,659	-160,659
ARRA Loan Subsidy Cancellation [c]	0	0	-523,212	-523,212

[a] The current estimate for offsetting collections in FY 2019 is $20 million and the Congressional estimate for FY 2019 was $15 million. In FY 2018, $24 million of spending authority was derived from offsetting collections received in prior years and $2 million in fees were credited as offsetting collections but not made available.
[b] The FY 2020 Budget proposes to cancel $161M unobligated balances appropriated by the Department of Defense and Full-Year Continuing Appropriations Act of 2011 (Pub. L. 112-10) for the cost to guarantee loans for renewable energy or efficient end-use energy technologies under section 1703 of the Energy Policy Act of 2005.
[c] The FY2020 Budget proposes to cancel $523 million in unobligated balances appropriated by the American Reinvestment and Recovery Act of 2009 (Pub. L. 111-5).

Overview

The Budget proposes the elimination of the Title 17 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 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 the program 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 $21.10 billion has been obligated and $18.75 billion has been disbursed to date.

Organization

The Loan Programs Office (LPO) currently utilizes five divisions to proactively monitor the portfolio: Portfolio Management Division (PMD), the Risk Management Division (RMD), Technical and Project Management Division (TPMD), and Legal Division, and Management Operations Division (MOD).

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.

The Risk Management Division (RMD) conducts continuous risk assessments of the assets in the portfolio to comply with regulatory requirements such as OMB Circular No. A-129 of the Federal Credit Reform Action of 1990.

The Technical and Project Management Division (TPMD) evaluates 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 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 2020, 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.

Highlights and Major Changes in the FY 2020 Budget Request.

In FY 2020, LPO will stop originating loans for the Title 17 Loan Guarantee Program but will continue to monitor the existing portfolio. It is assumed that the recently-issued conditional commitment for $3.7 billion in loan guarantees to the owners of the Plant Vogtle Expansion Project will reach financial close in FY 2019. No other projects are assumed to reach financial close prior to FY 2020.

Title 17 Innovative Technology Loan Guarantee Program
Funding by Congressional Control ($K)

	FY 2018 Enacted	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
Title 17 Innovative Technology Loan Guarantee Program				
Administrative Expenses				
Appropriation	33,000	33,000	3,000	-30,000
Offsetting Collections[a]	-2,108	-20,000	-3,000	17,000
Total, Title 17 Innovative Technology Loan Guarantee Program	**30,892**	**13,000**	**0**	**-13,000**
Federal FTEs	**102**	**79**	**77**	**-2**
FY 2011 Loan Subsidy Cancellation [b]	0	0	-160,659	-160,659
ARRA Loan Subsidy Cancellation [c]	0	0	-523,212	-523,212

[a] The current estimate for offsetting collections in FY 2019 is $20 million and the Congressional estimate for FY 2019 was $15 million. In FY 2018, $24 million of spending authority was derived from offsetting collections received in prior years and $2 million in fees were credited as offsetting collections but not made available.

[b] The FY 2020 Budget proposes to cancel $161M in unobligated balances appropriated by the Department of Defense and Full-Year Continuing Appropriations Act of 2011 (Pub. L. 112-10) for the cost to guarantee loans for renewable energy or efficient end-use energy technologies under section 1703 of the Energy Policy Act of 2005.

[c] The FY 2020 Budget proposes to cancel $523 million in unobligated balances appropriated by the American Reinvestment and Recovery Act of 2009 (Pub. L. 111-5).

Administrative Expenses
Funding ($K)

	FY 2018 Enacted	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
Administrative Expenses				
Salary & Benefits	18,944	14,700	3,000	-11,700
Travel	892	820	0	-820
Support Services	6,850	8,860	0	-8,860
Other Related Expenses	6,314	8,620	0	-8,620
Total, Administrative Expenses	**33,000**	**33,000**	**3,000**	**-30,000**

Administrative Expenses
Explanation of Major Changes ($K)

	FY 2020 Request vs FY 2019 Enacted
Administrative Expenses	
Salaries and Benefits: In addition to the $3,000,000 requested for salaries and benefits, LPO will utilize approximately $12 million in unobligated balances carried forward from prior appropriations to provide salaries and benefits for 77 full-time equivalent employees (FTEs).	**-11,700**
Travel: LPO will utilize approximately $1 million in unobligated balances carried forward from prior appropriations to support the travel of staff members for site visits, training, and attending meetings and conferences.	**-820**
Support Services: LPO will utilize approximately $8 million in unobligated balances carried forward from prior appropriations to support outside expertise in finance, legal, engineering, technology, credit analysis, and market assessments.	**-8,860**
Other Related Expenses: LPO will utilize approximately $8 million in unobligated balances carried forward from prior appropriations to support DOE working capital, DOE IT services, and training requirements.	**-8,620**
Total, Administrative Expenses	**-30,000**

