DOE/CF-0163
Volume 3 Part 1

Department of Energy
FY 2021 Congressional Budget Request

Energy Efficiency and Renewable Energy
Electricity
Cybersecurity, Energy Security, and Emergency Response
Southeastern Power Administration
Southwestern Power Administration
Western Area Power Administration
Bonneville Power Administration

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DEPARTMENT OF ENERGY
Appropriation Summary
FY 2021
(Dollars in Thousands)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs. FY 2020 Enacted $	FY 2021 Request vs. FY 2020 Enacted %
Department of Energy Budget by Appropriation					
Energy Efficiency and Renewable Energy	2,379,000	2,777,277	719,563	-2,057,714	-74.09%
Electricity	156,000	190,000	195,045	5,045	2.66%
Cybersecurity, Energy Security and Emergency Response	120,000	156,000	184,621	28,621	18.35%
Nuclear Energy*	1,180,000	1,340,000	1,042,131	-297,869	-22.23%
Uranium Reserve	0	0	150,000	150,000	0.00%
Interim Storage and Nuclear Waste Fund Oversight	0	0	27,500	27,500	0.00%
Fossil Energy Research and Development	740,000	750,000	730,601	-19,399	-2.59%
Strategic Petroleum Reserve	235,000	195,000	187,081	-7,919	-4.06%
Naval Petroleum and Oil Shale Reserve	10,000	14,000	13,006	-994	-7.10%
Strategic Petroleum Reserve Petroleum Account	10,000	10,000	0	-10,000	-100.00%
Northeast Home Heating Oil Reserve	10,000	10,000	0	-10,000	-100.00%
Total, Fossil Energy Petroleum Reserve Accounts	**265,000**	**229,000**	**200,087**	**-28,913**	**-12.63%**
Total, Fossil Energy Programs	**1,005,000**	**979,000**	**930,688**	**-48,312**	**-4.93%**
Uranium Enrichment Decontamination and Decommissioning (D&D) Fund	841,129	881,000	806,244	-74,756	-8.49%
Energy Information Administration	125,000	126,800	128,710	1,910	1.51%
Non-Defense Environmental Cleanup	310,000	319,200	275,820	-43,380	-13.59%
Science	6,585,000	7,000,000	5,837,806	-1,162,194	-16.60%
Artificial Intelligence Technology Office	0	0	4,912	4,912	0.00%
Advanced Research Projects Agency - Energy	366,000	425,000	-310,744	-735,744	-173.12%
Departmental Administration	165,858	161,000	136,094	-24,906	-15.47%
Indian Energy Policy and Programs	18,000	22,000	8,005	-13,995	-63.61%
Inspector General	51,330	54,215	57,739	3,524	6.50%
International Affairs	0	0	32,959	32,959	0.00%
Title 17 Innovative Technology Loan Guarantee Program	12,311	29,000	-160,659	-189,659	-654.00%
Advanced Technology Vehicles Manufacturing Loan Program	5,000	5,000	0	-5,000	-100.00%
Tribal Energy Loan Guarantee Program	1,000	2,000	-8,500	-10,500	-525.00%
Total, Credit Programs	**18,311**	**36,000**	**-169,159**	**-205,159**	**-569.89%**
Total, Energy Programs	**13,320,628**	**14,467,492**	**10,057,934**	**-4,409,558**	**-30.48%**
Federal Salaries and Expenses	410,000	434,699	454,000	19,301	4.44%
Weapons Activities	11,100,000	12,457,097	15,602,000	3,144,903	25.25%
Defense Nuclear Nonproliferation	1,930,000	2,164,400	2,031,000	-133,400	-6.16%
Naval Reactors*	1,788,618	1,648,396	1,684,000	35,604	2.16%
Total, National Nuclear Security Administration	**15,228,618**	**16,704,592**	**19,771,000**	**3,066,408**	**18.36%**
Defense Environmental Cleanup	6,024,000	6,255,000	4,983,608	-1,271,392	-20.33%
Nuclear Energy	146,090	153,408	137,800	-15,608	-10.17%
Other Defense Programs	860,292	906,000	1,054,727	148,727	16.42%
Total, Environmental and Other Defense Activities	**7,030,382**	**7,314,408**	**6,176,135**	**-1,138,273**	**-15.56%**
Total, Atomic Energy Defense Activities	**22,259,000**	**24,019,000**	**25,947,135**	**1,928,135**	**8.03%**
Southwestern Power Administration	10,400	10,400	10,400	0	0.00%
Western Area Power Administration	89,372	89,196	89,372	176	0.20%
Falcon and Amistad Operating and Maintenance Fund	228	228	228	0	0.00%
Colorado River Basins Power Marketing Fund	0	-42,800	-21,400	21,400	**-50.00%**
Total, Power Marketing Administrations	**100,000**	**57,024**	**78,600**	**21,576**	**37.84%**
Total, Energy and Water Development and Related Agencies	**35,656,628**	**38,527,516**	**36,083,669**	**-2,443,847**	**-6.34%**
Excess Fees and Recoveries, FERC	-16,000	-16,000	-9,000	7,000	-43.78%
Title XVII Loan Guarantee Program Section 1703 Negative Credit Subsidy Receipt	-107,000	-15,000	-49,000	-34,000	226.67%
Sale of Northeast Home Heating Oil Reserve	0	0	-75,000	-75,000	0.00%
Sale of Oil from Strategic Petroleum Reserve**	0	0	-589,000	-589,000	0.00%
Total, Funding by Appropriation	**35,533,628**	**38,512,516**	**35,361,669**	**-3,150,847**	**-8.18%**
DOE Budget Function	**35,533,628**	**38,512,516**	**35,361,669**	**-3,150,847**	**-8.18%**
NNSA Defense (050) Total	15,228,618	16,704,592	19,771,000	3,066,408	18.36%
Non-NNSA Defense (050) Total	7,030,382	7,314,408	6,176,135	-1,138,273	-15.56%
Defense (050)	*22,259,000*	*24,019,000*	*25,947,135*	*1,928,135*	*8.03%*
Science (250)	6,585,000	7,000,000	5,837,806	-1,162,194	-16.60%
Energy (270)	6,689,628	7,493,516	3,576,728	-3,916,788	-52.27%
Non-Defense (Non-050)	*13,274,628*	*14,493,516*	*9,414,534*	*-5,078,982*	*-35.04%*

* Funding does not reflect statutory transfer of funds from Naval Reactors to Nuclear Energy for maintenance and operation of the Advanced Test Reactor ($85.5M in FY19; $88.5M in FY20).

**Includes a $50M sale from the Northeast Gasoline Supply Reserve.

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, [$2,848,000,000] $719,563,000, to remain available until expended: Provided, That of such amount, [$165,000,000] $122,563,000 shall be available until September 30, [2021] 2022, for program direction.[: Provided further, That of the unobligated balances from prior year appropriations available under this heading, $58,000,000 is hereby rescinded: Provided further, That no amounts may be rescinded from amounts that were designated by the Congress as an emergency requirement pursuant to the Concurrent Resolution on the Budget or the Balanced Budget and Emergency Deficit Control Act of 1985.] (Energy and Water Development and Related Agencies Appropriations Act, 2020.)

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. 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"
P.L. 115-246, "Department of Energy Research and Innovation Act" (2018)

Energy Efficiency and Renewable Energy
($K)

FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted
2,379,000	2,848,000	719,563	-2,128,437

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, commercialization, and deployment of energy technologies. This Budget Request emphasizes energy technologies best positioned to support American energy independence and resilience in the near- to mid-term.

The FY 2021 Budget Request maintains America's leadership in transformative science and emerging energy technologies in sustainable transportation, renewable power, and energy efficiency. Knowledge generated by EERE early-stage R&D enables U.S. industries, businesses, and entrepreneurs to develop and deploy innovative energy technologies and gives them the competitive edge needed to excel in the rapidly changing global energy economy. Industry deployment of these technologies creates jobs, increases energy affordability, improves energy security and resilience, ensures environmental responsibility and offers Americans a broader range of energy choices.

The Budget request for EERE supports Departmental goals to include developing energy technologies that increase the affordability of domestic energy resources as well as improve electric grid reliability and resiliency. To meet the demands of an increasingly diverse and complex energy infrastructure, this Budget Request focuses on collaboration across offices, sectors, and Federal agencies.

The Budget request for EERE includes the following cross-cutting topics:

- Grid Modernization Initiative ($105,500,000) — Develops new architectural concepts, tools, and technologies that will better measure, analyze, predict, protect, and control the grid of the future. Topic areas include beyond LCOE (Levelized Cost of Energy), electricity affordability, generation and hybrid systems, resilience modeling, cyber-physical security, advanced sensing, energy storage and system flexibility.
- Energy Storage Grand Challenge (ESGC) ($97,000,000) — DOE is taking a holistic approach to accelerate the development, commercialization, and utilization of next-generation energy storage technologies. The Department integrated the existing disparate storage efforts from the Office of Science, Grid Modernization Initiative (GMI), Advanced Energy Storage Initiative (AESI) and others into the Energy Storage Grand Challenge (ESGC), an integrated, comprehensive DOE-wide strategy. The ESGC will deploy the Department's extensive resources and expertise to address technology development, commercialization, manufacturing, valuation, and workforce challenges. The vision for the ESGC is to create and sustain global leadership in energy storage utilization and exports, with a secure domestic manufacturing supply chain that is independent of foreign sources of critical materials, by 2030.
- Critical Minerals Initiative ($52,600,000) — In support of Executive Order (EO) 13817, the Budget elevates the existing critical minerals activities across DOE to an intradepartmental initiative. Specifically, the Budget dissolves the current Critical Materials Institute and replaces it with a broader National Laboratory-led consortium modeled after the Grid Modernization Laboratory Consortium. This new consortium is tasked with developing and implementing a multi-year program plan, including aggressive, yet achievable goals, encompassing all efforts across the Applied Energy Offices and the Office of Science to diversify supply of, develop substitutes for, and drive recycling, reuse, and more efficient

use of critical minerals. Specifically, EERE will increase activity at all levels of the supply chain, including exploration, mining, concentration, separation, alloying, recycling, and reprocessing critical minerals called for in EO 13817.

- Plastics Innovation Challenge ($20,500,000) — Plastics are used in thousands of products essential to modern life, but plastic waste is also a growing global challenge. Last year, DOE announced a comprehensive program to accelerate innovations in energy-efficient plastics recycling technologies. EERE plans to explore novel technologies and approaches to economically deconstruct existing plastics, increase opportunities for upcycling, and develop infinitely recyclable polymers. The purpose of the Plastics Innovation Challenge is to reduce the energy costs associated with the current lifecycle of plastics; develop new polymers that are recyclable-by-design; and develop biological and chemical methods to deconstruct plastic waste, including from rivers and oceans, into useful chemical feedstock streams. This includes emphasis on designing and manufacturing new technologies for both recyclability and reliability across our technologies entering the marketplace.
- Water Security Grand Challenge ($20,000,000) — A White House-initiated, DOE-led challenge to advance transformational technology and innovation to meet the global need for safe, secure, and affordable water. EERE will focus on desalination technologies, resource recovery from municipal wastewater, and small modular energy-water systems (in coordination with DOE's Offices of Fossil Energy and Nuclear Energy).
- Energy Sector Cybersecurity ($13,600,000) — EERE supports early stage R&D, provides technical assistance, and develops best practices to identify and mitigate cyber risks to energy systems. Work supported by EERE complements the DOE Multiyear Plan for Energy Sector Cybersecurity.
- Harsh Environment Materials Initiative ($6,500,000) — EERE supports this coordinated effort to exploit synergies in materials and component manufacturing R&D for advanced thermoelectric power plants.

EERE early-stage research focuses on technology challenges that present a significant degree of scientific or technical uncertainty across a relatively long timeframe, making it unlikely that industry will invest in 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 with industry, utilize Agreements for Commercializing Technology, 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 2019, 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 2018 decreased by 69 percent.[2] In the past 10 years, 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 2.6 percent energy intensity reduction among industry partners.[4]

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

Major Changes in the FY 2021 Budget Request

In developing the FY 2021 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 $719.563 million focused on early-stage research

[1] Utility Scale Solar 2019, Figure 21 (LBNL) https://emp.lbl.gov/sites/default/files/utility-scale-solar-2019-edition-public-data-file.xlsx

[2] 2018 Wind Technologies Market Report Figure 51 (LBNL) https://emp.lbl.gov/sites/default/files/2018_wtmr_data_file.xlsx.

[3] Advancing U.S. Battery Manufacturing and a Domestic Critical Minerals Supply Chains https://www.energy.gov/eere/articles/advancing-us-battery-manufacturing-and-domestic-critical-minerals-supply-chains

[4] Better Plants Progress Update (Fall 2019) https://betterbuildingsinitiative.energy.gov/sites/default/files/attachments/2019%20Better%20Plants%20Progress%20Update.pdf

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 Energy, 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 2021. Therefore, no funds are requested in this Budget Request for the Weatherization and Intergovernmental Program.

The FY 2021 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.

Highlights of the FY 2021 Budget Request

Sustainable Transportation ($160,900,000) — 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 options across sectors; and (4) mobility energy productivity, 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 $74,400,000 in FY 2021 funding to support early-stage research to generate knowledge upon which industry can develop and deploy a broad range of affordable, efficient, and clean transportation choices to move 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 Energy Storage Grand Challenge 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 subprogram will create breakthrough modeling and simulations to understand how new mobility technologies can improve mobility energy productivity, and apply new artificial intelligence capabilities developed by the National Laboratories to increase transportation system efficiency for passengers and freight through new mobility solutions, including connected, shared, and automated vehicles. In Advanced Engine and Fuel Technologies, research will advance and improve our understanding 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 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 $44,500,000 in FY 2021 to support R&D of transformative, sustainable, bioenergy technologies that can support a growing bioeconomy[1]. 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.[2] The program's early-stage R&D emphasizes advanced technologies to produce renewable-gasoline, -diesel, -jet, and -marine fuels, as well as, co-produced bioproducts from biomass and waste streams in order to provide affordable, domestically sourced and produced fuels across the full range of transportation modes. The Request prioritizes consortium-based research that brings together unique capabilities from across the DOE National Laboratories and focuses them on key challenges and opportunities for bioenergy technologies, including: (1) detailed understanding and optimization of the physics and chemistry of feedstocks and pre-processing 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. Funding will support joint research with the Advanced Manufacturing Office under the Plastics Innovation Challenge to develop new plastic recycling technologies and the bio-derived plastics that are recyclable by design in order to decrease the energy intensity and reduce environmental costs associated with the current lifecycle of plastics. In collaboration with the Vehicles Technologies Office, 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 $42,000,000 in FY 2021 to support early-stage R&D to develop novel hydrogen and fuel cell technologies that provide new, domestic fuel options for transportation and position the U.S. as a leader in the growing hydrogen technology market. FY 2021 funding will continue to focus on the H2@Scale concept which will enable affordable and reliable hydrogen generation, transport, storage, and utilization across sectors and expand fuel cell applications beyond light duty vehicles. Investments in hydrogen fuel R&D technologies will help avoid curtailing variable renewables like solar and wind; optimize baseload operation of nuclear, coal, and natural gas plants; and will support innovations in the industrial sector like steel manufacturing, manufacturing for low cost hydrogen production, and the development of carriers for economical storage and transport of hydrogen, including export potential. Investments in fuel cell technologies will increase the emphasis on heavy-duty vehicles and new applications (e.g. trucks, marine, rail, aviation, data centers). In addition, the Budget funds materials and component R&D for affordable hydrogen infrastructure, electrolyzer R&D, and carbon fiber R&D. FY 2021 funding will focus on reducing the cost and improving the performance/durability of fuel cells, as well as developing affordable and efficient technologies supporting hydrogen production, delivery, and storage for new uses. Targets are application specific, for instance for medium/heavy-duty truck applications, the 2030 targets are: 25,000 hours for fuel cell durability; $80/kW for fuel cell cost; and $9/kWh for onboard hydrogen storage. However, the ultimate targets for the application are 30,000 hours for fuel cell durability, $60/kW for fuel cell cost, and $8/kWh for onboard hydrogen storage costs. As a transportation fuel, the program has a hydrogen fuel production cost target of <$2/kg. Achieving these targets will allow hydrogen fuel cell powered trucks to be competitive in terms of cost and performance with incumbent technologies.

Renewable Power ($160,100,000) — 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. Research on improved integration is executed through the Energy Storage Grand Challenge and the Grid Modernization Initiative. Through investments in DOE National Laboratories, 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 2021 to support the DOE in improving the affordability, reliability, and performance of solar technologies on the grid. Reflecting the recent and projected future growth in PV deployment, the program is placing a continued emphasis on addressing the challenges and opportunities related to integrating high penetrations of solar onto the electric grid, including the integration of solar energy with energy storage

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

and other technologies to enable solar energy to be available on demand. The program will also continue its efforts to build the knowledge base upon which industry can achieve further reductions in the cost of solar electricity, promoting greater energy affordability. Taken together, these objectives will invigorate American technological leadership in solar energy, diversify the Nation's electricity supply, enhance grid resilience and reliability, 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 photovoltaic (PV) systems and $0.05/kWh for baseload concentrating solar power (CSP) systems. 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 40-65 percent from 2018 benchmarks for utility-scale, commercial and residential PV as well as CSP. The program has a history of success in enabling solar energy cost reduction: the original SunShot 2020 goal for unsubsidized, utility-scale solar PV electricity of $0.06/kWh was achieved in 2017, three years ahead of schedule.

- **Wind Energy:** The Budget Request provides $22,100,000 in FY 2021 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 2021 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 operations and maintenance costs, 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.

- **Water Power:** The Budget Request provides $45,000,000 in FY 2021 to support 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 Energy Storage Grand Challenge and continues its focus on hydropower and Pumped-Storage Hydropower's (PSH) 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. The program also supports an ongoing effort in hydropower plant upgrades and modernization to help provide the tools, technology, and analysis necessary to maintain and enhance the existing hydropower fleet. 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 at least one wave device 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 in non-utility scale markets under its Powering the Blue Economy Initiative. This initiative includes the advancement of research to demonstrate marine energy's potential to desalinate seawater, prove the feasibility of tidal devices in remote communities, and scoping and analyzing the viability of designing marine 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 $26,000,000 in FY 2021 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) in Milford, Utah in FY 2021 with prior year funds. Requested funding in FY 2021 will support two new subsurface enhancement and sustainability efforts. The first will target advanced completions and wellbore engineering to facilitate successful isolation of targeted zones for stimulation, and the other will focus on methods or tools for assessing and tracking fundamental hydraulic properties of

EGS reservoirs, including the amount of time it takes fluid to pass through a reservoir. The Hydrothermal subprogram will focus on drilling technologies; building on the work awarded under the 2018 EDGE Funding Opportunity. The program will continue the development of efficient drilling technologies. The Request also provides funding to validate technologies developed under the Energy Storage Grand Challenge. Following on prior year work, the program will initiate an effort to attract innovative technologies that can effectively separate critical minerals from geothermal brines. The program will focus on a set of increasingly sophisticated modeling and bench-scale test phases. Combined efforts across the program will strengthen the body of knowledge necessary to enable industry to meet the potential outlined in the recent GeoVision report, 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 contributions.

Energy Efficiency ($164,000,000) — EERE's energy efficiency portfolio advances American energy competitiveness through the pursuit of early-stage R&D targeted at high impact technology areas such as critical materials, plastics recycling, manufacturing processes, grid-interactive building systems, advanced lighting, space heating and cooling, and building envelopes. 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 $94,600,000 in FY 2021 to support early-stage 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 includes funding to develop technologies to enable domestic supply of critical materials related to energy applications, substitutes for critical materials, and technologies for reuse and recycling of critical materials. Funding is also requested for the Energy Storage Grand Challenge to develop innovative manufacturing processes for energy storage systems; the Harsh Environment Materials Initiative, a 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; and joint research with the Bioenergy Technologies Office under the Plastics Innovation Challenge to develop new plastic recycling technologies and the next generation of bio-derived polymers that are recyclable by design. 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 2021 that will allow FEMP to strengthen agencies' ability and agility to manage their critical missions and to provide strategic energy management assistance for agencies to become resilient, efficient, and secure in support of Administration priorities for American energy dominance. FEMP will strive to increase government accountability and development of a future-focused workforce. FEMP supplies agencies with the information, tools, and technical assistance they need to meet and track their energy-related requirements and goals through the following focus areas:
  - Strategic Programming and Integration Planning – Providing agencies with information and resources to help them develop strategic programs and plans to successfully reduce Federal energy and water use. FEMP also develops, analyzes, and shares information about Federal laws and requirements.
  - Facility and Fleet Optimization – Coordinating processes to integrate mission assurance with optimized and cost-effective facility and fleet operations. Specialty areas include: strategic energy management, commissioning, data centers, Federal fleet management, guiding principles for sustainable Federal buildings, laboratories, metering, net zero energy, water, and waste, and operations and maintenance plans.
  - Federal Leadership and Engagement – Providing accountability on Federal agency and Government-wide energy and water performance, engaging agencies in interagency working groups and workforce development opportunities, and recognizing their efforts. Specialty areas include: agency reporting and data, the annual Federal Energy and Water Management Awards, interagency working groups, training, and veteran internships.

- **Building Technologies:** The Budget Request provides $61,000,000 in FY 2021 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 Energy Storage Grand Challenge, particular focus will be placed on building system interaction with the grid in terms of controllable loads and thermal energy storage technologies. A key 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, to enhance energy efficiency. Building Technologies' research also focuses on developing the physics-based algorithms for improved energy modeling and system controls required to better predict and manage energy efficient appliance/equipment, system, and whole-building energy usage. Additionally, Building Technologies' early-stage R&D on cyber-secure advanced sensors and controls will help strengthen the body of knowledge to enable industry to develop and deploy "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. Through the Better Buildings Initiative, the Building program will foster the accelerated adoption of energy efficient technologies and practices by attracting and establishing close, trusted relationships with key market leaders and encourage private sector investment into energy efficient technologies. Buildings' partnership platform has goals to work with market leaders to publish replicable strategies and make energy efficiency investment easier through information sharing. 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 2021 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 2021 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.

Energy Efficiency and Renewable Energy
($K)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted	
				$	%
Discretionary Summary by Appropriation					
Energy Efficiency and Renewable Energy					
Sustainable Transportation					
Vehicle Technologies	344,000	396,000	74,400	-321,600	-81.2%
Bioenergy Technologies	226,000	259,500	44,500	-215,000	-82.9%
Hydrogen and Fuel Cell Technologies	120,000	150,000	42,000	-108,000	-72.0%
Renewable Power					
Solar Energy Technologies	246,500	280,000	67,000	-213,000	-76.1%
Wind Energy Technologies	92,000	104,000	22,100	-81,900	-78.8%
Water Power Technologies	105,000	148,000	45,000	-103,000	-69.6%
Geothermal Technologies	84,000	110,000	26,000	-84,000	-76.4%
Energy Efficiency					
Advanced Manufacturing	320,000	395,000	94,600	-300,400	-76.1%
Federal Energy Management Program	30,000	40,000	8,400	-31,600	-79.0%
Building Technologies	226,000	285,000	61,000	-224,000	-78.6%
Weatherization and Intergovernmental Programs					
Weatherization Assistance Program	254,000	305,000	0	-305,000	-100.0%
Training and Technical Assistance	3,000	3,500	0	-3,500	-100.0%
State Energy Program	55,000	62,500	0	-62,500	-100.0%
Total, Weatherization and Intergovernmental Programs	312,000	371,000	0	-371,000	-100.0%
Corporate Support Programs					
Facilities and Infrastructure (NREL)	97,000	130,000	107,000	-23,000	-17.7%
Program Direction	162,500	165,000	122,563	-42,437	-25.7%
Strategic Programs	14,000	14,500	5,000	-9,500	-65.5%
Subtotal, EERE	**2,379,000**	**2,848,000**	**719,563**	**-2,128,437**	**-74.7%**
P.L. 116-94 Unobligated Balance Rescission	0	-58,000	0	58,000	+100.0%
P.L. 116-94 Section 308: Energy Program Rescission		-12,723	0	12,723	+100.0%
Total, EERE	**2,379,000**	**2,777,277**	**719,563**	**-2,057,714**	**-74.1%**

SBIR/STTR:

- FY 2019 Transferred: SBIR $51,536,000; STTR $7,333,000
- FY 2020 Projected: SBIR $59,532,000; STTR: $8,371,000
- FY 2021 Request: SBIR $14,476,000; STTR: $2,036,000

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 approximately 30 percent of total U.S. energy needs[3] and the average U.S. household spends over 15 percent of its total family expenditures on transportation,[4] making it the most expensive spending category after housing.

The Vehicle Technologies Program funds early-stage, high-risk research to develop new, affordable, efficient and clean transportation options that increase domestic economic opportunity. 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 to include: 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). The Program 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 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.[5] 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 payback period expectations.

Highlights of the FY 2021 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, as part of the Broader Energy Storage Grand Challenge, identify new battery chemistry and cell technologies with the potential to reduce the cost of electric vehicle battery packs by more than half, to less than $100/kWh (ultimate goal is $60/kWh battery cell cost), increase range to 300 miles, and decrease charge time to 15 minutes or less by 2028.
- 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. Activities also prioritize 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.

[1] Bureau of Transportation Statistics, DOT, Transportation Statistics Annual Report 2018, Table 4-1. https://www.bts.gov/tsar.
[2] Transportation Energy Data Book 37th Edition, ORNL, 2019. Table 3.8 Shares of Highway Vehicle-Miles Traveled by Vehicle Type, 1970-2017.
[3] Ibid. Table 2.1. U.S. Consumption of Total Energy by End-use Sector, 1950-2018.
[4] Ibid. Table 10.1 Average Annual Expenditures of Households by Income, 2016.
[5] See Record #17008, which can be accessed at https://www.hydrogen.energy.gov/program_records.html#program_related. Both energy and cost per mile are based on a 15-year vehicle lifetime and are based on meeting VTO technical targets.

- 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 an increased cost of less than $5/lb.-saved by 2030 (vs. 2012 baseline of 2,430 lbs.)[1]. Focus on the development of high temperature materials to increase strength of components by 25 percent relative to A356 aluminum for high-efficiency engines in 2025.
- 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. Identify feasible system-level pathways to improve mobility energy productivity by 20 percent by 2040, relative to a 2020 baseline.
- 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.
- Data, Modeling, and 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.
- Departmental Cross-cuts:
  - Energy Storage Grand Challenge ($35,000,000) – R&D focused on high-energy and high-power battery materials and systems;
  - Critical Minerals Initiative ($15,000,000) – Addresses cobalt use and recycling for batteries; reducing heavy RE in EV drive systems;
  - Grid Modernization Initiative ($4,000,000) – Projects for managing grid charging of EVs, and Medium Duty – Heavy Duty (MD/HD) 1+MW EV charging; and
  - Cybersecurity Crosscut ($1,000,000) – Grid-connected vehicle charging.

[1] For conventional, internal combustion engine-powered (ICEVs), a 10% reduction in total weight increases fuel economy by about 7% which reduces lifetime fuel cost for the consumer. The reduced fuel cost provides added value for car buyers, enabling a higher sticker price and thus tolerance for an increase in vehicle manufacturing cost in order to save weight. (Ward, et al. The Importance of Powertrain Downsizing in a Benefit-Cost Analysis of Vehicle Lightweighting, April 2017 JOM: the journal of the Minerals, Metals, & Materials Society 69(6) DOI: 10.1007/s11837-017-2330-x)

Vehicle Technologies
Funding ($K)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted
Vehicle Technologies				
Battery and Electrification Technologies	163,200	174,700	39,400	-135,300
Advanced Engine and Fuel Technologies	64,000	70,000	9,000	-61,000
Materials Technology	30,000	40,000	7,000	-33,000
Energy Efficient Mobility Systems	40,500	45,000	14,000	-31,000
Technology Integration	41,300	60,300	3,500	-56,800
Data, Modeling, and Analysis (formerly Analysis)	5,000	6,000	1,500	-4,500
Total, Vehicle Technologies	**344,000**	**396,000**	**74,400**	**-321,600**

SBIR/STTR:

- FY 2019 Transferred: SBIR: $9,788,000; STTR: $1,608,000
- FY 2020 Projected: SBIR: $10,450,000; STTR: $1,470,000
- FY 2021 Request: SBIR: $2,269,000; STTR: $319,000

Vehicle Technologies
Explanation of Major Changes
($K)

	FY 2021 Request vs FY 2020 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 Energy Storage Grand Challenge and the Grid Modernization initiative. In FY 2021, 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 from two multi-lab research teams focused on intermetallic anodes to one group to focus resources on the most promising innovations. The program will also downselect the next generation cathode portfolio to focus on low- or no-cobalt materials. The Behind the Meter Storage activity will expand to develop innovative, critical minerals-free battery energy storage technologies applicable to plug-in electric vehicles and high power charging systems. Fewer Electrification R&D projects will be awarded, focusing resources on only the highest -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 minerals and utilizes recycled material feedstocks.	**-135,300**
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 multi-lab initiative will continue to consolidate fundamental combustion research, including experimental, computational, and modeling work. The initiative's goal is 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 (SI/ACI) engines. A multi-lab initiative for medium- and heavy-duty on- and off-road vehicles will continue to focus on early-stage research to improve engine 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.	**-61,000**

	FY 2021 Request vs FY 2020 Enacted
Materials Technology: The reduction in funding level for this subprogram reflects the prioritization of the most critical early-stage activities, within the broader priorities of EERE and the Department. Early-stage research will focus on reducing the cost of specific lightweight, high-strength materials. In particular, affordable polymeric matrix composite materials, composite preforms, advanced processes, and innovative component fabrication techniques for high-volume, high-performance vehicle applications will be developed. 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.	**-33,000**
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 Computational Modeling and Simulation activity will include the SMART Mobility National Laboratory Consortium (a multi-disciplinary approach to assess the energy productivity impacts from future mobility technologies and transportation systems), which will emphasize the application of transportation system-level models to multiple geographies to identify pathways to improve mobility energy productivity. A new transportation system optimization project using data science and strategic computing capabilities validated in the previous year will be initiated. The subprogram will also maintain a critical set of core vehicle modeling and validation tools and capabilities within the Computational Modeling and Simulation activity, enabling research across multiple subprograms. Within the Connectivity and Automation Technology activity, a new advanced connected and automated vehicle system R&D project will be initiated to remove technical barriers and accelerate the efficiency and mobility benefits of these promising technologies.	**-31,000**
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. No funding is provided for the Clean Cities program or other deployment-oriented activities.	**-56,800**
Data, Modeling, and Analysis (formerly 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.	**-4,500**
Total, Vehicle Technologies	**-321,600**

Description

The Battery and Electrification Technologies subprogram supports research with partners in academia, National Laboratories, and industry, focusing on generating knowledge of high-energy and high-power battery materials and battery systems that will lead to a significant reduction in the cost, weight, volume, and charge-time of plug-in electric vehicle (PEV) batteries. Through its key activities supporting battery energy storage, this subprogram supports the Advanced Energy Storage initiative, as part of the broader Energy Storage Grand Challenge, which is focused on a flexible, resilient electrical grid as well as 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. These activities focus on generating knowledge and addressing technology barriers for batteries, electric drive systems, and electrification technologies that can enable industry to significantly reduce the cost, weight, volume and charge time of PEV batteries. Subprogram goals include: (1) reducing the cost of battery packs to less than $100/kWh while increasing vehicle range to 300 miles and decreasing charge time to less than 15 minutes by 2028, and (2) reducing the cost of electric drive systems to less than $6/kW by 2025. This 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 to achieve a battery cell manufactured cost of $60/kWh, which achieves an LCD of $0.26/mile.

Battery R&D

The Battery R&D activity supports early-stage R&D of high-energy and high-power battery materials, cells, and battery systems that can enable industry to significantly reduce the cost, weight, volume and charge time of PEV batteries to less than $100/kWh while increasing vehicle range to 300 miles and decreasing charge time to less than 15 minutes by 2028. This activity is organized into sub-activities: advanced battery materials research, advanced battery cell R&D, and battery system R&D. Advanced battery materials research is coordinated with the Critical Minerals Initiative and includes: early-stage research of new lithium-ion cathode, anode, and electrolyte materials (currently accounting for 50-70 percent of PEV battery cost); development of innovative battery materials recycling and reuse technologies, and the Lithium-Ion Battery Recycling Prize, both to assure sustainability and domestic supplies; and the development of “beyond lithium-ion” technologies, such as lithium metal anodes, solid-state electrolytes, and sulfur-based cathodes, that have the potential to significantly reduce weight, volume, and cost by three times, with a target of $60/kWh. Advanced battery cell R&D includes: 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; and high-fidelity battery performance, life, fast charging, and safety testing of innovative battery technologies including recycled material and cells. Battery system R&D includes: innovative solutions capable of mitigating potential grid impacts of PEV high-power charging systems, such as critical minerals-free battery energy storage technologies; and advanced power electronics and controls to assure seamless integration of energy storage, vehicle charging, and behind-the-meter power transmission.

Electric Drive R&D

The Electric Drive R&D activity supports early-stage R&D for extreme high power density motor and power electronics that have the potential to enable radical new vehicle architectures by dramatic volume/space reductions and increased durability and reliability. Core research of power electronics and motors to reduce the cost of electric traction drive systems to $6/kW for a 100kW peak system by 2025 through high-density integration technologies, leveraging high performance computing for modeling and optimization, and utilizing new materials for high-density electric motors. 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.

Electrification R&D

The Electrification R&D activity supports early-stage R&D to understand the potential impacts on, and benefits of, PEV charging to the Nation's electric grid. This research will inform the development of communication and cybersecurity protocols; enable industry to enhance the interoperability between charging equipment, the on-board vehicle charger, and charging networks; and foster technology innovations to improve PEV refueling through extreme fast charging. Core research focuses on developing smart charging, extreme fast charging, and wireless charging technologies for reliable and cost effective charging of light-, medium-, and heavy-duty electric vehicles. This includes the research of technologies related to cybersecurity of electric vehicle charging/supply equipment, and integration with the electric grid.

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Battery and Electrification Technologies $174,700,000	**$39,400,000**	**-$135,300,000**
Battery R&D $115,000,000	$30,000,000	-$85,000,000
• Fund National Laboratory advanced battery materials research projects focused on next-generation Lithium Ion and Beyond Lithium Ion chemistries. Research areas include silicon-based anodes, novel electrolyte formulations, low and/or no cobalt cathode materials, lithium metal anodes, sulfur based cathodes, solid-state materials, and other promising battery technologies. Research into these different material systems are based on their potential to significantly reduce battery weight, volume, and cost.	• Continue to fund high potential National Laboratory advanced battery materials research projects focused on next-generation Lithium Ion and Beyond Lithium Ion chemistries. The most promising of the early stage materials research projects will be downselected to focus on the approaches that show the highest potential of meeting performance targets including cost reduction.	• The most promising of the early stage materials research projects will be downselected to focus on the approaches that show the highest potential of meeting performance targets including cost reduction.
• Fund National Laboratory advanced battery cell projects focused on novel anode and cathode pairing, new electrode structures, fast charging capabilities, and cell manufacturing improvements.	• Fund National Laboratory advanced battery cell projects focused on material component (cathode, electrolyte, and anode combinations) electrochemistry optimization to advance battery cell technologies that offer the greatest performance improvements in terms of cell cost and the use of recycled materials.	• Advanced battery cell R&D projects will prioritize cost reduction and recycled material use since these are likely the largest barriers to electrochemical storage success in transportation and stationary applications.
• Fund National Laboratory battery systems research addressing barriers such as pack and module fast charging, thermal management, and design for recycling or second use. Supports R&D to enable affordable lithium ion battery recycling technologies and the Lithium Ion Battery Recycling Prize. Continue support for the Behind the Meter Storage (BTMS) in collaboration with the Solar Energy and Buildings Technology Offices.	• Continue to fund downsselected National Laboratory battery systems research projects, support the Lithium Ion Battery Recycling Prize, and support the BTMS efforts to use vehicle batteries for small-scale stationary storage (up to 10 MWh).	• Projects will be downselected to focus on lithium ion battery recycling technologies that have the potential to profitably recover critical battery materials. Support for BTMS will focus on the most promising battery technology with the potential to meet the performance and cost targets developed in FY 2020.

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Electric Drive R&D $40,000,000	$4,400,000	$35,600,000
• Support National Laboratory-led projects with university participation for early stage research targeting the development of technologies that will enable low cost, high power density electric drive systems, including wide bandgap devices, semiconductor packaging, passive devices, motor materials, and electromagnetic and thermal analysis.	• Support National Laboratory-led projects with university participation for early stage research, concentrating only on research areas that can have the biggest impact on meeting long-term targets for power density and cost reduction.	• Projects will focus on most promising pathways as guided by previous year simulation and test results.
• Continue competitively awarded research and development projects, awarded in FY 2019, focused on removing technology barriers to full electrification for heavy-duty battery electric vehicle technologies capable of increasing efficiency and productivity of electric drive systems.	• No funding requested.	• Projects will continue using prior year funds.
• Support competitively award industry led R&D projects focused on the research and development of advanced motor and inverter drive systems that are heavy rare earth mineral free and reduce drive system cost, increase power density and durability.	• No funding requested.	• Projects will continue using prior year funds.
• 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 for current SuperTruck II competitive awards.	• SuperTruck II activities will continue to cost obligated carryover until completion.

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
	• Competitively select and award industry-led projects and/or new laboratory research projects focused on improving the energy and operational efficiency of moving freight with medium- and heavy-duty trucks. This effort will focus on truck hybridization and electrification to improve overall vehicle efficiency. This effort will integrate and coordinate work in the areas of advanced engines, materials technology, and mobility systems that can reduce fuel consumption through more efficient operation. This effort will be coordinated with the Fuel Cell Technologies Office.	• New competitively selected projects will improve Medium-Duty – Heavy-Duty (MD/HD) truck energy efficiency and improve the operational efficiency of freight transportation. New effort will capitalize on work completed in SuperTruck II.
Electrification R&D $19,700,000	$5,000,000	-$14,700,000
• Support competitively award industry led R&D projects to research, develop, and demonstrate affordable and secure plug-in electric vehicle smart charging systems.	• No funding requested.	• Projects will continue using prior year funds.
• Support National Laboratory research projects focused on enabling extreme fast charging of electric vehicles, wireless charging, limiting grid impacts, and controlling smart charging.	• Continue support for downselected National Laboratory research projects focused on enabling extreme fast charging of electric vehicles, wireless charging, limiting grid impacts, and controlling smart charging.	• Limit funding to projects with the highest potential impact.
• Support vehicle cybersecurity risk assessment projects at the National Laboratories evaluating cybersecurity for grid connected vehicles.	• Issue a FOA and award competitively selected, industry-led projects to develop secure vehicle-grid connection and communication technologies.	• Build upon completed risk assessments by competitively selecting industry-led projects that address the most critical needs and highest vulnerabilities.
• Fund Industry-led projects focused on high power charging systems, wireless charging, and increased vehicle efficiency for heavy-duty battery electric vehicles.	• No funding requested.	• Projects will continue using prior year funds.

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 two major activities: (1) Fundamental Combustion and Emissions Research and (2) Integrated Powertrain Systems Development.

<u>Fundamental Combustion and Emissions Research</u>

Activity will support National Laboratory development of predictive, high-fidelity sub-models and simulation tools that are scalable and can leverage future exascale computing capabilities. These tools will use high performance computing (HPC) 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 activity 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.

The activity will also support experimental combustion projects conducted by the National Laboratories and will provide data for the new exascale modeling initiative 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 with HPC, 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 activity will support experiments conducted by the National Laboratories 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 that simulate the chemical reaction rates using high performance computing will be developed.

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

The Integrated Powertrain Systems Development

This activity will support a new research portfolio focused on long-term, high risk R&D to improve the efficiency of medium- and heavy-duty vehicles. The portfolio will focus on crosscutting medium- and heavy-duty engine and vehicle technologies that will identify new barriers and will enable significant gains in energy efficiency. Trucks move 11 billion tons of freight in the U.S., but as more people order goods to be delivered to their homes, this statistic is expected to rise. The goal of this portfolio is to conduct coordinated early-stage research with industry, universities, and at National Laboratories having unique facilities and capabilities specific to heavy-duty vehicles. Technologies will include both traditional combustion engines, as well as new opportunities, to electrify truck operations or use system approaches to reduce energy during operation. The subprogram will coordinate with and utilize expertise from other subprograms as needed.

The activity will also support the development of natural gas engines while reducing their cost. The activity will conduct research on topics including high-efficiency lean-burn engine technologies and accompanying emission control systems that together 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.