Administrative Expenses

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Administrative Expenses $33,000,000	**$3,000,000**	**-$30,000,000**
Salaries and Benefits $14,700,000	**$3,000,000**	**-$11,700,000**
• Provides for salaries and benefits of 79 full-time equivalent employees to administer the following functions to the office: Director, Origination, Legal, 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 77 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 combination with the $3 million requested, the program is expected to have sufficient unobligated carryover balances to fund salaries and benefits necessary to monitor the existing loan portfolio as proposed.
ravel $820,000	**$0**	**-$820,000**
• Supports the travel of staff members for site visits, as well as attending meetings and conferences.	• Prior year funds will support the travel of staff members for site visits, as well as outreach to applicants, attending meetings and conferences.	• The program is expected to have sufficient unobligated carryover balances to fund travel necessary to monitor the existing loan portfolio as proposed.
Support Services $8,860,000	**$0**	**-$8,860,000**
• Supports range of contract services including administrative support, subject matter experts, legal services, information technology, publications, credit analysis, and market assessments.	• Prior year funds will supports range of contract services including administrative support, subject matter experts, legal services, information technology, publications, credit analysis, and market assessments.	• The program is expected to have sufficient unobligated carryover balances to fund support services necessary to monitor the existing loan portfolio as proposed.
Other Related Expenses $8,620,000	**$0**	**-$8,620,000**
• Supports DOE Working Capital Fund, DOE IT Services expenses, and federal staff training.	• Prior year funds will support DOE Working Capital Fund, DOE IT Services expenses, and federal staff training.	• The program is expected to have sufficient unobligated carryover balances to fund other related expenses necessary to monitor the existing loan portfolio as proposed.

Department Of Energy

FY 2020 Congressional Budget

Funding by Appropriation by Site

($K)

Innovative Tech Loan Guarantee Prog	FY 2018 Total Enacted	FY 2019 Enacted	FY 2020 Request
Washington Headquarters			
Administrative Operations			
Administrative Operations	33,000	33,000	3,000
Total, Washington Headquarters	**33,000**	**33,000**	**3,000**
Total, Innovative Tech Loan Guarantee Prog	**33,000**	**33,000**	**3,000**

Tribal Energy Guarantee Loan Program

Tribal Energy Guarantee Loan Program

Tribal Energy Loan Guarantee Program
(Including Cancellation of Funds)
Proposed Appropriation Language

[For Department of Energy administrative expenses necessary in carrying out the Tribal Energy Loan Guarantee Program, $1,000,000, to remain available until September 30, 2020.**]** *Of the unobligated balances available under this heading for the cost of loan guarantees, $8,500,000 are hereby permanently cancelled. (Energy and Water Development and Related Agencies Appropriations Act, 2019.)*

Explanation of Changes

The FY 2020 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 2018 Enacted	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
Administrative Expenses	1,000	1,000	0	-1,000
Loan Subsidy Cancelation [a]	0	0	-8,500	-8,500
Total, Administrative Expenses	1,000	1,000	-8,500	-9,500

[a] The FY 2020 Budget proposes to cancel $8.5 million in unobligated credit subsidy balances appropriated by the Consolidated Appropriations Act of 2017 (P.L. 115-31).

Overview

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 FY 2020 Budget eliminates the Tribal Energy Loan Guarantee Program (TELGP) and proposes to cancel the $8,500,000 appropriated for credit subsidy. The Loan Programs Office will utilize unobligated balances carried forward from prior-year appropriations to cover administrative expenses. In FY 2020, LPO will stop originating loans for TELGP but will continue to monitor any loans that may close by October 1, 2019.

History

Authorized by the Energy Policy Act of 2005, funding was first appropriated for the Tribal Energy Loan Guarantee Program in FY 2017. In FY2018, the U.S. Department of Energy (DOE) issued the first Tribal Energy loan guarantee solicitation to support tribal energy development. To date, TELGP has not issued a tribal energy loan guarantee.

Organization

LPO currently utilizes five divisions to proactively monitor the portfolio: Portfolio Management Division (PMD), the Risk Management Division (RMD), Technical and Project Management Division (TPMD), and Legal Division, and Management Operations Division (MOD).

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.

The Risk Management Division (RMD) conducts continuous risk assessments of the assets in the portfolio to comply with regulatory requirements such as OMB Circular No. A-129 of the Federal Credit Reform Action of 1990.

The Technical and Project Management Division (TPMD) evaluates 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 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 2020 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 tenure of the remaining loans.

Highlights and Major Changes in the FY 2020 Budget Request

In FY 2020, LPO will terminate the Tribal Energy Loan Guarantee Program.

Tribal Energy Loan Guarantee Program
Funding by Congressional Control ($K)

	FY 2018 Enacted	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
Tribal Energy Loan Guarantee Program				
Administrative Expenses	1,000	1,000	0	-1,000
Total, Tribal Energy Loan Guarantee Program	**1,000**	**1,000**	**0**	**-1,000**
Federal FTEs	**5**	**5**	**2**	**-3**
Loan Subsidy Cancelation [a]			-8,500	

[a] The FY 2020 Budget proposes to cancel $8.5 million in unobligated credit subsidy balances appropriated by the Consolidated Appropriations Act of 2017 (P.L. 115-31).

Tribal Energy Loan Guarantee Program
Administrative Expenses
Funding ($K)

	FY 2018 Enacted	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
Administrative Expenses				
Salaries & Benefits	775	775	0	-775
Travel	25	25	0	-25
Support Services	100	100	0	-100
Other Related Expenses	100	100	0	-100
Total, Administrative Expenses	**1,000**	**1,000**	**0**	**-1,000**

Administrative Expenses
Explanation of Major Changes ($K)

	FY 2020 Request vs FY 2019 Enacted
Administrative Expenses	
Salaries and Benefits: LPO will utilize approximately $775,000 in unobligated balances carried forward from prior appropriations to provide salaries and benefits for 2 full-time equivalent employees (FTEs).	-775
Travel: LPO will utilize $0 in unobligated balances carried forward from prior appropriations to support the travel of staff members for site visits, training, and attending meetings and conferences.	-25
Support Services: LPO will utilize approximately $125,000 in unobligated balances carried forward from prior appropriations to support outside expertise in finance, legal, engineering, technology, credit analysis, and market assessments.	-100
Other Related Expenses: LPO will utilize approximately $100,000 in unobligated balances carried forward from prior appropriations to support DOE working capital, DOE IT services, and training requirements.	-100
Total, Administrative Expenses	**-1,000**

Administrative Expenses

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Administrative Expenses $1,000,000	**$0**	**-$1,000,000**
Salaries and Benefits $775,000	**$0**	**-$775,000**
• Provides for salaries and benefits of 5 full-time equivalent employees to administer the following functions to the office: Director, Origination, Legal, Management Operations, Environmental Compliance, Portfolio Management, Risk Management, and Technical and Project Management.	• Prior year funds will support the salaries and benefits of 2 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.	• The program is expected to have sufficient unobligated carryover balances to fund salaries and benefits necessary to implement program termination.
Travel $25,000	**$0**	**-$25,000**
• Supports the travel of staff members for site visits, as well as attending meetings and conferences.	• No funding requested.	• The program does not anticipate any travel necessary to implement program termination.
Support Services $100,000	**$0**	**-$100,000**
• Supports range of contract services including administrative support, subject matter experts, legal services, information technology, publications, credit analysis, and market assessments.	• Prior year funds will support range of contract services including administrative support, subject matter experts, legal services, information technology, publications, credit analysis, and market assessments.	• The program is expected to have sufficient unobligated carryover balances to fund support services necessary to implement program termination..
Other Related Expenses $100,000	**$0**	**-$100,000**
• Supports DOE Working Capital Fund, DOE IT Services expenses, and LPO federal staff training.	• Prior year funds will support DOE Working Capital Fund, DOE IT Services expenses, and LPO federal staff training.	• The program is expected to have sufficient unobligated carryover balances to fund other related expenses necessary to implement program termination.