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Advanced Engine and Fuel Technologies $70,000,000	**$9,000,000**	**-$61,000,000**
Fundamental Combustion and Emissions Research $33,000,000	$8,000,000	-$25,000,000
• Predictive Modeling of Engine Combustion and Fuels: Develop computer simulations and sub-models of engine combustion and fuels, including adaption for future exascale-based high performance computing using facilities at the National Laboratories. Develop detailed models 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.	• Predictive Modeling of Engine Combustion and Fuels: Develop high fidelity sub-models for fuel sprays and in-cylinder turbulence for adaption to future exascale-based high performance computing at the National Laboratories. Continue the development of detailed models of chemical kinetic mechanisms of combustion and fuels and emissions formation in the combustion process.	• Focus on high fidelity sub-models and detailed chemical kinetic models while maintaining some effort to develop numerical techniques that decrease processing time. Defer work on heat transfer sub-models.
• Lean/Next Generation Combustion Engines and Fuels R&D and Heavy-Duty Combustion Engines and Fuels R&D: Conduct engine and fuels research at National Laboratories through six projects focused on single-cylinder engines and four 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.	• Lean/Next Generation Combustion Engines and Fuels R&D and Heavy-Duty Combustion Engines and Fuels R&D: 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 sub-models.	• Prioritize efforts on applying advanced research tools to validate engine simulations and sub-models. Reduce efforts to generate experimental chemical kinetics data. Defer lower priority work on single- and multi-cylinder engines for experimental validation of simulation models.

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
• Co-Optimization of Engines and Fuels (Co-Optima): Support more than 40 projects at National Laboratories, with industry, and universities focused on performance tailored bio-derived, synthetic, and petroleum-based blend stocks to improve combustion efficiency in engines. Focus light-duty 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 in heavy-duty engines.	• Co-Optimization of Engines and Fuels (Co-Optima): Support Co-Optima projects at National Laboratories. 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) heavy-duty engine technologies.	• Reduce support for Co-Optima work at National Laboratories to focus on multi-mode and kinetically controlled combustion; eliminate light-duty research within Co-Optima.
• Catalyst R&D for Emission Control/After-Treatment: Support four cost-shared CRADAs with industry to address advanced emission control technologies.	• Catalyst R&D for Emission Control/After-Treatment: Competitively downselect to one or two cost-shared CRADAs with industry to address advanced emission control technologies.	• Discontinue two to three lower-priority CRADAs with industry.
• Conduct two atomistic-scale design projects at the National Laboratories that include scalable synthesis of multi-functional catalyst for emissions reduction at low exhaust temperatures.	• Conduct research at the National Laboratories on single-atom catalysis to improve conversion efficiency and reduce precious metal content. Competitively downselect to one project.	• Discontinue one the two single-atom catalysis projects at the National Laboratories.
• 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.	• Continue development of computer models to simulate the performance of multi-functional emission control systems optimized for multi-mode combustion systems and hybrid powertrains.	• Discontinue discrete component level (LNT, SCR) modeling and move to multi-functional emission control system modeling to meet regulated emissions with minimum energy penalty.
• Integrated Powertrain Systems Development $37,000,000	• $1,000,000	• -$36,000,000
• Conduct natural gas and propane engine technology R&D focused on reducing vehicle total cost of ownership, improving engine efficiency and emissions, and expanding natural gas and	• Conduct early-stage research projects at the National Laboratories to improve the efficiency of natural gas engines as a primary means of reducing vehicle total cost of ownership.	• Focus only on early-stage research at the National Laboratories to improve natural gas engine efficiency. Continue projects selected in FY 2019 and FY 2020 using prior-year funding.

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
propane engine and vehicle availability through three to four awards to industry and universities.		
• Continue two cost-shared research projects, competitively selected in FY 2019 that will design and demonstrate a lightweight high-efficiency engine that will enable a 25 percent fuel economy improvement and 15 percent powertrain weight reduction relative to a 2015 baseline.	• No funding requested.	• Projects will continue to outlay obligated carryover until completed.
• Conduct early-stage research, through competitively awarded projects, that can significantly decrease energy use, harmful emissions, and total cost of ownership across the off-road vehicle sector, and develop/validate technologies capable of increasing work specific energy efficiency of commercial off-road vehicles that are directly applicable to the agricultural sector.	• No funding requested.	• Projects will continue to outlay obligated carryover until completed.
• Conduct research on opposed-piston two-stroke engines to increase efficiency and reduce emissions through competitively awarded projects to industry-led teams.	• No funding requested.	• Projects will continue to outlay obligated carryover until completed.
• 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 for current SuperTruck II competitive awards.	• SuperTruck II activities will continue to cost obligated carryover until completion.

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
	• Competitively select and award industry-led projects and/or new laboratory research projects focused on improving the energy and operational efficiency of moving freight with medium and heavy-duty trucks. This effort will focus on improving engine efficiency with co-optimized fuels while reducing emissions. This effort will integrate and coordinate work in the areas of electrified driveline systems (both battery and hydrogen fuel cell), powertrain hybridization, materials, vehicle-level technologies, and mobility systems that can reduce fuel consumption through more efficient operation. This effort will be coordinated with the Fuel Cell Technologies Office	• New competitively selected projects will improve Medium Duty – Heavy Duty (MD/HD) truck energy efficiency and improve the operational efficiency of freight transportation. New effort will capitalize on work completed in SuperTruck II.

Vehicle Technologies
Materials Technology

Description

The Materials Technology subprogram supports early-stage R&D of technologies for vehicle light weighting and improved propulsion (powertrain) efficiency applicable to light- and heavy-duty vehicles. The Materials Technology research portfolio supports Vehicle Technologies' goals of affordable transportation and energy security. Reducing the weight of a conventional passenger car by 10 percent results in a 6-8 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; and
- Validate a 25 percent improvement in high temperature (300° C) component strength relative to components made with 2010 baseline cast aluminum (Al) alloys (A319 or A356) for improved efficiency light-duty engines by 2025.

Lightweight Materials

Lightweight Materials 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. Current priority focus areas for the subprogram include new joining technologies for multi-material structures in vehicles as well as reducing the cost of polymer matrix composite components. Polymer composites have the potential to reduce component weight by up to 70 percent but suffer from high raw material and manufacturing costs. Increased used of composites in vehicles requires the development of affordable matrix and filler materials, efficient intermediate processes, and manufacturing methods suitable for high volume production. New joining materials will be required in order to incorporate these lightweight composites and other new lightweight materials into the vehicle assembly. 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.

Powertrain Materials

Powertrain Materials 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. Research funded through this activity applies 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. Current priority focus areas for the subprogram include : (1) high temperature materials for high efficiency engines for heavy-duty and light-duty vehicles, (2) 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. The Powertrain Materials portfolio is closely aligned with other Vehicle Technologies subprograms to identify critical future materials needs of next generation high-efficiency powertrains for both heavy- and light-duty vehicles that are beyond current market drivers.

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Materials Technology $40,000,000	**$7,000,000**	**-$33,000,000**
Lightweight Materials $30,500,000	$4,000,000	-$26,500,000
• Expand the Joining Core Program, a multi-lab research effort, to include new research on machine learning for process control 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.	• Initiate 3 to 4 new Joining Core Program research efforts to build upon the work completed in FY 2020 to further address challenges in joining dissimilar materials including corrosion, coefficient of thermal expansion mismatch, and chemical incompatibility.	• The joining methods and material pairs selected for the new research efforts will be down-selected from the joining technologies identified as having the highest potential as a follow-up to the previous year's work.
• Support composite materials research at the National Laboratories, including the operation of the CFTF at Oakridge National Laboratory (ORNL), initiating seven new projects in Composites Core Program targeting core innovation science R&D, and continued funding for one research project focused on novel additively manufactured hierarchical composite materials.	• Support composite materials research at the National Laboratories, to improve the affordability of polymer composite components.	• Projects will continue to outlay obligated carryover until completed. The Budget does not request direct funding for the operation of the CFTF at ORNL.
• Expand National Laboratory research on lightweight automotive metal alloys with novel microstructure and properties including the continuation of one project on solid phase processing techniques.	• No funding requested.	• Projects will continue to outlay obligated carryover until completed.
• Initiate three new CRADA projects utilizing the LightMAT Consortium to engage the automotive industry in accelerating the discovery and development of advanced materials technology.	• No funding requested.	• Projects will continue to outlay obligated carryover until completed.
• Initiate 2-4 competitively awarded projects targeting specific on-vehicle applications to research, develop, and demonstrate novel materials, composites preforms and	• No funding requested.	• Projects will continue to outlay obligated carryover until completed.

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
intermediates, processes, and components capable of weight reduction when compared to current baseline vehicle components for high-volume, high-performance, and affordable fiber-reinforced polymer composite vehicle applications.		
• 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 early-stage research at the National Laboratories 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.
Powertrain Materials $9,500,000	$3,000,000	-$6,500,000
• Continue 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 ICME approach to address materials needs for developing a suite of next generation powertrain materials.	• Fund research tasks focused on the development of high temperature materials for high-efficiency engines for both heavy- and light-duty vehicles. Advanced characterization tools and computational methods through the National Laboratories Powertrain Core Program will be maintained.	• Research of additive manufacturing for powertrain materials and exploratory seedling projects through the Powertrain Core Program will be deprioritized.
• Continue two cost-shared research projects, competitively selected in FY 2019 that will design and demonstrate a lightweight high-efficiency engine that will enable a 25 percent fuel economy improvement and 15 percent powertrain weight reduction relative to a 2015 baseline.	• No funding requested.	• Projects started in FY 2019 will continue using prior-year funds.
• 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-	• No funding requested for current SuperTruck II competitive awards.	• SuperTruck II activities will continue to cost obligated carryover until completion. Some unobligated portions of the originally awarded cost-shared projects to build a physical prototype will be reduced or eliminated.

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
effectiveness of these technologies to heavy-duty Class 8 regional-haul vehicles.		
	• Competitively select and award industry-led projects and/or new laboratory research projects focused on improving the energy and operational efficiency of moving freight with medium and heavy-duty trucks. This effort will focus on lightweight materials and propulsion system materials to reduce weight, improve vehicle efficiency and overall performance. This effort will integrate and coordinate work in the areas of engine and fuels, electrified driveline systems (both battery and hydrogen fuel cell), powertrain hybridization, waste energy recovery, vehicle-level technologies, and mobility systems that can reduce fuel consumption through more efficient operation. This effort will be coordinated with the Fuel Cell Technologies Office.	• New competitively selected projects will improve Medium Duty – Heavy Duty (MD/HD) truck energy efficiency and improve the operational efficiency of freight transportation. New effort will capitalize on work completed in SuperTruck II.

Vehicle Technologies
Energy Efficient Mobility Systems

Description

The Energy Efficient Mobility Systems (EEMS) subprogram supports early-stage research to enable industry innovation that improves the affordability, accessibility, and energy productivity of the overall transportation system. 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. This expertise will be used 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 resources. The EEMS subprogram consists of two primary activities: Computational Modeling and Simulation and Connectivity and Automation Technology. The subprogram's overall goal is to identify pathways and develop innovative technologies and systems that can dramatically improve mobility energy productivity for individuals and businesses when adopted at scale. In FY 2020, the EEMS subprogram completed the development a quantitative metric for mobility energy productivity, which measures the affordability, energy efficiency, convenience, and economic opportunity derived from the mobility system. The metric, while encompassing multiple vehicle classes and modes for passenger and goods movement, will be used by the subprogram to evaluate success and by the transportation community to inform planning decisions.

Computational Modeling and Simulation

The Computational Modeling and Simulation activity includes the SMART (Systems and Modeling for Accelerated Research in Transportation) Mobility National Laboratory Consortium, a multi-disciplinary approach to transportation research that is beyond the scope or capability of a single company or organization, which will assess the energy productivity impacts from future mobility technologies and transportation systems. The current priority is the development and application of city/regional-scale multi-fidelity transportation system-level models to identify pathways to improve mobility energy productivity, benefiting the U.S. economy and improving American competitiveness in the transportation sector.

As part of the Computational Modeling and Simulation activity, the high performance computing-enabled data analytics effort will use unique National Laboratory capabilities to apply artificial intelligence, machine learning, high-performance computing, and data science tools to improve vehicle and transportation efficiency. This effort aligns with the Administration's push for increased development and application of artificial intelligence as an identified Industry of the Future. 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. However, challenges exist in management, analysis, and visualization of these large and complex data sets. The EEMS subprogram will initiate a new transportation system optimization project using data science and strategic computing capabilities, validated in the previous year, aimed at solving specific transportation energy challenges faced by cities, states, and regions of the U.S.

The Computational Modeling and Simulation activity also includes the development of core evaluation tools and mobility testbed facilities. This effort will develop and maintain a critical set of experimental evaluation capabilities that support EEMS' early-stage R&D and analysis of transportation systems, vehicles, and advanced powertrains. 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.

Connectivity and Automation Technology

Significant opportunities exist to improve mobility efficiency, affordability, accessibility, and convenience through connected and automated transportation system-level solutions. The Connectivity and Automation Technology activity will support private sector efforts to develop technology solutions that improve the mobility energy productivity for both passengers and freight movement through the development of connectivity, communication, automation, and other technologies. EEMS will initiate 1-2 new competitively selected advanced connected and automated vehicle system R&D projects to remove technical barriers and accelerate the efficiency and mobility benefits of these promising technologies. By collaborating with industry, the EEMS subprogram will create novel solutions to improve the transition of efficient automated vehicle technologies and breakthrough connected mobility systems to practical use.

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Energy Efficient Mobility Systems $45,000,000	**$14,000,000**	**-$31,000,000**
Computational Modeling and Simulation $27,000,000	$9,000,000	-$18,000,000
• Complete modeling, simulation, analysis, and experimental testing through five coordinated research pillars in the SMART Mobility Laboratory Consortium: connected and automated vehicles, urban science, multimodal freight transport, and advanced fueling infrastructure. Initiate SMART Mobility Phase 2 effort to validate and deploy transportation system models.	• Funding will support the validation and application of previously created transportation system models to specific cities and regions, to simulate mobility and energy outcomes across various future transportation scenarios, through the downselection of specific projects initiated through a lab call in FY 2020.	• Focus within SMART Mobility will shift from model development/refinement and experimental validation to simulation studies applied to specific locations.
• 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.	• Building upon transportation data science and strategic computing capabilities validated in the previous year, funding will be used to initiate one new transportation system optimization project that uses artificial intelligence and deep-learning techniques to accelerate the pace of solution discovery in mobility operations.	• A downselection of the most promising of three previously selected National Laboratory projects will focus high-performance computing and artificial intelligence research into a single effort.
• Update core vehicle modeling and simulation tools, including the Autonomies software, and establish new connected and automated vehicle testing validation capabilities. Implement a 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 for core laboratory evaluation and data management activities will continue, using laboratory capabilities developed through prior year funding.
Connectivity and Automation Technologies $18,000,000	$5,000,000	-$13,000,000
• Initiate five to eight advanced research and development projects to develop cost-effective approaches to improve the transportation system efficiency through connectivity and automation.	• EEMS will initiate one to two new competitively selected advanced R&D projects to remove technical barriers and accelerate the efficiency and mobility benefits of connected and automated vehicle/transportation systems.	• Support for the development of advanced connected and automated vehicle technologies will continue, with a focus shifting to specific high-priority transportation applications.

• Use state-of-the-art mobility testbed capabilities to generate experimental data to validate simulation models of connected and automated vehicle technologies. • 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.	• Testing and model validation work will continue using prior year funds, generating experimental test data of connected and automated vehicle technologies operating in a variety of scenarios. • No funding requested for current SuperTruck II competitive awards.	• Previously awarded connected and automated vehicle testbed activities will continue using prior year funds as planned. • SuperTruck II activities will continue to cost obligated carryover until completion.
	• Competitively select and award industry-led projects and/or new laboratory research projects focused on improving the energy and operational efficiency of moving freight with medium and heavy-duty trucks. This effort will integrate and coordinate work in the areas of efficient freight mobility systems, engine and fuels, electrified driveline systems (both battery and hydrogen fuel cell), powertrain hybridization, waste energy recovery, advanced materials, and vehicle-level technologies. This effort will be coordinated with the Fuel Cell Technologies Office.	• New competitively selected projects will improve Medium Duty – Heavy Duty (MD/HD) truck energy efficiency and improve the operational efficiency of freight transportation. New effort will capitalize on work completed in SuperTruck II.

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.

Technical Assistance

The Technical Assistance activities support projects to provide information, insight, online tools, and technology assistance to cities and regions working to implement alternative fuels and energy efficient mobility technologies and systems. Projects will; demonstrate proof-of-concept of alternative fuel/advanced technology vehicles, charging infrastructure, new mobility systems for goods and people movement and modeling and simulation. For FY 2021, the subprogram will provide minimum funding to maintain technical assistance activities, including the State and Alternative Fuel Provider regulatory program, along with funding for 1-2 living lab projects to validate emerging transportation technologies and systems.

Data Collection and Dissemination

The Data Collection and Dissemination activity will collect and provide objective, unbiased data, information and real-world lessons learned to inform future research needs and support local decision making. This includes projects to disseminate data, information, and insights. For FY 2021, the subprogram will maintain minimum funding for the statutory requirements related to the Alternative Fuels Data Center and the annual Fuel Economy Guide.

STEM and Workforce Development

The EcoCar Mobility Challenge challenges 12 university teams to apply advanced powertrain systems, as well as connected and automated vehicle technology to improve efficiency, safety, and consumer appeal. In FY 2021, student teams will complete and implement their vehicle design through hardware development and engineering.

Vehicle Technologies
Technology Integration

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Technology Integration $60,300,000	**$3,500,000**	**-$56,800,000**
Technical Assistance $49,100,000	$1,500,000	-$47,600,000
• Complete competitively awarded, prior year funded, 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.
• 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.	• No significant change
• Initiate four to eight small-scale competitively awarded alternative fuel or advanced technology vehicle fleet projects in communities, fleets, or geographic areas with little or no experience with these technologies but where the technology shows economic or efficiency opportunities.	• No funding requested.	• Projects will continue using prior year funds.
Data Collection and Dissemination $8,200,000	$1,000,000	-$7,200,000
• 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.	• In accordance with "Public Information Program" requirements in section 405 of the Energy Policy Act of 1992, update alternative fuel, vehicle, and infrastructure information in the Alternative Fuels Data Center.	• 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.

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
• 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.
STEM and Workforce Development $3,000,000	$1,000,000	-$2,000,000
• Support 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 the next phase of the EcoCAR Mobility Challenge, during which student teams will implement designs developed in FY 2020 into hardware.	Provide minimal support to enable student teams' to complete vehicle design, development, and engineering.

Vehicle Technologies
Data, Modeling, and Analysis
(Formerly Analysis)

Description

The Data, Modeling, and 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 2021 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 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, Data, Modeling, and 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.

Data, Modeling, and Analysis (formerly Analysis)

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Data, Modeling, and Analysis $6,000,000	**$1,500,000**	**-$4,500,000**
• 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.
• Fund three to six competitively awarded industry or university led projects for transportation and energy analysis focusing on analytical methods and illustrative applications that identify future transportation technology energy opportunities.	• No funding requested.	• Projects will continue using prior year funds.

Bioenergy Technologies

Overview

The Bioenergy Technologies Program focuses on applied research and development (R&D) of transformative, sustainable bioenergy technologies that can support a growing bioeconomy[1]. 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 affordability, economic productivity, energy security, 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, -jet, and -marine fuels. The program also supports 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.

Transportation is the second most expensive spending category, after housing, for U.S. households.[3] Affordable biofuels, biopower, and co-products offer an opportunity to increase fuel options and diversify energy supplies while creating American jobs across the supply chain and boosting 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.[4] 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 bring additional jobs and revenue to the U.S. economy.[5] However, DOE R&D can help realize this potential by focusing on early stages of innovation in areas that industry either does not have the technical capability to undertake or where there is too much technology uncertainty to merit sufficient industry focus.

To improve transportation energy affordability, increase domestic fuel options, support energy dominance, and promote future economic growth, DOE performs R&D on several advanced transportation technology options in the Vehicle Technologies, Bioenergy Technologies and Hydrogen and Fuel Cell Technologies Programs. Common metrics across all three of these programs have been developed to evaluate these advanced options compared to the lifecycle costs and energy consumption of today's technologies. Over a lifecycle basis, (vehicle manufacture, fuel production, and fuel use) future (~2030) modeled conventional technology of a gasoline internal combustion engine vehicle (ICEV) is expected to cost approximately 27 cents per mile and consume 4,700 Btu per mile.[6] 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.

The Bioenergy Technologies Program employs EERE's technology readiness level metric (TRL) to prioritize work within a subprogram and across the portfolio. 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.[7] This can involve first-of-a-kind integration of innovative bioenergy processes at the pilot/engineering-scale, but does not include pioneer commercial-scale

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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] 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.

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

[5] 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.*

[6] 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.

[7] 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.

biorefineries that are intended to operate and generate revenue if successful. 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.

The request provides $8,000,000 in support of the Plastic Innovation Challenge for preprocessing of municipal solid waste, new strategies for recycling plastics, new biobased plastics that are designed for recycle, technologies to convert carbon dioxide and wet wastes into fuels and products, and a sustainable bioproducts framework for the bioeconomy. In FY 2021 the multi-laboratory Bio-Optimized Technologies for keeping Thermoplastics from the Landfill and the Environment (BOTTLE™) consortium which is jointly funded between the Advanced Manufacturing Program and the Bioenergy Technologies Program will continue to support the Plastics Innovation Challenge. The BOTTLE consortium conducts high-impact research and development to change the way we recycle. The primary metrics for the BOTTLE consortium include:

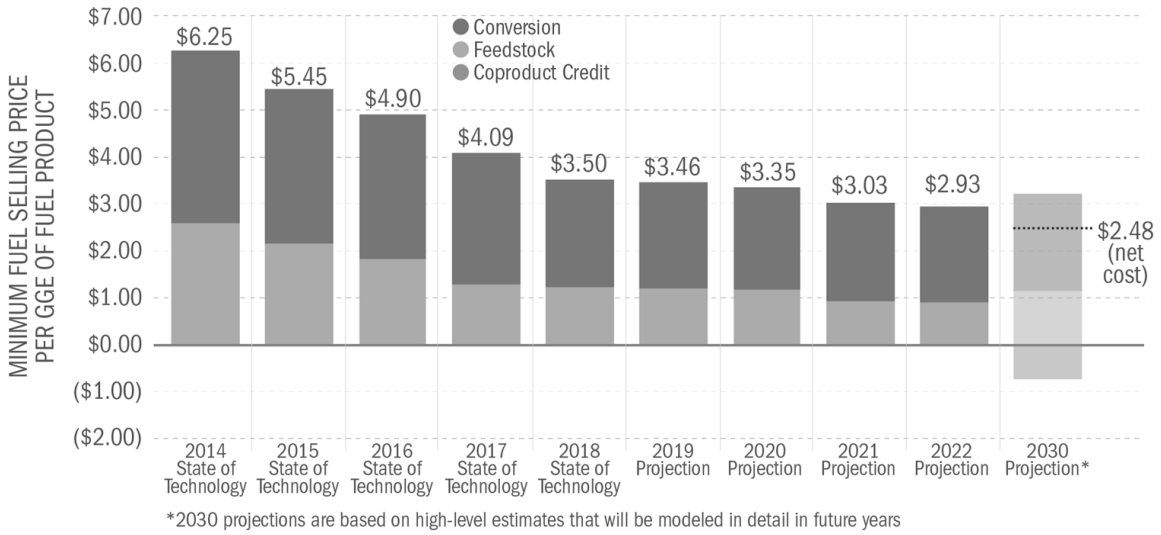
- Energy: ≥50 percent energy savings relative to virgin material production for upcycled plastics;
- Carbon: ≥75 percent carbon utilization from waste plastics in an upcycled product; and
- Economics: ≥2x economic incentive for upcycled products relative to today's standard recycling.

The request also provides $1,500,000 for the Energy-Water Challenge including catalytic upgrading of wet waste to renewable fuels and sustainable designs in algae cultivation (including addressing harmful algal blooms) with bioenergy systems.

Highlights of the FY 2021 Budget Request

- All Bioenergy Technologies Program research funding in the FY 2021 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 Technologies subprogram supports the Feedstock Conversion Interface Consortium (FCIC) of National Laboratories and industry experts. FCIC seeks to quantify, understand, and manage variability in biomass from field through downstream conversion and to understand how feedstock composition, structure, and behavior impacts overall system performance. This science-oriented R&D will provide tools for the entire industry to build upon as markets for feedstocks expand. Specifically, in FY 2021 the Feedstock Technologies subprogram will deliver feedstocks meeting the defined Critical Material Attributes (CMAs) for the 2022 verification, supporting a modeled minimum fuel selling price of $3/gge and a 60 percent reduction in GHG emissions relative to petroleum derived fuels.
- The Advanced Algal Systems subprogram will fund 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. Specifically, in FY 2021 the Advanced Algal Systems subprogram will develop technologies with algae biomass productivity of 19.6 grams per meter^2 per day, an increase over the previous FY 2018 milestone of 13 grams per meter^2 per day.
- The Conversion Technologies subprogram will support transformative R&D in synthetic biology of engineered organisms through the Agile BioFoundry and explore the potential of novel catalysts through the Chemical Catalysis for Bioenergy (ChemCatBio) consortium to 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,[1] including bio-derived plastics, with the potential to improve the economics and efficiency of biomass utilization. The program will also fund exploratory work by 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. Specifically in FY 2021 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 $3.03/gge, a reduction of $0.47/gge compared to the FY 2018 state of technology baseline of $3.50/gge. Additionally in FY 2021, the Conversion Technologies subprogram will increase yield of upgradeable co-products from an industrially relevant lignin waste stream to 44 percent by mass, an increase over the previous FY 2018 milestone of 35 percent by mass.

[1] Performance advantaged biobased products are defined as novel products where the biobased product molecule does not resemble an existing petroleum-derived molecule in structure, but offer a performance advantage over existing products. Moving Beyond Drop-In Replacements: Performance –Advantaged Biobased Chemicals, Workshop Summary Report, June 2018 .
https://www.energy.gov/sites/prod/files/2018/06/f53/Performance-Advantaged%20Biobased%20Chemicals%20Workshop%20Report.pdf.



Illustrative biofuel technology pathway progress toward $3/gge in FY 2022

- The Systems Development and Integration 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 medium- and heavy-duty fuel economy by 4 percent and reduce vehicle emissions by 2030 compared to 2015 compression ignition vehicles. Support of the integrated testing and pilot-scale work will continue in FY 2021 as BETO will leverage previous investments in integrated process development/pilot-scale/systems research capabilities at the DOE National Laboratories, universities, and industry.
- The Data, Modeling, and Analysis subprogram will develop a sustainable bioproducts framework in support of the Plastic Innovation Challenge to guide development of bioproducts that are environmentally-benign throughout their product lifecycle and provide a performance advantage over incumbent materials. Specifically in FY 2021 the Data, Modeling, and Analysis subprogram will verify a reduction of at least 12 percent in direct water consumption for one biofuel production pathway versus its 2018 state of technology baseline.

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 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted
Bioenergy Technologies				
Feedstock Technologies (formerly Feedstock Supply and Logistics)	30,500	40,000	6,000	-34,000
Advanced Algal Systems	32,000	40,000	4,000	-36,000
Conversion Technologies	96,000	110,000	21,500	-88,500
System Development and Integration (formerly Advanced Development and Optimization)	57,500	60,000	8,000	-52,000
Data, Modeling, and Analysis (formerly Strategic Analysis and Crosscutting Sustainability)	10,000	9,500	5,000	-4,500
Total, Bioenergy Technologies	**226,000**	**259,500**	**44,500**	**-215,000**

SBIR/STTR:

- FY 2019 Transferred: SBIR $7,232,000; STTR $1,017,000
- FY 2020 Projected: SBIR $8,178,000; STTR $1,150,000
- FY 2021 Request: SBIR $1,424,000; STTR $200,000

Bioenergy Technologies
Explanation of Major Changes ($K)

	FY 2021 Request vs FY 2020 Enacted
Bioenergy Technologies	
Feedstock Technologies: The reduction in funding level for this subprogram reflects the prioritization of the pre-processing R&D which integrates advances in feedstock logistics to improve the quality of raw biomass and waste streams with preprocessing to produce conversion-ready feedstocks. The subprogram will prioritize research on model feedstocks such as corn stover and pine residues through the Feedstock-Conversion Interface Consortium to produce conversion-ready feedstocks in support of the FY 2022 verification on catalytic fast pyrolysis and upgrading to drop-in biofuels. 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, not dedicated energy crops or other renewable carbon sources. Limited funding is requested outside of FCIC for new work in pre-processing municipal solid waste to produce a conversion-ready feedstock. No funds are requested for infrastructure upgrades at National Laboratory facilities.	**-34,000**
Advanced Algal Systems: The reduction in funding level for this subprogram reflects the prioritization of the most critical algal system activities within the broader priorities of EERE and the Department. The subprogram will continue to prioritize 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 discontinued. The subprogram will support small competitive selections for development of biological tools to improve algal productivity.	**-36,000**
Conversion Technologies: The reduction in funding level for this subprogram reflects the prioritization of the most critical conversion technology 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 2021 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	**-88,500**

biofuels and co-produced bioproducts as well as develop new polymers designed for recyclability will also continue, but 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 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.

System Development and Integration: The reduction in funding level for this subprogram reflects the prioritization of the most critical early-stage systems development and integration 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 discontinue 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 2021 for demonstration scale projects. **-52,000**

Data, Modeling, and Analysis: The reduction in funding level for this subprogram reflects the prioritization of the most critical data, modeling, and analysis activities that support the Bioenergy Technologies Program's mission. Activities will focus on techno-economic analyses 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. **-4,500**

Total, Bioenergy Technologies	**-215,000**

Bioenergy Technologies
Feedstock Technologies
(Formerly Feedstock Supply and Logistics)

Description

The primary goal of the Feedstock Technologies subprogram is to conduct research and development focused on supporting industry as they develop and supply high-quality, energy-dense, and sustainable conversion-ready feedstocks. The subprogram 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 will deliver conversion-ready feedstocks for the 2022 verification through the fundamental R&D supported in the Feedstock-Conversion Interface Consortium (FCIC). Specifically, the Feedstock Technologies subprogram will conduct research through FCIC on the identification of material attributes that, after pre-processing, can meet specific quality attributes necessary to produce conversion-ready feedstocks. To meet this goal, the Feedstock Technologies subprogram supports R&D in the following two activities:

Feedstock Supply

This activity includes supply chain analysis and the development of methods to identify, quantify, and mitigate supply chain risk. This activity is expected to increase the type and availability of new cost-advantaged feedstocks into the subprogram portfolio and to lower the cost of producing biofuels and bioproducts.

Pre-processing R&D

Pre-processing R&D integrates advances in feedstock logistics to improve the quality of raw biomass and waste streams with pre-processing to produce conversion-ready feedstocks. This activity seeks to increase understanding of biomass materials and the fundamental physical properties that govern feedstock behavior, energy density, and conversion performance. This integration is designed to mitigate the flowability and abrasiveness issues of feedstocks that have caused deleterious feed handling events at integrated biorefineries. Pre-processing R&D supports logistics research activities considered upstream of the interface activities, such as harvest logistics and quality assurance, biomass densification, and biomass analytics tools. Collectively, these activities will lower cost and reduce risk by improving the operational reliability of integrated biorefineries both in terms of reliability of equipment and process operation, as well as reliability of the throughput and quality of finished products coming out of the biorefinery. While this work has historically focused on biomass, such as agricultural and woody residues, the Feedstock Technologies subprogram is supporting new work in characterization and pre-processing of municipal solid wastes and plastics to support of the Program's broader efforts to use economically-advantaged waste streams as feedstocks for production of fuels, chemicals, and co-products.

A key mechanism for implementing Pre-processing R&D is the Feedstock-Conversion Interface Consortium. The FCIC is a consortium involving eight National Laboratories and is directed toward addressing feed handling issues encountered by integrated biorefineries. The consortium will analyze both the impacts of pre-processing operations on feedstock physical, mechanical, and chemical characteristics and the impacts of those characteristics on conversion performance, system reliability, and process economics. FCIC will then be able to identify the most cost-effective ways to deliver high-quality, conversion-ready feedstocks to the biorefinery, and maintain biofuel and co-product yield, quality, and minimum fuel selling price (MFSP) targets.[2] FCIC connects core capabilities across eight National Laboratories and 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.

[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' and
- Develop techno-economic 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.

Feedstock Technologies
(Formerly Feedstock Supply and Logistics)

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Feedstock Technologies (Formerly Feedstock Supply and Logistics) $40,000,000	**$6,000,000**	**-$34,000,000**
Feedstock Supply $11,500,000	$500,000	-$11,000,000
• National Laboratory research on supply scenario analysis and resource mobilization.	• Support ongoing National Laboratory research on supply chain analysis and developing methods to identify, quantify, and mitigate supply chain risk and mobilization of model woody and herbaceous feedstocks.	• National Laboratory R&D will deemphasize resource mobilization, specifically verifying and qualifying the key challenges and drivers in increasing energy crop grower participation, and modelling the effect of socio-economic factors on grower decision-making.
• Competitive selections on quantifying environmental and economic benefits associated with energy crop production.	• No funds are requested for new competitive selections.	• No funds are requested for new competitive selections.
Pre-processing R&D $28,500,000	$5,500,000	-$23,000,000
• 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.	• 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.	• FCIC research will deemphasize low-temperature conversion of corn stover and focus on high temperature conversion of pine residues in preparation for BETO's FY 2022 verification on catalytic fast pyrolysis and upgrading.
• National Laboratory research on harvest logistics and quality assurance, biomass densification, and biomass analytics tools.	• Support ongoing National Laboratory research on harvest logistics and biomass analytics.	• National Laboratory R&D will focus on harvest logistics and biomass analytics tools for model woody and herbaceous feedstocks, not dedicated energy crops, or other renewable carbon sources. Biomass densification and storage will be deemphasized.
• New competitive selections on biomass feedstock research to reduce the costs of feedstocks logistics.	• Competitive awards for biomass composition variability will continue using prior funds.	• No funds are requested for competitive awards.
	• Support new work in preprocessing of municipal solid wastes and plastics.	• Limited funding for new work in area of waste utilization.

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
• Facility upgrades at the Biomass Feedstock National User Facility at Idaho National Laboratory.	• No funding requested.	• Facility upgrades at the Biomass Feedstock National User Facility will be implemented using prior year funds.

Description

The Advanced Algal Systems subprogram supports R&D of algal biomass[1] production and logistics systems, as well as the interface between algal biomass and conversion processes. 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 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] Accordingly, the subprogram activities are oriented towards the long-term subprogram goal of delivering technologies by 2030 that, if scaled up by industry, could produce cost-competitive algal biofuels such as gasoline, diesel, and jet fuel blendstock components, along with valuable, co-produced bioproducts such as building-block commodity chemicals, plastics (including foams), fertilizers, and animal feed components. The production of bioproducts directly supports BETO's mission to lower the cost of biofuels. In FY 2020, the subprogram met its milestone of 3,700 gallons of algal biofuel intermediate per acre per year through R&D delivered by competitively selected recipients via the Advancements in Algae Biomass Yield 2 (ABY2) FOA, funded in FY 2016 and FY 2017. The next subprogram goal on the critical path to the 2030 cost goal is to increase the productivity of algae cultivation as measured by grams of algae biomass produced via photosynthesis per meter squared of open pond area per day ($g/m^2/d$). This goal is the basis for the subprogram FY 2025 GPRA milestone of 25 $g/m^2/d$ algae productivity. The subprogram is organized in two activity areas to deliver progress towards its goals.

Strain and Process R&D

Activities related to Strain and Process R&D includes 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. Efforts also include the deep characterization of highly productive and resilient microalgae strains with the overall goal of delivering new robust performers for year-round outdoor cultivation via the "Development of Integrated Screening, Cultivar Optimization, and Verification Research" (DISCOVR) multi-national laboratory consortium. In addition, the activities include R&D on harvest and processing considerations for algae biomass and the interface between algae biomass production and the conversion of algae feedstocks to fuels and co-products, including convertibility and targeted fuel and co-product development.

Systems Integration R&D

Activities related to Systems Integration R&D include identifying and addressing gaps in bringing multiple areas of algae R&D together in advanced systems of research-scale technologies, as well as producing reliable and repeatable algal system performance data from relevant outdoor algae cultivation systems to increase the yield of conversion processes making algal biofuels and bioproducts. Additionally, activities in this area integrate the latest technological advances into robust state of technology techno-economic, resource, and life-cycle analyses. This work allows the subprogram to 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.

[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.

Advanced Algal Systems

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Advanced Algal Systems $40,000,000	**$4,000,000**	**-$36,000,000**
Strain and Process R&D $20,000,000	$3,500,000	-$16,500,000
• DISCOVR Consortium.	• DISCOVR Consortium.	• DISCOVR consortium shifting R&D priorities to early-stage strain screening activities to identify potential strains of interest for hand-off to industry for further development.
• Three competitive awards for synergistic integration of algae with wastewater treatment to develop new sources of biomass for bioeconomy while meeting stringent wastewater treatment metrics.	• No funds are requested for integration of algae with wastewater treatment.	• Research on integration of algae with wastewater treatment will continue with prior year investments.
• National Laboratory research on strain and process R&D.	• National Laboratory research on strain and process R&D.	• National Laboratory research shifting R&D priorities to early-stage strain development to meet harvest and conversion targets established in previous state of technology assessments.
	• National Laboratory research on resource use and sustainable designs in algae cultivation (including addressing harmful algal blooms) with bioenergy systems.	• Research to leverage development and prioritization on resource use and sustainable designs in algae cultivation with bioenergy systems.
System Integration R&D $20,000,000	$500,000	-$19,500,000
• Up to five competitive awards for integration of algae bioproducts and CO2 Direct-Air-Capture (DAC) to enhance direct air capture of carbon dioxide while delivering high-quality algae biomass for conversion to fuels and products.	• No funding is requested for competitive awards for integration of DAC and algae production for biofuels and co-produced bioproducts.	• Integration of DAC and algae production for biofuels and co-produced bioproducts funding opportunities funded with prior year investments.
• State of technology cultivation trials to verify progress towards productivity improvements in outdoor environments.	• State of technology cultivation trials to verify progress towards productivity improvements using indoor simulations.	• State of technology cultivation trials will shift to small-scale, indoor climate simulations to establish mechanistic drivers of biomass productivities for hand-off to industry for further testing.

Description

The Conversion Technologies subprogram pursues 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, waste feedstocks, and other complex organic polymers into "drop-in" biofuels (gasoline, diesel, jet, and marine fuels), fuel components, 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 to convert all the biomass and waste streams across America. 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 modeled mature price-competitive fuels (less than $3/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.

Bio-Processing R&D

The goal of this activity is to reduce the time and cost for developing and implementing biological conversion of biomass and other materials into useful fuels and products. This includes organism development, metabolic pathway engineering and optimization, and novel approaches such as cell-free biocatalysis. One component of this effort, the Agile Biofoundry (ABF) consortium, is seeking to industrialize synthetic biology tools and machine learning to develop a Design-Build-Test-Learn infrastructure, accessible to all, that will reduce the time and cost to develop an industrially-relevant host organism producing a user-defined target molecule. This will substantially reduce the time, and up-front investment required to bring new fuel and product molecules to market with improved conversion efficiencies. The ABF consortium consists of several DOE National Laboratories and industrial partners guided by an Industrial Advisory Board.

Catalysts R&D

The goal of the this activity is to significantly reduce the time and cost required to develop new catalysts for converting organic molecules derived from biomass and other relevant feedstocks via inorganic catalysis into fuels, chemical intermediates, and products. This is being accomplished through advanced chemical and surface characterization techniques, novel and advanced catalyst preparation strategies, numerical modeling of surface chemistry and mass and heat transfer, and understanding the performance and cost implications of various catalytic materials, support structures, and preparation methods. A principle implementing entity for the effort is the multi-lab ChemCatBio (CCB) consortium. Additionally, advanced numerical modeling techniques for computational chemistry and fluid dynamics are being developed to address numerous challenges in the bioenergy space related to the design and operation of processes and equipment in an integrated biorefinery.

Co-Products R&D

This activity focuses on employing the rich, functional nature of biomass to produce value-added and performance-advantaged bioproducts to enhance the economic feasibility of biorefineries. The lignin valorization activity focuses on novel chemical, enzymatic, and biological techniques to decompose and re-assemble the lignin component of biomass into useful and valuable chemicals and materials. Although lignin has a rich chemical functional structure, investigators have to this point been unable to successfully access, funnel, and utilize this structure in an economical process. Since lignin comprises approximately one third of biomass by mass, valorizing this material is essential to the economic viability of

many biorefineries. The Performance Advantaged Bioproducts activity focuses on developing chemicals and materials from biomass, such as new polymers designed for recyclability, that perform better in their target applications than the current incumbents derived from petroleum. In addition, since biomass is highly originated relative to petroleum feedstocks, performance advantaged bioproducts may not only provide improved function but also require less energy to produce than incumbent petroleum-based polymers. The activity is developing structure-function relationships and models to assist in prospecting for these biobased products as well as working with ABF and CCB to develop synthesis pathways for creating them. Early successes include plastics with decreased gas permeability and increased Ultra-Violet resistance. These value-added products can contribute significantly to the economic viability of biorefinery and biofuel processes.

Deconstruction and Synthesis R&D

This activity examines and develops more efficient and effective technologies to convert biomass to products and fuels via well-defined conversion technology pathways. The Deconstruction and Synthesis activity investigates more energy efficient and cost-effective techniques for disassembling biomass feedstocks, separating the constituents, and identifying catalytic, biochemical, and hybrid pathways for synthesizing desired end products using the organisms and catalysts developed elsewhere in the Program. Additionally this activity includes development of novel techniques for process measurement and control to benefit the R&D and industry.

Waste or residue materials represents a widely available and relatively affordable feedstock for the production of biofuels and bioproducts. As well, many wastes such as animal waste, food waste, municipal solid waste (including plastics), and biosolids represent significant environmental challenges. The Waste-to-Energy component of this activity examines technologies to efficiently and economically convert these wastes and residues into useful and valuable products including biofuels, bioproducts while also reducing environmental impacts from these materials.

Separation processes can represent up to 40 percent of the capital and energy cost for many processes. Many separation techniques currently in use are either unsuitable for application to biobased processes or require one-off and trial and error approaches which is costly and time consuming. The Bioprocessing Separations consortium under this activity is developing novel separation techniques specific to biorefineries.

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Conversion Technologies $110,000,000	**$21,500,000**	**-$88,500,000**
Bio-Processing R&D $28,800,000	$3,700,000	-$25,100,000
• Agile BioFoundry consortium to accelerate the R&D of new biologically-derived molecules through the completion of ≥ three cycles of Design-Build-Test-Learn (DBTL) on ≥ three target host pairs with at least 100 percent improvement in baseline titer, rate, and yield, including competitive selections for industry and academic partners.	• Agile BioFoundry consortium to accelerate the R&D of new biologically-derived molecules through the completion of at least two additional cycles of DBTL on up to three target host pairs with a further 100 percent improvement in baseline titer, rate, and yield over FY 2020 accomplishments, including competitive selections for industry and/or academic partners.	• Funds will be focused on Agile Biofoundry lab-led activities and will be reduced in the areas of host on-boarding and additional DBTL cycles and support the most meritorious project proposed by industry and academic partners to complement the lab consortium research.
• Selection of cost-shared, industrial-collaboration projects utilizing capabilities of the Agile Biofoundry.	• Selection of cost-shared, industrial-collaboration projects utilizing capabilities of the Agile Biofoundry.	• The Agile Biofoundry will prioritize fewer and smaller cost-shared, industrial-collaboration projects utilizing capabilities of the Agile Biofoundry.
• Research on organisms for the biological upgrading of sugars and aqueous waste streams to fuels and chemical intermediates.	• No funds are requested for the research on biological upgrading of sugars and aqueous waste streams.	• Selected biological upgrading strategies will continue using prior year funds.
• Research on improving biological process operations including continuous enzymatic hydrolysis, optimization of enzymes for production of sugar from mechanically refined biomass, and development of novel cell-free biological processing systems.	• No funds are requested for improving biological process operations.	• R&D on strategies deemed critical for improving biological process operations will continue using prior year funds.
Catalyst R&D $ 17,400,000	$3,700,000	-$13,700,000
• National Laboratory and industry-collaborative 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 development of catalytic processes.	• 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.

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Co-Products R&D $22,400,000	$7,900,000	-$14,500,000
• National Laboratory R&D 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.	• Performance-Advanced Bioproducts research at the National Laboratories will synthesize and verify the predicted performance for at least one performance-advanced bioproduct.	• Work on performance advantaged bioproducts will focus on verifying the predicative capabilities of the model developed in FY 2020.
• 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 and investigation of novel feedstocks including those derived electrocatalytically.	• Lignin valorization research at the National Laboratories will increase the yield of upgradable compounds from lignin beyond the 50 percent baseline while maintaining carbon efficiency.	• Research will begin to address yield improvements in addition to carbon efficiency.
• Initiate national laboratory consortium for innovative technologies for plastics recycling and up-cycling (BOTTLE). Competitively-selected projects with industry and academia for deconstruction of plastics and design of plastics for enhanced recyclability.	• Continued funding for national laboratory plastics BOTTLE consortium. Competitively-selected projects with industry and academia on development of new biobased plastics designed for recyclability.	• New competitive projects will focus on up to two new R&D strategies for biobased plastics that could be co-produced with fuels in an integrated biorefinery.
Deconstruction and Synthesis R&D $41,400,000	$6,200,000	-$35,200,000
• National Laboratory-based research on pretreatment, process hydrolysis and integration of these unit operations into functional bench scale systems.	• Research on a focused number of pathways for biomass deconstruction and upgrading to cost-competitive fuels and higher value co-products through AOP project plans and research facilities at the DOE National Laboratories.	• Pathways for biomass conversion will be down-selected for R&D prioritization based on modeling and analysis results.
• National Laboratory research on conversion of wet wastes to energy and modeling and analysis of these systems.	• Continued R&D on conversion of wet waste and technology for improving the economics of waste to energy systems through production of liquid fuels and co-products.	• No funding is requested for lab research on strategies that produce gaseous fuels or power from wastes.
• National Laboratory research under the Bioprocessing Separations Consortium to reduce cost and increase efficiency of separations for thermochemical and biochemical processes through experimentation and modeling.	• Separations research critical to achieving one FY 2022 conversion pathway fuel target price of approximately $3/gge.	• Separations research will focus on separations required for one most promising example conversion pathway.
• At least one competitively-selected, multi-university partnership on research and education	• No funds are requested to support a multi-university partnership on renewable energy from urban and suburban wastes.	• Multi-university partnership(s) will continue using prior year funding.

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
on renewable energy from urban and suburban wastes.		
• Selection of cost-shared, industrial-collaboration projects utilizing capabilities of the Consortium for Computational Physics and Chemistry.	• No funds are requested to cost-shared, industrial-collaboration projects utilizing capabilities of the Consortium for Computational Physics and Chemistry.	• Industrial-collaboration projects utilizing capabilities of the Consortium for Computational Physics and Chemistry will continue using prior year funding.
• Competitively-selected projects to improve the efficiency of community-scale digesters.	• No funds are requested to support competitively-selected projects to improve the efficiency of community-scale digesters.	• Competitively-selected projects to improve the efficiency of community-scale digesters will continue using prior year funding.
• Competitively-selected projects to develop the foundation for scalable technologies to use carbon dioxide produced in biorefineries to produce higher value fuels, chemicals or materials.	• No funds are requested to support a competitively-selected projects to develop the foundation for scalable technologies to use carbon dioxide produced in biorefineries to produce higher value fuels, chemicals or materials.	• Competitively-selected projects to develop the foundation for scalable technologies to use carbon dioxide will continue using prior year funding.

Bioenergy Technologies
Systems Development and Integration
(Formerly Advanced Development and Optimization)

Description

The Systems Development and Integration subprogram (Formerly Advanced Development and Optimization) supports research and development with partners in industry, academia, and the National Laboratories to reduce technology risk and enable industry scale-up of integrated biorefinery systems for the production of biofuels, biopower, and bioproducts. This subprogram focuses on the development, testing, and verification of engineering-scale research and development for integrated biorefinery process performance, development of novel methods to expand end-user acceptance of biofuel and bioproducts, and identification of new, robust market opportunities in the future bioeconomy. The key upcoming SDI Subprogram Goal is to verify integrated systems research at engineering scale for hydrocarbon biofuel technologies that achieve a mature modeled MFSP of $3/gge with a minimum 60 percent reduction in emissions relative to petroleum-derived fuels by 2022.

Production Process R&D

The Production Process R&D activity area will develop, test, and verify engineering-scale research and development for integrated biorefinery process performance to reduce technology uncertainty and to enable industry-led subsequent scale-up activities. Through portfolio assessment and project reviews of prior smaller scale work, this activity area will identify existing capital engineering scale resources and initiate implementation of necessary improvements critical to achieving 2022 verification goals.

Fuels and Co-Products R&D

The Fuels and Co-Products R&D activity area will identify fuel properties that can enhance engine efficiency and reduce emissions for multiple end uses, including light- and heavy-duty vehicles and non-road applications (e.g., marine, aviation), enabling new, robust market opportunities. This activity area will identify high performance, biofuel blendstocks that impart these desired properties and develop novel methods to expand end-user acceptance of biofuels and bioproducts. This activity area includes work in partnership with the Vehicle Technologies Program on the Co-Optimization of Fuels and Engines (Co-Optima) consortium. The 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.

Systems Development and Integration
(Formerly Advanced Development and Optimization)

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Systems Development and Integration $60,000,000	**$8,000,000**	**-$52,000,000**
Production Process R&D $46,000,000	$4,000,000	-$42,000,000
• National Lab research and development to lower risk and enable scale-up of integrated systems to produce biofuels, bioproducts, and biopower.	• FY 2021 will focus investments in National Laboratory process development units to successfully complete the Program goal to verify R&D to produce drop-in biofuels from biomass feedstocks at a minimum fuel selling price of $3.00/gge [FY 2022 End-Point GPRA Goal.]	• The activities to develop, test, and verify engineering-scale research and development for integrated biorefinery process performance will continue, but at a lower level to support industry-led subsequent scale-up via development at the DOE National Laboratories.
• Competitive selections for research and testing of innovative efficient wood heaters.	• No funds are requested to support competitive selections for research and testing of innovative efficient wood heaters.	• Projects to research and test innovative efficient wood heaters will continue using prior year funding.
• Competitive selections for the scale-up of bench application with industry and academia on a unit operations basis in order to reduce risk and aid in the development of reliable processes.	• No funds are requested to support competitive selections for the scale-up of bench application with industry and academia on a unit operations basis in order to reduce risk and aid in the development of reliable processes.	• Competitively selected projects for the scale-up of bench application with industry and academia on a unit operations basis will continue using prior year funding.
Fuels and Co-Products R&D $14,000,000	$4,000,000	-$10,000,000
• Co-Optimization of Fuels and Engines (Co-Optima) National Laboratory consortium to conduct R&D to identify and evaluate the most promising biofuel candidates to improve efficiency and emissions for mixing controlled compression ignition (MCCI) engines for heavy duty and multi-mode engines for light duty (in collaboration with the Vehicle Technologies Program), includes competitive selections with industry and academia.	• 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 investigation of biofuel candidates for advanced compression ignition engines conducted by the National Laboratories. Research on fuels for multi-mode engines for light-duty vehicles and work to identify desirable fuel properties for multiple end uses will be deprioritized. No funding is requested for competitive selections.
• National Lab research and development to investigate Sustainable Aviation Fuels (SAF) and Marine biofuel usage.	• No funding is requested to investigate SAF and Marine biofuels.	• Projects to investigate SAF and Marine biofuels will continue using prior year funding.

Bioenergy Technologies
Data, Modeling, and Analysis
(Formerly Strategic Analysis and Crosscutting Sustainability)

Description

The Data, Modeling, and Analysis subprogram activities provide quantitative analysis to inform the Bioenergy Technologies Office's decisions regarding the future direction and scope of its 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.

The subprogram's sustainability activities are focused on developing science-based strategies to understand and enhance the environmental and socio-economic benefits of advanced bioenergy and bioproducts while minimizing potential negative impacts. This includes research targeting underproductive aspects of agricultural and forestry systems and leveraging the ability of biomass to improve degraded soil and water resources. Sustainability research also fills critical knowledge gaps about how to increase bioenergy production without detriment to food security, air, land, and water resources.

Data, Modeling, and Analysis
(Formerly Strategic Analysis and Crosscutting)

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Data, Modeling, and Analysis $9,500,000	**$5,000,000**	**-$4,500,000**
• Update models and tools (including GREET, WATER and LEAF) and apply them to conduct high-priority analyses.	• Update models and tools (including GREET, WATER, FPEAM) and apply them to conduct high-priority analyses.	• Funding will prioritize updates to widely-used, publically available models.
• National Laboratory analysis on the potential for integrated landscape management strategies to reduce the cost of biofuels.	• No funds are requested to fund National Lab analysis on the potential for integrated landscape management strategies to reduce the cost of biofuels.	• National Lab analysis on the potential for integrated landscape management strategies to reduce the cost of biofuels will be discontinued.
• Bioenergy sustainability research by the National Laboratories to identify and fill knowledge gaps related to food security, air, land, and water resources.	• Bioenergy sustainability research by the National Laboratories to identify and fill knowledge gaps related to land and water resources, and develop a sustainable bioproducts framework to guide R&D toward bioproducts that are environmentally-benign throughout their product lifecycle and provide a performance advantage over incumbent materials.	• Funding will focus on highest-priority issues such as the energy-water nexus, and sustainable bioproducts in support of the Plastics Innovation Challenge.
• Competitive selections on testing energy crops in new regions that restore water and soil conditions.	• No funds are requested for new competitive selections on testing energy crops in new regions that restore water and soil conditions.	• Testing energy crops in new regions that restore water and soil conditions will continue using prior year funding.

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 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. Affordable hydrogen from diverse domestic resources supports other important industrial and chemical sectors, including steel manufacturing, fertilizer production, and production of liquid fuels.

The affordable generation, storage, and use of hydrogen as an energy currency can facilitate integration across transportation, industrial, and energy sectors, offering unique economic and environmental benefits. Integrated hydrogen and fuel cell systems, for example, 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 also support resiliency in the electric grid through voltage and frequency stabilization. Hydrogen and fuel cell technologies can safely and efficiently harness domestic resources in support of multiple U.S. sectors, thus enhancing American energy security and resiliency as well as economic growth. 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 multisector partnership efforts to develop and deploy hydrogen and fuel cell technologies which are cost competitive with conventional technologies.

The overarching program goal, supporting the DOE H2@Scale initiative, is to facilitate wide-spread adoption of hydrogen and fuel cells across sectors by reducing the cost and improving the performance/durability of fuel cells, as well as developing affordable and efficient technologies for hydrogen production, delivery, and storage. The scope is technology-neutral and feedstock-flexible, emphasizing diverse end uses including energy storage, transportation (e.g., trucks, marine, rail, aviation), chemicals (e.g., ammonia, synthetic fuels), backup power (e.g., emergency power, data centers), industry (e.g., iron and steel making) and others. The program has established application-specific targets relevant to the affordability of these emerging options, taking into account consumer expectations regarding pay back periods. As one example for medium/heavy-duty truck applications the ultimate targets are 30,000 hours for fuel cell durability; $60/kW for fuel cell cost and $8/kWh for onboard hydrogen storage costs. Achieving these targets, in conjunction with the program's hydrogen production target of <$2/kg, can allow hydrogen fuel cell powered vehicles to be competitive in terms of cost and performance with incumbent technologies.

In addition to its core materials-, component-, and systems-level R&D in fuel cells and hydrogen production, storage, and distribution technologies, the program's supporting activities include efforts to: reduce vulnerabilities and build supply chain resilience for rare earth and critical minerals (e.g. for fuel cell catalysts); accelerate R&D through machine learning and high performance computing; build and strengthen the STEM workforce in the hydrogen and fuel cell communities, and prioritize investments that facilitate and strengthen multisector partnerships consistent with H2@Scale.

To improve transportation energy affordability, increase domestic fuel options, support energy dominance, and promote future economic growth, DOE performs 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 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.

[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 and are based on meeting VTO technical targets.

Highlights of the FY 2021 Budget Request

- **Fuel Cell Technologies** will focus on early-stage fuel cell component and systems R&D with potential for transportation and crosscutting applications to meet application-specific targets (e.g. $60/kW and 30,000 hour durability for heavy duty trucks). 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. In FY 2021, there will be an increased focus on machine learning, ionomers and gas diffusion layers to meet durability for heavy-duty vehicles, and R&D focused on systems and systems integration, including stacks and innovative balance of plant (BOP) systems (e.g. innovative low cost, oil-free air handling for fuel cell systems to reduce cost and improve durability). 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 Technologies** will emphasize applied materials research and early-stage component and process development to support industry to develop and deploy novel hydrogen production, storage, and infrastructure technologies capable of utilizing diverse domestic energy resources. To support the H2@Scale concept, activities include R&D on modular, scalable concepts for dispatchable hydrogen production, delivery and storage, liquefaction, materials development, and integration with diverse generation sources. Hydrogen production efforts will focus R&D on materials to enable high-performing, durable, cost-competitive hydrogen production technologies, including low and high-temperature electrolysis, photo-electrochemical, and solar-thermal hydrogen production, to enable $2/kg for hydrogen production from sources other than conventional natural gas reforming. Hydrogen storage efforts will 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, as well as carbon fiber tanks to meet $8/kWh cost goals. These technologies may also be applicable to natural gas storage such as for medium and heavy-duty applications. In FY 2021, increased emphasis will be on R&D to enable efficient and cost-effective bulk storage, including chemical carriers. Infrastructure R&D will also focus on innovative, low-cost, durable materials and components to enable step-change improvements in the cost of hydrogen delivery/infrastructure at scale for applications beyond only FCEVs (e.g., cryopumps, compressors, liquefaction, dispensing, nozzles, hoses, seals, metals for pipelines and other components).
- **Systems Development & Integration** is focused on developing and integrating the technologies needed to deliver a full H2@Scale vision from a wide array of domestic resources. It includes R&D on hybrid systems and grid integration to enable grid stability/resiliency and enable innovations to generate hydrogen as an energy carrier, coupling nuclear, fossil fuels, the grid and renewables to enhance the economics of both baseload plants (nuclear and coal) and intermittent solar and wind, enhancing resiliency and avoiding curtailment. Key priorities include verification of novel, early-stage technologies in industrially relevant environments (e.g. steelmaking, ammonia production), and innovations to enable affordable megawatt- and gigawatt-scale hydrogen technologies to achieve H2@Scale. R&D includes integration of electrolyzers with grid profiles to validate concepts for the stability of the power grid through responsive load management and energy storage. This subprogram also includes R&D to enable the development of codes and standards for adoption of hydrogen and fuel cell technologies (e.g. sensor R&D), and develops and shares best practices on hydrogen safety.
- **Data, Modeling and Analysis** is focused on analytical research that provides a technical basis for informed decision making for the program's R&D direction and prioritization. Results from this activity also support annual updates to key planning documents that provide direction and milestones for the program, including peer reviews, and supports Federal advisory committee.

Departmental Cross-cuts:

- Energy Storage Grand Challenge ($15,000,000) - Electrolyzer R&D, HyMARC Hydrogen Storage R&D, and H2@Scale;
- Critical Minerals Initiative ($3,000,000) - PGM-Free Catalysts R&D; and
- Cybersecurity Crosscut ($1,000,000) - H2@Scale Systems Integration R&D.

Hydrogen and Fuel Cell Technologies
Funding ($K)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted
Hydrogen and Fuel Cell Technologies				
Fuel Cell Technologies (formerly Fuel Cell R&D)	30,000	26,000	8,000	-18,000
Hydrogen Technologies (formerly Hydrogen Fuel R&D and Hydrogen Infrastructure R&D)	60,000	70,000	23,000	-47,000
Systems Development & Integration (formerly Technology Acceleration and Safety, Codes, and Standards)	28,000	51,000	10,000	-41,000
Data, Modeling & Analysis (formerly Systems Analysis)	2,000	3,000	1,000	-2,000
Total, Hydrogen and Fuel Cell Technologies	**120,000**	**150,000**	**42,000**	**-108,000**

SBIR/STTR:

- FY 2019 Transferred: SBIR $3,735,000; STTR $645,000
- FY 2020 Projected: SBIR: $3,984,000; STTR: $560,000
- FY 2021 Request: SBIR: $1,333,000; STTR: $187,000

Budget Structure Crosswalk ($K)

FY 2020 Budget Structure	Proposed FY 2021 Budget Structure				
Hydrogen and Fuel Cell Technologies	Fuel Cell Technologies	Hydrogen Technologies	Systems Development & Integration	Data, Modeling & Analysis	Total
Fuel Cell R&D	8,000				8,000
Hydrogen Fuel R&D		23,000			23,000
Hydrogen Infrastructure R&D					
Systems Analysis				1,000	1,000
Safety, Codes and Standards			10,000		10,000
Technology Acceleration					
Total, Hydrogen and Fuel Cell Technologies	8,000	23,000	10,000	1,000	42,000

	FY 2021 Request vs FY 2020 Enacted
Hydrogen and Fuel Cell Technologies	
Fuel Cell Technologies (formerly Fuel Cell R&D): In FY 2021, the subprogram will focus on early-stage R&D to enable lower cost and improved durability, efficiency, and performance for transportation and crosscutting applications. Efforts will include use of artificial intelligence techniques, computational tools, and high throughput approaches to identify materials (e.g. catalysts) with potential to achieve activities and durability required for relevant applications. By greatly reducing the amount of precious metals required, this effort is coordinated with the Critical Minerals Initiative and will reduce dependence on platinum and other critical materials. 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 later-stage work. The subprogram will also defer R&D efforts on reversible fuel cells that store energy and generate power until feedback from innovative projects initiated in prior years can inform the direction of future R&D. Increased focus on systems and balance of plant R&D.	**-18,000**
Hydrogen Technologies (Formerly Hydrogen Fuel R&D and Hydrogen Infrastructure R&D): In FY 2021 the subprogram will focus on early-stage applied materials R&D for hydrogen production, storage, and will integrate activities from the former hydrogen infrastructure subprogram. The program will reduce efforts within the HydroGEN consortium until prior year activities generate results, and will reduce infrastructure related R&D that solely targets light duty vehicle dispensing. Rather than long distance delivery technologies, the program will focus on R&D relevant to co-location of large scale production and utilization. R&D will also focus on innovative, low cost, durable materials and components to enable step-change improvements in the cost of hydrogen delivery/infrastructure at scale for applications beyond only FCEVs (e.g., cryopumps, compressors, liquefaction, dispensing, nozzles, hoses, seals, metals for pipelines and other components). Materials related research, such as for hydrogen storage, will apply artificial intelligence techniques, machine learning, and other computational tools. In addition, R&D will emphasize reduction of precious metals that are conventionally used in electrolyzer technologies, in coordination with the Critical Minerals Initiative.	**-47,000**
Systems Development & Integration (Formerly Technology Acceleration and Safety, Codes and Standards): In FY21, the subprogram will integrate activities from the former Technology Acceleration and Safety, Codes and Standards subprogram. The subprogram will support the Advanced Energy Storage Initiative, as part of the broader Energy Storage Grand Challenge, through a focus on hybrid systems and grid integration to enable grid stability/resiliency and enable innovations to generate hydrogen as an energy carrier, coupling nuclear, fossil fuels, the grid and renewables to enhance the economics of both baseload plants (nuclear and coal) and intermittent solar and wind, enhancing resiliency and avoiding curtailment. Key priorities include verification of novel, early-stage technologies in industrially relevant environments (e.g. steelmaking, ammonia production), and innovations to enable affordable megawatt- and gigawatt-scale hydrogen technologies to achieve H2@Scale. R&D on hybrid systems includes high temperature electrolyzers using both thermal and electrical inputs to optimize efficiencies, and grid integration capabilities/dynamic response of electrolyzers. Activities also include R&D for integration across applications and sectors, as well as R&D to enable the development of needed codes and standards.	**-41,000**

	FY 2021 Request vs FY 2020 Enacted
Data, Modeling & Analysis (formerly Systems Analysis): In FY 2021, the program will focus on providing analysis to identify key areas in which to strategically prioritize R&D efforts. Minimal changes.	**-2,000**
Total, Hydrogen and Fuel Cell Technologies	**-108,000**

Description

The Fuel Cell Technologies subprogram supports early-stage R&D and innovative concepts to simultaneously reduce costs, improve durability, and enhance performance of fuel cells (including, power density, efficiency, start-up time, transient response, etc.). Key goals include developing and validating concepts to meet a number of metrics to enable fuel cells to be competitive with incumbent and other advanced technologies. Targets are application specific, such as $60/kW and 30,000 hour durability for heavy-duty trucks, or $30/kW and 8,000 hour durability for automotive applications. Despite the differences in targets, the fundamental knowledge gained from this subprogram will focus on key materials and components and can thus have impact on a range of applications, including crosscutting applications such as stationary and portable power. Because today's fuel cells rely on expensive Platinum Group Metals (PGM) as catalysts within the electrodes, a key objective of this subprogram is to reduce the amount of PGMs used in fuel cells, while also meeting durability, efficiency and other performance requirements (such as fast start, cold weather operation and rapid transient response). Other components that contribute to cost include membranes, ionomer, bipolar plates, gas diffusion layers, as well as balance-of-plant (BOP) components such as air systems. While significant work has been done on fuel cell light duty vehicles, minimal work has been done on other applications such as heavy-duty vehicles, marine, rail, and aviation. The early-stage R&D done in this subprogram will ultimately foster substantial technology advances by industry in new applications with wide-scale commercialization expected beyond the near-term (~5 year) investment focus of industry.

Materials and Component R&D

The materials and component R&D activity area encompasses all R&D that is needed to make a membrane electrode assembly (MEA), as well as other stack components (such as bipolar plates, gas diffusion layers, etc.). Fuel cells must simultaneously react and transport oxygen, hydrogen, protons, and electrons in a robust fashion, which places severe demands on the materials and how the components are integrated. The primary areas of focus include catalysts, electrodes, membranes, ionomer, and gas diffusion layers, as well as advances in modeling and MEA manufacturing approaches. Advances in low-cost materials and components are critical to reaching the Fuel Cell Technologies subprogram's application-specific targets (e.g. heavy-duty ultimate 30,000 hour durability). Compared to today's status of approximately 4,200 hours for automotive applications, this represents a significant challenge. Innovative concepts will be explored with increased emphasis on a combination of theory, high throughput synthesis and screening, as well as machine learning to help guide R&D to the most promising approaches. The program's ElectroCaT and Fuel Cell Performance and Durability (FC-PAD) National Laboratory consortia will provide critical contributions by providing unique capabilities in synthesis, characterization and computation to competitively selected projects at universities, industry, and other National Laboratories. More specifically, activity under ElectroCaT directly relates to the Fuel Cell Technologies GPRA target of improving the catalyst activity of PGM-free catalysts to 35 mA/cm^2 in FY 2021, more than a 2-fold improvement over the FY 2016 baseline of 16 mA/cm^2.

Systems Integration R&D

The systems Integration R&D activity area focuses on systems and systems integration R&D, including the integration of MEAs and other stack components (e.g., bipolar plates) developed in the Materials and Component R&D key activity, into systems. This includes fuel cell stacks and balance of plant components (e.g., innovative low cost air handling for fuel cell systems to reduce cost and improve durability). For example, because recent advances in fuel cell power density have relied on higher pressure operation for the cathode, this has resulted in cost and reliability issues due to the air handling system. Therefore, innovative concepts will be explored to enable such systems to achieve optimal performance and to better understand the integration of components into subsystems and full systems. This activity area targets the development and demonstration of innovative concepts for fuel cell stacks and systems across applications, supported by modeling and incorporating manufacturing advances for power generation as well as energy storage (e.g. unitized reversible fuel cells). Advances in these areas will enable the US to retain and establish global leadership, strengthen the supplier base and expand domestic manufacturing capability.

Fuel Cell Technologies (Formerly Fuel Cell R&D)

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Fuel Cell Technologies (Formerly Fuel Cell R&D) $26,000,000	**$8,000,000**	**-$18,000,000**
Materials and Component R&D $18,900,000	$5,000,000	-$13,900,000
• Develop innovative fuel cell components and integrate state-of-the-art components in advanced MEAs that will help achieve the 2025 fuel cell system cost ($40/kW) and durability (5,000 hours) metrics.	• Focus R&D on low PGM MEAs through lab consortia and lab/industry/university projects to enable meeting ultimate fuel cell cost targets across applications (e.g. $60/kW, 30,000 hour durability).	• Reduces scope to focus on most promising low-PGM technology pathways based on prior year results.
• PGM-free catalyst, and electrode research and development (ElectroCat and industry/university projects) by applying high-performance computing, high-throughput combinatorial based approaches and advanced modeling to facilitate meeting the ultimate fuel cell cost target $30/kW.	• Fund R&D on PGM-free catalysts and electrodes through lab consortium (ElectroCat) and funding opportunities to enable meeting ultimate fuel cell cost targets across applications (e.g. $60/kW, 30,000 hour durability)) and mitigate US dependence on foreign precious metal imports.	• Maintains critical mass of activities in support of ElectroCat while shifting priorities from light duty vehicles to heavy-duty/heavy load applications and focuses on innovative materials and components R&D.
• High-temperature (peak 120°C) proton exchange membrane R&D to enable low-cost and efficient fuel cell operation with emphasis on heavy-duty transportation applications.	• Screen high temperature membranes to identify most promising concepts for heavy duty applications.	• Maintains reduced effort on high-temperature (peak 120°C) proton exchange membrane R&D.
• Develop durable MEAs for heavy-duty applications that will help achieve targeted ultimate fuel cell durability (30,000 hours).	• Emphasize R&D on MEA components and MEAs to improve the durability and efficiency of MEAs for heavy-duty applications meeting ultimate targets of 72 percent peak efficiency and 30,000 hour durability.	• Shifts priorities from light duty vehicles to heavy-duty/heavy load applications and focuses on innovative materials and components R&D.
• Focus on innovative R&D to advance longer-term alkaline membrane fuel cell technologies.	• No funding requested.	• Reduces effort on alkaline membrane fuel cell R&D to focus on immediate heavy-duty application needs.
Systems Integration R&D $7,100,000	$3,000,000	-$4,100,000
• Component integration R&D to develop a low-cost domestically manufacturable fuel cell stack meeting high durability (> 25,000 hours) and system efficiencies (68 percent and above) that	• R&D on BOP components that would be relevant to both reversible fuel cells and fuel cells for a range of applications.	• Shifts focus towards BOP components (innovative low-cost air handling) to meet fuel cell system targets.

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
is applicable across a range of medium- and heavy-duty applications (trucks, marine, rail). • Fuel cell system analysis to guide R&D for heavy-duty transportation (trucks, rail, marine, aviation) and stationary (data center, reversible) applications.	• Analysis efforts will focus on new applications.	• Reduces number of analysis efforts to focus on new applications.

Description

The Hydrogen Technologies sub-program supports foundational and applied materials R&D to enable industry to develop and successfully deploy novel hydrogen production, storage, and infrastructure technologies for a range of applications. Hydrogen can play a pivotal role as a: highly efficient, sustainable energy carrier for energy storage; a valuable feedstock for chemical processes (e.g., steel manufacturing and ammonia production); and versatile fuel for both transportation (e.g., heavy- and light-duty vehicles, marine, rail, aviation) and stationary applications. The dispensed cost of hydrogen is a key focus area across the applications. Hydrogen must be less than $4/kg hydrogen (1 kg is approximately energy equivalent to one gallon of gasoline (gge)) untaxed, and at high volume to be competitive for transportation applications. This cost target includes all costs related to hydrogen production, transport, and dispensing to a vehicle while meeting all performance and quality requirements for a fuel cell electric vehicle (FCEV). However, the cost at which hydrogen will be competitive will be application specific. In the long term, to offer the highest impact potential and affordability and to meet the goals of the H2@Scale initiative for widespread use of hydrogen, the subprogram's stretch goal is $1/kg hydrogen for energy storage and chemical processes, where lower quality and lower pressure hydrogen is utilized, and production can occur onsite. To reach these cost goals, the subprogram focuses on early-stage, innovative strategies for highly-efficient, sustainable hydrogen production from diverse domestic resources, high-density hydrogen storage and transport technologies, and low-cost, durable infrastructure technologies.

Production R&D

The hydrogen production R&D activity area addresses early-stage, advanced water splitting R&D focusing on the following key areas: (1) low- and high-temperature electrolysis, (2) direct photo-electrochemical (PEC) hydrogen production, and (3) high-temperature, thermochemical hydrogen production. Activities leverage the capabilities within the DOE National Laboratories through the HydroGEN consortium, comprising six core National Laboratories, including initiatives to encourage partnerships with industry and academia. Leveraged capabilities include 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 developed materials enable reduction in hydrogen production cost through more efficient and durable systems, and thus are the basis for the sub-program's GPRA target for hydrogen production of identifying at least 11 materials with potential to enable an ultimate cost goal of less than $2/kg hydrogen.

In addition to advanced water splitting, the activity area includes early-stage, foundational research on hydrogen production through biological processes and other innovative concepts. Approaches include dark- and photo-fermentation processes; microbial electrolysis; novel catalytic and thermochemical processes; and hybrid systems that leverage fossil, nuclear, and renewable resources – including technologies that use biomass or industrial waste streams.

Storage R&D

The hydrogen storage R&D activity area supports foundational and applied R&D on advanced technologies to enable efficient, high-density, and cost-effective hydrogen storage for stationary and mobile applications. Today, most hydrogen storage systems rely on high-pressure, carbon fiber composite tanks, but costs are still high (e.g. twice as high as the target of $8/kWh for vehicular applications, even at high manufacturing volumes). Therefore, this activity will include R&D to reduce the cost of carbon fiber composite tanks. However, materials-based storage technologies have potential to provide high energy density storage at significantly lower pressure and at ambient temperature compared to compressed and liquid hydrogen storage technologies. Therefore, the hydrogen storage activity will focus primarily on early-stage R&D of innovative hydrogen storage materials (e.g. sorbents, chemical carriers, metal hydrides) with potential to surpass performance of high pressure tanks. This R&D will be done through the Hydrogen Materials Advanced Research Consortium (HyMARC) leveraging capabilities of National Laboratories and incorporating university, industry and other National Laboratory projects. This activity directly relates to the Hydrogen Carrier Materials GPRA target of identifying two materials with the potential to meet the applications' specific dispensed hydrogen cost.

Infrastructure R&D

The hydrogen infrastructure R&D activity area supports foundational and applied R&D on materials and components to enable industry to develop a low-cost hydrogen infrastructure. R&D includes investigating and developing materials (e.g., metals, polymers) compatible for hydrogen service as well as innovative and novel infrastructure components, such as compression technologies, liquefaction technologies, and dispensing technologies. The overall objective of this activity area is to enable achieving the overall cost target for produced, delivered and dispensed hydrogen. These targets will be application-specific. For the lowest cost, the program will explore approaches that can co-locate production with utilization, to minimize transport. However, irrespective of transport, the interface between the end-use of hydrogen and the dispensing will depend on requirements such as flow rate, temperature, pressure, and will require innovations to ensure affordability, safety, and reliability. Efforts will include the H-Mat consortium leveraging capabilities of National Laboratories to develop a fundamental understanding of materials compatibility with hydrogen in service.

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Hydrogen Technologies $70,000,000	**$23,000,000**	**-$47,000,000**
Production R&D $29,000,000	$9,000,000	-$20,000,000
Fund competitively selected early-stage university and industry seedling projects aimed at achieving $2/gge and early-stage advanced water splitting projects through the HydroGEN National Laboratory consortium. In FY 2020, this activity was funded under the Hydrogen Fuel R&D subprogram.	Fund early-stage advanced water splitting projects through the HydroGEN National Laboratory consortium and new biological approaches to hydrogen production through competitively selected projects.	Prioritizes National Laboratory research focused on advanced water splitting through the HydroGEN consortium. Competitively selected projects will continue with outlay of carryover obligation.
Storage R&D $16,000,000	$7,000,000	-$9,000,000
• Fund competitively selected university, industry, and National Laboratory projects aimed at developing low cost composite overwrap pressure vessels and support National Laboratory work which improves high energy density storage materials relevant for use onboard medium- and heavy-duty truck applications through the HyMARC Consortium. This activity was funded in FY 2020 under the Hydrogen Fuel R&D subprogram.	• Fund R&D on materials-based hydrogen storage technologies (e.g. sorbents, metal hydrides) storage, doubling hydrogen energy density over state-of-the-art commercial technologies through the HyMARC Consortium to enable efficient and cost-effective hydrogen storage (application specific targets: e.g. $9/kWh by 2025).	• Reduces work on carbon fiber for composite overwrap pressure vessels and shifts focus to most promising materials R&D through HyMARC Consortium.

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Infrastructure R&D $25,000,000	$7,000,000	-$18,000,000
• Competitively select university, industry and National Laboratory projects on foundational R&D to determine technology status, opportunities and challenges in using hydrogen for iron refining, in support of H2@Scale.	• Fund R&D on the most promising concepts to reduce cost and improve performance for use of hydrogen in steel production (e.g. plasma based processes).	• Shift from initial efforts in FY 2020 to identify challenges to funding R&D that addresses those challenges for affordable use of hydrogen in steel manufacturing.
• Conduct early stage R&D through the H-Mat National Laboratory-led consortium on key challenges in materials compatibility (including hydrogen-natural gas blends) and develop database on material properties and behavior to hydrogen exposure with a focus on metals.	• Continue materials compatibility R&D through the H-Mat National Laboratory-led consortium that focuses on reducing the cost of hydrogen service by at least 10 percent without sacrificing safety and develop a publicly available technical reference for non-metallic material behavior in the presence of hydrogen (and natural gas blends) and testing of high priority materials from the coupon to system level.	• Shifts R&D priorities to focus more on materials compatibility for new materials including polymers, instead of conventional metals.
• Support National Laboratory efforts within HyMARC to develop improved, high-energy density hydrogen carriers relevant for the efficient, low transport of hydrogen to support H2@Scale initiative. In addition, HyMARC will support four new hydrogen carrier R&D seedling projects selected in FY 2019.	• Continue to support National Laboratory R&D within HyMARC on priority hydrogen carriers with potential to reduce the cost of hydrogen infrastructure.	• Downselect to the most promising hydrogen carrier materials.
• Fund National Laboratory projects on foundational R&D and computational model development to characterize high throughput fueling for heavy duty trucks.	• Competitively select new industry led projects on component R&D for high throughput refueling components for heavy-duty applications (e.g., marine, rail, trucks).	• Shift away from model development for high throughput fueling for trucks and focus on fueling infrastructure for new heavy duty applications.

Hydrogen and Fuel Cell Technologies
Systems Development & Integration

Description

The Systems Development and Integration subprogram is focused on developing and integrating the technologies needed to deliver a full H2@Scale vision from a wide array of domestic resources. This subprogram will focus on R&D for hydrogen generation and storage to enable grid stability/resiliency and hydrogen utilization for applications that can achieve scale. It will enable innovations to generate hydrogen as an energy carrier that can couple nuclear, fossil fuels, the grid, and renewables to enhance the economics of both baseload plants (e.g., nuclear and coal) and intermittent solar and wind, enhancing resiliency and avoiding curtailment.

The goal of the Systems Development and Integration subprogram is to enable crosscutting innovations to integrate hydrogen with diverse domestic sectors. Key priorities include verification of novel, early-stage technologies in industrially relevant environments (e.g. marine, trucking, rail, steelmaking, ammonia production, e-fuels production from CO_2 and hydrogen produced from renewable and nuclear resources), and manufacturing R&D to enable affordable megawatt- and gigawatt-scale hydrogen technologies, to achieve H2@Scale.

Hybrid Systems and Grid Integration

The Hybrid Systems and Grid Integration activity is focused on innovative concepts and solutions that can accelerate the transition from R&D to commercial viability. While previously described subprograms focus on materials such as catalysts and membranes to reduce the cost and improve the performance of specific components, this activity will address the challenges of integrating components, sub-systems and systems for optimal performance, affordability and durability.