Department Of Energy

FY 2020 Congressional Budget

Funding by Appropriation by Site

($K)

Tribal Indian Energy Loan Guarantee Program	**FY 2018 Total Enacted**	**FY 2019 Enacted**	**FY 2020 Request**
Washington Headquarters			
Tribal Indian Energy Loan Guarantee Program			
Administrative Operations	1,000	1,000	0
Total, Washington Headquarters	**1,000**	**1,000**	**0**
Total, Tribal Indian Energy Loan Guarantee Program	**1,000**	**1,000**	**0**

Energy Information Administration

Energy Information Administration

U.S. Energy Information Administration
Proposed Appropriation Language

For Department of Energy expenses necessary in carrying out the activities of the Energy Information Administration, **[**$125,000,000**]** *$118,000,000*, to remain available until expended.

Explanation of Change

Added P.L. 95-619, 42 U.S.C. 7141, National Energy Conservation Policy Act (1978)
Added P.L. 99-509, 42 U.S.C. 7135, Omnibus Budget Reconciliation Act of 1986

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. 95-619, 42 U.S.C. 7141 National Energy Conservation Policy Act (1978)
P.L. 95-620, 42 U.S.C. 8301, Power Plant 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. 99-509, 42 U.S.C. 7135, Omnibus Budget Reconciliation Act of 1986
P.L. 100-42, 42 U.S.C. 8312, Power Plant 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

U.S. Energy Information Administration
Congressional Control: National Energy Information System (NEIS)
($K)

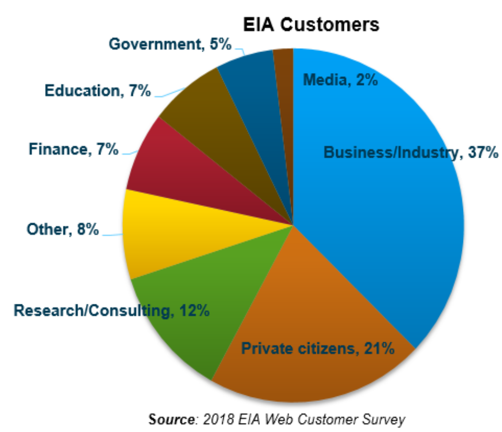
FY 2018 Enacted	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
125,000	125,000	118,000	-7,000

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 governments, the private sector, the public, and the media, have ready access to timely, reliable, and relevant energy information. EIA's data and analysis inform important energy-related decisions, such as the availability of energy sources; government, business, and personal investment decisions; and policy development.

Highlights of the FY 2020 Budget Request
The FY 2020 Budget Request of $118,000,000 will enable EIA to continue core statistical and analysis activities that produce reports critical to the nation, 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 projected out 12 to 24 months
- *Annual Energy Outlook* (AEO), which projects U.S. energy supply, consumption, and trade over the next 25- to 30-year period



The FY 2020 Budget Request will also enable EIA to continue planned cybersecurity initiatives to bolster information security.

Energy Data Program
EIA's comprehensive energy data program conducts surveys of energy suppliers and consumers and then processes the data to produce a full range of publicly available reports. EIA provides this high-quality, relevant, and timely data in a range of formats and structures to serve the various 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. Information from these surveys is published in more than 300 reports a year across weekly, monthly, quarterly, and annual product lines. EIA also collects and disseminates near real-time electricity demand data from the nation's balancing authorities, a first for a government statistical agency. The energy supply survey program collects comprehensive data that illustrate the complex flows of energy production, distribution, and end uses across the nation, including oil and natural gas, coal, refined products, nuclear power, renewables, biofuels, and electric power. The program is staffed with a broad range of statistical expertise to support its data collection efforts, including sampling, unit and item imputation, estimation, survey-frame management, quality assurance, and periodic development of new survey instruments. Producers, consumers, investors, traders, and analysts use EIA energy statistics in their day-to-day activities. The WPSR and WNGSR, for example, typically spur price formation activity to balance energy markets.

Energy Consumption and Efficiency Surveys
EIA collects and publishes national, end-use consumption data for commercial buildings, residential buildings, and manufacturing through three 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 national sample of housing units, including data on energy characteristics of homes, usage patterns, and household demographics. The *Manufacturing Energy Consumption Survey* (MECS), which is linked to production and employment data from Census Bureau economic surveys, provides information on energy throughput and economic and operational characteristics of U.S. manufacturers. These surveys are critical to understanding changes in U.S. energy use and are the basis for forecasting future U.S. energy scenarios. Because of the scale and complexity of these surveys, EIA continues to explore innovative methods for collecting valid data at lower costs.

Energy Analysis Program
EIA conducts a robust energy analysis program to help explain the complex and changing energy marketplace. The program maintains and operates the *National Energy Modeling System* (NEMS), the nation's leading tool for developing long-term projections of U.S. energy production, consumption, prices, and technology usage. EIA's energy models support the production of its flagship publications: the AEO, the *International Energy Outlook* (IEO), and the STEO, as well as other special and periodic topical analyses.

In addition to modeling and forecasting work, EIA produces many recurring reports, such as *Today in Energy*, *Drilling Productivity Report,* and *This Week in Petroleum (TWIP).* Regional data are also used in analysis like the *Refinery Outages Report*, which assesses risk and oil-related supply conditions, and in monthly updates on movements of crude oil, ethanol, and propane by rail. The program is staffed with experts in all areas of the energy sector, including oil, gas, coal, nuclear, renewables, electricity, transportation, and energy consumption and efficiency.

EIA has also expanded the depth and breadth of its international energy coverage, especially regarding international trade flows and their impact on U.S. energy markets. For example, EIA analyzed the implications of removing restrictions on U.S. crude oil and natural gas exports—which included modeling of prices, production, and trade effects. In addition, EIA publishes updated reports that focus on the energy sectors in specific countries and regions.

Communications
EIA's communications program interacts with a diverse external customer base and manages the public website (www.eia.gov), press and media relations, marketing and outreach services, and the employee intranet. EIA's website features state-of-the-art tools such as customizable data browsers; interactive state, national, and North American energy infrastructure maps; and open data initiatives such as Application Programming Interfaces (APIs) that have increased information availability to EIA's customers. The design and customization of EIA's website and multimedia content features are expanded and improved based on external feedback, including web traffic analytics and input from the annual web customer survey. The program maintains EIA's award-winning educational products, such as *Energy Kids* and *Energy Explained*, and executes a thriving social media and state outreach strategy.

Resource and Technology Management
This function provides overall business management, analysis, and mission support to EIA and responds to requests from other DOE offices and programs. 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) platform to ensure a stable, operable IT infrastructure that meets data confidentiality and cybersecurity requirements.

Cybersecurity
EIA will allocate funding for cybersecurity, while continuing to modernize its IT processing platform. EIA's cybersecurity program identifies vulnerabilities and develops strategies to minimize potential vulnerabilities.

Using Administrative Data for Statistical Purposes
EIA is actively engaged in an Administration initiative to better share and utilize administrative data sets for statistical purposes. Using administrative and third-party data sets is a key strategy for EIA to close energy information gaps while minimizing the costs and respondent burden of survey data collection. EIA currently uses more than 60 administrative data sets and has negotiated successfully to obtain movements of commodities (crude oil, ethanol, coal) by rail using data from the Surface Transportation Board; and weekly petroleum export data from Customs and Border Protection. EIA maintains strict measures to safeguard the privacy and confidentiality of the businesses, individuals, and institutions providing the data.

Information Technology Modernization
EIA is modernizing the technological platform that supports its critical surveys. The expected outcome of the multi-year IT Modernization project is for all in-scope surveys to be migrated to a modern, maintainable, and consistent IT platform. The updated platform will become the standard for future survey development and will be used to execute more efficient business processes.

Accomplishments

EIA delivered timely, innovative new energy information platforms:
- Launched the Natural Gas Storage Dashboard, an interactive tool that provides weekly context to EIA's only Principal Federal Economic Indicator—the WNGSR. The dashboard is a comprehensive way for users to identify Lower 48 and regional storage activity and the key market fundamentals that affect natural gas underground storage activity.
- Responded to hurricanes Florence and Michael with hurricane status reports, Energy Disruptions Maps, and related *Today in Energy* articles that provided information on each storm's potential to disrupt the energy system and analyses of the resulting impacts after landfall.
- Added new layers to the U.S. Energy Mapping System, a comprehensive visual reference for energy infrastructure in the United States.

EIA significantly enhanced its flagship forecasts and projections:

- Introduced new charts to the STEO, including figures to illustrate changing natural gas and hydrocarbon gas liquids markets.
- Enhanced the AEO 2018 with many detailed side cases based on an improved set of models and a broad set of alternative policy scenarios.
- Enhanced the IEO 2018 by developing new side cases that focused on how different macroeconomic conditions and economic growth rates might affect international energy markets in three key regions of the world: China, India, and Africa.