Hybridized systems such as coupling thermal sources with electrolyzers or other hydrogen generation methods can help reduce overall electricity requirements and improve efficiencies. The co-location of large scale hydrogen generation with utilization to minimize the cost of transport and storage will be key to achieving the H2@Scale vision, and the optimization of a number of application-specific parameters must be considered. Depending on the application (e.g., heavy duty trucks, marine, rail, air, or industrial/stationary use such as steel manufacturing, ammonia production, power for critical loads, and energy storage), the dispensing technology for providing hydrogen may vary and needs to be addressed, in addition to generation and storage. Research efforts will focus on development and validation of low cost, modular, scalable concepts for dispatchable hydrogen production, delivery, storage, and use; technologies to enable integration of hydrogen technologies with diverse generation sources; and technologies to enhance the stability of the power grid through responsive load and energy storage. Efforts within this key activity will help generate a fundamental understanding of optimally integrating electrolyzers to reduce fluctuations (e.g. power/voltage/frequency) due to intermittent renewables or other dynamic changes such as fast charging of electric vehicles.

This subprogram will also explore innovative concepts to enable new end uses for hydrogen, such as production of steel and ammonia, or use in maritime or other heavy-duty fuel applications. For example, steel may be produced through direct reduction of iron ore using hydrogen instead of conventional coal-based process. However, fundamental understanding is still required to develop hydrogen-based methods such as: evaluating the impact of particle size; morphology and porosity of iron pellets; process flow modeling, thermodynamics and kinetics of iron ore reduction with hydrogen under varying conditions of pressure and temperature; and/or understanding of plasma-iron interfaces. Systems integration to optimize the thermal inputs and outputs related to releasing hydrogen from chemical carriers is another area where R&D may ultimately enable hydrogen to be used for heavy-duty maritime and other fuel applications. Efforts will also build strong foundations for science, technology, engineering and mathematics (STEM) literacy, to increase diversity, equity and inclusion in STEM for workforce development and training in skilled trades relevant to hydrogen and fuel cell technologies ($300,000).

Codes and Standards

The Codes and Standards activity conducts R&D to enable the development of codes and standards for adoption of hydrogen and fuel cell technologies (e.g. sensor R&D, quantitative risk assessments, hydrogen release/flame propagation impacts, etc.), in support of H2@Scale. Depending on the application (e.g. heavy duty trucks, marine, rail, air, industrial use,

energy storage, etc.), specific issues such as the amount of hydrogen that may be stored in a given location, or the requirement for hydrogen metering/flow rate, the transport of hydrogen in tunnels, or the footprint restrictions of stations, must be addressed. Fundamental scientific information such as the behavior of hydrogen upon release at certain conditions (e.g. temperatures/pressures) must be understood to inform the development of appropriate codes and standards. In addition, the global harmonization of codes and standards is critical to ensure the U.S. develops a robust and competitive supply chain to serve both domestic and international markets. The activity also ensures safety considerations are incorporated into R&D projects, and develops and shares best practices and lessons learned from R&D projects. Efforts will focus on National Laboratories, based on their technical capabilities, and will also include industry, university, and other stakeholder participation.

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Systems Development & Integration $51,000,000	**$10,000,000**	**-$41,000,000**
Hybrid Systems and Grid Integration $41,000,000	$8,000,000	-$33,000,000
• Competitively select an industry-led project to reduce the cost of polymer electrolyte membrane electrolyzer manufacturing technologies.	• No funding requested.	• Project will continue through the outlay of carryover obligation.
• Competitively select projects for first-of-a-kind industry-led efforts to enable energy systems using high- and low-temperature electrolyzers with nuclear energy applications to advance the H2@Scale concept.	• Fund competitively selected industry-led projects for grid-integration with hydrogen technologies to enhance the stability of the power grid through responsive load and energy storage, in support of H2@Scale.	• Reduce funding on low temperature electrolyzers and focus on high temperature systems and thermal integration.
• Competitively award university and industry first-of-a-kind projects on marine, data center, and steel applications with the intent of advancing the H2@Scale concept.	• Continue support for National Laboratory projects focused on modular/scalable concepts for dispatchable hydrogen production, storage, and delivery, coupled with utilization for multiple applications and across sectors such as ammonia and other applications, in support of H2@Scale.	• Reduce funding on data center and marine applications and focus effort on modular/scalable concepts for hydrogen across applications.
• 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 for hydrogen production.	• Fund National Laboratory first-of-a-kind systems integration and validation projects to guide early stage R&D, in support of H2@Scale.	• Refocused efforts on first-of-a-kind systems integration and validation projects.
• Fund National Laboratory projects that advance R&D on fueling technologies for heavy-duty applications, in collaboration with Infrastructure R&D activity.	• Establish new research projects, including industry led teams, focused on improving the energy and operational efficiency of moving freight with medium and heavy-duty trucks. This effort will integrate and coordinate work in the areas of engine and fuels, electrified driveline systems (both battery and hydrogen fuel cell), powertrain hybridization, waste energy recovery,	• New competitively selected projects will be initiated to shift focus from enabling high-throughput infrastructure to improving heavy-duty truck energy efficiency and improve the operational efficiency of freight transportation.

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
	vehicle-level technologies, and mobility systems that can reduce fuel consumption through more efficient operation. This effort will be coordinated with the Vehicle Technologies Office.	
Codes and Standards $10,000,000	$2,000,000	-$8,000,000
• Continue to directly fund National Laboratory projects that enable the development of codes and standards and ensure activities include safety considerations. These include projects that support the reduction of bulk liquid hydrogen storage separation distances as required by hydrogen technology safety codes and projects that inform improvements in existing quantitative risk assessment models.	• Continue to directly fund National Laboratory projects that enable the development of codes and standards, with an emphasis on large-scale applications, and ensure activities include safety considerations.	• Focuses efforts on R&D to enable adoption of codes and standards applicable to hydrogen and fuel cell technologies for large-scale applications.
• Expand outreach, education, training, and workforce development activities to support the public acceptance of hydrogen and fuel cell technologies, beyond light duty vehicles.	• Develop and share best practices and lessons learned by expanding education and training activities.	• Focuses efforts on best practices and lessons learned.
• Evaluate metallic materials that could potentially be used in hydrogen service to reduce cost by at least 10 percent without sacrificing safety. Initiate the development of a publicly available technical reference for non-metallic material behavior in the presence of hydrogen and testing of high priority materials from the coupon to system level.	• No funding requested.	• This activity was moved into the Hydrogen Infrastructure Technologies subprogram.

Hydrogen and Fuel Cell Technologies
Data, Modeling, and Analysis (Formerly Systems Analysis)

Description

The Data, Modeling, and 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 Data, Modeling, and Analysis subprogram 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 and energy storage 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), e-fuels production from CO_2, and hydrogen from renewable and nuclear resources, heavy-duty transportation modes such as marine, medium/heavy-duty vehicles, rail, aviation, and energy systems. The subprogram will support approximately three 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.

Data, Modeling and Analysis
(Formerly Systems Analysis)

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Data, Modeling & Analysis (Formerly Systems Analysis) $3,000,000	**$1,000,000**	**-$2,000,000**
• Conduct National Laboratory project to assess cost and impact of hydrogen and fuel cell technologies beyond light duty vehicles. Analysis will be used to prioritize R&D activities and inform updates to multi-year plans.	• Perform analytical research that provides a technical basis for informed decision making for the program's R&D direction and prioritization. Results also support annual updates to key planning documents that provide direction and milestones for the program.	• Shifts focus to emerging applications.
• Conduct National Laboratory project to identify early-stage 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, including biofuels production.	• Fund analysis of synthetic fuels and export opportunities.	• Resource analysis completed in FY 2020. New focus for FY 2021 prioritizes analysis of synthetic fuels and export opportunities.
• Conduct National Laboratory project to assess program milestones and technology readiness goals.	• Continue National Laboratory project to assess program milestones and technology readiness goals.	• No significant change.
• Conduct 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.	• No funding requested.	• Hybrid systems R&D within the Systems Development & Integration subprogram will build upon work conducted in prior years.

Solar Energy

Overview

EERE's Solar Energy Program funds early-stage research and development (R&D) to improve the affordability and performance 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 placing a continued 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 40-65 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 64 GW installed at the end of 2018 — a 25-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, employing 242,000 workers in 2018[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 improve solar's ability 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 2021 Budget Request

The Solar Energy Program will support focused activities in FY 2021:

- With solar contributing two percent of U.S. electricity supply today and projected to increase to seven percent by 2030[6] — 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. FY 2021 activities will continue to support DOE's Grid Modernization Initiative ($35,000,000) through the Grid Modernization Laboratory Consortium (GMLC) projects and other Systems Integration activities which support cybersecurity ($4,000,000). FY 2021 activities also focus on understanding the interactions between power electronics-based generation resources (including solar PV and energy storage) and power systems at large, particularly the dynamic characteristics, as well as developing control solutions for safe and reliable grid operation. Other activities support the development of industry standards on interconnection requirements, testing, and validation related to solar grid integration.
- The Solar Energy Program will contribute $5,000,000 to the Advanced Energy Storage Initiative, as part of the broader Energy Storage Grand Challenge, 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 Energy

[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] "2018 U.S. Solar Market Insight Report," GTM Research and SEIA, March 2019.
[4] EIA, Electric Power Monthly, Table 1.1 (July 2018).
[5] "National Solar Jobs Census 2018," The Solar Foundation. https://www.thesolarfoundation.org/national/
[6] EIA, Annual Energy Outlook 2019.

Storage Grand Challenge will enhance coordination across EERE and DOE and establish aggressive, achievable, and comparable goals for cost-competitive energy storage services and applications.

- To advance solar desalination, $4,000,000 is requested to support the Water Security Grand Challenge, which will fund desalination technologies that deliver cost-competitive clean water. FY 2021 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 industrial processes, with a specific focus on desalination. FY 2021 will also focus on the development of a test facility that can validate novel heliostat designs, including wireless, closed-loop control systems, at commercially relevant scales.
- PV Research at the National Laboratories will center on improving the reliability of PV devices and production of new PV structures with the potential to achieve the 2030 cost targets. FY 2021 funding maintains 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 an additional round in FY 2021. The FY 2021 Solar Prize work will build on the prior three rounds from FY 2018 – FY 2020. The Prize incentivizes the rapid transformation of research and development results into new products and services with an emphasis on catalyzing domestic manufacturing across the value chain.

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 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted
Solar Energy				
Concentrating Solar Power Technologies (formerly Concentrating Solar Power)	55,000	60,000	11,500	-48,500
Photovoltaic Technologies (formerly Photovoltaic R&D)	72,000	72,000	16,000	-56,000
Systems Integration	54,500	53,000	35,000	-18,000
Balance of Systems Soft Cost Reduction	35,000	35,000	0	-35,000
Manufacturing and Competitiveness (formerly Innovations in Manufacturing Competitiveness)	30,000	60,000	4,500	-55,500
Total, Solar Energy	**246,500**	**280,000**	**67,000**	**-213,000**

SBIR/STTR:

- FY 2019 Transferred: SBIR $8,308,000; STTR $308,000
- FY 2020 Projected: SBIR $8,768,000; STTR $1,233,000
- FY 2021 Request: SBIR $2,125,000; STTR $299,000

Solar Energy
Explanation of Major Changes ($K)

	FY 2021 Request vs FY 2020 Enacted
Concentrating Solar Power Technologies: Funding continues efforts at the National Laboratories on developing high temperature components for next generation CSP systems with thermal energy storage. Relative to FY 2020, CSP efforts in the FY 2021 request will support the development of a test facility for advanced heliostat designs and controls.	**-48,500**
Photovoltaic Technologies: Funding prioritizes targeted efforts at the National Laboratories to improve PV reliability and pursue research on production of new PV structures. No funding is requested to issue new competitive solicitations.	**-56,000**
Systems Integration: Funding maintains core efforts at the National Laboratories to advance grid integration models and technologies. Funding builds on the FY 2020 competitive funding opportunity by proposing a new targeted competitive solicitation focused on understanding the dynamic interactions between power electronics-based generation resources (i.e., solar and battery storage) and power systems at large, and developing control solutions for safe and reliable grid operation.	**-18,000**
Balance of Systems Soft Cost Reduction: No funding is requested for this subprogram due to focus on early stage R&D.	**-35,000**
Manufacturing and 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. No funding is requested for the incubator program or research and development of inherently scalable production methods.	**-55,500**
Total, Solar Energy	**-213,000**

Solar Energy
Concentrating Solar Power Technologies

Description

The Concentrating Solar Power Technologies (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 $0.10/kWh in FY 2018 (for CSP with 14 hours of storage in the U.S. Southwest). 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.

Within the activities listed below, 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.

Thermal Systems R&D

Research and development to test and integrate the components - including the receiver, heat transport media, and thermal energy storage systems - of a CSP thermal transport system capable of operation at 700 degrees Celsius (°C) or above. This activity includes research into novel materials as well as manufacturing and fabrication methods of materials and components that will allow high temperature systems to be cost effective.

Power Cycles R&D

Research and development of power cycles capable of net thermal-to-electric efficiency of 50 percent or greater. This activity is particularly focused on power cycles that use supercritical carbon dioxide as the working fluid and have a capital cost of $900/kW-electric or lower, working in collaboration with the Offices of Fossil Energy and Nuclear Energy. This activity also includes the development of primary heat exchangers that can transfer heat between high temperature thermal energy storage and supercritical carbon dioxide.

Solar Collector R&D

Research and development of solar collectors with installed capital costs less than $50 per square meter and the ability to maintain high accuracy through autonomous operation, without the need for manual calibration.

Industrial Applications R&D

Research and development of low-cost solar collector and thermal energy storage for temperatures in the range of 100 to 300 °C at a levelized cost of heat (LCOH) of 1 cent per kWh-thermal or lower, which would constitute at least a 50% decrease in current LCOH. Additionally, this activity includes the development of thermal processes, including thermal desalination, which can efficiently couple with a solar thermal energy input. This activity also includes the development of solar thermal pathways for the production of energy-intensive chemicals and fuels that can be used for long-term energy storage.

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Concentrating Solar Power Technologies		
$60,000,000	**$11,500,000**	**-$48,500,000**
Thermal Systems R&D $25,000,000	$1,500,000	-$22,500,000
• Support 5 merit-reviewed R&D projects at the National Laboratories to develop high-temperature thermal systems components and perform foundational CSP analysis.	• Support to continue the third year of a targeted subset of National Laboratory work.	• Funding will focus on a subset of down-selected projects determined to have the greatest potential impact.
• Funding approximately 3 merit-reviewed seedling projects targeting high-temperature thermal systems concepts and components.	• No additional funding is requested for competitive awards in FY 2021.	• Funding for new competitive solicitations is eliminated to prioritize budgetary resources for National Laboratory research projects initiated in FY 2019.
• Support to the National Solar Thermal Test Facility (NSTTF) at Sandia National Laboratories (SNL).	• Support to the National Solar Thermal Test Facility (NSTTF) at Sandia National Laboratories (SNL).	• No significant change.
Power Cycles R&D $24,000,000	$1,000,000	-$23,000,000
• Continue 1 merit-reviewed R&D project at the National Laboratories to develop primary heat exchangers for advanced supercritical CO_2 power cycles.	• Support to continue the third year of National Laboratory work.	• No significant change.
• Funding 1-2 competitive projects demonstrating a commercially relevant supercritical CO_2 power cycle integrated with currently available thermal energy storage and approximately 3 merit-reviewed seedling projects targeting advanced power cycles and their components.	• No additional funding is requested for competitive awards in FY 2021.	• Funding for new competitive solicitations is eliminated to prioritize budgetary resources for National Laboratory research projects initiated in FY 2019.
Solar Collector R&D $4,000,000	$4,000,000	$0
• Continue 4 merit-reviewed R&D projects at the National Laboratories to develop optical components for CSP collector fields.	• Support to continue the third year of a targeted subset of National Laboratory work.	• Funding will focus on a subset of down-selected projects determined to have the greatest potential impact.
• Funding approximately 3 merit-reviewed seedling projects targeting advanced collector design, components, and metrology.	• Funding for a test facility that can validate novel heliostat designs, particularly including wireless, reliable control systems, at commercially relevant scales.	• Additional funding prioritizes the strategic importance of establishing a facility to validate properties of advanced heliostat technologies.

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Industrial Applications R&D $7,000,000	$5,000,000	-$2,000,000
• Continue 1 merit-reviewed R&D project at the National Laboratories to research novel pathways for the solar thermal production of ammonia for long-term energy storage.	• Support to continue the third year of a targeted subset of National Laboratory work.	• Funding will focus on a subset of down-selected projects determined to have the greatest potential impact.
• Fund a prize competition for developing innovative advanced solar thermal desalination technologies.	• Funding will support an additional round of the American Made Challenge: Solar Desalination prize.	• No significant change.

Solar Energy
Photovoltaic Technologies

Description

The Photovoltaic Technologies (PV) subprogram funds early-stage R&D to support the development of affordable energy options. 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 subprogram advances state-of-the-art PV technologies with National Laboratory, industry, and academic partners. Funded 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.

Within the activities listed below, 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.

Conversion Efficiency R&D

Research and development to increase the power conversion efficiency and reduce the manufacturing costs of PV modules, spanning established and emerging materials. This activity also includes research in improved system design to increase initial energy production of the full PV system.

Durability R&D

Research and development to better understand and mitigate performance degradation of PV systems. This activity includes development of robust and reproducible accelerated degradation protocols to simulate outdoor degradation mechanisms of PV systems to predict and reduce failure, and better estimate lifetime.

[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.

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Photovoltaic Technologies $72,000,000	**$16,000,000**	**-$56,000,000**
Conversion Efficiency R&D $32,000,000	$6,000,000	-$26,000,000
• Support approximately 15 merit-reviewed R&D projects at the National Laboratories to improve performance of PV technologies and conduct foundational analytical research.	• Support to continue the third year of a down-selected subset of National Laboratory work.	• Funding will focus on a subset of down-selected projects determined to have the greatest potential impact.
• Continue the collaboration (year 10 of 10) with the National Science Foundation to support the Quantum Energy and Sustainable Solar Technologies Engineering Research Center at Arizona State University.	• No funding requested.	• FY 2020 was the planned final year of the program from the onset.
• Fund approximately 15 competitive projects targeting priority research and increasing performance of PV technologies by exploring new materials such as perovskites and understanding material defects in industrial absorbers such as CdTe.	• No funding is requested for competitive awards in FY 2021.	• The FY 2021 request prioritizes budgetary resources for National Laboratory research projects initiated in FY 2019.
• Fund 1-2 emerging leaders that will pursue breakthrough solar energy technologies at universities, National Laboratories, and other research facilities as well as at DOE.	• Fund 1-2 emerging leaders that will pursue breakthrough solar energy technologies at universities, National Laboratories, and other research facilities as well as at DOE.	• No significant change.
Durability R&D $40,000,000	$10,000,000	-$30,000,000
• Support for DuraMat which is the National Laboratory Consortium funded to perform research dedicated to modeling and measuring durable coatings and packaging materials for PV modules including advanced encapsulants and flexible packaging concepts.	• Funding maintains the DuraMat shared data hub.	• The FY 2021 request prioritizes budgetary resources for maintaining the data hub capabilities in support of National Laboratory and industry research over initiating new DuraMat R&D projects.
• Support approximately 10 merit-reviewed R&D projects at the National Laboratories to improve reliability and understand degradation of PV technologies	• Support to continue the second year of a down-selected subset of National Laboratory work.	• Funding will focus on a subset of down-selected projects determined to have the greatest potential impact.

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
• Fund approximately 5 competitive projects targeting priority advanced reliability research.	• No funding is requested for competitive awards in FY 2021.	• The FY 2021 request prioritizes budgetary resources for National Laboratory research projects initiated in FY 2019.

Solar Energy
Systems Integration

Description

The Systems Integration (SI) subprogram, in coordination with the DOE Grid Modernization Initiative (GMI), funds early-stage research and development as well as field validation to better enable solar energy to integrate into the electric power system while supporting grid reliability, resilience and security. 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. The SI research addresses key technical challenges including solar generation variability and flexibility, voltage control, frequency regulation, situation awareness, system stability and protection, cybersecurity, and optimal power flow control. The outcomes of this research will create fundamental understanding and validated solutions necessary to support industry efforts to more effectively integrate solar onto the electric grid. Further, SI activities support the development of industry's standards and best practices on interconnection requirements, testing, and validation methods so that utilities, regulatory agencies, and solar developers have the most advanced tools for timely and cost-effective interconnection and integration of solar generation sources. The portfolio supports activities under the broad areas of SI subprogram research as listed below.

Within the activities listed below, 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.

Planning and Modeling R&D

Modeling and simulation methodologies and software tools for short-term and long-term planning of solar energy grid integration under various system constraints. The topics include generation variability, voltage and frequency stability, system flexibility, interconnection standards, grid services, and co-optimization.

Operation and Control R&D

Hardware and software technologies for real-time situation awareness and control that ensure system reliability during normal and abnormal operations with high penetrations of solar energy on the grid. Topics include power electronic devices, sensing and communication, system protection and fault recovery, dynamic power flow control, and data analytics and control algorithms.

Resilience and Security R&D

Technologies that provide greater resilience to critical infrastructure and critical loads by integrating distributed solar PV and other distributed energy resources (DERs) into emergency response and recovery. Solutions will consider various cyber and physical hazards to ensure the continuity of electric power service and/or faster service recovery.

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Systems Integration $53,000,000	**$35,000,000**	**-$18,000,000**
Planning and Modeling R&D $9,000,000	$10,000,000	$1,000,000
• Support approximately 7 National Laboratories R&D projects.	• Fund the third year of these lab projects to completion.	• No significant change.
• Support approximately 3 R&D projects related to planning and modeling under the FY 2019-2021 GMLC Foundational Lab Call.	• Support the third year of these FY 2019-2021 GMLC Lab Call projects to completion.	• No significant change.
Operation and Control R&D $30,000,000	$15,000,000	-$15,000,000
• Support approximately 8 National Laboratories R&D projects.	• Fund the third year of these lab projects to completion.	• No significant change.
• Support approximately 2 R&D projects related to operation and control under FY 2019- 2021 GMLC Foundational Lab Call.	• Support the third year of these FY 2019-2021 GMLC Lab Call projects.	• No significant change.
• Fund approximately 5-8 competitively selected projects researching advanced hybrid plants that operate collaboratively with other resources as well as new operations and control technologies to support microgrids powered by solar.	• Fund competitively selected projects to investigate the dynamic characteristics of power electronic-based solar generation and to develop new inverter and master PV plant control methods.	• The new solicitation will build upon insights from the FY 2019-funded projects by focusing on a specific priority area. FY 2019 projects will continue to completion through outlay of obligated balances.
Resilience and Security R&D $14,000,000	$10,000,000	-$4,000,000
• Support approximately 5 National Laboratories R&D projects.	• Fund the third year of these lab projects to completion.	• No significant change.
• Support approximately 2 project related to PV cybersecurity R&D under FY 2019- 2021 GMLC Foundational Lab Call.	• Support the third year of these FY 2019-2021 GMLC Lab Call projects to completion.	• No significant change.
• Fund 2-3 competitively selected projects to enhance the cybersecurity of PV inverters and power systems.	• Fund competitively selected projects to develop low cost, efficient, secure methods for real time data management to enhance visibility and controllability of distributed PV systems.	• The new solicitation will build upon insights from the FY 2019-funded projects by focusing on a specific priority area. FY 2019 projects will continue to completion through outlay of obligated balances.

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, siting, project development and other related 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 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.

As overall solar prices have dropped, the U.S. has enjoyed unprecedented growth in solar installations. Between 2008 and 2019, the U.S. saw a rapid increase in renewable energy generation from solar. The solar sector of the economy now employs over 240,000 people representing more than a 150 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 and soft cost reduction activities.

Data, Modeling and Analysis

Foundational analysis projects at the National Laboratories on the cost and value of solar energy technologies in order to inform and benchmark R&D strategies and provide objective information to the public.

Technical Assistance

Work by a broad range of stakeholders to develop new approaches to soft cost reduction, expand access to solar energy and identify and disseminate best practices leveraging experts from National Labs and other experts, as needed.

STEM and Workforce Development

Develop, test and disseminate educational materials and training methods for relevant industry stakeholders to ensure strong STEM and technical knowledge for a broad workforce interacting with solar energy technologies. This work includes targeted programming, per congressional direction, to specific groups, such as veterans.

Reflecting the shift in focus to early-stage research and development, no funding is requested for the BOS subprogram in FY 2021. 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 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Balance of Systems Soft Cost Reduction $35,000,000	**$0**	**-$35,000,000**
Data, Modeling, and Analysis $22,000,000	$0	-$22,000,000
• Support approximately 25 projects at the National Laboratories researching the cost and value of solar technologies alone and integrated with other technologies on the grid.	• No funding requested in FY 2021.	• Reflects focus on early stage R&D. FY 2020 projects will continue until completion.
Technical Assistance $10,000,000	$0	-$10,000,000
• Fund approximately 20 competitively selected projects. • Support the National Community Solar Partnership to provide technical assistance to low and moderate income individuals, businesses, non-profit organizations, and state, local and tribal governments to increase use of community solar installations.	• No funding requested in FY 2021.	• Reflects focus on early stage R&D. FY 2020 projects will continue until completion.
STEM & Workforce Development $3,000,000	$0	-$3,000,000
• Fund one project developing workforce training to better position America's veterans to enter the solar industry.	• No funding requested in FY 2021.	• Reflects focus on early stage R&D. FY 2020 projects will continue until completion.

Solar Energy
Manufacturing and Competitiveness

Description

The Manufacturing and Competitiveness (MC) 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 MC 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.

American-Made Challenges

Prize (and associated support structures, like the American Made Network) focused programming to increase America's market share for added-value manufacturing. Focus of the work is on incentivizing the development of solutions by individuals and new entrants to the solar technology development space in addition to connecting these people to a network of experienced commercialization partners in order to accelerate the process to develop new, innovative solar products. The goal is to enable products to go from concept to pilot testing within one calendar year.

Manufacturing and Value Chain R&D

Cooperative agreements and grants focused on developing new manufacturing technologies, developing products which can be domestically manufactured, and establishing programming that could bring more private capital funding into solar energy technology development and help companies de-risk technologies to enable investment by private sector entities.

Manufacturing and Competitiveness

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Manufacturing and Competitiveness $60,000,000	**$4,500,000**	**-$55,500,000**
American-Made Challenges $5,000,000	$4,500,000	-$500,000
• Run an additional round of the American Made Solar Prize to support innovators in launching new products that advance the solar industry and support U.S. manufacturing.	• Run an additional round of the American-Made Challenges.	• Slight reduction due to operating costs of Prize being lower after initial round.
Manufacturing and Value Chain R&D $55,000,000	$0	-$55,000,000
• Fund approximately 10 competitively selected projects working to reduce solar electricity costs. Projects have strong potential for rapid commercialization but are at an early stage where they are too risky for private investment.	• No funding is requested.	• Funding is eliminated in order to focus efforts on the American Made Solar Prize.

Wind Energy

Overview

DOE's Wind Energy Program drives innovation through research, development, and testing of advanced wind energy technologies. The portfolio focuses on land-based, offshore, and distributed wind, as well as integration of wind energy on the grid. The primary goal is cost reduction, while also informing market choices; ensuring the reliability, resilience and security of wind power and the grid; exploring means for mitigating siting and environmental challenges; and nurturing a robust U.S. manufacturing sector and related workforce. The work is underpinned by investments in related science, modeling and analytical tools complemented by competitively selected, cost-shared projects carried out in collaboration with industry, academia, and National Laboratories.

Reflecting the recent and projected future growth in wind energy deployment, the program emphasizes three objectives:

- Reduce the cost of wind energy for all applications (offshore, land-based utility-scale, and distributed);
- Improve the reliable and seamless integration of high penetrations of wind energy into the electric grid; and
- Mitigate key barriers to U.S. wind deployment through research and development.

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 over 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 (maximum of 100kW capacity) wind turbine sales, and has over 83,000 wind turbines deployed in distributed applications 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 complementary state policies. While the wind industry is relatively mature, with the phase out of the Production Tax Credit and Investment Tax Credit (PTC and ITC), significant work remains to ensure wind energy can continue to compete and add value to the grid on an unsubsidized basis across the country. Program research addresses high-risk, early-stage R&D that provides a foundation for future industry innovation by addressing research topics where industry does not have the technical resources or capabilities to address on its own, where time horizons for commercial application are too long to warrant industry investment, and/or where competitive pressures prevent collective action needed to solve problems facing the wind industry as a whole. With continued research and technology innovation to drive down wind energy costs and overcome grid integration, environmental and siting, and workforce development challenges, wind energy has the potential to serve as a key building block of an affordable, reliable, and secure energy future.

Highlights of the FY 2021 Budget Request

- Enable reliable, resilient, and cost-effective operation of the power grid with increasing amounts of wind through enhanced wind plant controls and wind hybridization with other technologies in support of the Grid Modernization crosscut ($10,000,000).
- Enhance wind plant cybersecurity by developing reference models, identifying and assessing vulnerabilities, and developing protection strategies in coordination with the Office of Cybersecurity, Energy Security, and Emergency Response in support of the Cybersecurity crosscut ($500,000).
- Improve 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.
- Focus on fundamental R&D in the areas of controls, sensors, algorithms, materials, and manufacturing to lower wind energy costs and improve operational performance.

[1] Wiser, R., and M. Bolinger. 2018 Wind Technologies Market Report. U.S. Department of Energy. DOE-GO-102019-5191. https://www.energy.gov/eere/wind/downloads/2018-wind-technologies-market-report.
[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. 2018 Distributed Wind Market Report. U.S. Department of Energy. DOE/EE-1980. August 2019. https://www.energy.gov/eere/wind/downloads/2018-distributed-wind-market-report.

- Address offshore wind challenges unique to the U.S. by designing tools and technologies required for deep-water floating turbines; improving the understanding and modeling of met-ocean conditions; and addressing marine wildlife, radar, and human use considerations.
- Develop models and tools to facilitate offshore wind grid integration and interconnection studies.
- Develop solutions to key barriers to wind siting and development, including research to resolve environmental performance challenges, radar interference, and community impacts such as noise.
- Educate and train a workforce for the 21st century economy through a focus on science, technology, engineering, and math (STEM) activities to support development of a robust domestic wind energy workforce ($200,000).

Wind Energy
Funding ($K)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted
Wind Energy				
Technology Research, Development & Testing and Resource Characterization (Land, Offshore, Distributed)	59,000	0	0	-
Technology Validation and Market Transformation	10,000	0	0	-
Mitigate Market Barriers	16,000	0	0	-
Modeling and Analysis	7,000	0	0	-
Offshore Wind	0	52,500	6,500	-46,000
Land-Based Wind	0	31,800	3,500	-28,300
Distributed Wind	0	10,000	700	-9,300
Grid Integration & Analysis	0	9,700	0	-9,700
Systems Integration	0	0	10,500	+10,500
STEM & Workforce Development	0	0	200	+200
Data, Modeling, & Analysis	0	0	700	+700
Total, Wind Energy	**92,000**	**104,000**	**22,100**	**-81,900**

SBIR/STTR:

- FY 2019 Transferred: SBIR $2,793,000; STTR $200,000
- FY 2020 Projected: SBIR $2,546,000; STTR $358,000
- FY 2021 Request: SBIR $701,000; STTR $99,000

Budget Structure Crosswalk
($K)

FY 2020 Budget Structure	Proposed FY 2021 Budget Structure						
	Offshore Wind	Land-Based Wind	Distributed Wind	Systems Integration	STEM & Workforce Development	Data, Modeling, & Analysis	Total
Offshore Wind	6,500	0	0	0	0	0	**6,500**
Land-Based Wind	0	3,500	0	0	200	0	**3,700**
Distributed Wind	0	0	700	0	0	0	**700**
Grid Integration & Analysis	0	0	0	10,500	0	700	**11,200**
Total, Wind Energy	**6,500**	**3,500**	**700**	**10,500**	**200**	**700**	**22,100**

Wind Energy
Explanation of Major Changes (K)

	FY 2021 Request vs FY 2020 Enacted
Wind Energy	
Offshore Wind: The reduction in funding level for this subprogram reflects the prioritization of the most critical early-stage offshore wind activities, within the broader priorities of EERE and the Department. As such, no new funds are provided for Offshore Demonstration Projects. Targeted funding will support National Laboratory efforts to improve offshore wind resource characterization and forecasting. Wind farm controls research will focus on the most promising controls methodology. Turbine/foundation design tools development will focus on modeling using previously acquired validation data. Materials and manufacturing research will prioritize the most promising pathways to improve material performance and manufacturing innovation. No funding is requested for field research on environmental performance. However, environmental monitoring and mitigation research will prioritize work at the National Laboratories.	**-46,000**
Land-Based Wind: The reduction in funding level for this subprogram reflects the prioritization of the most critical land-based wind activities, within the broader priorities of EERE and the Department. In FY 2021, no new funds are provided for Tall Tower Demonstration projects. Targeted funding will prioritize the development of technical solutions to environmental and siting challenges associated with land-based wind energy development, with an emphasis on maintaining existing tools, prioritizing established efforts at the National Laboratories, and managing work funded in prior years. This R&D will reduce siting costs and risks, and will lower the cost of land-based wind energy by minimizing operational constraints, such as curtailment, on current and next-generation wind plants. The subprogram's science and technology activity will concentrate on developing control methodologies for highly flexible, rail-transportable blades. The subprogram will continue efforts related to the Atmosphere to Electrons initiative (A2e) through planning of the AWAKEN experiment, a field measurement campaign to capture verification and validation data for atmospheric inflow simulation, turbine performance, and active plant control to refine advanced high-performance computing modeling capabilities. Reliability research will prioritize application of artificial intelligence methodologies to prognostic health management tools to decrease unplanned maintenance and increase mean time between failures.	**-28,300**
Distributed Wind: This subprogram will lower the cost of distributed wind through technology development and validation activities including turbine R&D and testing, focusing on support for existing awardees, and balance of system cost reduction activities. Existing efforts focused on integration of distributed wind with storage and other distributed energy resources will transition to the Systems Integration subprogram.	**-9,300**

Wind Energy Explanation of Major Changes (K)	FY 2021 Request vs FY 2020 Enacted
System Integration: New subprogram will prioritize activities under Grid Integration and Analysis subprogram established in FY 2020 to ensure cost-effective, reliable, cyber-secure, and resilient operation of the power grid with increasing levels of wind energy deployment. The subprogram will prioritize and advance efforts to address wind grid integration challenges, expanding on existing R&D activities to develop and refine the capability of wind plants to provide essential reliability services; increase wind energy's contribution to grid resiliency; improve grid infrastructure investment and utilization for wind deployment; address wind-specific cybersecurity needs; integrate wind power with storage and other technologies; and improve the understanding of electricity market operation with high penetrations of wind energy.	**+10,500**
STEM & Workforce Development: New subprogram will focus on providing national assessments of current and future wind workforce growth trajectories and training needs, as well as the development of programs to fill critical wind workforce and STEM gaps.	**+200**
Data, Modeling, and Analysis: In FY 2021, under the new program structure, the subprogram will streamline its work to prioritize required GPRA and other metric tracking and reporting, and identifying opportunities to increase the value of wind to the electricity system, in concert with other EERE and DOE offices.	**+700**
Grid Integration & Analysis: Activities funded under this subprogram, established in FY 2020 appropriations, will be subsumed within the broader Systems Integration subprogram as well as the Data, Modeling, and Analysis subprogram.	**-9,700**
Total, Wind Energy	**-81,900**

Description

The Offshore Wind subprogram aims to advance offshore wind technology and scientific understanding in order to reduce costs and risks given unique U.S. challenges, including weather conditions, coastal infrastructure, technical hurdles, and competing human-use considerations. 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. The subprogram will also focus on the evaluation and development of technical solutions to environmental and siting challenges associated with offshore wind energy development in U.S. waters.

Through these activities, the Offshore Wind subprogram aims to achieve breakthroughs in reducing the levelized cost of energy (LCOE) by 50 percent from a 2015 benchmark to $.051/kWh by 2030 without subsidies. Reaching this 2030 goal will make offshore wind energy a cost-competitive option in coastal markets.

Science and Technology Innovation

This activity seeks to advance offshore wind technology and scientific understanding in order to reduce cost and risks given unique U.S. challenges, including weather conditions, coastal infrastructure, and technical hurdles. Due to differences in sea currents, sea surface temperatures, and nearby land interfaces, the U.S. has a unique offshore environment relative to Northern Europe and Asia, where most of the world's offshore wind plants have been built to date. Better understanding this environment is critical to predicting offshore wind resources and potential structural loading impacts that will be experienced by future U.S.-based offshore wind systems. Site-specific field data quantifying the offshore wind resource characteristics and operating environment are critical in order to (1) estimate the structural loads on offshore wind turbines, (2) better understand air-sea interactions driving design and operation, (3) improve weather and energy forecast models, and (4) assess annual wind plant energy production. The Atmosphere to Electrons (A2e) initiative will improve predictions of wind/wave resources in offshore wind energy development areas around the U.S. coastline, with particular focus on improving the characterization of the offshore marine boundary layer.

To advance floating offshore wind technology and make it cost competitive in the U.S., the capability of designing these innovative systems must be improved to increase confidence in the numeric modeling tools, which will in turn minimize the need for costly scale and prototype testing. Fully coupled integrated design of the turbine and its floating support platform is critical to lowering the cost of energy for a floating offshore wind system. Through integrated systems engineering toolsets, high-fidelity simulation capabilities, individual and plant-level controls research, and cost modeling, the cost of floating offshore wind systems can be significantly reduced. Offshore wind turbine and plant optimization will be achieved by adapting the existing Wind-Plant Integrated System Design & Engineering Model (WISDEM™) platform previously developed by DOE. Additional enhancements to WISDEM™ and the OpenFAST multiphysics turbine engineering modeling tool will enable the development of innovative and optimized floating designs.

Manufacturing and Materials R&D

This activity aims to develop and build national capabilities for cost-effectively manufacturing and installing, and maintaining offshore wind plants in the U.S. The complexity and risks associated with offshore wind installation and maintenance activities require specialized infrastructure not yet developed in the U.S. Identifying strategies to leverage the nation's existing infrastructure to reduce the need for specialized vessels and installation equipment will reduce both capital expenditures and long-term operating costs. Through this activity, the Wind program will conduct R&D in technologies that will: (1) ease the technical challenges of installation, e.g. reducing the turbine weight or finding turbine installation methods that do not require large European-type turbine installation vessels; (2) develop remote, autonomous inspection and repair methods for blades and drivetrains; (3) enable remote health status and prognostic health monitoring of turbine components; and (4) utilize advanced materials and manufacturing technologies to reduce the fabrication costs associated with floating offshore turbine foundations. Activities include investigating and prototyping advanced manufacturing processes, assessing the use of advanced materials in specific turbine component applications such as low-cost carbon fiber, and incorporating innovations in machine learning and robotics into turbine systems to limit the need for O&M personnel to travel to remote sites.

Environmental and Siting R&D

This activity will focus on reducing costs and key barriers associated with offshore wind siting and environmental performance through targeted research, development, and validation of technology solutions, as well as knowledge transfer activities. Environmental performance research of first-generation offshore wind projects will be supported, with an emphasis on addressing issues causing permitting uncertainty and risks for pioneer offshore wind projects including questions regarding impacts on marine mammals, birds, and habitat changes affecting protected and commercially important species. These data will be used to inform the design of effective and affordable technical mitigation solutions that reduce costs and barriers to offshore wind development. Research efforts will focus on developing monitoring and mitigation solutions for novel offshore issues that pose unique challenges compared with land-based wind, including the need to develop automated wildlife monitoring systems and the continued innovation of tools to minimize impacts of construction noise on protected species. International collaboration through the IEA will promote knowledge transfer from Europe to reduce the amount of novel research needed to resolve impact questions in the US. This activity also supports research on community impacts and the development of information resources and tools on the costs and benefits of offshore wind development.

Through this activity, the Wind Program will collaborate under the interagency Wind Turbine Radar Interference Mitigation memorandum of understanding (MOU) to characterize and address the unique impacts of offshore wind development on critical missions, which are less well understood than the impacts of land-based facilities. Effort will focus on radar missions where offshore wind is likely to have a greater effect, such as over-the-horizon surveillance systems, coastal high frequency systems for ocean wave and current measurement, and marine navigation radars. Activities will include research to better evaluate the impacts of planned wind energy installations; development of mitigation measures to increase the resilience of existing radar systems to offshore wind turbines; and encouraging the development of next-generation radar systems that are resistant to interference from offshore wind turbines.