EIA provided relevant new data across multiple energy sectors:

- Expanded the *Petroleum Supply Monthly* to include U.S. petroleum export data by region of origin and country of destination.
- Added more than 20 new electricity end uses to the Residential Energy Consumption Survey to provide more detailed insights on energy use in the home.
- Released new electricity data for U.S. territories in the *Electric Power Annual*, and introduced monthly electricity generating information for Puerto Rico.
- Provided new information in the *Annual Coal Report* on key trends in coal production, productivity, and prices.
- Published a new *Monthly Solar Photovoltaic Module Shipments Report* to deliver insights on the fastest-growing U.S. energy source.

Congressional Control: National Energy Information System (NEIS)
Explanation of Major Changes
($K)

	FY 2020 Request vs FY 2019 Enacted
Salaries and Benefits: The decrease from $54,250,000 to $52,875,000 reflects the reduction from 370 to 359 FTEs.	-1,375
Support Services: The decrease from $49,946,000 to $44,946,000 reflects the reduction in Energy Supply Surveys, Energy Consumption and Efficiency Surveys, Energy Modeling and Analysis, and Communications.	-5,000
Other Related Expenses The decrease from $20,498,000 to $19,873,000 reflects the reduction in the Working Capital Fund and subscriptions.	-625
Total, Program Direction	**-7,000**

Program Direction
Funding
($K)

	FY 2018 Enacted	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
Program Direction				
Salaries and Benefits	56,389	54,250	52,875	(1,375)
Travel	278	306	306	-
Support Services	47,870	49,946	44,946	(5,000)
Other Related Expenses	20,463	20,498	19,873	(625)
Total, Program Direction	125,000	125,000	118,000	(7,000)
Federal FTEs	375	370	359	(11)
Support Services				
Technical Support				
Administrative Support Services	9	9	9	-
Human Resources Support Services	4	4	4	-
E-Government Support Services	1	1	1	-
Scientific/Technical and IT Training	40	40	40	-
Data Center (Application Hosting/Housing)	180	180	180	-
IT Management Services	5,508	5,508	5,508	-
Other Advisory and Assistance Services	40,698	42,774	37,774	(5,000)
Total, Technical Support	46,440	48,516	43,516	(5,000)
Management Support				
Program Management	1,430	1,430	1,430	-
Total, Management Support	1,430	1,430	1,430	-
Total, Support Services	47,870	49,946	44,946	(5,000)
Other Related Expenses				
Communications, utilities, and misc. charges	4,257	4,257	3,770	(487)
Training	466	466	466	-
Other goods and services from Federal sources	310	345	345	-
Working Capital Fund	9,694	9,694	9,556	(138)
O&M of IT systems or equipment	1,144	1,144	1,144	-
Printing, supplies and materials	1,300	1,300	1,300	-
Equipment	2,967	2,967	2,967	-
Grants, subsidies, and contributions	325	325	325	-
Total, Other Related Expenses	20,463	20,498	19,873	(625)

Program Direction

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 Enacted
Salaries and Benefits $54,250,000	**$52,875,000**	**-$1,375,000**
Provide salaries and benefits for 370 FTEs.	Provide salaries and benefits for 359 FTEs.	Reduced salary and benefit costs with 11 fewer FTEs. Vacancies will be re-established at lower grades.
Travel $306,000	**$306,000**	**$0**
Provide essential travel for EIA stakeholder engagement—for representing EIA in public forums and engaging with industry experts.	Provide essential travel for EIA stakeholder engagement—for representing EIA in public forums and engaging with industry experts.	Maintain travel costs at FY 2019 level.
Support Services $49,946,000	**$44,946,000**	**-$5,000,000**
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 detailed petroleum supply surveys • Continue partnership with the Ground Water Protection Council (GWPC) to host well-level data	*Energy Supply Surveys $13,915,000* Continue to operate the core energy supply data collection program.	*Energy Supply Surveys -$2,050,000* Postpone petroleum survey updates for capturing impacts of policy and industry changes. Delay enhancements to EIA's electricity data program.
Energy Consumption and Efficiency Surveys $12,321,000 Conduct commercial, residential, and manufacturing surveys: • Continue CBECS 2018	*Energy Consumption and Efficiency Surveys $11,571,000* Conduct commercial, residential, and manufacturing surveys: • Conduct field survey collection phase of CBECS. • On-time completion of the 2020 Residential Energy Consumption Survey.	*Energy Consumption and Efficiency Surveys -$750,000* Discontinue alternative fuel vehicle survey.
Energy Modeling and Analysis $9,326,000 Continue core forecasting and analysis work leading to the AEO, IEO, STEO and other domestic and international reports: • 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 $7,626,000* Deliver core analysis, forecasts, and projections (e.g., AEO, IEO, and STEO).	*Energy Modeling and Analysis -$1,700,000* Reduce investments in international modeling and analysis. Scale back topical analytic capability for addressing emerging industry trends.