Offshore Wind

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Offshore Wind $52,500,000	**$6,500,000**	**-$46,000,000**
Science & Technology Innovation $34,324,000	$3,800,000	-$30,524,000
• Award competitively selected projects to improve offshore wind resource characterization and forecasting in collaboration with the National Oceanic Atmospheric Administration and DOE National Laboratories to support the Atmosphere to electrons (A2e) initiative goals.	• Continue DOE National Laboratories' support of offshore wind resource characterization and forecasting. No funding is requested for new competitively selected projects.	• Competitive award will continue using prior year funds. DOE National Laboratories' support funded separately.
• Competitively award projects for the development and demonstration of advanced offshore wind technologies.	• No funding requested.	• Projects will continue using prior-year funds.
• Support National Laboratory led project to develop offshore wind turbine controller for a range of possible turbine and foundation combinations.	• Support National Laboratory led project to develop offshore wind full-farm controller using consensus control methodology.	• Project will focus on application of consensus control applied to most promising offshore turbine/platform configuration.
• Support National Laboratory led projects to develop and validate improved, fully-coupled turbine/foundation engineering design tools for offshore wind.	• Support National Laboratory led projects to advance fully-coupled turbine/foundation engineering design tools for fixed-bottom and floating foundations.	• Validation test campaigns will be completed using prior year funds.
Manufacturing and Materials R&D $3,681,000	$1,700,000	-$1,981,000
• Support for National Laboratory led research projects addressing optimized design for manufacturing enabled by additive manufacturing for electrical generators and wind turbine blade core materials.	• Building on FY20 activities, initiate National Laboratory led analytical studies for additive design and feasibility of prospective additive processes.	• Projects will focus on identifying most promising potential pathways for future research.
• Support for National Laboratory research to develop optimized carbon fiber material for wind turbine blade application through fiber shape changes.	• Support for National Laboratory research to develop non-circular, hollow fibers with larger surface areas (for bonding) and larger inertia for bending and buckling resistance.	• Prioritize research to focus on theoretically best option for improved material properties.
Environmental and Siting R&D $14,138,000	$1,000,000	-$13,138,000
• Competitively select and award projects on the environmental performance of offshore wind plants, with an emphasis on evaluating impacts of	• No funding requested.	• Continue research funded through FY20 obligations.

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
noise on protected species, impacts to birds and bats, and impacts of habitat changes on protected species.		
• Fund National Laboratory Development and validation of environmental monitoring and mitigation technologies, with an emphasis on tools that allow for autonomous monitoring and impact mitigation.	• Development and validation of environmental monitoring and mitigation technologies, with an emphasis on tools that allow for autonomous monitoring and impact mitigation.	• No significant change.
• Support efforts to share international research findings, through IEA Wind Energy Task 34 (WREN) and the Tethys database to catalyze knowledge transfer and minimize novel research needed in U.S. waters.	• Continue international research sharing and dissemination through IEA Wind Energy Task 34 (WREN) and the Tethys database.	• Focus FY21 budget resources on database maintenance activities, as opposed to growth.
• Co-fund National Laboratory research and development to address wind/radar challenges unique to offshore wind and facilitate the definition of next-generation radar requirements. Key funded partnerships with DOD, DHS, DOT, DOI and DOC.	• Co-fund National Laboratory research and development to address wind/radar challenges unique to offshore wind and facilitate the definition of next-generation radar requirements. Key funded partnerships with DOD, DHS, DOT, DOI and DOC.	• No significant change.
• Fund the WINDExchange, including development and provision of information to ensure use of the best available science to support wind energy policy and deployment decisions. Continue support for the National Wind Turbine Database and research on community impacts.	• Maintain WINDExchange, to ensure use of the best available science to support wind energy policy and deployment decisions. Continue support for the National Wind Turbine Database and research on community impacts.	• No significant change. Focus on database maintenance as opposed to growth
STEM & Workforce Development $357,000	$0	-$357,000
• Continue the Collegiate Wind Competition for development of a robust domestic wind energy workforce. Support domestic offshore wind workforce needs research.	• No funding is requested for STEM & Workforce Development activities under Offshore Wind in FY 2021.	• All STEM and Workforce Development activities will be consolidated under a new subprogram starting in FY 2021.

Description

The Land-Based Wind subprogram emphasizes efforts to develop technical solutions to environmental and siting challenges associated with land-based wind energy development that currently impact the vast majority of the U.S. wind resource. Additional activities focus on addressing "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 the cost of utility-scale land-based wind and provide options for significant expansion of U.S. wind power deployment.

Through these efforts, the subprogram seeks to reduce the levelized cost of energy (LCOE) for land-based wind by 50 percent from today's LCOE, to $.023/kWh without subsidies, by 2030. Achieving this 2030 goal would make wind electricity one of the most affordable forms of electricity in the U.S.

Science and Technology Innovation

The land-based wind science and technology research activity concentrates on addressing the challenges specifically associated with tall wind, primarily technologies to address transportation constraints of very large components over land. This activity seeks to advance land-based wind technology innovation and scientific understanding to decrease cost and improve the performance and reliability of next-generation tall wind plants and turbine technology. The primary effort is the Big Adaptive Rotor (BAR) initiative, which focuses on development of innovative, transportable, very large rotor designs with longer, highly flexible blades that capture substantially more energy both through a greater swept area and by accessing increased wind speeds higher above the ground than accessed by conventional technology. Larger rotors also allow for higher capacity factor wind plants, which creates less variability in power production. The BAR initiative addresses 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.

Efficiency and usability of wind technology depends on the reliability and lifetime of components. Operations can be optimized—and thus O&M costs decreased—with the proper tools and data to decrease unplanned maintenance and extend the lifetime of components. As wind turbines get larger and more flexible, O&M costs and reliability issues continue to increase and become more critical to the performance of the entire turbine and the deployment of wind power and its economic competitiveness. The activity advances optimized O&M practices facilitated by prognostic health management tools driven by artificial intelligence and automated fault detection and repair that will benefit both land-based and offshore wind plant operations.

The Wind Program will continue to maintain 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 Wind Program will also continue its support of maintenance activities for the National Wind Technology Center (NWTC) as part of the National Renewable Energy Laboratory's Flatirons Campus — an EERE-wide asset focused on energy systems integration of multiple generators, loads, and storage technologies with the grid.

Manufacturing and Materials R&D

The land-based wind manufacturing and materials research activity concentrates on addressing the challenges specifically associated with tall wind, and mitigating transportation/logistical constraints of very large components. This activity aims to develop cost-effective, lightweight turbine components that are more efficient, stronger, and more reliable for the full life-cycle of the wind turbine through advanced manufacturing, materials science, and mechanical systems R&D. Efforts will focus on composite material research to develop recyclable blade materials and other advanced materials science to develop lubricants, composite materials, and metallic coatings that are resistant to damage in operating conditions that benefit both land-based and offshore wind applications. This activity also seeks to develop new manufacturing methodologies using additive manufacturing techniques coupled with automated assembly approaches to reduce fabrication costs and mitigate transportation challenges of large and complex wind turbine components.

Environmental and Siting R&D

This activity emphasizes efforts to develop technical solutions to reduce cost and regulatory barriers associated with wind energy siting and environmental performance challenges, which currently affect the entirety of the nation's land-based wind resource, through targeted research, development, and validation of technology solutions, as well as knowledge transfer activities. The activity works to develop solutions to terrestrial wind environmental impacts by developing mitigation tools and technologies, as well as supporting and disseminating the underlying research needed to inform these solutions. Research focuses on evaluating and addressing impacts on bats, eagles, and grouse species, with a particular emphasis on minimizing impacts on bats in 2021. The activity also supports research and the development of information resources and tools on community impacts of land-based wind development.

Through this activity, the Wind Program will collaborate with other agencies through the interagency Wind Turbine Radar Interference Mitigation MOU to address the impacts of land-based wind development on air surveillance and weather radar missions. The objectives include developing technology solutions to evaluate the impacts of existing and planned wind energy installations on sensitive radar systems; developing 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 interference.

Land-Based Wind

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Land-Based Wind $31,800,000	**$3,500,000**	**-$28,300,000**
Science & Technology Innovation $13,794,000	$750,000	-$13,044,000
• Support for maintenance and operations activities of research test facilities at the NREL Flatirons Campus and SNL SWiFT facility	• Facilities will be kept in Standby Operational Readiness mode.	• Systems will be fully operative, with some preventative maintenance.
• Support for National Laboratory led Big Adaptive Rotor collaboration to mitigate transportation constraints of conventional, very large wind turbine rotors by focusing R&D on adaptive load control and innovative design and materials research to enable highly flexible, rail-transportable large rotors.	• Support for National Laboratory led Big Adaptrive Rotor collaboration to mitigate transportation constraints of very large rotors by focusing R&D on methodologies to control the aerodynamic and aeroelastic behavior of slender, high tip-speed ratio, highly flexible blades.	• Program will focus on key technical challenge of highly flexible blades and reduce emphasis on adaptive load control technologies.
• Continue National laboratory research to improve wind turbine reliability. Addresses turbine blade and drivetrain prognostic health management, failure analysis and mitigation, and reliability predictions of remaining useful life.	• Continue National laboratory research to improve wind turbine reliability by focusing on application of big data analysis and artificial intelligence techniques to optimize operations and maintenance.	• Prioritize the application of artificial intelligence methodologies to wind turbine reliability.
• Continued support for the Atmosphere to electrons (A2e) initiative.	• Develop the American Wake Experiment (AWAKEN). National laboratories will organize, and design a landmark international wake observation and validation campaign for A2e wind farm modeling tools.	• A2e activities are being split between land-based and offshore subprograms, with increased emphasis on offshore. Land-based A2e effort shifts focus to validation of capabilities.
Manufacturing and Materials R&D $10,580,000	$750,000	-$9,830,000
• Competitive award for Tall Tower Demonstration. Funding is being provided for an Alternate Selection from the FY 2019 DE-FOA- 0002071.	• No funding requested.	• Project will continue using prior-year funds.
• Continue support for National Laboratory led collaboration to characterize the mechanisms of predominant and unaccounted failure modes of wind turbine drivetrains; developing and validating mitigation solutions; and developing accurate life models for improved component design specifications.	• Build upon previous National Laboratory activities and advanced materials science research to develop new novel coatings and lubricants for improved reliability of bearings and gears.	• Focus on improving lubricants and coatings as a mechanism to mitigate wind turbine drivetrain failure.

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
• Continue support for development of advanced manufacturing technologies for wind turbine applications including additive manufacturing, and recyclable blade materials.	• Design, implementation, and validation of fusion joining of thermoplastic composites applied to wind turbine blades	• Prioritize research to develop recyclable blade materials
Environmental and Siting R&D $5,230,000	$2,000,000	-$3,230,000
• Continue National Laboratory research to characterize the environmental performance land-based wind projects, with an emphasis on understanding drivers of risk for bat species at wind farms.	• Build upon National Laboratory research to characterize the environmental performance land-based wind projects, by focusing on identifying potential bat deterrent signals and to better understand drivers of risk for bat species at wind farms.	• No significant change.
• Development and validation of environmental monitoring and mitigation technologies by the National Laboratories.	• Development and validation of environmental monitoring and mitigation technologies by the National Laboratories, with an emphasis on developing and optimizing bat deterrent technologies.	• Focus work on bat deterrent technologies. Continue work funded through prior year obligations.
• Support efforts to share international research findings, through IEA Wind Energy Task 34 (WREN) and the Tethys database in to catalyze knowledge transfer to inform technical solution development for land-based issues.	• Continue international research sharing and dissemination through IEA Wind Energy Task 34 (WREN) and the Tethys database.	• Focus FY21 budget resources on database maintenance activities, as opposed to growth.
• Co-fund National Laboratory research and development to address wind/radar challenges unique to land-based wind and facilitate the definition of next-generation radar requirements. Key funded partnerships with DOD, DHS, DOT, DOI and DOC.	• In partnership with DOD, DHS, DOT, DOI and DOC, validate one or more mitigation measures at a radar site where the mission is currently impacted by wind turbine interference.	• Priority shifts from research and development on wind turbine interference mitigation measures to mitigation project to implement one or more solutions developed in prior years for land-based wind/radar challenges.
• Fund the WINDExchange, including development and provision of information to ensure use of the best available science to support wind energy policy and deployment decisions. Continue support for the National Wind Turbine Database and research on community impacts.	• Maintain WINDExchange, to ensure use of the best available science to support wind energy policy and deployment decisions. Continue support for the National Wind Turbine Database and research on community impacts.	• No significant change. Focus on database maintenance as opposed to growth
STEM & Workforce Development $2,196,000	$0	-$2,196,000
• Continue Wind for Schools and the Collegiate Wind Competition for development of a robust	• No funding is requested for STEM & Workforce Development activities under Land-Based Wind in FY 2021.	• All STEM and Workforce Development activities will be consolidated under a new subprogram starting in FY 2021.

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
domestic wind energy workforce. Support domestic wind workforce needs research.		

Wind Energy
Distributed Wind

Description
The Distributed Wind subprogram focuses on achieving breakthroughs in reducing the levelized cost of energy (LCOE) by 50 percent from a 2015 benchmark to $0.04/kWh by 2030 without subsidies for megawatt-scale systems, and $0.07/kWh for kilowatt-scale systems. Achieving this 2030 goal would enable distributed wind to compete on an unsubsidized basis with other distributed energy resources (DERs) and cost-effectively integrate with other DERs in hybrid plants and microgrids. To accomplish this, the program invests in activities ranging from improving understanding of atmospheric physics for distributed wind site assessment to R&D aimed at reducing the balance of system costs associated with distributed wind.

Science and Technology Innovation
This activity will continue work to improve the science around rapid, computationally-based wind resource and site assessment for standalone and hybrid distributed wind systems, for which traditional meteorological instrumentation and field measurements are cost-prohibitive, and current practices are too uncertain and inaccurate to support the third-party financing, grid planning, and operational tools needed for industry growth.

Testing and Reliability
Testing and Reliability efforts for distributed wind will support existing awardees under the Competitiveness Improvement Project to reduce turbine costs, improve system performance, and test turbine designs to national and international safety and performance standards to achieve certification. Efforts will also include engagement to improve national wind turbine performance and safety standards.

Balance of Systems R&D
Balance of systems activities will focus on reducing capital costs through standardization of project assessment, permitting, interconnection, system design, and installation of distributed wind systems. The activity will fund R&D that enhances accuracy of distributed wind performance assessments in tools used to inform siting and system design, evaluate grid impacts, and reduce project development risk. Efforts to focus on maximizing the value and resiliency of microgrids powered by wind energy, in combination with other distributed energy resources such as solar and storage, will transition to the Systems Integration subprogram and be consolidated with similar efforts for land-based and offshore wind.

Distributed Wind

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Distributed Wind $10,000,000	**$700,000**	**-$9,300,000**
Science and Technology Innovation $4,836,000	$300,000	-$4,536,000
• Continue multi-lab project, Tools Assessing Performance, by developing a beta version desktop computational framework that can be used by industry to rapidly and accurately estimate project performance and improve turbine reliability models.	• Tools Assessing Performance work will continue improving and validating the science around rapid, computationally-based wind resource and site assessment for distributed wind systems, for which traditional meteorological instrumentation and field measurements are cost-prohibitive.	• Focus will shift from high-fidelity model development and simulation, to verification and validation of the physics identified in previous work in reduced fidelity models suitable for industry use.
• Continue multi-lab project, Defense and Disaster Deployable Turbine, by developing system design requirements in partnership with military stakeholders.	• Defense and Disaster Deployable Turbine work will complete evaluation of current technologies against military design requirements and close out.	• Work will prioritize desktop evaluation of current technologies against military design requirements, the development of a gap analysis, and project closeout.
Testing & Reliability $2,676,000	$200,000	-2,576,000
• Continue NREL operated request for proposals, Competitiveness Improvement Project, by monitoring prior year awards and soliciting proposals to make new awards aimed at reducing system costs, increasing system performance and grid support capabilities, and conducting system testing to national standards for achieving certification. Work with stakeholders to revise national and international distributed wind turbine performance and safety standards.	• Testing and Reliability efforts for distributed wind will support existing awardees under the Competitiveness Improvement Project to reduce turbine costs, improve performance, and test their designs to national safety and performance standards for achieving certification.	• No new awardees. Funds requested for work with existing awards. Reduced focus on revising small wind turbine standards.
Balance of System R&D $2,488,000	$200,000	-$2,188,000
• Continue multi-lab project, Microgrids, Infrastructure Resilience, and Advanced Controls Launchpad, by advancing research to cost effectively and securely integrate wind with other distributed energy resources in grid connected and microgrid applications.	• Microgrids, Infrastructure Resilience, and Advanced Controls Launchpad work under the Distributed Wind subprogram will develop capabilities to evaluate distributed wind in microgrid applications in decision support tools.	• Complete and document evaluation of decision support tools and transition remainder of work to Systems Integration subprogram.

Wind Energy
Systems Integration

Description

The Systems Integration 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 from all wind technology applications: land-based utility-scale, offshore, and distributed. The subprogram will aim to generate the knowledge that electric grid operators, utilities, regulators, and industry need to develop and deploy novel technologies that support incorporation of wind energy into a reliable and resilient power system. Efforts will focus on strategic opportunities to develop and refine the capability of wind to provide essential reliability services; increase wind energy's contribution to grid resiliency; improve grid infrastructure investment and utilization; address wind-specific cybersecurity needs; integrate wind power with storage and other technologies; and improve the understanding of electricity market operation with high penetrations of wind energy.

Grid Integration

The subprogram will develop new technologies and analytical tools that improve grid reliability and resiliency through increased flexibility and grid services. This body of research will focus on designing, developing, and testing controllers for wind plants to provide essential reliability services, taking into account wind plant atmospheric forecasting, and developing and validating wind's capability to support grid resiliency.

The subprogram will also coordinate through the Grid Modernization Initiative to invest in cross-cutting R&D activities in wind-hybrid energy storage systems, cybersecurity foundational studies, and technical assistance support to Independent System Operators and Regional Transmission Organizations.

Other planned activities include implementing the first phase of the program's wind plant cybersecurity roadmap, assessing wind plant cyber vulnerabilities using reference models, and developing detection and mitigation technologies that harden wind plant communication from cyber-attacks; new research initiative to ensuring reliable and resilient integration of offshore wind to the grid by developing advanced planning and operation models, tools, and interconnection studies; and continuing the Distributed Wind Microgrid, Infrastructure Resilience and Controls Launchpad (MIRACL) project, which will advance approaches for integrating distributed wind in hybrid wind/solar/storage systems and microgrid applications to support resilience and reliability on distribution systems.

Systems Integration

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Systems Integration $0	**$10,500,000**	**+$10,500,000**
Systems Integration $0	$10,500,000	+$10,500,000
• Under Grid Integration and Analysis subprogram established in FY20, multi-lab projects to develop control theory and analyze grid needs for designing plant controller for wind to provide reliability and resilience service.	• National Laboratory projects to design and develop wind plant controllers to provide various essential reliability services while taking into account of wind plant atmospheric condition forecasting. Develop and validate wind's capability to support grid resiliency.	• FY 2021 activities will expand to designing, testing and preparing for field validations of wind plant controllers from the control theory and control architecture development conducted in FY 2020.
• Under Grid Integration and Analysis subprogram established in FY20, multi-lab projects to develop reference model as the first step to harden wind plant communication system.	• National Laboratory projects to implement the first phase of the program's wind plant cybersecurity roadmap. Assess wind plant cyber vulnerabilities and develop detection and mitigation technologies that harden wind plant communication from cyber-attacks.	• FY 2021 efforts will focus on testing the cybersecurity wind farm reference models developed in FY 2020 and developing mitigation strategies for identified vulnerabilities.
• Under Grid Integration and Analysis subprogram established in FY20, provide support for cross-cutting grid modernization activities competitively selected from the Grid Modernization Lab Consortium lab call in late FY19.	• Continue support for cross-cutting Grid Modernization Initiative activities such as wind-hybrid energy storage systems and cybersecurity foundational research competitively selected from the Grid Modernization Lab Consortium lab call in FY 2019.	• No significant change.
	• Initiate new research with National Laboratories to ensure reliable and resilient integration of offshore wind to the grid by developing advanced planning and operation models and tools to facilitate offshore wind grid integration and interconnection studies	• New effort in FY 2021 will focus on offshore grid integration and interconnection research to develop tools and models to analyze offshore transmission system options, onshore connections options, and offshore wind impact and solutions to grid stability and reliability.
• Under the Distributed Wind subprogram in FY 2020, continue multi-lab project, Microgrids, Infrastructure Resilience, and Advanced Controls Launchpad, by advancing research to cost effectively and securely integrate wind with other distributed energy resources in grid connected and microgrid applications.	• The Distributed Wind Microgrid, Infrastructure Resilience and Controls Launchpad (MIRACL) project will advance approaches for integrating distributed wind in hybrid wind/solar/storage systems and microgrid applications to support resilience and reliability on distribution systems.	• In FY 2021, MIRACL will advance from development and buildout of integrated research capabilities to directed R&D and industry collaboration to support the cyber-secure integration and control of wind technologies in hybrid, microgrid, and other distributed applications.

Wind Energy
STEM & Workforce Development

Description

The subprogram supports STEM and workforce programs designed to promote wind energy literacy at a range of learning levels and to ensure students are exposed to possible careers in wind power through wind-related curricula. Programs include a collegiate level wind turbine design competition– the Collegiate Wind Competition–as well as the Wind for Schools project, which partners universities with K-12 institutions to develop and promote wind energy curricula, provide teacher trainings, and build wind turbines at schools and study data produced by these turbines. Currently, the program is engaging with a non-profit partner to transition the Wind for Schools program to long-term, sustained external management and funding.

STEM & Workforce Development

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
STEM and Workforce Development $0	**$200,000**	**+$200,000**
STEM and Workforce Development $0	$200,000	+$200,000
• Funding for the Collegiate Wind Competition and the Wind for Schools program, including efforts to transition Wind for Schools to an independent funding model. Wind workforce analyses to understand national workforce training needs. FY20 efforts were funded through the land-based, offshore wind, and distributed wind subprograms.	• Support for the Collegiate Wind Competition and the Wind for Schools program.	• Maintain Collegiate Wind Competition and Wind for Schools program, but evaluate alternatives to transition one or both to an independent funding model. No funding requested for workforce training needs analysis.

Wind Energy
Data, Modeling, and Analysis

Description

The Data, 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 techno-economic conditions as well as state-of-the art systems engineering, cost and deployment models, and tools. These analyses are used to identify R&D needs as well as to prioritize activities within the portfolio.

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 for wind energy's role in the electric sector, as well as providing detailed analytical data in the form of technology and analytical reports to inform decisions. The subprogram will also continue to contribute to numerous EERE and DOE cross-cutting analysis initiatives.

Data, Modeling and Analysis

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Data, Modeling, and Analysis $0	**$700,000**	**+$700,000**
Data, Modeling, and Analysis $0	$700,000	+$700,000
• Under Grid Integration and Analysis subprogram established in FY20 appropriations, the office conducts wind data collection and analysis efforts, including cost-modeling, benchmarking and scenario analysis to evaluate the cost, value, and impact of land-based and offshore wind R&D opportunities.	• Track and report GPRA and other metrics. Evaluate the impacts of innovation in land-based, distributed, and offshore wind. In collaboration with other Renewable Power offices, develop capabilities to better evaluate the value of wind to the electricity system.	• Streamline work under new program structure to prioritize required GPRA reporting and participation in EERE and DOE crosscutting analysis efforts.

Water Power

Overview

Hydropower and marine and hydrokinetic (MHK) energy technologies generate renewable electricity that can support domestic economic prosperity and energy security while enhancing the reliability and resiliency of the U.S. electric grid. The 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 R&D conducted by the National Laboratories, industry, and academia 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 2018, hydropower supplied 7 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 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. The 2016 Vision also included a Roadmap of 64 action areas to track progress toward realizing those development opportunities. In FY 2021, in conjunction with a broad spectrum of external stakeholders, the program will revisit the Roadmap to note progress and assess the continued applicability of the 2016 action areas.

In part due to the increasing value of hydropower's ability to provide flexibility and balancing services at scale, 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 R&D to reduce costs and construction timelines, improve environmental performance, and understand hydropower's ability to operate flexibly and provide reliability and resilience services to the grid.

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 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 relative to those that are commercially available. 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 informs 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 multiple-use demands of energy generation, irrigation, flood control, and recreation.

[1] U.S. Energy Information Administration. Table 7.2A Electricity Net Generation: Total (All Sectors). Accessed September 17th, 2019. 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.

The program's HydroWIRES (Water Innovation for a Resilient Energy System) initiative invests in R&D 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, 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.

HydroWIRES activities support the Advanced Energy Storage Initiative, as part of the broader Energy Storage Grand Challenge, 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 Energy Storage Grand Challenge enhances coordination across EERE and DOE and establish aggressive, achievable, and comparable goals for cost-competitive energy storage services and applications.

The program also supports an ongoing effort to help provide the tools, technology and analysis necessary to maintain and modernize the existing hydropower fleet. To support the effort, the Water Power Program is undertaking a broad portfolio of activities associated with hydropower digitalization, cybersecurity, and maintenance. Initial digitalization efforts focus on assessing the broad landscape of digitization opportunities and articulating their value and applicability to the diverse hydropower fleet. The program's cybersecurity work focuses not only on documenting the broad topologies of hydropower cyber-physical systems but also assessing the broad "Cybersecurity State of the Hydropower Fleet." Maintenance efforts are focused around enabling data driven decisions regarding operations, cost, and reliability tradeoffs through the development of a digital hydroplant simulation with enhanced high-speed computing.

Modernization of the existing fleet also includes 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 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 emerging at-sea and coastal distributed applications as described in the 2019 "Powering the Blue Economy" report, which can provide valuable in-water experience to accelerate learning curves for larger-scale systems and attract additional investment to the sector.[1]

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

[1] "Powering the Blue Economy, Exploring Opportunities for Marine Renewable Energy" U.S. Department of Energy. April, 2019. https://www.energy.gov/sites/prod/files/2019/09/f66/73355-v2.pdf

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-stage MHK R&D 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 2021 Budget Request

The Water Power Program will pursue the following major activities in FY 2021:

- Investments in R&D for innovative standardized and modular hydropower technologies using advanced manufacturing techniques to lower overall project costs and improve environmental performance by developing tools for streamlined site evaluation and regulatory best practices at new stream reaches and non-powered dams.
- In support of the Grid Modernization Initiative and the Energy Storage Grand Challenge ($15,000,000), 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.
- Expand valuation methodologies of hydropower flexibility from PSH to conventional hydropower. Improve reservoir inflow forecasting tools and the representation of hydropower in power system models.
- Develop a digital representation of a hydropower plant (Digital Twin) to better understanding of the health, mechanical, hydrological and electrical status of hydropower plants by partnering with the industry to use operational and fleet condition data for creation of a numerical model capable of predicting hydropower plant system condition.
- In support of the Cybersecurity crosscut, the program's cybersecurity work ($1,000,000) focuses on documenting the broad topologies of hydropower cyber-physical systems and assessing the broad "Cybersecurity State of the Hydropower Fleet."
- 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.
- Test and validate performance of wave devices at PacWave, the Nation's first accredited grid-connected MHK test facility in a high-energy site.
- Continue support of Testing Expertise and Access for Marine Energy Research (TEAMER), a rolling test campaign supported in collaboration with U.S. universities and National Laboratories for early stage marine energy systems.
- 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 and other ocean markets, ultimately leading to reduced costs and increased competitiveness of marine energy devices.
- To further the development of MHK-powered systems that desalinate seawater, the program will invest in R&D to determine the technical potential of wave power to provide freshwater, including continuation of support for the Waves to Water initiative and the Energy-Water Crosscut ($4,000,000).
- 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.
- 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 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted
Water Power				
Hydropower Technologies	35,000	39,000	25,000	-14,000
Marine and Hydrokinetic Technologies	70,000	109,000	20,000	-89,000
Total, Water Power	**105,000**	**148,000**	**45,000**	**-103,000**

SBIR/STTR:

- FY 2019 Transferred: SBIR $3,483,000; STTR $92,000
- FY 2020 Projected: SBIR $4,447,000; STTR $625,000
- FY 2021 Request: SBIR $1,440,000; STTR $203,000

Water Power

Explanation of Major Changes ($K)

	FY 2021 Request vs FY 2020 Enacted
Water Power	
Hydropower Technologies: In FY 2021, no funding is provided for implementation of Section 242 of the Energy Policy Act of 2005. Reduced funding is provided for small, modular hydropower to advance energy-water security and to identify opportunities for small, modular hydropower systems like irrigation systems modernization or groundwater recharge. Funding is also provided to support the Energy Storage Grand Challenge, to include activities in support of increasing the flexibility of hydropower to the grid and advanced storage capabilities, like pumped storage hydropower. The program will also develop a digital representation of a hydropower plant to better understanding the health, mechanical, hydrological and electrical status of hydropower plants for the purpose of predicting hydropower plant system conditions.	**-14,000**
Marine and Hydrokinetic Technologies: The FY 2021 Request 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 provides funding for advancement of wave energy's potential to desalinate water, including follow-on activities to support the Waves to Water initiative, part of the Water Security Grand Challenge. It also maintains funding necessary for FY 2021 scope of work for advanced wave energy converter modeling and controls; wave, tidal, and current resource classification; and sharing of environmental and regulatory data among researchers, developers, and regulators.	**-89,000**
Total, Water Power	**-103,000**

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 to be 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 supports industry efforts to develop and deploy new technologies, reducing the levelized cost of energy from non-powered dams and new stream reaches,[1] quantifying the value of grid reliability services, addressing regulatory requirements, and maintaining and improving 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.

New Low Impact Hydropower

The development of new hydropower is limited by the customized and the site-specific approach to construction, powerhouse design/installation, and environmental mitigation. New standardized, modular approaches to hydropower project design at non-powered dams and new stream reaches have the potential to significantly reduce costs and incorporate environmental performance at the initial design stages. 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, numerical modeling, validation, and testing 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, 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.

Grid Integration

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 (restoration) 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 Energy Storage Grand Challenge, the hydropower subprogram, under the HydroWIRES initiative, 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. The subprogram will also 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. These activities drive needed 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.

[1] FY 2021 targets for reduced levelized cost of energy from non-powered dams is 9.1 cents per kWh and from new stream reaches is 10.7 cents per kWh.

Existing Hydropower

Efforts to improve sustainability and environmental performance of the Nation's existing hydropower systems are inherently linked to the modernization of the existing fleet. Scientific advances that allow developers and operators to more effectively identify and mitigate potential impacts ultimately allows for 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.

Efforts in hydropower plant upgrade and modernization will focus on developing tools to better understand the health, mechanical, hydrological, and electrical status of hydropower plants based on operating regimes by means of a fleet condition data analysis and creation of a numerical model capable of predicting hydropower plant system conditions. These tools will play a critical role in maximizing hydropower plant reliability in the face of increasingly variable and more flexible hydropower operation in the wake of increasing penetration of wind and solar generation into the U.S. grid. In addition, the program will support projects that advanced sensor analytics, capitalizing on the range of existing hydropower sensor data, to provide unprecedented insight into hydropower plant operation, maintenance, and environmental interaction. Finally, cybersecurity R&D efforts focus on standardizing cyber-physical typologies to establish a hydropower "State of the Fleet" analysis highlighting both the opportunities to improve security, and understanding the value of effective cybersecurity, as well as the risk and consequence sensitivities of hydropower plant cyberattacks. Hydropower has certain unique characteristics due to the age and diversity of the fleet that may exacerbate cybersecurity risks, including a widely diverse set of network layouts and 50+ year-old infrastructure. Water Power Program cybersecurity activities focus on those risks and mitigation activities unique to hydropower.

Data, Modeling, & Analysis

Throughout the course of its funded R&D activities, the subprogram, its National Laboratories and awardees identify and aggregate large amounts of data from across the hydropower industry and hydrologic science disciplines. Non-proprietary data are validated and made publically-available through the program-maintained HydroSource data portal[1]. These data are useful to inform R&D, investment, advocacy, and regulatory decisions for researchers, technology developers, conservation advocates, policy-makers and regulatory agencies. These data also underpin the publically-available U.S. Hydropower Market Report, compiled and released by the program and Oak Ridge National Laboratory every 2-3 years, with select data updates released in intervening years. Another full version of the report is scheduled for release in FY 2020. Many different types of data collected by the subprogram are also used to conduct analyses and provide unbiased scientific data to facilitate targeted improvements to regulatory processes.

The Hydropower Vision report included a Roadmap of detailed actions recommended to advance sustainable hydropower in the U.S., with the potential of allowing it to grow nearly 50 GW (13 GW of new hydropower and 36 GW of new pumped storage hydropower) by 2050. The Roadmap is intended to function as a guidepost for not only the Hydropower subprogram but the entire hydropower community. The subprogram, with support from its National Laboratories, has used the Roadmap as an evolving plan against which it has tracked progress of its own research and activities throughout the broader hydropower community on the way to realizing the Hydropower Vision. Regular updates to the Roadmap will ensure that the hydropower communities' path to achieving the sustainable hydropower future laid out in the Vision remains relevant and up-to-date.

[1] https://hydrosource.ornl.gov/

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Hydropower Technologies $39,000,000	**$25,000,000**	**-$14,000,000**
New Low Impact Hydropower $9,000,000	$3,500,000	-$5,500,000
• Advance standard modular hydropower systems development through competitive solicitations, including leveraging advanced manufacturing techniques and supporting the development of foundations that are modular and more easily adaptable to a variety of site conditions.	• Fund National Laboratory work to develop a strategy for advanced manufacturing technologies to support standard modular hydropower and modernize the hydropower fleet.	• FY 2021 efforts will build on FY 2020 work with more limited scope by focusing on laboratory work in support of competitive solicitations made in FY 2020.
• Continue National Laboratory efforts to develop design specifications and computer modeling tools for standardized, modular hydropower technologies.	• Continue National Laboratory efforts to develop design specifications and computer modeling tools for standardized, modular hydropower technologies.	• No change.
• In support of the Water Security Grand Challenge, the subprogram supports National Laboratory research to identify opportunities where small, modular hydropower technologies could support other infrastructure needs, like irrigation systems modernization.	• The subprogram will continue support of the Water Security Grand Challenge by funding National Laboratory projects investigating where small, modular hydropower technologies could complement other water-related objectives like irrigation systems modernization or groundwater recharge.	• In FY 2021, funding will support National Laboratory projects focused on small, modular hydropower technologies with ancillary benefits for applications like irrigation systems modernization or groundwater recharge.
• With the National Laboratories, initiate scoping a hydropower technology test facility.	• No funding.	• Scoping efforts for a hydropower test facility are fully funded with FY 2020 funds.
Grid Integration $12,200,000	$15,000,000	$2,800,000
• In support of the Energy Storage Grand Challenge, competitively solicit 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 includes technology and analytical research at National Laboratories to evaluate hydropower's contributions to grid resiliency.	• Building on foundational National Laboratory work under the HydroWIRES initiative, the subprogram will quantify and improve the accuracy and resolution of inflow forecasting tools to enable more flexible operation, as well as improve the representation of hydropower in power system models to more accurately capture its unique capabilities.	• In FY 2021, the subprogram will focus on improving industry-led modeling and forecasting capabilities so that industry can utilize the FY 2020 foundational research in flexible operations to implement actionable hydropower operating strategies that contribute to increased grid resiliency.

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
• Continue National Laboratory work to identify technology gaps and pathways to support unit- and/or plant-level technology advancements that can increase capabilities for flexible operation.	• Building on industry-led work funded in FYs 2018-2019 to identify and quantify sources of flexibility in hydropower plants, subprogram efforts will result in development of technology solutions that enable enhanced flexibility at the unit, plant or cascading system level.	• In FY 2021, the subprogram's efforts will shift from identifying gaps in technology to identification of new hydropower powertrain designs and advancements that will support the changes, as well as unit- and/or plant-level technology advancements that can increase capabilities for flexible operation.
• Complete National Laboratory work to develop and apply PSH valuation guidance to Goldendale and Banner Mountain projects.	• Apply the PSH valuation guidance previously developed to develop generally applicable methodologies for valuing hydropower and PSH projects.	• FY 2021 efforts build on prior-year efforts to develop valuation methodologies for grid services provided by specific projects, and will lead to rigorous, widely applicable methodologies that can accurately value hydropower and PSH.
Existing Hydropower $7,100,000	$3,500,000	-$3,600,000
• The subprogram will continue its work to develop turbine design and evaluation tools that improve both fish passage and turbine efficiency (third year of the four-year Phase II of a multi-lab project).	• The subprogram will continue its work to develop turbine design and evaluation tools that improve both fish passage and turbine efficiency (final year of the four-year Phase II of a multi-lab project).	• No change.
• The subprogram will develop a scientific framework for identifying the key factors that contribute to environmental impacts of hydropower.	• The FY 2021 effort will apply the framework in a regulatory setting to assess its ability to minimize the time and costs for scientific studies needed for regulatory permitting.	• FY 2021 activities will apply the framework developed in previous years to determine its efficacy.
• Continuation of the Hydropower Fleet Intelligence project.	• Completion of the Hydropower Fleet Intelligence project and development of a digital representation of a hydropower plant (Digital Twin).	• FY 2021 represents a lower level of effort for developing tools to better understand the health and status of hydropower plants based on operating regimes.
Data, Modeling, & Analysis $3,700,000	$3,000,000	-$700,000
• Updates to the Hydropower Vision Roadmap.	• Updates to the Hydropower Vision Roadmap.	• No significant change.
• Funding supports the third and final Report to Congress under the SECURE Water Act Section 9505, due in 2021.	• Funding supports the third and final Report to Congress under the SECURE Water Act Section 9505, due in 2021.	• No significant change.

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
EPACT Section 242 $7,000,000	$0	-$7,000,000
• Incentive payments to hydropower owners/operators for production at eligible projects.	• No funding requested.	• Funding incentive payments for deployment is inconsistent with the focus on early-stage R&D.

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 complementary to other renewables such as onshore wind and solar, enhancing it's 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 and reduce the levelized cost of energy for marine energy technologies to 52 cents per kWh in FY 2021.

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. Successfully serving these markets simultaneously reduces costs for larger utility-scale markets that are still developing – by providing real in-water experience that drives down learning curves – and increases near-term investment in the sector. In addition, cost-effective energy provision at sea enables major advances in scientific understanding of the ocean and technology innovation and commercial opportunities in the ocean.

Materials and Components R&D

MHK energy technologies have difficult engineering challenges specific and inherent to the marine energy environment. MHK resources have large ranges in intensity and present other fundamental difficulties for designing systems to efficiently capture usable energy, as a result of the unique physics of the systems. MHK devices must operate in environments with resource characteristics (e.g., high energy-density waves and currents with often complex, low-velocity, highly turbulent characteristics) that vary significantly on timescales ranging from seconds to seasonal cycles, resulting in a complex set of systems design and optimization challenges. The subprogram works to support foundational science and early-stage R&D to tackle these difficult engineering challenges to rapidly improve and reduce costs of MHK energy generation technologies.

Advanced controls research remains a major programmatic focus, as studies have shown that advanced controls improvements can provide significant increases in energy capture at varying timescales, and recent work has achieved advances doubling the energy capture of previous methods. Controls strategies and technologies are also being leveraged from other industries (e.g., aerospace and 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 National Laboratory 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 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

[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).

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.

System Integration and Validation

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, where the cost of energy can be near or over $1 kWh electricity 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 also 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.

Testing & Reliability

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.

Data, Modeling, & Analysis

The aforementioned priorities are areas where targeted government support can broadly benefit the entire research and technology development community. MHK technologies are at an early stage of development due to the fundamental scientific and engineering challenges as well as high costs and lengthy permitting processes associated with in-water testing. The subprogram works to aggregate, analyze, and disseminate data to as wide an audience as possible to ensure

project successes and lessons learned are shared throughout the community and the impact of subprogram support is maximized. These efforts include the continued development of the new PRIMRE system (Portal and Repository for Information on Marine Renewable Energy). This knowledge management system incorporates previously separate databases and tools, all developed and supported by the MHK subprogram. They include a testing and performance data repository, a testing facilities database, an instrumentation and sensor catalogue, a knowledge management system for environmental monitoring data and research (TETHYS), resource assessments, and an MHK technology and device database. From these data, new techno-economic and market analyses are conducted, and new performance and testing results are evaluated.

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Marine and Hydrokinetic Technologies $109,000,000	**$20,000,000**	**-$89,000,000**
Materials and Components R&D $27,200,000	$4,000,000	-$23,200,000
• Continue DOE's commitment to a joint DOE/Navy project targeting advanced controls. This includes testing co-designed control and power take-off systems, building on findings from FY 2017 – FY 2019 research and tests.	• Continued R&D into controls for MHK devices following up on strategy developed in recent FY to dramatically reduce costs and/or increase energy capture.	• The Budget prioritizes funding for controls modeling work., No funding is requested for testing work, including tank testing at the Navy's Carderock facility.
• 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 Budget prioritizes funding for controls modeling work. No funding is requested for the development of coatings, new advanced materials, or durability testing.
• Competitively select university-led partnerships and research projects to support foundational and crosscutting R&D for marine energy systems development.	• No funding requested.	• Projects selected in FY 2020 are fully funded. No new partnerships or projects will be initiated.
Systems Integration & Validation $15,300,000	$10,000,000	-$5,300,000
• Continue National Laboratory support for marine energy technologies, including supporting selected recipients competitively selected in FY 2019 to design wave energy converter systems targeted at grid-scale testing, and current energy capture prototypes.	• Fund down-select of one new MHK device design and build that targets grid-scale testing at PacWave.	• Efforts in FY 2021 will build on previous years design efforts but be limited to one build and test project funded.
• Competitive solicitations to support the development of prototypes of MHK devices designed for promising early-market opportunities.	• Launch additional opportunities in FY 2021 for new MHK device designs that target a range of markets including non-grid-scale "Powering the Blue Economy" markets.	• Continued subprogram R&D focuses on MHK technologies designed for promising early-market opportunities and builds off of previous years' analytical efforts. Work will prioritize 1-3 opportunities and scope out a potential future R&D competition. This includes funding activities to support the advancement of wave energy powered desalination systems.

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
• Launch competitive solicitations in partnership with other agencies, including Department of Commerce Economic Development Administration, to support developers entering into non-grid-scale markets. This includes entrepreneurial assistance to developers and technical assistance to remote communities seeking to increase the resiliency of their energy and water systems.	• No funding requested.	• Projects selected to provide entrepreneurial assistance will be fully funded from FY 2020 funds. No funding is requested for technical assistance to remote communities.
Testing & Reliability $57,300,000	$4,000,000	-$53,300,000
• Initiation of TEAMER, a rolling test campaign supported in collaboration with U.S. universities and National Laboratories for early stage marine energy systems, which is needed to achieve goal of Energy Affordability by reducing LCOE for MHK.	• Continue support of TEAMER, a rolling test campaign supported in collaboration with U.S. universities and National Laboratories for early stage marine energy systems.	• Effort in FY 2020 focused on launching the TEAMER program, including recruitment of suitable test facilities and launching a first round of applications for developers through the Network Director, selected in FY 2019. In FY 2021, funding will prioritize competitively selected projects as opposed to launching TEAMER.
• Continue National Laboratory work begun in FY 2017 on large-scale field study to evaluate environmental effects of marine energy devices, including strike-risk to fish from tidal turbines, and acoustic and other environmental impacts of wave energy devices.	• Continued support to collect data from large-scale field studies.	• Data will be collected and analyzed from a reduced number of field studies.
• 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.	• Project ending in FY 2020.
• Infrastructure upgrades at marine energy test sites and National Laboratories, funded through competitive solicitations.	• No funding requested.	• Upgrades identified in FY 2020 fully funded from FY 2020 funds.
• Launch a competitive solicitation to select the performer(s) to lead the Atlantic Marine Energy Center.	• No funding requested.	• Performer(s) selected in FY 2020 fully funded from FY 2020 funds.

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
• Distribute funding as directed to the open water test facility.	• No funding requested.	• Funding provided to the test facility fully funded from FY 2020.
Data, Modeling, & Analysis $9,200,000	$2,000,000	-$7,200,000
• Continued support for data sharing and results dissemination, including PRIMRE – dissemination database and tool to ensure information from program-funded research and testing results are aggregated and widely accessible.	• Continued support for data sharing and results dissemination, including PRIMRE – dissemination database and tool to ensure information from program-funded research and testing results are aggregated and widely accessible.	• No significant change.
• Continued techno-economic analysis, including aggregation and dissemination of environmental data and data for maritime markets.	• Limited National Laboratory analysis of R&D challenges and opportunities for maritime markets (Powering the Blue Economy).	• No new techno-economic analysis conducted on maritime markets. No funding for environmental data dissemination, or for maintaining the Marine and Hydrokinetic Data Repository (MHKDR).
• Develop impact analysis framework for MHK portfolio.	• No funding requested.	• Impact analysis framework for MHK portfolio fully funded from FY 2020.

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] The 2019 DOE study, *GeoVision: Harnessing the Heat Beneath Our Feet,* showed that with improved technologies, reduced permitting timelines, and increased public awareness of geothermal and its benefits, geothermal power capacity could reach 60 GWe by 2050, a 26-fold increase from today's levels, and geothermal heating could be used in up to 17,500 district heating systems and in 28 million geothermal heat pumps installations.[2] The *GeoVision* report clearly shows that technological innovation is required for industry to convert geothermal resources efficiently into useful energy services. The mission of the Geothermal Technologies Program 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, Enhanced Geothermal Systems (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 R&D supports efforts in the geothermal sector to develop innovative technologies that will help harness American energy resources safely and efficiently.

Highlights of the FY 2021 Budget Request

The Geothermal Technologies Program will pursue the following major activities in FY 2021:

- Advanced Wellbore Completions for EGS Longevity ($4,500,000): In the Subsurface Enhancement and Sustainability R&D activity area, the EGS subprogram will focus on developing alternative completion techniques, the adoption of cutting-edge unconventional oil and gas stimulation methods, and identifying links between completion techniques and reservoir development and operation.
- Diagnostics for Fluid Residence Time/Hydraulic Properties ($4,500,000): In the Subsurface Enhancement and Sustainability R&D activity area, the EGS Subprogram will support R&D projects that address fundamental challenges in understanding reservoir properties including developing methods to assess fluid residence time, fracture connectivity, and reservoir volume critical to determining reservoir performance.
- Drilling technologies ($3,500,000): The program will continue to emphasize R&D for advanced drilling technologies. Building on the work awarded under the 2018 Efficient Drilling for Geothermal Energy (EDGE) Funding Opportunity, the program will issue a new funding opportunity to move to the next phase of development for efficient drilling technologies.
- Energy Storage Grand Challenge ($6,000,000): In support of DOE's Grid Modernization Initiative, the program will validate technologies developed in FY 2020 under the Advanced Energy Storage Initiative as part of the broader Energy Storage Grand Challenge. Geothermal can provide a range of benefits including the following: grid stability, reliability, and resiliency from thermal and reservoir energy storage and the development of technologies that enable flexible geothermal power generation.

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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] GeoVision: Harnessing the Heat Beneath Our Feet (DOE 2019); www.energy.gov/GeoVision. The *GeoVision* Roadmap outlines a compilation of technical, economic, and institutional actions that the entire geothermal community including DOE, other government agencies, industry, and academia must address in order for geothermal technologies to play a larger role in the Nation's energy mix.

[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.

- Critical Minerals - Li Recovery R&D ($4,000,000): Following on FY 2020 work, the program will initiate a multi-phase effort in FY 2021 to attract innovative technologies that can effectively separate critical minerals from geothermal brines. The focus of the initial phase will be on a set of increasingly sophisticated modeling and bench-scale tests. This effort will provide meaningful impact on addressing the technical challenges associated with tapping the significant upstream domestic supply capacity and midstream separations and processing of critical minerals from geothermal power generation.

Geothermal Technologies
Funding ($K)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted
Geothermal Technologies				
Enhanced Geothermal Systems	53,000	69,000	10,000	-59,000
Hydrothermal Resources (formerly Hydrothermal)	15,000	20,000	4,000	-16,000
Low Temperature and Coproduced Resources	10,000	15,000	10,000	-5,000
Data, Modeling, and Analysis (formerly Systems Analysis)	6,000	6,000	2,000	-4,000
Total, Geothermal Technologies	**84,000**	**110,000**	**26,000**	**-84,000**

SBIR/STTR:

- FY 2019 Transferred: SBIR $2,688,000; STTR $378,000
- FY 2020 Projected: SBIR: $3,520,000; STTR: $495,000
- FY 2021 Request: SBIR: $832,000; STTR: $117,000

Geothermal Technologies
Explanation of Major Changes ($K)

	FY 2021 Request vs FY 2020 Enacted
Geothermal Technologies	
Enhanced Geothermal Systems: Funding for R&D under the Enhanced Geothermal Systems (EGS) Subsurface Enhancement & Sustainability R&D Activity is prioritized in FY 2021. The FY 2021 Request provides $10,000,000 for two new initiatives within this activity. The first targets advanced completions and wellbore engineering to facilitate successful isolation of targeted zones for stimulation. The second focuses on interrogation methods or tools for assessing and tracking fundamental hydraulic properties of EGS reservoirs, including the amount of time it takes fluid to pass through a reservoir. The reduction in funding is attributed in large part to the decreased request for FORGE (- $30,000,000) from FY 2020 Enacted which funds the final year of Phase 3 at the FORGE site in Milford, UT, in FY 2024; additional R&D awards in the early years of Phase 3; as well as additional drilling and characterization of the FORGE site.	**-59,000**
Hydrothermal Resources: The Budget prioritizes funding for R&D under the Hydrothermal resources Subsurface Enhancement & Sustainability R&D Activity in FY 2021. The program will prioritize funding to continue R&D of drilling technologies; building on the work awarded under the 2018 EDGE Funding Opportunity, the program will issue a new funding opportunity to move to the next phase of development for efficient drilling technologies. No funding is requested in FY 2021 for work in Exploration and Characterization R&D, which represents a decrease of $20,000,000 from FY 2020 Enacted. Efforts under this activity, including Machine Learning for Geothermal, Exploration RD&D of Hidden Systems in the Basin & Range, Subsurface Imaging R&D, and the GEOTHERMICA R&D international collaborative, are funded with prior year appropriations.	**-16,000**
Low Temperature and Coproduced Resources: In FY 2021, the Budget prioritizes funding for efforts under the Resource Maximization R&D Activity in the Low Temperature & Coproduced Resources subprogram with an emphasis on R&D related to the Energy Storage Grand Challenge and Critical Minerals Initiative (an increase of $1,000,000 from FY 2020). The request supports the Advanced Energy Storage Initiative, as part of the broader Energy Storage Grand Challenge, by providing $6,000,000 for validating technologies developed in FY 2020. Following on FY 2020 work, the program will fund a $4,000,000 competitive solicitation to support the development of innovative technologies that can effectively separate critical minerals from geothermal brines. The program will focus on a set of increasingly sophisticated modeling and bench-scale tests. This effort will provide meaningful impact on addressing the technical challenges associated with tapping the significant upstream domestic supply capacity and midstream separations and processing of critical minerals from geothermal power generation. A decrease of $5,000,00 relative to FY 2020 Enacted levels is attributed to ongoing activities funded in full through prior year obligations.	**-5,000**
Data, Modeling, and Analysis: Funding change in the Systems Analysis subprogram is largely attributed to the decrease in number of studies and analyses following the GeoVision report, as these analyses will be fully funded and mostly complete by FY 2021. In addition, the Budget requests the minimum amount necessary to maintain strategy development and techno-economic tools & data.	**-4,000**
Total, Geothermal Technologies	**-84,000**

Description

Enhanced Geothermal Systems (EGS) are engineered reservoirs, created where there is hot rock but little to no natural permeability or fluid saturation present in the subsurface. Underpinning the EGS subprogram's major technical thrusts are fundamental geoscience challenges whose resolution hinge on collaborative, early-stage R&D. The focus of the EGS subprogram is to gain an evidence-based understanding of these basic science challenges surrounding long-term subsurface heat flow, permeability enhancement, and stress evolution to enable development of sustainable, man-made heat exchangers. In the long term, strengthening the body of EGS knowledge through early-stage R&D will enable industry to develop a baseload energy resource as shown in the *GeoVision* report to be a huge contributor to the potential geothermal power capacity of 60 GWe by 2050.

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 such as the research that is underway in the EGS subprogram's flagship initiative, the Frontier Observatory for Research in Geothermal Energy (FORGE). In addition to FORGE, all other research in the EGS subprogram is categorized into the following activities: Resource Characterization R&D, Subsurface Accessibility R&D, Subsurface Enhancement & Sustainability R&D, and Resource Maximization R&D.

The research supported under these activities will address the goal of meeting $0.06/kWh by 2050 from newly developed enhanced geothermal systems.

Exploration and Characterization R&D

EGS site characterization technologies focus on assessing the subtle subsurface properties that are paramount to EGS success: temperature, state of stress, fracture morphology, permeability, and thermal-hydrologic-mechanical-chemical (THMC) parameters. Assessing these parameters at the outset can inform well placement and the design of stimulation programs, and tracking their evolution over time can improve the likelihood of successful long-term flow through EGS reservoirs. Characterization technologies seek to fully understand the conditions in the subsurface such that reservoir development and operation can be optimized to maximize heat extraction, thereby reducing risks and costs of EGS development and the final levelized cost of energy (LCOE) of produced energy. Ultimately, success in this space includes remote assessment capabilities for this suite of characterization technologies incorporated in real-time into fully coupled, 3D stress and reservoir models.

Subsurface Accessibility R&D

Technical challenges in accessing EGS resources include a need for more efficient and cost-effective drilling in high temperature environments and hard-rock formations. Opportunities exist for using real-time surface and down-hole data to better control well profiles, adapting and creating drilling technologies and techniques for cost-effective subsurface access, and designing effective completions that will facilitate multi-zone stimulations. EGS efforts in accessing the subsurface aim to reduce the cost of development, which reduces the final LCOE.

Subsurface Enhancement & Sustainability R&D

Engineering the subsurface is paramount to the commercial and technological success of enhanced geothermal systems. For EGS to be sustainable and commercial, fracture stimulation at depth must be reliable, reproducible, zone-specific, and tailorable (meaning that flow can be optimized by directing fluid through specific fractures depending on where heat is available). Advancements are necessary to understand the complex interactions and impacts of chemical, biological, and physical properties on permeability, pressure, and heat flow and provide predictive capabilities to tailor stimulation plans to site-specific conditions. Effective geothermal field management requires identifying and understanding the long-term evolution and real-time changes in these properties. Research in these areas will reduce the costs and risks of EGS; resulting in a lower ultimate LCOE for these energy sources; and is paramount to the commercial and technological success of enhanced geothermal systems.

Resource Maximization R&D

Geothermal resources can provide a range of benefits, including grid stability, reliability, and resiliency; thermal and reservoir energy storage; the ability to harvest critical minerals from its brines; and partnering with other energy resources for even greater return. Maximizing the value of the country's geothermal resources will include R&D in these and related areas.

Frontier Observatory for Research in Geothermal Energy (FORGE)

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.

Enhanced Geothermal Systems

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Enhanced Geothermal Systems $69,000,000	**$10,000,000**	**-$59,000,000**
Exploration and Characterization R&D $5,100,000	$0	-$5,100,000
• EGS Near-Field Monitoring & Characterization R&D: The goal of this effort is to design a seismic monitoring system/protocol that can be implemented by a commercial EGS operator with minimal outside assistance/guidance to meet both reservoir creation, sustainability, and induced seismicity mitigation requirements in an affordable and cost effective fashion.	• EGS Near-Field Monitoring & Characterization R&D: No funding is requested in FY 2021.	• EGS Near-Field Monitoring & Characterization R&D: This effort is fully funded with prior year funds. Funding is decreased in this effort in FY 2021 to prioritize R&D within the Subsurface Enhancement & Sustainability R&D Activity.
Subsurface Enhancement & Sustainability R&D $33,900,000	$10,000,000	-$23,900,000
	• Advanced Wellbore Completions for EGS Longevity: This new R&D focus will address developing alternative completion techniques, adoption of relevant unconventional oil and gas stimulation methods, and identifying links between completion techniques and reservoir development and operation.	• Advanced Wellbore Completions for EGS Longevity: The recent release of the DOE GeoVision study supports a focus on EGS technologies to hit the potential of 60GW of generating capacity by 2050. This work represents the continuation of a long-term, strategic emphasis on developing more cost effective methods for developing sustainable, economic EGS reservoirs
	• Diagnostics for Fluid Residence Time/Hydraulic Properties: This new R&D focus will address solutions for assessing fluid residence time, fracture connectivity, and reservoir volume critical to determining reservoir performance. New technologies and new real-time data collection and processing methods to be developed under this effort will facilitate the collection of these critical data, which will help operators understand and address changes that occur in the subsurface before, during, and after	• Diagnostics for Fluid Residence Time/Hydraulic Properties: The recent release of the DOE GeoVision study supports a focus on EGS technologies to hit the potential of 60GW of generating capacity by 2050. This work represents the continuation of a long-term, strategic emphasis on developing more cost effective methods for developing sustainable, economic EGS reservoirs.

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
	stimulation and will aid in designing more efficient, sustainable reservoirs.	
• Induced Seismicity Protocol: In FY 2019, a 2-year project was initiated to study recent seismic events in South Korea said to be associated with an active EGS project. FY 2020 includes a major study among relevant labs to perform real-time machine learning on seismic risk, through big data crunching on how risk changes over time as data is collected during the near-field RD&D and FORGE Pilot Wells.	• Induced Seismicity Protocol: No funding is requested in FY 2021.	• Induced Seismicity Protocol: This effort is fully funded and is scheduled to be completed in early FY 2021.
• Wells of Opportunity – FORGE Pilot Wells: Initiated in FY 2020, this effort facilitates high-risk tests in available unused geothermal wells across the U.S., prior to testing in the high-value main injection/production wells at the FORGE site. Progress in these areas of R&D will help reduce the LCOE of energy captured through EGS.	• Wells of Opportunity – FORGE Pilot Wells: No funding is requested in FY 2021.	• Wells of Opportunity – FORGE Pilot Wells: Effort will continue in FY 2021 with prior year funding.
• Wells of Opportunity – Amplify: EGS Near-Field RD&D: This FY 2020 investment includes demonstration projects at up to five sites on the margins of existing hydrothermal fields ("near-field EGS"). These demonstrations will use new stimulation techniques and other recently developed EGS technologies to create new permeable pathways and connect to the existing geothermal reservoir. Increasing the resource in a given area will lower the overall LCOE of the resource.	• Wells of Opportunity – Amplify_ EGS Near-Field RD&D: No funding is requested in FY 2021.	• Wells of Opportunity – Amplify: EGS Near-Field RD&D: Effort will continue in FY 2021 with prior year funding.
• GEOTHERMICA R&D: In FY 2020, participation in the GEOTHERMICA effort enables U.S. researchers to work in collaboration with European scientists as well as the well-funded European geothermal industry, leverage their knowledge, experience, and data. Funds National Laboratories to collaborate with academic institutions and industry in critical research areas such as	• GEOTHERMICA R&D: No funding is requested in FY 2021.	• GEOTHERMICA R&D: Effort will continue in FY 2021 with prior year funding.

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
enhanced geothermal systems, hydrothermal resources, and low-temperature resources. In the long term, strengthening the body of geothermal R&D knowledge through this collaborative supports industry to develop a baseload energy resource estimated at over 100 GW. • Land Grant University Graduate Education: In FY 2020, GTO will fund leading-edge interdisciplinary research that promoted workforce development in emerging fields by supporting a coordinated expansion of existing joint graduate education programs with national laboratories to prepare the next generation of scientists and engineers.	• Land Grant University Graduate Education: No funding is requested in FY 2021.	• Land Grant University Graduate Education: Effort fully funded in FY 2020.
Frontier Observatory for Research in Geothermal Energy (FORGE) $30,000,000	$0	-$30,000,000
• Phase 3 FORGE field operations continues throughout FY 2020 and into 2021. FY 2020 funding supports additional drilling and characterization of the FORGE site through advanced drilling techniques and additional state-of-the-art monitoring wells, additional competitive R&D awards in the early years of FORGE Phase 3. Funding also supports 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.	• No funding is requested in FY 2021. FY 2021 will mark year two of Phase 3 of FORGE. Field operations will continue into FY 2021, with year two marked by drilling of a second full-size wellbore, additional stimulations in the initial well, and the release of an additional competitive R&D solicitation.	• This effort is fully funded by prior year appropriations.

Description

Hydrothermal resources are currently the primary source of geothermal power and heat worldwide, and the *GeoVision* study indicates that technology innovation can help unlock additional hydrothermal resources to contribute to the potential 60 GWe of geothermal power capacity by 2050. Thus, the program sponsors R&D that can lower cost and risk throughout the lifecycle of a hydrothermal project to bring more hydrothermal power on line: from exploration and resource confirmation, to drilling and field development, to reservoir management over multi-decadal timescales. Because cost and risk are both concentrated in the early phases of a geothermal development, many of the biggest opportunities for advancement relate to the exploration phase of a project (both pre- and post- confirmation drilling). Improving capabilities for characterization of both known and "hidden" hydrothermal resources will encourage geothermal development by reducing project cost and risk through improved drilling success rates. New and innovative exploration technologies can improve a geothermal developer's ability to infer reservoir properties, map out major geologic structures, and understand the subsurface stress state prior to drilling. These technologies can reduce project risk by greatly reducing the number of unsuccessful wells that are drilled.

Following initial reconnaissance and exploration, resource confirmation (understanding the location, extent, and quality of a geothermal resource) and field development ultimately require extensive drilling. Advanced drilling technologies have the potential to improve project economics significantly by attaining improved rates of penetration, avoiding problems with surface and downhole equipment, and offering low-cost, high-performance materials for well construction.

Reducing the risk in the exploration and development stages of geothermal projects will lower the LCOE of the geothermal energy produced by reducing the number of expensive wells that are required; shortening the length of time spent developing the field, and enhancing access to capital for geothermal developers. Improved subsurface characterization and drilling technologies yield improved economics in the operational phase of a project by lowering operations and maintenance (O&M) costs and extending resource life. Other paths to improved O&M economics focus on sustaining the resource and maximizing its value; efforts include the application of machine learning and artificial intelligence (e.g., big-data techniques and autonomous systems) in field management, and the implementation of newer business models, e. g. mineral recovery, grid-scale energy storage, and dispatchable power generation. Research in the Hydrothermal Resources subprogram is categorized into the following activities: Exploration and Characterization R&D, Resource Characterization R&D, Subsurface Accessibility R&D, Subsurface Enhancement & Sustainability R&D, and Resource Maximization R&D.

<u>Exploration and Characterization R&D</u>

Hydrothermal resources are typically discovered through the application of conventional exploration technologies and methods, or because of the presence of some surface expression such as a geyser, hot spring, fumarole, or other indication that a hydrothermal resource may exist at depth. However, most of the remaining undiscovered hydrothermal resources in the U. S. are difficult to identify with existing exploration technologies and methods, largely because these resources lack the traditional surface manifestations that indicate resource potential. Advanced techniques that work reliably in oil and gas exploration do not yet perform similarly in a geothermal setting. Hydrothermal exploration and characterization R&D therefore focuses largely on capabilities for locating and mapping the extent of the requisite components of a resource: heat, fluids, and permeable pathways; as well as high-resolution subsurface imaging that is needed to develop an identified resource. These technologies can reduce LCOE primarily by lowering the capital cost of a geothermal project.

<u>Subsurface Accessibility R&D</u>

The ability to access the subsurface effectively is critical to hydrothermal development. Integrating improved drilling and well-completion technology, better well designs and construction materials, and improved decision-making can help industry realize better drilling efficiencies and effectiveness. Additionally, as the most commercialized geothermal resource setting, newly developed drilling techniques deployed in a hydrothermal setting can have spillover benefits to the development of less commercialized EGS and low-temperature systems. Hydrothermal efforts in accessing the subsurface aim to reduce the cost of field development, which is a large component of LCOE.

<u>Subsurface Enhancement and Sustainability R&D</u>

Long-term stability of hydrothermal systems relies on the maintenance of fluid flow pathways as related to sustaining temperature and flow rate of the resource. Furthermore, stability also depends on controlled interaction of geothermal brines with surface equipment and advanced operational strategies to divert flow to maximize production. Significant opportunities exist to optimize hydrothermal reservoir management through the application of machine learning and artificial intelligence, which can augment existing modeling tools and provide a basis for developing autonomous systems for field management.

The overall goal for operations in the hydrothermal sector is to reduce operating costs ($/kWh) and optimize and maximize heat extraction. The ability to sustain a hydrothermal resource over time will reduce the costs and risks of geothermal energy, resulting in a lower ultimate LCOE for these energy sources.

Resource Maximization R&D

Geothermal resources can provide a range of benefits, including grid stability, reliability, and resiliency; thermal and reservoir energy storage; the ability to harvest critical minerals from its brines; and partnering with other energy resources for even greater return. Maximizing the value of the country's geothermal resources will include R&D in these and related areas.

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Hydrothermal Resources $20,000,000	**$4,000,000**	**-$16,000,000**
Exploration and Characterization R&D $20,000,000	$0	-$20,000,000
• Hydrothermal Subsurface Imaging: The program initiated new research in subsurface imaging of geothermal environments. Improved imaging methods are needed to identify permeable targets and improve drilling success rates, especially in difficult to image environments, e.g., targets under volcanic cover. High-resolution imaging at deeper depths will improve the ability to pinpoint hidden geothermal systems and thereby reduce costs and risks.	• Hydrothermal Subsurface Imaging: No funding is requested in FY 2021.	• Projects funded with prior year funds will finish in FY 2021; results from these projects will be assessed before making additional investments. For FY 2021, the program is prioritizing drilling technology R&D for Hydrothermal Resources under the Subsurface Accessibility R&D Activity.
• Machine Learning for Geothermal: In FY 2020, the program is collaborating with the US Geological Survey on an Earth Mapping Resources Initiative (Earth MRI) to survey and obtain terabytes of geophysical data in regions of geothermal interest. This effort also includes curation and analysis of the data.	• Machine Learning for Geothermal: No funding is requested in FY 2021.	• Machine Learning for Geothermal: Projects funded with prior year funds will finish in FY 2021; results from these projects will be assessed before making additional investments. For FY 2021, the program is prioritizing drilling technology R&D for Hydrothermal Resources under the Subsurface Accessibility R&D Activity.
• Exploration RD&D: Hidden Geothermal Systems in the Basin and Range: In FY 2020, the program builds on the success of its Play Fairway Analysis initiative with a new effort aimed to progress to demonstration. This work began with R&D in the initial investigation of each site and progress toward demonstration, including drilling to confirm permeability, temperature, and the presence of a geothermal fluid.	• Exploration RD&D: Hidden Geothermal Systems in the Basin and Range: No funding is requested in FY 2021.	• Exploration RD&D: Hidden Geothermal Systems in the Basin and Range: Effort will continue in FY 2021 with prior year funding. For FY 2021, the program is prioritizing earlier stage drilling technology R&D for Hydrothermal Resources under the Subsurface Accessibility R&D Activity.
• GEOTHERMICA R&D: In FY 2020, participation in the GEOTHERMICA effort enables U.S. researchers to work in collaboration with European scientists as well as the well-funded European geothermal industry, leverage their knowledge, experience,	• GEOTHERMICA R&D: No funding is requested in FY 2021.	• GEOTHERMICA R&D: Effort will continue in FY 2021 with prior year funding. For FY 2021, the program is prioritizing drilling technology R&D for Hydrothermal Resources under the Subsurface Accessibility R&D Activity.

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
and data. Funds National Laboratories to collaborate with academic institutions, and industry in critical research areas such as enhanced geothermal systems, hydrothermal resources, and low-temperature resources. In the long term, strengthening the body of geothermal R&D knowledge through this collaborative supports industry to develop a baseload energy resource estimated at over 100 GW.		
• Land Grant University Graduate Education: In FY 2020, GTO funded leading-edge interdisciplinary research that promotes workforce development in emerging fields by supporting a coordinated expansion of existing joint graduate education programs with national laboratories to prepare the next generation of scientists and engineers.	• Land Grant University Graduate Education: No funding is requested in FY 2021.	• Land Grant University Graduate Education: Effort fully funded in FY 2020. For FY 2021, the program is prioritizing drilling technology R&D for Hydrothermal Resources under the Subsurface Accessibility R&D Activity.
Subsurface Accessibility R&D $0	$4,000,000	+$4,000,000
	• Drilling Technologies: The program will continue to emphasize R&D for advanced drilling technologies. Building on the work awarded under the 2018 Efficient Drilling for Geothermal Energy (EDGE) Funding Opportunity, the program will issue a funding opportunity to support the next phase of development for selected EDGE technologies	• Drilling Technologies: The recent release of the DOE GeoVision study supports a focus on lowering drilling costs as a means for increasing utilization of hydrothermal resources. For FY 2021, the program is prioritizing funding for a competitive downselect of promising projects resulting from the EDGE solicitation.

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. These low-temperature resources have a lower power conversion efficiency than other geothermal resources, so, while these resources are abundant throughout the country, it will require EGS tools and techniques to unlock their full potential. The 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. The subprogram supports R&D for harvesting critical materials from geothermal brines to maximize ancillary benefits of geothermal resources; this work in parallel with and contributes to the Critical Materials Initiative.

A U.S. Geological Survey (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] The recently published *GeoVision* study estimates that through the adoption of advanced technology scenarios, geothermal district-heating installations could increase to 17,500 nationwide and 28 million U. S. households could realize cost-effective heating and cooling solutions through geothermal heat pumps.

Whether used to produce distributed power or directly for heating and cooling, low-temperature resources 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., reservoir thermal energy storage, 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.

Exploration and Characterization R&D

Characterization of the subsurface for low-temperature power production and direct use applications, including temperature gradients at varying depths and in varying environments (urban/rural, residential/industrial, etc.), is critical for understanding where these low-temperature resources can most effectively be harnessed.

The overall goal of exploration and characterization in the Low-Temperature and Coproduced Resources subprogram is to understand the conditions in the subsurface such that both low-temperature power production and direct use systems are effective and affordable to contribute to the thermal capacity on line and facilitate nationwide deployment of low-temperature power production.

Subsurface Accessibility R&D

Drilling wells and boreholes, along with trenching, are critical to enable direct use and power-producing low-temperature geothermal systems. Challenges in accessing low-temperature resources are similar to those in EGS and hydrothermal because of the depths at which these resources may be located, especially in the Eastern half of the U.S., with additional challenges associated with thermal storage systems.

Low Temperature & Coproduced Resources efforts in accessing the subsurface aim to reduce the cost of development, which reduces the final Levelized Cost of Heat (LCOH) and LCOE for low-temperature resources. A lower LCOH and LCOE will result in increased thermal capacity on line and facilitating nationwide deployment of low-temperature power production.

Subsurface Enhancement and Sustainability R&D

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

Enabling cost-effective subsurface engineering technologies, specifically the ability to increase permeability at depth, can facilitate geothermal district heating and cooling through the U.S. Currently, inefficient injection strategies limit the ability to produce at high volumes for direct use or storage purposes. Likewise, subsurface engineering is critical to developing synthetic geothermal reservoirs for advanced energy storage. Increasing production of low-temperature resources at depth (Deep Direct Use) will reduce the LCOH for these district heating and cooling systems. A lower LCOH can result in increased thermal capacity on line.

Coupled thermal, hydraulic, mechanical and chemical (THMC) modelling and testing are needed to optimize and balance low-temperature injection and production temperatures against heating and cooling demands to prevent well fields and systems from being depleted. Another challenge to sustainability of low-temperature and storage systems is related to restricted flow rates because of mineral and solid particle deposition. Sustaining production from low-temperature resources for direct use and power production will reduce the LCOH and LCOE for these systems. A lower LCOH and LCOE will result in increased thermal capacity on line and facilitating nationwide deployment of low-temperature power production.

Resource Maximization R&D

Geothermal resources can provide a range of benefits, including grid stability, reliability, and resiliency; thermal and reservoir energy storage; and partnering with other energy resources for even greater return. In particular, the ability to harvest critical minerals such as lithium and manganese, as well as other valuable minerals such as zinc and silica, from geothermal brines can help maximize the value of the country's geothermal resources. R&D can help overcome challenges of proving extracting technologies and scaling them up to commercial level, especially addressing the issue of high concentrations of dissolved solids that can clog up extraction membranes; R&D can improve tools and techniques for characterizing provenance and sustainability of these types of mineral resources.

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Low Temperature and Coproduced Resources $15,000,000	**$10,000,000**	**-$5,000,000**
Resource Maximization R&D $15,000,000	$10,000,000	-$5,000,000
• Energy Storage Grand Challenge: Bi-directional Energy Storage Using Low-Temperature Geothermal Applications: In FY 2020, the program provides funding for Reservoir Thermal Energy Storage (RTES) R&D that includes deep direct use (DDU) engineering and 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. Deep Direct-Use (DDU) technologies are anticipated to serve as large distributed geothermal systems that directly heat and possibly cool geothermal districts (using little if any grid electricity) for heating and cooling, which supports AESI's focus to provide grid resiliency by delivering backup power or primary heating and cooling to critical infrastructure such as hospitals, military installations, and university campuses.	• Energy Storage Grand Challenge: Bi-directional energy storage (RTES) Testing & Validation: The program requests funding to continue R&D with lab teams to test and validate reservoir thermal energy storage systems at a grid-integrated or system back-up level. • Flexible Generation Testing: The program requests funding to support the next stage of development with research teams collaborating to develop geothermal generation technologies that can start and stop easily, increase or decrease generation on demand, and respond quickly to ensure the stability and reliability of the grid.	• Energy Storage Grand Challenge: Increase funding requested to support additional competitively selected projects.
• Critical Minerals – Salton Sea: Follows-on from the comprehensive study assessing the potential to capture the Salton Sea's brine resources (e.g., Li, Mn, Si, Zn), the program will collaborates with the Advanced Manufacturing and Vehicle Technologies programs to determine the best path forward for harnessing the Li resources in the Salton Sea. Additive value streams, such as mineral recovery, lower the LCOE and LCOH of low-temperature resources.	• Critical Minerals in Geothermal Brines: Li Recovery R&D: Contributing to the Critical Minerals Initiative, the program will initiate a multi-phase R&D effort in FY 2021 to attract innovative technologies that can effectively separate critical minerals from geothermal brines. The R&D effort will focus on a set of increasingly sophisticated modeling and bench-scale test.	• Critical Minerals in Geothermal Brines: Increased budget for Critical Minerals to address the technical challenges associated with tapping the significant upstream domestic supply capacity and midstream separations and processing of critical minerals from geothermal power generation.

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
• Assessments and Engineering Design for Geothermal Energy on University Campuses: Jointly funded by the Data, Modeling, and Analysis subprogram in FY 2020, the program explores the feasibility of integrating geothermal resources into the energy strategies of selected university campuses. The FY 2020 funding supports Phases II & I. ▪ Phase I: Feasibility studies for harnessing known geothermal resources (hydrothermal, low-temperature) for power production and direct-use at university campuses. ▪ Phase II: Engineering design	• Assessments and Engineering Design for Geothermal Energy on University Campuses: No funding requested in FY 2021.	• Assessments and Engineering Design for Geothermal Energy on University Campuses: Projects funded with prior year funds will finish in FY 2021; results from these projects will be assessed before making additional investments. For FY 2021, the program is prioritizing AESI and Critical Minerals R&D within the Low Temperature and Coproduced Resources portfolio.
• Geothermal District Heating Analysis: In FY 2020, the program will conduct a joint analysis with the Advanced Manufacturing program on geothermal district heating to investigate the most effective combination of technologies to lower the LCOH of low-temperature resources.	• Geothermal District Heating Analysis: No funding requested in FY 2021.	• Geothermal District Heating Analysis: Results from the analysis will be assessed before making additional investments. For FY 2021, the program is prioritizing AESI and Critical Minerals R&D within the Low Temperature and Coproduced Resources portfolio.
• Low Temperature & Coproduced Resources Lab Core R&D: The program supports National Laboratory capabilities in novel and high impact early stage R&D focused on maximizing the return from low-temperature resources through R&D on equipment components (pipes, coils) and predictive tools for commercial and residential applications.	• Low Temperature & Coproduced Resources Lab Core R&D: No funding requested in FY 2021.	• Low Temperature & Coproduced Resources Lab Core R&D: Projects funded with prior year funds will finish in FY 2021; results from these projects will be assessed before making additional investments. For FY 2021, the program is prioritizing AESI and Critical Minerals R&D within the Low Temperature and Coproduced Resources portfolio.
• GEOTHERMICA R&D: In FY 2020, participation in the GEOTHERMICA effort enables U.S. researchers to work in collaboration with European scientists as well as the well-funded European geothermal industry, leverage their knowledge, experience, and data. Funds National Laboratories to collaborate with academic institutions and industry in critical research areas such as enhanced geothermal systems, hydrothermal resources, and low-temperature resources. In the	• GEOTHERMICA R&D: No funding is requested in FY 2021.	• GEOTHERMICA R&D: Effort will continue in FY 2021 with prior year funding. For FY 2021, the program is prioritizing AESI and Critical Minerals R&D within the Low Temperature and Coproduced Resources portfolio.

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
long term, strengthening the body of geothermal R&D knowledge through this collaborative supports industry to develop a baseload energy resource estimated at over 100 GW.		
• Land Grant University Graduate Education: In FY 2020, GTO will fund leading-edge interdisciplinary research that promoted workforce development in emerging fields by supporting a coordinated expansion of existing joint graduate education programs with national laboratories to prepare the next generation of scientists and engineers.	• Land Grant University Graduate Education: No funding is requested in FY 2021.	• Land Grant University Graduate Education: Effort fully funded in FY 2020. For FY 2021, the program is prioritizing AESI and Critical Minerals R&D within the Low Temperature and Coproduced Resources portfolio.

Geothermal Technologies
Data, Modeling, and Analysis

Description

The goal of the Data, Modeling, and 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 Data, Modeling, and 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 Data, Modeling, and Analysis subprogram 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 Data, Modeling, and 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, the program released *GeoVision*: *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. Leveraging the results from the *GeoVision* analysis, in FY 2019, the program 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.

Data, Modeling, and Analysis

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Data, Modeling, and Analysis $6,000,000	**$2,000,000**	**-$4,000,000**
Data, Modeling, and Analysis $6,000,000	$2,000,000	-$4,000,000
• Strategy Development and Techno-Economic Tools & Data: Funding 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 continue to provide independent expert consultation to DOE on major GTO projects.	• Strategy Development and Techno-Economic Tools & Data: All three activities (GETEM, GDR, and TMT) will be funded at a lower level than in FY 2020.	• Strategy Development and Techno-Economic Tools & Data: Building on previous years' work, these activities can be accomplished with less funding than in previous years.
• Assessments and Engineering Design for Geothermal Energy on University Campuses: Jointly funded by the Low Temperature & Coproduced Resources subprogram in FY 2020, the program will explore the feasibility of integrating geothermal resources into the energy strategies of selected university campuses. The FY 2020 funding supports Phases II & I. ▪ Phase I: Feasibility studies for harnessing known geothermal resources (hydrothermal, low-temperature) for power production and direct-use at university campuses. ▪ Phase II: Engineering design	• Assessments and Engineering Design for Geothermal Energy on University Campuses: No funding requested in FY 2021.	• Assessments and Engineering Design for Geothermal Energy on University Campuses: Projects funded with prior year funds will finish in FY 2021; results from these projects will be assessed before making additional investments.
• *GeoVision* Non-Technical Barriers Study: The program collaborated with the Department of Interior's Bureau of Land Management and other agencies with land-management responsibilities to conduct a study evaluating opportunities for optimizing permitting and regulatory processes associated with geothermal deployment.	• *GeoVision* Non-Technical Barriers Study: No funding is requested in FY 2021.	• *GeoVision* Non-Technical Barriers Study: The project is fully funded with prior year appropriations.

Advanced Manufacturing

Overview

Manufacturing generates 11 percent of U.S. gross domestic product (GDP)[1] and employs more than 12 million Americans[2]. 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.[3] 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 crosscutting, 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, Advanced Manufacturing Office (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 new energy technologies invented in the U.S. ultimately result in the manufacture of products in the U.S.

The budget for the 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 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 R&D of manufacturing processes 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 R&D, can be further developed by industry to improve productivity through advanced manufacturing processes.

AMO technology areas address scientific knowledge gaps related 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 R&D, the new knowledge discovered in this work will be applicable to two or more sectors in energy technology and manufacturing. The research supported by AMO is targeted at processes and technological challenges that present a significant degree of scientific or technical uncertainty and require long timeframe solution sets. 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 manufacturing energy technologies 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 conversion or end-use efficiency applications;
- Additive Manufacturing Processing: Processes capable of direct net-shape formation of metals, polymers, and ceramic materials for energy efficient manufacturing and application in manufacturing of energy technologies;
- 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;

[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] National Income and Product Accounts Tables – Section 6: Income and Employment History, Table 6.4D: Full-Time and Part-Time Employees by Industry (A)." U.S. Bureau of Economic Analysis. Available online at: https://apps.bea.gov/iTable/iTable.cfm?reqid=19&step=2&isuri=1&1921=survey.