FY 2019 Enacted	FY 2020 Request	Explanation of Changes FY 2020 Request vs FY 2019 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 data	*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 data.	*Communications $-500,000* Curtail planned website upgrades to coverage of regional energy markets.
Resource and Technology Management $10,672,000 Provide overall business management, IT and network services, and administrative support to EIA staff.	*Resource and Technology Management $10,672,000* Continue providing business management, IT and network services, and administrative support to EIA staff.	*Resource and Technology Management $0* Continue cybersecurity initiatives and IT systems and infrastructure modernization efforts.
Other Related Expenses $20,498,000	**$19,873,000**	**-$625,000**
Pay rent and shared services through the DOE Working Capital Fund and provide IT equipment and licenses, subscriptions, and employee training among other activities.	Pay rent and shared services through the DOE Working Capital Fund and provide IT equipment and licenses, subscriptions, and employee training among other areas.	Reduction in projected DOE Working Capital Fund and subscription expenses.

Department Of Energy

FY 2020 Congressional Budget

Funding by Appropriation by Site

($K)

Energy Information Administration	FY 2018 Total Enacted	FY 2019 Enacted	FY 2020 Request
Washington Headquarters			
Energy Information Administration			
National Energy Information System	125,000	125,000	118,000
Total, Washington Headquarters	**125,000**	**125,000**	**118,000**
Total, Energy Information Administration	**125,000**	**125,000**	**118,000**

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 a contract covered by the Federal Acquisition Regulation;

(C) issue a letter of intent to make an allocation, award, or Agreement in excess of the limits in subparagraph (A) or (B); or

(D) 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 "Conference" column in the "Department of Energy" table included under the heading "Title III—Department of Energy" in the joint 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, and obtain the prior approval of, 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.
(h) 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. 302. 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**]***2020* until the enactment of the Intelligence Authorization Act for fiscal year **[**2019**]***2020*.

SEC. 303. 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. 304. 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. 305. The Secretary of Energy may not transfer more than $274,833,000 from the amounts made available under this title to the working capital fund established under section 653 of the Department of Energy Organization Act (42 U.S.C. 7263): *Provided*, That the Secretary may transfer additional amounts to the working capital fund after the Secretary provides notification in advance of any such transfer to the Committees on Appropriations of both Houses of Congress: *Provided further*, That any such notification shall identify the sources of funds by program, project, or activity: *Provided further*, That the Secretary shall notify the Committees on Appropriations of both Houses of Congress before adding or removing any activities from the fund.**]**

SEC. **[**306**]***305*. (a) None of the funds made available in this or any prior Act under the heading "Defense Nuclear Nonproliferation" may be made available to enter into new contracts with, or new agreements for Federal assistance to, the Russian Federation. (b) The Secretary of Energy may waive the prohibition in subsection (a) if the Secretary determines that such activity is in the national security interests of the United States. This waiver authority may not be delegated. (c) A waiver under subsection (b) shall not be effective until 15 days after the date on which the Secretary submits to the Committees on Appropriations of both Houses of Congress, in classified form if necessary, a report on the justification for the waiver.

[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**]***306*. Notwithstanding section 161 of the Energy Policy and Conservation Act (42 U.S.C. 6241), upon a determination by the President in this fiscal year that a regional supply shortage of refined petroleum product of significant scope and duration exists, that a severe increase in the price of refined petroleum product will likely result from such shortage, and that a draw down and sale of refined petroleum product would assist directly and significantly in reducing the adverse impact of such shortage, the Secretary of Energy may draw down and sell refined petroleum product from the Strategic Petroleum Reserve. Proceeds from a sale under this section shall be deposited into the SPR Petroleum Account established in section 167 of the Energy Policy and Conservation Act (42 U.S.C. 6247), and such amounts shall be available for obligation, without fiscal year limitation, consistent with that section.

SEC. 307. Section 310 of the Omnibus Appropriations Act, 2009 (Public Law 111–8; 50 U.S.C. 2743a note) and section 306 of the Consolidated Appropriations Act, 2012 (Public Law 112–74; 50 U.S.C. 2743a) are repealed.