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

- Wide Bandgap Power Electronics: Wide bandgap semiconductors to reduce energy losses and improve reliability in electric power systems;
- Automation, Novel Sensors, and Process Controls: Technologies that leverage advanced sensors, controls, artificial intelligence, high performance computing, platforms, and models to facilitate real-time, cybersecure, operational energy efficiency improvements in materials and manufacturing process technologies;
- Chemical and Thermal Process Intensification: Chemical and thermal process intensification to reduce the size and energy intensity of manufacturing processes through higher reaction efficiency, novel mixing and separations, and low thermal budget heating and cooling;
- Grid and Resource Integration in Manufacturing: Grid and resource integration, including new technologies for high efficiency Combined Heat and Power (CHP), waste heat to power, distributed generation, and real-time manufacturing demand response; and
- Sustainable Manufacturing: Sustainable manufacturing, including sustainable product design and technologies for the efficient use, recycling and reuse of raw materials and water in manufacturing.

Highlights of the FY 2021 Budget Request

FY 2021 activities support Administration, Department and programmatic goals. Highlights include:

- R&D projects: Focus on R&D in materials and process knowledge relevant to manufacturing, including application of high performance computers for modelling and simulation relevant to energy use in manufacturing. Executed through competitive merit reviewed individual projects researching a technical solution to a specific manufacturing challenge. Funding is requested: for the Energy Storage Grand Challenge (ESGC) focused on improving manufacturing processes for energy storage systems and grid and resource integration in manufacturing; for the Harsh Environment Materials Initiative, a crosscutting activity with the Offices of Fossil Energy and Nuclear Energy to exploit synergies in materials and component manufacturing research for thermoelectric power plants; and to collaborate with other EERE programs to apply principles of materials reuse and recycling to batteries, wind turbines, solar panels and polymers.
- R&D consortia: Focus on coordinated R&D in high-priority areas essential to energy in manufacturing, including foundational knowledge in rare-earth materials, new materials, additive processes, innovative process controls, cybersecurity, 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. The FY 2021 Budget Request favors a transition away from the hub and institute funding models because the mortgaging of future appropriations reduces budgetary flexibility. Instead, the Budget Request proposes a set of smaller and more directly managed, early-stage, R&D consortia activities.
- Technology partnerships: Support partnerships between National Laboratories, universities, and the private sector related to energy management including field validation, tool development and student led research.
- Departmental Crosscuts:
  - Critical Minerals ($30,600,000) – Early-stage R&D to enable domestic supply of critical materials related to energy applications, substitutes for critical materials and reuse and recycling of critical materials;
  - Energy Storage ($7,000,000) – Manufacturing processes for energy storage systems and flexible manufacturing plants with increased electricity dispatchability;
  - Grid Integration ($2,000,000) – Flexible manufacturing plants with increased electricity dispatchability (Note this is part of the $7M for Energy Storage);
  - Energy-Water ($11,000,000) – Energy-Water early stage R&D Consortia;
  - Cybersecurity ($4,000,000) – Cybersecurity manufacturing early stage R&D Consortia;
  - Plastic Innovation Challenge ($13,500,000) – Accelerate innovations in energy-efficient plastics recycling and new polymer design; and
  - Harsh Environment Materials Initiative ($6,500,000) – In collaboration with the Offices of Fossil Energy and Nuclear Energy, will support R&D projects for materials and devices to enable operation in harsh environments.

- 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 2021, EERE will fund only early-stage R&D projects that utilize the MDF and CFTF facilities.

Advanced Manufacturing
Funding ($K)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted
Advanced Manufacturing				
R&D Projects (formerly Advanced Manufacturing R&D Projects)	113,100	151,135	48,500	-102,635
R&D Consortia (formerly Advanced Manufacturing R&D Consortia)	166,900	198,865	41,100	-157,765
Technical Partnerships (formerly Advanced Manufacturing Technical Partnerships)	40,000	45,000	5,000	-40,000
Total, Advanced Manufacturing	320,000	395,000	94,600	-300,400

SBIR/STTR:

- FY 2019 Transferred: SBIR $7,752,000; STTR $2,468,000
- FY 2020 Projected: SBIR: $11,072,000; STTR: $1,557,000
- FY 2021 Request: SBIR: $3,008,400; STTR: $423,000

Advanced Manufacturing
Explanation of Major Changes ($K)

	FY 2021 Request vs FY 2020 Enacted
R&D Projects (formerly Advanced Manufacturing R&D Projects): In FY 2021, AMO will limit new R&D Projects activity, reflecting higher priority activities to address gaps in knowledge or advance innovative approaches. Remaining efforts will prioritize early-stage advanced manufacturing technology R&D focused on novel materials and process technologies relevant to manufacturing specifically developing materials and components that can operate in harsh and extreme environments, domestic supply of critical materials and manufacturing processes for energy storage systems. AMO will fund a new round of High-Performance Computing for Manufacturing (HPC4MFG) projects that align industry proposals with challenges in computer science, and to collaborate with other EERE programs to apply principles of materials reuse and recycling to batteries, wind turbines, solar panels and plastics. Research on thermal process intensification, efficient drying technologies, and roll-to-roll manufacturing processes will be deemphasized until results from project awards made in FY 2019 and FY 2020 can be assessed to inform future R&D direction.	**-102,635**
R&D Consortia (formerly Advanced Manufacturing R&D Consortia): In FY 2021 AMO will focus on R&D in consortia led by National Laboratories and universities to more efficiently address the underlying scientific challenges in key advanced manufacturing technical areas. Emphasis will be placed on manufacturing challenges related to rare-earth materials and water security. In addition, funding will support solicitations for new consortia for innovative cyber secure 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 R&D projects.	**-157,765**
Technical Partnerships (formerly Advanced Manufacturing Technical Partnerships): 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. Requested funding will support partnerships between National Laboratories, universities, and the private sector related to energy management including field validation, tool development and student led research.	**-40,000**
Total, Advanced Manufacturing	**-300,400**

Advanced Manufacturing
R&D Projects
(formerly Advanced Manufacturing R&D Projects)

Description

Through renewed focus on competitively selected, 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 to the manufacturing of energy technologies. The Advanced Manufacturing R&D Projects subprogram will support 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 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 goal is to develop advanced materials and manufacturing process technologies relevant to energy-intensive and energy dependent manufacturing processes with at least 20 percent energy impact potential measured in a laboratory or relevant environment. 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.

Advanced Materials R&D

Advanced materials are broadly applicable to energy products, including energy conversion materials, materials for extreme or harsh conditions, and nanomaterials needing innovative approaches to processing. Within R&D Projects, the Advanced Materials R&D activity will advance materials and associated materials processing technologies in specific areas included in the AMO Multi-Year Program Plan.

Manufacturing Processes R&D

Advanced manufacturing processes include a wide variety of potential applications and products; and include continuous processes such as refining, batch processes, and discrete processes such as parts and assembled products. Within R&D Projects, the Manufacturing Processes R&D activity will advance early-stage manufacturing process technologies in specific foundational and platform manufacturing topic areas included in the AMO Multi-Year Program Plan.

Advanced Energy Storage

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. Within R&D Projects, the Advanced Energy Storage activity will improve manufacturing processes for energy storage materials resulting in lower manufactured cost and develop technologies to enable flexible manufacturing plants with increased control of electricity demand for enhanced grid stability and resiliency.

Research and Development Projects
(formerly Advanced Manufacturing R&D Projects)

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Research and Development Projects $151,135,000	**$48,500,000**	**-$102,635,000**
Advanced Materials R&D $ 24,205,000	$22,000,000	-$2,205,000
• Support the Harsh Environment Materials Initiative, in collaboration with the Offices of Fossil Energy and Nuclear Energy through competitively selected, merit-based, early-stage applied R&D projects at National Laboratories, universities, and companies. Specifically, projects will focus on increasing durability and capability, and reducing the cost of materials and components operating in harsh and extreme environments such as those found in high efficiency power plants and industrial operations.	• Support the Harsh Environment Materials Initiative, in collaboration with the Offices of Fossil Energy and Nuclear Energy through competitively selected, merit-based, early-stage applied R&D projects at National Laboratories, universities, and companies. Specifically, projects will focus on increasing durability and capability, and reducing the cost of materials and components operating in harsh and extreme environments such as those found in high efficiency power plants and industrial operations.	• Funding will support the highest quality competitively selected merit-based projects at National Laboratories, universities, and companies focused on harsh environment materials. No funds are requested to develop advanced steel materials.
• No Funding for critical materials R&D Projects.	• Support up to 10 early-stage R&D projects focused on the foundational knowledge related to critical and rare-earth materials separations and processing	• Funding will support the highest quality competitively selected merit-based projects at National Laboratories, universities, and companies focused on critical materials.
Manufacturing Process R&D $110,883,000	$19,500,000	-$91,383,000
• Support up to 30 new competitively selected, merit-based, early-stage applied R&D projects at National Laboratories, universities, and companies focused on advanced manufacturing processes including enhanced drying, wastewater, and chemical processes.	• No funding requested.	• Funding is prioritized for the HPC4MFG program and Departmental crosscuts.
• Support the HPC4MFG program including the funding of up to 15 competitively selected projects that apply modeling, simulation, and data analysis to industrial processes and products to lower production costs and shorten the time to market.	• Support the HPC4MFG program including the funding of up to 9 competitively selected projects that apply modeling, simulation, and data analysis to industrial processes and products to lower production costs and shorten the time to market.	• Funding will be limited to nine of the highest quality competitively selected merit-based HPC4MFG projects.
• Support projects led by early-career post-doctoral researchers to address fundamental manufacturing	• Support projects led by early-career post-doctoral researchers to address fundamental manufacturing	• No significant change. This activity will fund four new projects led by new early-career post-doctoral researchers through competitive solicitations.

challenges identified by industry through competitive solicitations. • No funds for R&D Projects as part of the Plastics Innovation Challenge. In FY 2020, the Plastics Innovation Challenge was funded as part of R&D Consortia.	challenges identified by industry through competitive solicitations. • Support efforts to apply principles of materials reuse and recycling with emphasis on plastics as part of Plastics Innovation Challenge activities.	• No significant change.
Advanced Energy Storage $16,047,000	$7,000,000	-$9,047,000
• Support R&D projects on improving manufacturing processes for energy storage systems including: flexible combined heat and power systems; flexible manufacturing plants with increased electricity dispatchability; and battery manufacturing processes toward lower cost, higher density batteries that do not rely on critical materials.	• Support of the Energy Storage Grand Challenge for R&D projects focused on improving manufacturing processes for energy storage systems resulting in lower manufactured cost and flexible manufacturing plants with increased electricity dispatchability for enhanced grid stability and resiliency.	• The Budget prioritizes Advanced Energy Storage R&D on improving manufacturing processes for advanced energy storage systems and manufacturing plant grid integration. Funding is reduced or eliminated for R&D on established technologies such as CHP operations and lithium ion-based battery manufacturing.

Advanced Manufacturing
Research and Development Consortia
(formerly Advanced Manufacturing R&D Consortia

Description

The R&D Consortia subprogram supports collaborative early-stage R&D 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 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.

Subprogram Goal: Advance America's manufacturing sector and workforce through innovative, energy efficient technologies and practices.

National Laboratory-Led Facilities

Public-private consortia focused on cost-shared early-stage applied R&D at the National Laboratories, particularly in areas of additive manufacturing and carbon fiber materials research relevant to energy technologies and energy-efficiency.

Clean Energy Manufacturing Institutes

Clean Energy Manufacturing Institutes were established to 1) engage industry, academia, non-profit institutions and National Laboratories in R&D to address crosscutting manufacturing challenges and accelerate private-sector adoption; 2) develop the next generation manufacturing workforce; and 3) create an innovation ecosystem that would be financially self-sustaining at the end of the Federal award. In prior years, five Clean Energy Manufacturing Institutes were selected through completive merit review processes, with a sixth competition underway. The technology areas addressed by these Institutes are: wide-band gap semiconductor manufacturing (PowerAmerica); carbon-fiber composite manufacturing (IACMI); smart manufacturing (CESMII); chemical process intensification (RAPID); sustainable manufacturing (REMADE); and cybersecurity for energy-efficient manufacturing (competition underway). The FY 2021 Budget Request favors a transition away from the institute funding model because the mortgaging of future appropriations reduces budgetary flexibility. No funds are requested for 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. Instead, the Budget Request proposes a set of smaller and more directly managed, early-stage, R&D consortia activities.

The prior year appropriations for the Institutes are summarized in the table below.

Institute	Key technology focus	Appropriations								Future Funding Plans
		FY13	FY14	FY15	FY16	FY17	FY18	FY19	FY20	
PowerAmerica	Accelerate the development of advanced semiconductor components made with silicon carbide and gallium nitride into a wide range of products and systems.	$14M	$14M	$14M	$14M	$14M	---	---	---	None- FY17 was 5th year of appropriations
IACMI	Develop cutting-edge manufacturing technologies for low-cost, energy-efficient manufacturing of advanced polymer composites for energy applications.	---	$14M	$14M	$14M	$14M	$14M	---	---	None - FY18 was 5th year of appropriations
CESMII	Develop advanced sensors, controls, modeling, data analytics simulation, and platform development to improve the efficiency of U.S. manufacturing.	---	$14M	$14M	$14M	$14M	$14M	---	---	None - FY18 was 5th year of appropriations
RAPID	Decrease energy consumption, and capital costs in chemical manufacturing through modular chemical process intensification innovations	---	---	$14M	$14M	$14M	$14M	$14M	---	None - FY19 was 5th year of appropriations
REMADE	Reduce energy consumption of materials manufacturing through the development of technologies for reuse, recycling, and remanufacturing.	---	---	---	$14M	$14M	$14M	$14M	$14M	None – FY20 represents 5th year of appropriations
Cybersecurity	Develop technologies to address the evolving cybersecurity threats to greater energy efficiency in manufacturing industries.	---	---	---	---	$14M	$14M	$14M	$14M	None

Energy Innovation Hubs

In prior years, AMO established two Energy Innovation Hubs. The Critical Materials Hub focused on R&D towards addressing supply chain challenges for critical materials applied R&D to assess materials criticality, diversify supply, improve recycling and reuse, and develop substitutes. Critical materials includes rare earth elements, lithium, and others - that are vital to a number of technologies central to U.S. energy security, including energy storage and high-power magnets for electric vehicles, turbines, energy-efficient motors. In FY 2019, AMO established the Energy-Water Desalination Hub focused on early-stage R&D for energy-efficient and low-cost desalination technologies, including manufacturing challenges, for treating non-traditional water sources for beneficial end use applications. The FY 2021 Budget Request favors a transition away from the hub funding model because the mortgaging of future appropriations reduces budgetary flexibility. No funds are requested for Critical Materials Institute or the Energy-Water Desalination Hub. Balances from prior year appropriations will be used to conduct an orderly wind-down and termination of these R&D Consortia. Instead, the Budget Request proposes a set of smaller and more directly managed, early-stage, R&D consortia activities.

Early Stage Manufacturing R&D Consortia

Public-private consortia among government, industry, and academia that focus on specific energy technology challenges and that are applicable to multiple industries and markets, including, but not limited to: critical materials, energy-water desalination, wide band-gap power electronics, advanced composites, smart manufacturing, process intensification and sustainable manufacturing. 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 development.

The FY 2021 Budget elevates the existing critical minerals activities across DOE to an intradepartmental initiative. Specifically, the Budget dissolves the current Critical Materials Institute and replaces it with a broader National Laboratory-led consortium modeled after the Grid Modernization Laboratory Consortium. This new consortium is tasked with developing and implementing a multi-year program plan, including aggressive, yet achievable goals, encompassing all efforts across the Applied Energy Offices and the Office of Science to diversify supply of, develop substitutes for, and drive recycling, reuse, and more efficient use of critical minerals.

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Research & Development Consortia $198,865,000	**$41,100,000**	**-$157,765,000**
National Laboratory-Led Facilities $ 25,000,000	$11,000,000	-$14,000,000
• Continue MDF/CFTF, including $5,000,000 for systems with potential to deposit multiple materials.	• Continue high-priority public-private projects related to additive manufacturing and carbon fiber materials research through the MDF/CFTF.	• The decrease in funding reflects an emphasis on early stage R&D activities at the MDF/CFTF. No funds are requested for systems with potential to deposit multiple materials or additive manufacturing of nanocellulosic feedstock materials.
Clean Energy Manufacturing Institutes $28,000,000	$0	-$28,000,000
• Support two CEMI institutes.	• No funding requested.	• The FY 2021 Budget Request favors a transition away from the institute funding model because the mortgaging of future appropriations reduces budgetary flexibility. Balances from prior year appropriations will be used to conduct an orderly wind-down and termination of these R&D Consortia. Funding is prioritized for similar topical areas within the Early-Stage Manufacturing R&D Consortia activity.
Energy Innovation Hubs $50,000,000	$0	-$50,000,000
• Support the Energy-Water Desalination Hub and the Critical Materials Institute.	• No funding requested.	• The FY 2021 Budget Request favors a transition away from the hub funding model because the mortgaging of future appropriations reduces budgetary flexibility. Balances from prior year appropriations will be used to conduct an orderly wind-down and termination of these R&D Consortia. Funding is prioritized for similar topical areas within the Early-Stage Manufacturing R&D Consortia activity.
Early Stage Manufacturing R&D Consortia $95,865,000	$30,100,000	-$65,765,000
• Support up to 10 competitively selected, merit-based, early-stage applied R&D consortia to address scientific and technical challenges relevant to U.S. manufacturing including additive manufacturing of nanocellulosic feedstock materials, field validation to address the technical	• Support up to 5 competitively selected, merit-based, early-stage applied R&D consortia Priority areas for FY 2021 include: critical and rare-earth materials supply, substitutes, recycling, reuse, and more efficient use; energy-efficient low-cost desalination technologies, including manufacturing	• A competitive funding opportunity will fund the highest priority R&D by the most meritorious consortia. No funds are requested for additive manufacturing of nanocellulosic feedstock materials and efforts to apply principles of materials reuse and recycling with emphasis on

challenges associated with upstream domestic supply and midstream separations and processing of critical materials, and efforts to apply principles of materials reuse and recycling with emphasis on plastics as part of Plastics Innovation Challenge.	challenges, to treat non-traditional water sources for beneficial end use applications; and new approaches to address cybersecurity challenges that limit adoption of energy-efficient manufacturing technologies.	plastics as part of Plastics Innovation Challenge. In FY 2021, the Plastics Innovation Challenge will be funded as part of R&D Projects.

Advanced Manufacturing
Technical Partnerships
(formerly Advanced Manufacturing Technical Partnerships)

Description

The 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.

Subprogram Goal: Manufacturing Energy Intensity - Improve manufacturing energy intensity by 17.5 percent by 2022 relative to a 2015 baseline.

Technical Assistance

In the manufacturing sector, significant cost savings are available through cost-effective investment in energy efficiency, such as the adoption of energy management practices and advanced technologies. These energy and cost savings contribute to competitiveness and reduce the embodied energy in manufactured products. A host of market and non-market barriers often prevent industrial companies from investing in greater energy efficiency. Within Technical Partnerships, the Technical Assistance activity supports R&D partnerships between National Laboratories, universities, and the private sector that emphasize student-led projects to developnew tools and processes that address energy management and advanced manufacturing challenges identified by private sector partners.

Combined Heat and Power and District Energy

Combined Heat and Power (CHP) and district energy systems generate electricity and heat, capturing energy that would normally be lost in power generation, transmission, and distribution and uses it to provide heating, cooling and other thermal energy at or near the site. Despite potential benefits, there are significant economic, regulatory, and informational barriers that are difficult for end-users focused on their core business to overcome to deploy CHP and district energy systems. Within Technical Partnerships, the Combined Heat and Power and District Energy activity assisted in transforming the market for CHP, waste heat to power, and district energy technologies/concepts through regional CHP Technical Assistance Partnerships (CHP TAPs). Due to the focus on early-stage R&D, no funding is requested for the CHP TAPs, which largely focused on deployment barriers to existing technology.

STEM & Workforce Development

A prosperous manufacturing sector requires workers with a wide range of technical skills, including in-plant production, manufacturing energy management and analysis, R&D, and information technology. In the plant, specific skills are required to optimize industry-specific processes. Additional specific skills are required to operate facility-wide systems equipment and data-driven platforms that are more broadly used across manufacturing. Within Technical Partnerships, the STEM & Workforce Development activity included the Industrial Assessment Centers (IACs) -- 31 university-based centers distributed throughout the country provide no-cost energy assessments to small and medium sized manufacturers to improve energy productivity and competitiveness through the deployment of existing technologies.

Technical Partnerships
(formerly Advanced Manufacturing Technical Partnerships)

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Technical Partnerships $45,000,000	**$5,000,000**	**-$40,000,000**
Technical Assistance $ 13,200,000	$5,000,000	-$8,200,000
• Supports partnerships between National Laboratories, universities, and the private sector related to energy management including field validation, tool development and student led research projects.	• Fund competitively selected R&D partnerships between National Laboratories, universities, and the private sector that emphasize student-led research projects to develop new tools and processes that address energy management and advanced manufacturing challenges identified by private sector partners.	• The Budget prioritizes funding for student-led research projects. No funding is requested for work focused on deployment barriers to existing manufacturing technologies.
Combined Heat and Power and District Energy $19,500,000	$0	-$19,500,000
• Support partnership efforts to address deployment barriers for CHP and district energy technologies through the CHP TAPs, related CHP activities, and district energy demonstrations.	• No funding requested.	• The Budget prioritizes funding for student-led research projects under the Technical Assistance activity. Due to the focus on early-stage R&D, no funding is requested for the CHP TAPs, which largely focused on deployment barriers to existing technology.
STEM & Workforce Development $ 12,300,000	$0	-$12,300,000
• Expand the reach of technical assistance provided by the IACs and fund up to 31 IAC centers focused on student-led assessments and recommendations for the deployment of existing technologies that cost effectively improve the energy efficiency of small- and medium-sized manufacturers.	• No funding requested.	• The Budget prioritizes funding for student-led research projects under the Technical Assistance activity. Due to the focus on early-stage R&D, no funding is requested for the IACs, which largely focused on deployment barriers to existing technology. Instead, support for STEM is emphasized within the Technical Assistance activity.

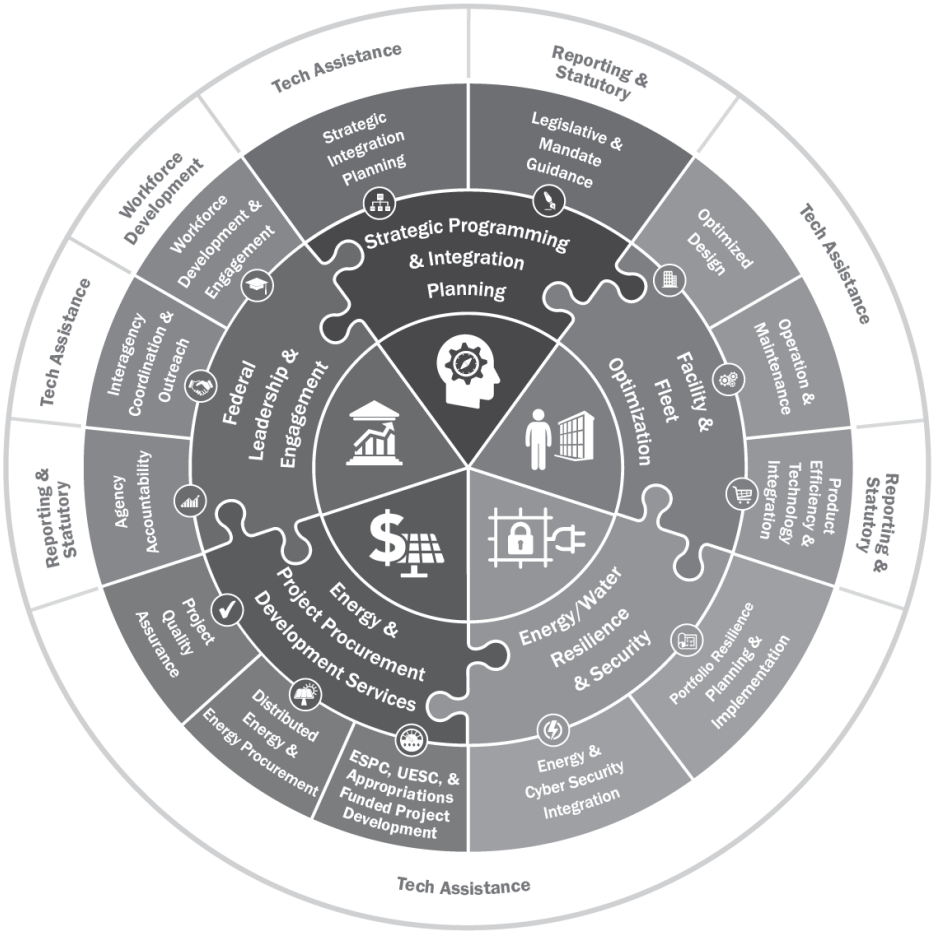
Federal Energy Management Program

Overview

The Federal Government is the single largest U.S. energy consumer with more than 350,000 buildings and 600,000 vehicles[1]. As such, the Federal Government carries significant opportunity and responsibility to lead in cutting energy costs and advancing America's progress toward energy independence, resilience, and security. The Federal Energy Management Program (FEMP) supports Federal agencies efforts to reduce their $16.6 billion annual energy bill, meet energy-related goals, and identify affordable solutions. FEMP achieves its mission by enabling Federal agencies in meeting Executive Order and statutory energy and water management-related goals through identifying Government best practices, providing technical assistance, tracking and reporting progress, and helping train both the Federal workforce and other stakeholders.

FEMP helps agencies leverage Federal investment in support of mission assurance goals for resilient, efficient, and secure facilities and operations. FEMP will collaborate, cooperate, and coordinate with other EERE programs to address Federal agencies' needs including resilience planning, system cybersecurity for facility related control systems, reliability, technology integration, and facility optimization.

FEMP's five focus areas are grouped into three activity categories: technical assistance, reporting and statutory requirements, and workforce development. FEMP supports the Administration's goal of energy dominance and the implementation of Executive Order (EO) 13834, Efficient Federal Operations, by providing resources and guidance to facilitate efficient, cost effective and secure energy usage and management in Government facilities.



[1] Whitehouse factsheet dated May 17, 2018 (https://www.whitehouse.gov/briefings-statements/president-donald-j-trump-prioritizes-efficiency-federal-government/).

FEMP strengthens agencies' ability and agility to manage their critical missions and provides strategic energy management assistance for agencies to become resilient, efficient, optimized, and secure in support of Administration priorities for American energy dominance, increased Government accountability, and development of a future-focused workforce. FEMP supplies agencies with tools and technical assistance to meet and track their energy-related requirements and goals through the following five focus areas:

- Strategic Programming and Integration Planning – Providing agencies with information and resources to help them develop strategic plans to successfully reduce Federal energy and water use. FEMP also assembles, analyzes, and shares information about Federal laws and requirements.
- Facility and Fleet Optimization – Focusing on cost and waste reduction to enhance performance and ensure mission fulfillment for facility and fleet operations, through: strategic energy and Federal fleet management assistance; sustainable Federal buildings guidance; metering, net-zero energy, water, and waste guidance/policy; and operations and maintenance plans.
- Energy and Water Resilience and Security – Providing a management framework to guide agencies through risk and consequence -informed resilience planning to address mission critical energy and water infrastructure and develop resilient, efficient, and secure solutions. Tools provide resilience and cybersecurity assessment as well as best practices.
- Energy and Project Procurement Development Services – Supporting Federal procurement projects with technical expertise, leveraging public-private partnerships through: life of contract support, quality assurance, oversight, contract management, procurement policy, and technical assistance.
- Federal Leadership and Engagement – Fostering interagency collaboration and accountability, and providing training and resources for workforce development. Recognizing efforts through the annual Federal Energy and Water Management Awards to foster replicable methods.

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 analysis, and best practices to improve overall Federal energy management. In FY 2018, the Federal Government used 1.3 quads of primary energy at a cost of $16.6 billion.[1] Energy used in buildings and facilities represents about 58 percent of the total energy use of the Federal Government, with vehicles and equipment energy use accounting for 42 percent.[2] Substantial opportunities exist for further energy cost reduction and conservation. Agencies estimated and reported $8 billion[3] of potential cost effective investment for energy savings exist in Federal buildings. In a 2017 study, Lawrence Berkley National Laboratory estimates up to $15 billion of potential ESCO investment for Federal buildings.[4] Approximately $150 billion would be required to bring Government owned property, plant, and equipment to an acceptable condition.[5]

Highlights of the FY 2021 Budget Request

The FEMP FY 2021 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]

- In FY 2021 FEMP will invest $1,100,000 to support the Cybersecurity Crosscut to focus on continuing to support FEMP energy system related cybersecurity program that incorporates the Federal agency expressed needs, and then provide appropriate guidance, tools, and/or training as outlined in the program plan.
- In 2021, FEMP will share existing solution sets including performance contracting models and business case methodologies that optimize facilities and increase energy efficiency. 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

[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] $8.2 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 13834. For full list of requirement refer to https://www4.eere.energy.gov/femp/requirements/.

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 and resources for strategic portfolio planning and facility optimization with Federal agencies. FEMP will 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 2021 will provide technical training, workforce core competency skills, and replicable solution sets while enhancing collaboration among agencies, and sharing of best practices.
- FEMP will continue to fulfill its statutory requirements to track progress and provide Federal accountability for energy facility performance through proactive engagement and enhanced workforce development services.

Federal Energy Management Program
Funding ($K)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted
Federal Energy Management Program				
Federal Energy Management	30,000	40,000	8,400	-31,600
Total, Federal Energy Management Program	**30,000**	**40,000**	**8,400**	**-31,600**

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

	FY 2021 Request vs FY 2020 Enacted
Federal Energy Management Program: Maintain minimum resources necessary for core activities in Technical Assistance, Reporting and Statutory Requirements, and Workforce Development. FEMP will concentrate these activities to focus on defined agencies whose scorecards reflect issues 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. The core of this will be on maintaining and updating currently existing sources. FEMP will not fund the Federal Energy Efficiency Fund (FEEF) Program in FY 2021 but will continue to manage prior year awards.	**-31,600**
Total, Federal Energy Management Program	**-31,600**

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. As part of the authorized responsibility of the program to respond to and support Federal agencies' requests for assistance, 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: 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, and facility evaluations; establish energy efficiency and sustainable design criteria for new Federal buildings; promote agency's effective utilization of performance contracting to increase facility efficiency, improve operations, and enhance resilience while also addressing needed capital improvements and maintenance backlogs; and maintain FleetDASH reporting for the Section 701 waiver process.

Within FEMP's five primary focus areas, the Federal Energy Management Program are grouped into three major activities:

Technical Assistance:

FEMP will work with agencies to provide necessary technical assistance to overcome barriers to design affordable, replicable energy and water projects that optimize facilities. FEMP will provide technical assistance that addresses specific facility, site, mission, and agency needs and utilize all available technologies and demonstrate best practices. FEMP will facilitate identification of barriers and capture lessons learned with a focus on continuous improvement. FEMP will assist Federal agencies in identifying, designing, and completing energy-saving projects and related infrastructure investments. FEMP provides necessary technical assistance to overcome barriers to design affordable, replicable, energy and water projects that optimize facilities and fleets. FEMP partners with Federal agencies to enhance energy and water mission assurance, resilience, and security, documenting lessons learned. Through increased collaboration with DOE's Office of Electricity and Reliability and the Department of Defense, FEMP enhances resilience of defense critical electric infrastructure.

Reporting and Statutory Requirements

DOE is statutorily required to carry out these 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.).

Workforce Development

Increase the agility and skills of the Federal workforce through training aligned with agency core competency needs and Federal Building Personnel Training Act requirements. Survey existing Federal workforce programs and collaborate with other EERE offices to explore opportunities for public-private partnership and technology field validation.

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2020 Enacted vs FY 2021 Request
Federal Energy Management $40,000,000	**$8,400,000**	**-$31,600,000**
Technical Assistance $24,149,000	$6,000,000	$-18,149,000
• Energy & Project Procurement Development: Update eProject builder to include additional high priority features required by Federal agencies, including tracking UESC projects. • Energy/Water Resilience & Security: Address the identified Federal agency cybersecurity information gaps. Develop and validate agency-universal systematic prioritized approach to energy and water portfolio planning. • Facility & Fleet optimization: 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. • Federal Leadership & Engagement: 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.	• Energy & Project Procurement Development: Maintain resources to help agencies leverage performance contracting to meet mission and energy management mandates and goals. • Energy/Water Resilience & Security: Continue to provide technical assistance, training and accountability. • Facility & Fleet optimization: Maintain FAST. • Federal Leadership & Engagement: Provide energy system related cyber security guidance, tools, and training to support Federal agencies improve cybersecurity and enhance resilience of critical smart energy technology,	• Energy & Project Procurement Development: Concentrate activities to focus on technical assistance leveraging performance contracting and power purchase agreements for limited agencies • Energy/Water Resilience & Security: Center on sustaining existing tools for evaluation, optimization and strategic management of energy resources instead of developing new tools to assist agencies with facility optimization and resilience implementation. • Facility & Fleet optimization: Minimum level of effort. Maintain core reporting only. • Federal Leadership & Engagement: Limit assistance to one selected agency with energy and water resilience and security.
Reporting and Statutory Requirements $3,197,000	$2,000,000	-$1,197,000
• Facility & Fleet optimization: Share best practices and verify actionable resources, in collaboration with agency partners, for a systems approach to facilitate prioritized mission driven energy management at the agency and	Facility & Fleet optimization: Continue to track the Government's progress in energy goal achievement.	• Facility & Fleet optimization: Minimum level of effort. Maintain core reporting only.

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2020 Enacted vs FY 2021 Request
installation level utilizing best practices and available optimization strategies. • Federal Leadership & Engagement: Provide statutorily required reporting and technical guidance. Complete reporting requirements for: Agency-level energy intensity, EISA 432 CTS Support, GHG Annual Reporting, FEMP Project Tracking (PTS), FAST Fleet Reporting, Renewable Energy Reporting.	• Federal Leadership & Engagement: Provide statutorily required reporting and technical guidance. Complete reporting requirements for: Agency-level energy intensity, EISA 432 CTS Support, GHG Annual Reporting, FEMP Project Tracking (PTS), FAST Fleet Reporting, Renewable Energy Reporting.	• Federal Leadership & Engagement: Maintain core reporting platforms and guidance.
Workforce Development $1,654,000	$400,000	-$1,254,000
• Federal Leadership & Engagement: Provide training content through the Energy Exchange. Develop 3-5 on-demand training courses. Satisfy training requirements mandated by and address requirements outlined in EPACT1992, EPACT 2005, Executive Order 13693, Energy Independence and Security Act of 2007 (EISA 2007), National Energy Conservation Policy Act (NECPA), Federal Building Personnel Training Act of 2010, FY 2012 Defense Authorization Bill Section 2826 and Section 2915a.	• Federal Leadership & Engagement: Provide training content through the Energy Exchange.	• Federal Leadership & Engagement: Concentrate on maintaining and updating current sources of workforce development rather than creating new on demand courses.
FEEF – AFFECT $11,000,000	$0	-$11,000,000
• AFFECT: Using the FEEF authority, process and protocols, competitively select agency programs that establish a process to systematically evaluate and prioritize mission-critical sites and implement projects that leverage performance contracting to enhance efficiency, resiliency, safety and security, as well as address the issue of aging infrastructure and deferred maintenance and repairs.	• AFFECT: No funds are requested for the FEEF Program in FY 2021	• AFFECT activities are limited to follow-up on projects funded in prior years.

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, as much as 80 percent or more of peak power demand, and 40 percent of its total energy consumption.[1,2] As a result, Americans spend some $400 billion annually to power their homes, offices, schools, hospitals, and other commercial and residential buildings.[3] 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 (BTUs per square foot, Energy Use Intensity) 30 percent by 2030. In 2018, the Energy Use Intensity (EUI) was nine percent lower than the EUI of the building sector in 2010.[4]

Reducing building energy use intensity helps conserve valuable natural resources and strengthens the U.S. economy by creating jobs, improving the productivity of businesses, and helping save money by making energy services (e.g., lighting, heating, and cooling) more affordable. 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, own, use, and/or 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. As an example, the construction, homebuilding, design, and engineering sectors are generally split among many small firms, 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 supports 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 demands 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 R&D on advanced and transactive controls will help strengthen the body of knowledge to support industry to develop and deploy grid-interactive efficient 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. As a result, BTO not only acts as a catalyst for innovation, but spurs U.S. economic competiveness through scientific and engineering leadership.

As part of the Advanced Energy Storage Initiative, BTO will contribute to the broader Energy Storage Grand Challenge ($14,000,000), which coordinates R&D across DOE to advance energy storage and other technologies that create more

[1] https://www.eia.gov/environment/emissions/carbon/.
[2] U.S. Energy Information Administration. *Annual Energy Outlook 2019 with projections to 2050*. Washington, DC: U.S. Department of Energy, January 2019. https://www.eia.gov/outlooks/aeo/pdf/aeo2019.pdf.
[3] Spending derived from the U.S. Energy Information Administration Monthly Energy Review. https://www.eia.gov/totalenergy/data/monthly/.
[4] Using micro datasets from AEO, BTO was able to calculate that the EUI of the building sector in 2018 was nine percent lower than the EUI of the building sector in 2010. Data accessed from EIA.

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 Energy Storage Grand Challenge 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 Energy Storage Grand Challenge is closely related to BTO's Grid-interactive Efficient Buildings (GEB) 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. While much work is focused on electrochemical batteries, similar capabilities can be achieved in other ways, potentially with additional benefits. For example, in the case of buildings, there is a unique and 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 and air conditioning [HVAC]) and/or the thermal mass of building envelope in combination with advanced controls. In coordination with other DOE offices, BTO's efforts as part of the Energy Storage Grand Challenge will focus on a range of early stage R&D into innovative, non-traditional energy storage approaches in two key areas: controllable building loads; and, thermal energy storage technologies 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 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 2021 Budget Request

FY 2021 activities support Administration, departmental, and programmatic goals. Highlights include:

- Energy Storage Grand Challenge ($14,000,000): 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.
- Grid Integration ($12,000,000) BTO's Buildings-to-Grid R&D will help strengthen the body of knowledge to support industry efforts to develop and deploy GEBs capable of connecting with the power grid in new and increasingly adaptive manners to help with overall energy system efficiency, resilience, and affordability.
- Cybersecurity Crosscut for Sensors and Controls R&D ($1,000,000): Early-stage R&D on sensors & control systems for advanced technologies for more sophisticated control of building energy loads and improvements in building operation and maintenance. To ensure assets are secure and resilient these technologies include advanced communication platforms and data management systems; advanced sensing, monitoring, and control capabilities; and data analytics.
- Buildings Integration Challenge ($6,000,000): Continue 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 2021 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 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted
Building Technologies				
Building Energy Research Development	109,000	140,000	30,000	-110,000
Commercial Buildings Integration	39,000	50,000	7,000	-43,000
Residential Buildings Integration	28,000	40,000	5,000	-35,000
Equipment and Buildings Standards	50,000	55,000	19,000	-36,000
Total, Building Technologies	**226,000**	**285,000**	**61,000**	**-224,000**

SBIR/STTR:

- FY 2019 Transferred: SBIR $5,757,000; STTR $617,000
- FY 2020 Projected: SBIR $6,567,000; STTR $923,000
- FY 2021 Request: SBIR $1,344,000; STTR $189,000

Building Technologies
Explanation of Major Changes ($K)

	FY 2021 Request vs FY 2020 Enacted
Building Energy Research Development: The FY 2021 Budget Request supports early stage R&D in solid-state lighting, heating, ventilation, air conditioning, and refrigeration technologies (HVAC&R), building envelope, and buildings-to-grid. This includes R&D coordinated through DOE's Energy Storage Grand Challenge to enhance grid resiliency and reliability. The Budget provides no funding for later-stage development, demonstration and deployment of solid-state lighting, HVAC&R, or transactive controls at the campus- and neighborhood-level. In addition, the Budget targets the annual Buildings Energy Efficiency Frontiers & Innovation Technologies (BENEFIT) FOA to support only the most promising projects. Previously competitively-selected work will continue to outlay prior year obligations carried forward to conduct close-out activities.	**-110,000**
Commercial Buildings Integration: The FY 2021 Budget Request supports R&D conducted through DOE's Energy Storage Grand Challenge by 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 $4,000,000 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 is 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.	**-43,000**
Residential Buildings Integration: The FY 2021 Budget Request supports R&D conducted through DOE's Energy Storage Grand Challenge by 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 efficiency technologies 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.	**-35,000**
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.	**-36,000**
Total, Building Technologies	**-224,000**

Description

The Building Energy Research 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 and systems levels in the following technology areas: Buildings-to-Grid R&D, Lighting, HVAC & Refrigeration, Building Envelope and Building Energy Modeling. In addition, BTO collaborates with industry, academia, and other leaders across the building sector to conduct research and validate the performance of connected, energy-efficient building components and sub-systems into efficient, resilient, and secure building systems. Through the BERD subprogram, BTO also advances building construction and retrofit technologies that help building owners and occupants reduce energy intensity while providing load flexibility to support the electricity grid. 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 at least 30 percent from 2010 levels (~150 kBTU/Sq. Ft) in the coming decade.