SEC. 308. 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. 309. (*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. 310. Notwithstanding provisions of title 5, United States Code, the Southeastern Power Administration shall pay power system dispatchers at basic pay and premium pay rates that are based on those prevailing for similar occupations in the electric power industry. Pay may not be paid, by reason of this section, at a rate in excess of the rate of basic pay for level V of the Executive Schedule.

SEC. 311. Section 3131 of the National Defense Authorization Act for Fiscal Year 2000 (Public Law 106–65; 10 U.S.C. 2701 note) is amended by striking "or the defense activities of the Department of Energy".

(Energy and Water Development and Related Agencies Appropriations Act, 2019.)

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. (a) None of the funds made available in title III of this Act may be transferred to any department, agency, or instrumentality of the United States Government, except pursuant to a transfer made by or transfer authority provided in this Act or any other appropriations Act for any fiscal year, transfer authority referenced in the joint explanatory statement accompanying this Act, or any authority whereby a department, agency, or instrumentality of the United States Government may provide goods or services to another department, agency, or instrumentality. (b) None of the funds made available for any department, agency, or instrumentality of the United States Government may be transferred to accounts funded in title III of this Act, except pursuant to a transfer made by or transfer authority provided in this Act or any other appropriations Act for any fiscal year, transfer authority referenced in the joint explanatory statement accompanying this Act, or any authority whereby a department, agency, or instrumentality of the United States Government may provide goods or services to another department, agency, or instrumentality. (c) The head of any relevant department or agency funded in this Act utilizing any transfer authority shall submit to the Committees on Appropriations of both Houses of Congress a semiannual report detailing the transfer authorities, except for any authority whereby a department, agency, or instrumentality of the United States Government may provide goods or services to another department, agency, or instrumentality, used in the previous 6 months and in the year-to-date. This report shall include the amounts transferred and the purposes for which they were transferred, and shall not replace or modify existing notification requirements for each authority.

SEC. 503. 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).

SEC. 504. (a) None of the funds made available in this Act may be used to maintain or establish a computer network unless such network blocks the viewing, downloading, and exchanging of pornography. (b) Nothing in subsection (a) shall limit the use of funds necessary for any Federal, State, tribal, or local law enforcement agency or any other entity carrying out criminal investigations, prosecution, or adjudication activities.

SEC. 505. Section 611 of the Energy and Water Development Appropriations Act, 2000 (P.L. 106–60; 10 U.S.C. 2701 note) is amended as follows: (*a*) *In subsection (a), by striking "the Army, acting through the Chief of Engineers" and inserting "Energy".* (*b*) *In subsection (a)(6), by striking "by the Secretary of the Army, acting through the Chief of Engineers" and striking ", which may be transferred upon completion of remediation to the administrative jurisdiction of the Secretary of Energy".* (*c*) *In subsection (a), by adding after paragraph (6) the following undesignated matter: "Upon completion of remediation of a site acquired by the Secretary of the Army prior to fiscal year 2020, the Secretary of the Army may transfer administrative jurisdiction of such site to the Secretary of Energy.".* (*d*) *In subsection (b), by striking "the Army, acting through the Chief of Engineers," and inserting "Energy".* (*e*) *In subsection (c), by striking "amounts made available to carry out that program and shall be available until expended for costs of response actions for any eligible site" and inserting "'Other Defense Activities' appropriation account or successor appropriation account and shall be available until expended for costs of response actions for any eligible Formerly Utilized Sites Remedial Action Program Site".* (*f*) *By redesignating subsection (f) as subsection (g).* (*g*) *By inserting after subsection (e) the following new subsection: "(f) The Secretary of Energy, in carrying out subsection (a), shall enter into an agreement with the Secretary of the Army to carry out the functions and activities described in subsections (a)(1) through (a)(6).".*

[SEC. 505. For an additional amount for "Department of the Interior—Bureau of Reclamation—Water and Related Resources", $21,400,000, to remain available until expended, for transfer to Reclamation's Upper Colorado River Basin Fund to carry out environmental stewardship and endangered species recovery efforts pursuant to the Grand

Canyon Protection Act of 1992 (Public Law 102–575), Public Law 106–392, the Colorado River Basin Project Act (43 U.S.C. 1551(b)), and the Act of April 11, 1956 (commonly known as the "Colorado River Storage Project Act") (43 U.S.C. 620n). This division may be cited as the "Energy and Water Development and Related Agencies Appropriations Act, 2019".**]**

(Energy and Water Development and Related Agencies Appropriations Act, 2019.)