The innovations supported through BTO's 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 building materials and building equipment within the context of the building as a whole. This supports industries' ability to innovate and develop novel technologies that ultimately improve the efficiency of energy services to consumers.

BENEFIT, an annual competitive funding opportunity announcement (FOA) ($12,000,000), will cover all of BERD's research portfolio, including solid-state lighting. The FOA will address R&D challenges at the intersection of building-energy modeling and advanced building controls as they relate to technologies that enable 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 2021 BENEFIT FOA include:

- Advanced Energy Storage: Early stage R&D into innovative, non-traditional thermal energy storage approaches for resilience, efficiency, and affordability needs at the building and campus/district scales and research to incorporate time-of-use energy consumption into core building energy modeling tools.
- Controllable loads: Applied research into integrated storage solutions and their interaction with, and impact on, existing dynamic building systems.
- 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 and understanding system level impacts.

In addition to the annual FOA, BTO directly funds DOE National Laboratory R&D that leverages their unique facilities and expertise and fosters collaboration and accessibility. This is encouraged through private sector and university engagement using mechanisms such as Cooperative Research and Development Agreements (CRADAs) for early-stage R&D efforts.

BTO will continue to fund research in the following areas:

Buildings-to-Grid R&D

The B2G R&D includes controllable building loads (load flexibility) as well as thermal energy storage technologies. This early-stage R&D will enhance grid reliability by making building loads more dynamic and flexible while meeting the needs of building occupants and improving in building operation and maintenance. B2G R&D activities support DOE's Energy Storage Grand Challenge.

Controllable building loads research includes advanced communication platforms and data management systems; advanced sensing, monitoring, fault detection and control capabilities; cybersecurity; and data analytics to optimize productivity and occupant comfort while ensuring assets are secure and resilient. Research areas of interest include:

- Integrated building control schemes at the whole-building level with multi-objective 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; and
- Data models and analytics to intelligently shut down devices or place devices in sleep mode to improve efficiency and provide demand response services, without reducing productivity or services.

Building thermal energy storage research includes technologies that are either dedicated or inherent to the building equipment or envelope. Nearly 26 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 campus/district scale becomes a compelling solution. 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.

Lighting R&D

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. This area expands on controllable lighting loads, by emphasizing innovations that improve efficiency while simultaneously improving occupant comfort and well-being. 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 HVAC and Refrigeration R&D

R&D targets fundamental and applied research that supports performance advances and cost reductions in HVAC&R 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. 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 activities will be a continuation of BTO's ongoing R&D:

- 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; and
- High part-load efficiency building equipment needed to facilitate building-to-grid integration.

Building Envelope R&D

Activities include the characterization of new materials properties, specifically around state-of-the-art approaches to managing and controlling heat through innovative materials (advanced window applications) and novel device design (e.g. next-generation heat exchangers or thermal diodes):

- 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; and
- Materials discovery and characterization to improve and enhance thermal storage in buildings.

Building Energy Modeling R&D

R&D seeks to characterize the physical phenomena in building components and systems that contribute to energy use and to develop physics-based software models of those phenomena and their interactions. These software models can be used by practitioners (e.g., architects and mechanical engineers) to design and operate new and existing U.S. buildings that are secure, resilient, and energy efficient. Combined with models of prototypical homes and commercial buildings, these tools are also used by utilities, manufacturers, and DOE itself to understand the potential impacts of new technologies on large building portfolios such as utility service territories, entire commercial building sectors, and even the entire U.S.

BTO develops open-source software that focuses on state-of-the-art, low-level, physics-modeling capabilities. It avoids development of end-use applications and services, preferring instead to let the private sector embed its open-source capabilities into commercial tools. Because of its open-source licensing and advanced capabilities, BTO software is the tool of choice for research and advanced development in National Laboratories, universities, and corporate research centers.

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Building Energy Research Development $140,000,000	**$30,000,000**	**-$110,000,000**
Buildings-to-Grid R&D $42,020,000	$20,000,000	-$22,020,000
• Support two to three National Laboratory projects in solid-state physics research for advanced sensor development as well as three to five projects focused on autonomous control, pattern matching, and integrated multi-scale data analytics.	• Support one to two National Laboratory projects in solid-state physics research for advanced sensor development as well as one to two projects focused on autonomous control, pattern matching, and integrated multi-scale data analytics.	• Focus budgetary resources on the most promising National Laboratory projects.
• Support three to five National Laboratory projects in thermal energy storage materials research for advanced salt hydrate and advanced phase-change materials development.	• Support 2 to 3 National Laboratory projects in thermal energy storage materials research for advanced salt hydrate and advanced phase-change materials development.	• Focus budgetary resources on the most promising National Laboratory projects.
• Conduct three to five laboratory scoping studies of the building envelope contribution to a building's virtual storage capacity, transactive and smart transformers R&D and analytics needed to intelligently shut down devices or place devices in sleep mode.	• No funding requested.	• Scoping studies will be completed with FY 2020 funds. No additional scoping studies are planned.
• Competitively select projects focused on flexible building technologies, including adaptive building controls for cybersecurity, advanced actuators, thermal storage materials, and embedded energy storage technologies.	• Competitively select projects focused on challenges at the intersection of building-energy modeling and advanced building controls as they relate to transactions between buildings and the power grid.	• Issue a new competitive solicitation. Projects selected in FY 2020 will continue to outlay obligations carried forward.
Lighting R&D $25,000,000	$3,500,000	$21,500,000
• Competitively select projects in which success will be measured based on progress in achieving an LED phosphor-converted package efficacy goal of 250 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.	• Competitively select solid state lighting projects focused on more efficient light extraction and more effective light utilization, in addition to increased luminous efficacy. More specifically, investigating materials and device architectures that go beyond the current state-of-the-art to enable both high luminous emittance and high	• While improving the efficiency of LED light emission has been a major focus in the development of solid-state lighting technology, it is increasingly clear that delivery of light to occupants has more considerations than just luminous efficacy (as has long been used to characterize lighting). For many current and

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
	efficacy and targeting end point of high luminance LED prototype models of 128 lm/W efficacy.	emerging applications in buildings, it is crucial to generate and direct light, affordably, to where they are most effective in a space. FY 2020 awards will continue to outlay carryover obligation.
• Direct-funded two National Laboratory projects that focus on connected lighting systems, lighting technology systems, and emerging lighting science.	• Direct-fund up to two National Laboratory projects that focus on connected lighting systems.	• Focus the scope of National Laboratory projects on connected lighting systems.
HVAC & Refrigeration R&D $32,160,000	$4,000,000	-$28,160,000
• Support National Laboratory funding for research in HVAC, water heating, and appliances with an increased emphasis on heat transfer and materials science. This included one to two mid-size projects as well as four to five scoping studies to inform future research directions.	• Support National Laboratory funding for research in HVAC with an increased emphasis on heat transfer and materials science. This includes one small-size project as well as 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 FOA projects on HVAC and natural gas technologies.	• No funding requested.	• No funding requested. Projects previously funded will continue to outlay prior year obligations carried forward to conduct close-out activities.
Building Envelope R&D $24,620,000	$1,000,000	-$23,620,000
• Award FOA projects that focuses on advanced envelope retrofit technologies, particularly those that can be mass produced and applied to existing facades and robotics.	• No funding requested.	• No funding requested. Projects previously funded will continue to outlay prior year obligations carried forward to conduct close-out activities.
• Direct-funded lab AOP projects (five to ten) that focus on thermal and optical characterization of materials for advanced envelope technologies, including windows, and thermal measurement science for building envelope materials.	• One to two 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.	• Prioritize the most promising National Laboratory projects.
Building Energy Modeling Research $16,200,000	$1,500,000	-$14,700,000
• Fund National Laboratories and their subcontractors to continue development and maintenance of open-source physics-based	• Fund labs and their subcontractors to continue maintenance of open-source physics-based whole-building modeling engine and large-scale	• Maintain existing capabilities and user base. Limit new development to capabilities critical to BTO itself.

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
whole building modeling engine and large-scale analysis toolkit to support evaluation of new technologies, systems, and strategies by BTO itself, utilities, states, and other organizations. Emphasize new capabilities for evaluating grid-supporting technologies like thermal energy storage.	analysis toolkit. Emphasize capabilities needed to support BTO analysis.	

Building Technologies
Commercial Buildings Integration

Description

The U.S. commercial building sector (representing over 91 billion square feet of real estate) uses roughly 18 percent of the Nation's total energy consumption, and accounts for 36 percent of all U.S. electricity consumption and nearly 20 percent of the nation's CO2 emissions.[1] This costs consumers approximately $175 billion each year, and over the next four years, the sector is projected to grow by more than 4 billion square feet of net additional floor area.

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 the voluntary integration of high-performing commercial buildings that could cost-effectively use 50-70 percent less energy than a typical building in a given region, sector with similar systems, with an emphasis on solutions that do not sacrifice the comfort of building occupants or the performance of labor-saving devices, appliances, and equipment. In FY 2021 CBI will launch the Buildings Integration Challenge at DOE's Better Buildings Summit, including signed letters of interest by purchasing partners and a technical performance specification to define specific criteria required by manufacturers to meet the Challenge.

Systems Integration R&D

CBI conducts research, development, and field testing of novel systems integration approaches including those that provide additive efficiency benefits (compared to single equipment-based solutions) using packaged approaches (i.e. retrofit lighting, plug control, and dynamic windows at the same time) and/or the optimization of infrastructure that touches multiple systems (i.e., air delivery systems). For example, results from a comparative study of lighting-only retrofits versus lighting retrofits packaged with plug and window shading control show 50-80 percent additional system level energy savings from the packaged retrofits approach[2]. Systems integration research in FY 2021 includes laboratory and field testing to document the additive savings from ubiquitous occupancy sensing achieved through advanced, controllable lighting systems to inform and optimize zone-level ventilation, heating and cooling.

Technical Assistance

CBI provides technical assistance to commercial building industry stakeholders via existing voluntary stakeholder networks including the Better Buildings Initiative. Based on engagement with industry, CBI identifies technical and structural barriers to building efficiency and prioritize systems integration research accordingly. CBI supports a robust technology field validation portfolio which includes voluntary hosting of technology pilots with third party verification. Outcomes are shared through peer reviewed publication and existing stakeholder networks. Collaboration with FEMP, GSA and DOD enables DOE to leverage Federal building operations and regional expertise which translate well to commercial operations, develop Federal field validation host sites and understand areas where hand off can support Federal energy savings priorities CBI actively supports inter-agency validation review, technology identification, and project selection including through technical committees, laboratory support, and an annual voluntary validation opportunity (with GSA's Proving Ground program).

Modeling and Analysis

CBI develops and maintains user-accessible, packaged analyses and metrics to enable the affordable evaluation of commercial building energy and cost trade-offs. This work is founded on the physics-based computational simulations supported through BERDs BEM activities, bringing complicated simulation activities to the level of the owner and operator. In addition, CBI facilitates the tracking, collection, and use of consistent and interoperable building data infrastructure by developing data description and schema standards, templates for data collection, and databases for organizing large collections of building energy data records. In FY 2021 CBI will continue support for data standardization to enable micro-level data (time-series control outputs at the sub-building level) in order to evaluate and manage macro-level grid and

[1] https://www.eia.gov/outlooks/aeo/pdf/aeo2019.pdf.

[2] "Getting Beyond Widgets: Enabling Utility Incentive Programs for Commercial Building Systems," https://buildings.lbl.gov/cbs/getting-beyond-widgets-enabling-utility-incentive, Lawrence Berkeley National Laboratory. Accessed December 5, 2019.

building efficiency opportunities (shift and shed across multiple commercial buildings based off of offsetting load and usage patterns).

Commercial Buildings Integration

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Commercial Buildings Integration $50,000,000	**$7,000,000**	**-$43,000,000**
Systems Integration R&D $21,900,000	$7,000,000	-$14,900,000
• FOA awards focused on cost-effective retrofit packages that produce grid and resiliency benefits in support of the Buildings Integration Challenge.	• Decrease breadth of projects and focus on Buildings Integration Challenge.	• Focus budgetary resources on the most promising National Laboratory projects. Projects previously funded will continue to outlay prior year obligations carried forward to conduct close-out activities.
• Continue five to ten National Laboratory projects that test and document the additive energy savings attributable to integrated HVAC, lighting, with smart sending and whole building data.	• Support two to four National Laboratory projects that test and document the additive energy savings attributable to integrated HVAC, lighting, with smart sending and whole building data.	• Focus budgetary resources on the most promising National Laboratory projects. Projects previously funded will continue to outlay prior year obligations carried forward to conduct close-out activities.
Technical Assistance $19,500,000	$0	-$19,500,000
• Fund technical engagement through the Better Buildings Initiative (via National Laboratories and other technical experts).	• No funding requested for Better Buildings Initiative.	• No funding requested. The Budget focuses on early-stage R&D. Projects previously funded will continue to outlay prior year obligations carried forward to conduct close-out activities.
• Fund technology field validation portfolio which includes voluntary hosting of technology pilots with third party verification.	• No funding requested for other technical assistance work.	• No funding requested. The Budget focuses on early-stage R&D. Projects previously funded will continue to outlay prior year obligations carried forward to conduct close-out activities.
Modeling and Analysis $8,600,000	$0	-$8,600,000
• Fund National Laboratories to continue development and maintenance of tools for accessible and affordable systems-based evaluation of commercial building energy efficiency trade-offs.	• No funding requested for tool development.	• No funding requested. The Budget focuses on early-stage R&D. Projects previously funded will continue to outlay prior year obligations carried forward to conduct close-out activities.
• Fund National Laboratories to continue development of building energy data interoperability standards and templates for collecting data in these formats and schema.	• No funding requested for data interoperability standards and templates development.	• No funding requested. The Budget focuses on early-stage R&D. Projects previously funded will continue to outlay prior year obligations carried forward to conduct close-out activities.

Building Technologies
Residential Buildings Integration

Description

The U.S. residential building sector (representing approximately 125 million homes, comprised of single family houses, multi-family units, and manufactured housing)accounting for roughly 21 percent of the Nation's total energy consumption. The residential sector accounts for 38 percent of all U.S. electricity consumption, costing consumers over $241 billion in non-renewable energy expenditures, resulting in 19 percent of the nation's CO2 emissions. Furthermore, residential energy use in certain regions can account for 50 percent of peak electric power demand, making it an even more important target for improving energy efficiency. The sector is expected to add nearly 4 million new housing units over the next four years. [1]

BTO's Residential Buildings Integration (RBI) program has a goal to reduce the energy used per square foot for space heating, cooling and water heating in single-family homes by 40 percent by 2025 (relative to a 2010 baseline). In FY 2019 and FY 2020, RBI has focused its activities on the DOE's Advanced Building Construction Initiative (ABC) – an effort aimed at integrating energy efficiency solutions into highly productive U.S. construction practices for new buildings and retrofits. RBI's investments focus on developing efficiency-related building technologies that require minimal onsite construction time, are affordable and appealing to the market, and leverage related efforts to increase the productivity of the construction industry. In addition to funding research on technologies, software, and digitization, ABC coordinates key building sector stakeholders to tackle efficiency-related challenges, including workforce training, business models, demand growth, and service delivery.

In FY 2021, RBI will participate in two Challenges that will focus on technologies and innovations in line with the objectives of ABC. First, RBI will contribute to the Energy Storage Grand Challenge by investing in technologies that create more flexible load, thereby increasing the reliability, resilience, and affordability of the U.S. electric grid. In residential buildings, the greatest opportunities for advancing storage are in water heating and envelope (thermal storage). Second, RBI will launch a Buildings Integration Challenge focused on one or more specific ABC technologies and/or practices, such as an emphasis on applying robotics and non-invasive approaches to improving the envelopes of existing residential buildings.

Systems Integration R&D

RBI has historically supported R&D and field testing aimed at achieving significantly improved energy efficiency in new and existing residential buildings. As part of ABC, RBI funds development of innovative technologies and practices that can more readily be applied to existing residential buildings as well as integration of state-of-the-art efficiency technologies in new construction. RBI's investments, in contrast to those of BERD, focus on technologies and practices that address building integration research needs and issues, including validation of technologies in non-laboratory testing environments. In FY 2021, RBI's areas of focus will be advanced storage and less-invasive efficiency improvements to existing residential buildings.

Technical Assistance

RBI works with industry, state and local governments, utilities, residential contractors (including home performance/efficiency contractors), builders, building owners and operators, training entities among other key stakeholders to understand the barriers hindering widespread uptake of efficiency in single and multifamily homes, including manufactured homes; and, develop technologies and approaches to overcome these barriers. RBI's technical assistance includes support for workforce training, STEM, Solar Decathlon, and information tools that assist builders and others in advancing building efficiency.

Modeling and Analysis

RBI's Modeling and Analysis activities develop energy models and tools to assist builders, homebuyers, utilities, and other decision-makers in accurately predicting energy use, savings and costs; and, employing best building science practices (e.g. Building Science Advisor, Home Energy Score). This work includes modeling and analysis to support new technology development, to assess grid-responsive building components for increased buildings/grid integration, and to provide

[1] https://www.eia.gov/outlooks/aeo/pdf/aeo2019.pdf.

homeowners and homebuyers with reliable information concerning the efficiency of homes as well as how to improve them.

Residential Buildings Integration

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Residential Buildings Integration $40,000,000	**$5,000,000**	**-$35,000,000**
Systems Integration R&D $25,430,000	$5,000,000	-$20,430,000
• Investing in a Buildings Integration Challenge to encourage widespread integration of AFDD (automated fault detection and diagnostics) technologies in heating and cooling systems used in both multi-family and single family buildings. AFDD holds tremendous promise for improving the energy performance of systems by insuring that building owners are notified when systems are installed improperly or when systems fail (e.g., refrigerant leaks) similar to automated notifications used in cars.	• Undertake two Challenges, one aimed at improving energy storage in residential buildings, and the other aimed at state-of-the-art innovations (e.g., robotics) to implementing envelope retrofits with little to no disruption to homeowners and tenants.	• Reflects Energy Storage Grand Challenge in addition to the ongoing work on the Buildings Integration Challenge.
• Investing in ABC technologies and approaches, including state-of-the-art innovations that dramatically scale deep energy retrofits to our nation's 120 million residential buildings.	• No funding requested.	• No funding requested.
• Investing in development and testing of "connected communities" to better understand and advanced improved methods for ensuring higher energy efficiency performance as well as grid reliability.	• No funding requested.	• No funding requested.
Technical Assistance $6,800,000	$0	-$6,800,000
• 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. The Budget focuses on early-stage R&D. Projects previously funded will continue to outlay prior year obligations carried forward to conduct close-out activities.
• Provide technical assistance to utilities, state and local governments, training facilities, and others to promote best practices in new construction and retrofit of existing buildings.	• No funding requested for technical assistance.	• No funding requested. The Budget focuses on early-stage R&D. Projects previously funded will continue to outlay prior year obligations carried forward to conduct close-out activities.

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Modeling and Analysis $7,770,000	$0	-$7,770,000
• Invest in the development of UrbanOpt, EnergyPlus, and other modeling tools and engines that ensure accurate understanding of how individual buildings use energy as well as how communities can optimize energy use across buildings.	• No funding requested for modeling and analysis.	• No funding requested. The Budget focuses on early-stage R&D. Projects previously funded will continue to outlay prior year obligations carried forward to conduct close-out activities.

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.

Standards
The Appliance and Equipment Standards subprogram is required by statute to develop and establish appliance/equipment energy efficiency standards for the purpose of saving the Nation energy is the program is legally required to meet legislative deadlines for issuing new and amended energy efficiency standards. Congress has mandated that the Equipment and Buildings Standards subprogram propose amended standards for covered products every six years.

The subprogram must ensure that the efficiency standards that it issues are technically feasible and economically justified, thereby ensuring the consumers incur no loss of appliance/equipment utility and realize net economic benefits. To maintain the legislative schedule mandated by Congress, the subprogram works with established contracts and National Laboratories to conduct analyses to determine the technical feasibility of new standards. Work also focuses on economic analyses to assess the economic justification of new standards. Each standards rulemaking presents its own unique challenges, which require significant data collection and primary research in order to address stakeholder issues as well as intra-governmental reviews. The analyses conducted for the subprogram often provide valuable information to other programs within EERE that need to assess the cost and benefits of specific research and deployment programs.

Test Procedures
The Appliance and Equipment Standards subprogram is legally required to review test procedures for covered equipment every seven years and either publish amended test procedures or publish a determination that existing test procedures do not need to be amended. In addition, the subprogram is also required to develop new test procedures where they do not exist for newly covered appliances and equipment for which standards will be proposed.

Test procedures are developed to provide additional rigor and accuracy during testing, to address testing requirements necessary to support DOE's certification and enforcement activities, and to better address or clarify testing of additional product designs within a given equipment type, including the need to respond to products and equipment for which testing waivers have been provided in the past. Any test procedures prescribed or amended must be reasonably designed to produce test results which measure energy efficiency, energy use, or in the case of certain products, water use, and in some cases provide a methodology to estimate the annual operating cost of a covered product during a representative average use cycle or period of use. Challenges include identifying and addressing any issues with the current testing and certification process, developing testing solutions which provide for consistent, repeatable, and precise performance measurement, documenting the issues and proposed solutions in the formal rulemaking process necessary to meet DOE's legal and policy requirements, and understanding and responding to stakeholder input as developed during the rulemaking process.

Certification and Enforcement
To ensure the implementation of current standards for covered appliances and equipment, the Equipment and Buildings Standards subprogram has published Certification, Compliance, and Enforcement (CC&E) regulations for these products and

equipment in the Code of Federal Regulations (CFR). These regulations describe how manufacturers must establish certified ratings based on conducting DOE test procedures using a sample of units of a covered product. The regulations also describe how manufacturers must submit certification reports to DOE, and how manufacturers maintain records underlying the certification.

In addition the regulations describe processes for DOE-initiated testing of products to support enforcing compliance with the certification provisions and the energy and water conservation standards. Efforts for this area of the subprogram through three primary activities: Support for negotiated rulemaking efforts in the area of CC&E, DOE certification of compliance evaluations as required, and review of manufacturer certification test data as part of product/equipment enforcement cases.

Building Energy Codes

Work under this activity supports energy efficiency in buildings through the development and implementation of national model codes and standards. DOE is directed by statute to review the technical and economic basis of building energy codes, and participate in processes for their review and modification, including seeking adoption of all technologically feasible and economically justified energy efficiency measures (42 USC 6836). In addition, DOE is directed to issue a Determination of energy savings upon publication of an updated edition of Standard 90.1 and the IECC, which triggers state building energy code review and update activities (42 USC 6833).

In fulfilling its statutory mission, BECP employs an array of strategies across the following sub-activities:

- Model Code Support & Review: Meet all statutory requirements and fulfill DOE's technical assistance role related to the review and updated of model building energy codes and standards. Participate in industry review and consensus processes. Provide robust and transparent analyses addressing critical issues and stakeholder needs. Review published model codes to ensure they are energy efficient and cost effective for U.S. homes and businesses, including statutorily-required determinations for the IECC and Standard 90.1. [42 USC 6833 & 6836]
- Implementation Support: Provide technical assistance to states and localities implementing building energy codes. Review the technical and economic basis of the national model building energy codes. Conduct technical analysis to assess cost and savings impacts associated with updated codes. Provide analysis, tools, and resources to streamline local compliance processes and reduce enforcement burden. [42 USC 6833]

Equipment and Buildings Standards
Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Equipment and Buildings Standards $55,000,000	**$19,000,000**	**-$36,000,000**
Standards $20,800,000	$10,500,000	-$10,300,000
• Develop appliance and equipment standards. By establishing national minimum energy efficiency standards. The program's Federal standards preempt product efficiency regulations at the state and local level, reduces regulatory burden for manufacturers and provides them with a larger national marketplace. Verify field use of appliances and equipment so that standards and test procedures represent the energy use that is found in actual use.	• The subprogram plans to meet statutory obligations for energy and water conservation standards.	• DOE will maintain only necessary activities regarding the development of appliance and equipment standards.
Test Procedures $17,950,000	$6,000,000	-$11,950,000
• Develop and update test procedures to ensure they remain technologically relevant and provide manufacturers with a level playing field and a platform to bring to market new product innovations. For consumers, the program's periodic review of test procedures lays the foundation for reliable and comparable operating cost information for the most common household and business appliances. Purchase and test appliances and equipment to explore the energy use in network/grid-connected mode.	• The subprogram plans to meet statutory obligations for test procedures. It will continue to issue test procedure waivers as budget allows.	• DOE will maintain only necessary activities regarding the development and update of test procedures. ENERGYSTAR-related activities are proposed to be reimbursed by fee funds collected by EPA. .
Certification and Enforcement $6,250,000	$1,500,000	-$4,750,000
• Ensure products sold in the U.S. meet the energy and water conservation standards.	• 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.	• Certification database will be maintained at FY 2020 implementation.

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Building Energy Codes $10,000,000	$1,000,000	-$9,000,000
• Participate in industry processes to develop, review, and update model building energy codes, including, as required by statute, making a formal determination as to whether updated editions of the IECC and Standard 90.1 improve energy efficiency in residential and commercial buildings, respectively, compared to preceding versions.	• Focus on fulfilling the statutory requirement for DOE to participate in industry processes to develop new model building energy codes.	• Limit participation in industry processes to review and modify national model codes to the minimum required for compliance with statute.
• Provide technical assistance to support implementation of state residential and commercial building energy efficiency codes, including technical analysis to quantify impacts of updated codes, and to inform state and local adoption and compliance processes.	• Assist states and localities when they adopt and enforce energy codes.	• Limit technical assistance to state and local government regarding code adoption, compliance and enforcement.

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 2021 Budget Request

WIP's FY 2021 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 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 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted
Weatherization and Intergovernmental Programs				
Weatherization				
Weatherization Assistance	254,000	305,000	0	-305,000
Training and Technical Assistance	3,000	3,500	0	-3,500
Total, Weatherization	**257,000**	**308,500**	**0**	**-308,500**
State Energy Program	55,000	62,500	0	-62,500
Total, Weatherization and Intergovernmental Programs	**312,000**	**371,000**	**0**	**-371,000**

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

	FY 2021 Request vs FY 2020 Enacted
Weatherization Assistance Program: The FY 2021 Budget Request does not include funding for weatherization training and technical assistance and formula grants. 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. This will allow DOE to focus limited resources on early-stage applied energy research and development activities.	**-308,500**
State Energy Program: The FY 2021 Budget Request does not include funding for State Energy Program formula grants, technical assistance, and competitive awards. 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. This will allow DOE to focus limited resources on early-stage applied energy research and development activities.	**-62,500**
Total, Weatherization and Intergovernmental Programs	**-371,000**

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 2021, 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 prior year funding.

Weatherization's Training and Technical Assistance (T&TA) activities supported the development and implementation of voluntary and comprehensive national certifications and standards in retrofit worker training, energy audits, and weatherization methods. In FY 2021, 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.

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Weatherization $308,500,000	**$0**	**-$308,500,000**
Weatherization Assistance $305,000,000	$0	-$305,000,000
• 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 $3,500,000	$0	-$3,500,000
• 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. • Enhancement and expansion of the multifamily capacity of the WAP network through coordination with training programs, local WAP agencies, and multifamily stakeholders. • Congressionally-directed activity: implement and demonstrate programs to treat harmful substances, including vermiculite, at the State and regional level. • Congressionally-directed activity: Conduct analysis and develop a report that analyzes the feasibility of community-scale weatherization efforts. • Congressionally-directed activity: Investigate the possibility of including health benefits from eliminated lead exposure in the calculation of the savings-to-investment ratio and how it will impact the Program. • Congressionally-directed activity: Continue DOE coordination with partner Federal agencies to ensure client eligibility is streamlined with Health and Human Services Low Income Home Energy Assistance Program, the HUD Lead Hazard Control	• No funding is requested.	• Existing balances will be used to conduct close-out activities.

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
and Healthy Homes Program, and the Department of Veterans Affairs. • 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

The State Energy Program allocates funds on a statutory basis, provides technical assistance, and makes awards to states, the District of Columbia, and the five U.S. Territories, to establish and implement energy plans and programs that enhance energy security, increase energy affordability, and support the adoption of energy efficiency and renewable energy technologies. Examples of the types of state-led programs supported with SEP funding that were developed and administered by state energy offices 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; energy savings measure for wastewater facilities; and activities that support overall energy emergency and assurance planning.

In FY 2021, 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 $70,000,000 to $90,000,000 in combined formula funds from prior years and continue to manage competitive awards made in previous years.

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
State Energy Program $62,500,000	**$0**	**-$62,500,000**
• Award and actively manage 56 formula grants supporting $56,000,000 in state energy projects. • Actively manage 20+ competitive awards focused on state planning, stakeholder engagement, analysis and innovative strategies/practices to advance the deployment of energy efficiency and renewable energy technologies and that provide replicable models for state and local government entities. • Provide technical assistance for innovative state/regional projects in a variety of areas, including comprehensive energy planning, public-private efforts to expand the use and development of financing models that include helping to coordinate the use of performance contracting nationally, and to assist state/local partnerships to lead by example on energy efficiency and renewable energy technologies, benchmarking and disclosure, etc. • Congressionally-directed activity: continue the Sustainable Wastewater Infrastructure of the Future (SWIFt) Accelerator. • DOE will provide additional technical assistance to states to enhance both their formula and competitive funded efforts in key areas such as energy security and workforce development in addition to scaling up partnerships with state and local governments through initiatives, providing technical resources developed by DOE laboratories and other experts, and delivering replicable models and solutions	• No funding is requested.	• Existing balances will be used to conduct close-out activities

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
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.		

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 2021 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 33 percent from its FY 2020 planned level of 675[1] 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 2021. 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 2021 Budget Request

The FY 2021 EERE Program Direction Budget Request will:

- Support 454 FTEs at HQ and the GFO;
- 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.

Salaries and Benefits: The request reflects a 1% pay raise for federal staff, FERS increase, and awards pool funding increase in FY 2021

[1] The 461 FTEs reported in the FY 2021 President's Budget Appendix for FY 2020 erroneously represents the level estimated for the FY 2020 Budget as opposed to FY 2020 enacted. In FY 2020, EERE aims to achieve the planned level of 675 FTEs.

Program Direction
Funding ($K)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted
Program Direction				
Washington Headquarters				
Salaries and Benefits	73,831	86,380	63,933	-22,447
Travel	3,038	3,700	2,150	-1,550
Support Services	17,902	13,100	7,400	-5,700
Other Related Expenses	35,799	26,376	30,680	+4,304
Total, Washington Headquarters	**130,570**	**129,556**	**104,163**	**-25,393**
Golden Field Office				
Salaries and Benefits	18,610	21,800	16,230	-5,570
Travel	209	216	150	-66
Support Services	1,160	1,100	700	-400
Other Related Expenses	606	1,400	1,320	-80
Total, Golden Field Office	**20,585**	**24,516**	**18,400**	**-6,116**
National Energy Technology Laboratory				
Salaries and Benefits	4,945	6,818	0	-6,818
Travel	175	240	0	-240
Support Services	300	300	0	-300
Other Related Expenses	5,925	3,570	0	-3,570
Total, National Energy Technology Laboratory	**11,345**	**10,928**	**0**	**-10,928**
Total Program Direction				
Salaries and Benefits	97,386	114,998	80,163	-34,835
Travel	3,422	4,156	2,300	-1,856
Support Services	19,362	14,500	8,100	-6,400
Other Related Expenses	42,330	31,346	32,000	+654
Total, Program Direction	**162,500**	**165,000**	**122,563**	**-42,437**

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted
Federal FTEs	**579**	**631**[1]	**454**	**-175**
Additional Office of Fossil Energy's FTEs at NETL[2]	34	44	0	-44
Total EERE-funded FTEs	**613**	**675**	**454**	**-219**
Support Services				
Technical Support	15,717	9,630	6,364	-3,266
Management Support	3,645	4,870	1,736	-3,134
Total, Support Services	**19,362**	**14,500**	**8,100**	**-6,400**
Other Related Expenses				
Other Services	21,787	18,746	6,800	-11,946
Working Capital Fund (WCF)	20,543	12,600	25,200	12,600
Total, Other Related Expenses	**42,330**	**31,346**	**32,000**	**+654**

[1] The 461 FTEs reported in the FY 2021 President's Budget Appendix for FY 2020 erroneously represents the level estimated for the FY 2020 Budget as opposed to FY 2020 enacted. In FY 2020, EERE aims to achieve the planned level of 675 FTEs.

[2] EERE funded 40-44 FTEs at NETL through a reimbursable agreement who supported EERE activities. These FTEs were not included in the EERE FTE totals shown in the table.

Program Direction

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Program Direction $165,000,000	**S122,563,000**	**-$42,437,000**
Salaries and Benefits $114,998,000	$80,163,000	-$34,835,000
• 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 454 FTEs, a decrease of 220 Federal FTEs (33 percent) from the planned FTE level for FY 2020[1]. The projections take into consideration grade/step levels for the current workforce and the programmatic needs at this reduced workforce level.
Travel $4,156,000	$2,300,000	-$1,856,000
• EERE's FY 2020 travel budget supports management of projects and close-outs, providing essential oversight of EERE-funded projects.	• EERE's FY 2021 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 $14,500,000	$8,100,000	-$6,400,000
• 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. • Includes one time investments in IT investments such as automation of workforce management processes.	• 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 44 percent reduction is a reduction of non-IT support contractors in HQ and Golden and the increase in FY 2020 for one-time investments in process automation.
Other Related Expenses $31,346,000	$32,000,000	+$654,000
• Other Related Expenses provides funds for overhead at DOE Headquarters and the Golden Field Office through EERE's contribution to the Working Capital Fund (WCF) and through direct payments in the field. Expenses covered include	• 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,	• Other Related Expenses decreased in the areas of supplies/equipment, computer equipment, and EERE's IT modernization project (i.e., EPIC) to support the out year needs for the multi-year

[1] The 461 FTEs reported in the FY 2021 President's Budget Appendix for FY 2020 erroneously represents the level estimated for the FY 2020 Budget as opposed to FY 2020 enacted. In FY 2020, EERE aims to achieve the planned level of 675 FTEs.

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
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).	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).	development effort and reduced requirements in support of a smaller workforce.
• EERE allocated WCF charges for common administrative services to each of the research and development programs, as well as the Program Direction account.	• EERE allocated the entire Working Capital Fund charges to the Program Direction Account, due to the decrease in programmatic funding.	• Absorbing the entire Working Capital Fund in the Program Direction account offset the decrease in other ORE expenses.

Strategic Programs

Overview

Strategic Programs funds high-impact, crosscutting, integrative activities most efficiently executed by a single crosscutting 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– 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 2021 Budget Request EERE's approach to integrated technology management will require corporate analysis to develop a framework for investments. Strategic Priorities and Impact Analysis (SPIA) will fund centralized analysis in several crosscutting EERE priority areas including grid integration, energy storage, critical materials and the Plastics Innovation Challenge.

In FY 2021, Strategic Programs will transition the following activities as indicated:

- 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 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted
Strategic Programs				
Technology-to-Market	2,500	3,000	0	-3,000
Strategic Priorities and Impact Analysis	7,000	7,000	5,000	-2,000
Communications and Outreach	4,500	4,500	0	-4,500
Total, Strategic Programs	**14,000**	**14,500**	**5,000**	**-9,500**

Strategic Programs
Explanation of Major Changes ($K)

	FY 2021 Request vs FY 2020 Enacted
Strategic Programs	
Technology-to-Market: No funds are requested for the T2M subprogram in FY 2021.	**-3,000**
Strategic Priorities and Impact Analysis: In FY 2021, SPIA will focus on corporate level analysis in support of crosscutting EERE priority areas including grid integration, energy storage, critical materials and the Plastics Innovation Challenge.	**-2,000**
Communications and Outreach: No funds are requested for the Communications and Outreach subprogram in FY 2021. Internal communications activities will be funded, as appropriate, by relevant EERE technology programs.	**-4,500**
Total, Strategic Programs	**-9,500**

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 2021. Some management activities related to the execution of prior year appropriations will continue until completion.

Technology-to-Market

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Technology-to-Market $3,000,000	**$0**	**-$3,000,000**
• Activities focused on the ongoing work of the Energy Transition Initiative (ETI).	• 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 supports EERE's cutting-edge, transformational research and development and to ensure 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 is accomplished by performing crosscutting, gap-filling, and corporate analyses associated with EERE technologies; developing tools and methods that enable consistent evaluation and analysis across EERE; and providing analytical thought leadership across DOE, other government agencies, and external stakeholders.

In FY 2021, SPIA will conduct corporate analysis in support of several priority crosscut efforts including grid integration, energy storage, critical materials and the Plastics Innovation Challenge. Planned analysis will evaluate potential mechanisms, such as enhanced storage capabilities, to support the integration of EERE technologies onto the grid. Analysis will also evaluate the ability of EERE technologies to provide a range of system services to the evolving grid. SPIA will coordinate with EERE program offices to build additional tools and methodologies to evaluate supply chain and end of life use options for EERE technologies. This work will complement EERE's Plastics Innovation Challenge and ongoing work on critical materials.

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Strategic Priorities and Impact Analysis $7,000,000	**$5,000,000**	**-$2,000,000**
• Complete retrospective evaluation studies that quantify the impact of EERE investments and guide future EERE program implementation. • Develop a strategy to evaluate and pursue opportunities to remanufacture, refurbish, repair, reuse and recycle EERE technologies in coordination with existing efforts such as the Plastics Innovation Challenge. • Support the Energy Storage Grand Challenge by enhancing modeling tools and conducting scenario analysis to evaluate how new storage technologies may enable integration of EERE technologies onto the grid. • Provide consistent and transparent cost and performance assumptions for renewable energy and sustainable transportation technologies.	• Provide analytical support for the Energy Storage Grand Challenge and identify opportunities to integrate EERE technologies with storage and enhance grid integration. • Provide ongoing analytical support to the Plastics Innovation Challenge. • Conduct corporate level analysis to evaluate supply risks associated with critical materials.	• Funding will focus primarily on crosscutting analysis efforts to ensure a harmonized framework for EERE investments. No retrospective evaluation studies are planned for FY 2021.

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 2021. 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 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 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.	• No funding is requested.	• Internal and External 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 2021 Budget Request ensures NREL's existing research and support infrastructure are maintained and upgraded in key 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 2021 Budget Request

To posture NREL's capabilities to support emerging technologies and future requirements, the FY 2021 F&I budget request focuses on sustaining NREL's world-class R&D environment by maintaining and upgrading its capabilities, equipment, and facilities. Demand for NREL facilities from government and industry partners is increasing. This request supports the last year of a four-year refresh/upgrade of the High Performance Computer (HPC) at the ESIF. High-performance computing enables unprecedented large-scale numerical models for studying and simulating material properties, processes, and fully integrated energy systems that would otherwise be too expensive, too dangerous, or even impossible to study by direct experimentation. With state-of-the-art computational modeling and predictive simulation capabilities, high-performance computing reduces the risks and uncertainty that are often barriers to industry adopting new and innovative technologies, thereby accelerating the transformation or our Nation's energy system.

EERE's FY 2021 Budget Request prioritizes reducing the backlog of deferred maintenance at NREL. Reducing deferred maintenance places NREL F&I on a fiscally responsible, and sustainable, path to continue to support DOE and industry research unburdened by an accumulation of overhead costs. This includes renovation and refurbishment of high-priority laboratories at the NREL South Table Mountain (STM) campus, including the Integrated Biorefinery Research Facility, the Field Test Laboratory Building, the Science and Technology Facility, and the Solar Energy Research Facility.

Additional investments in equipment to support Electrons-to-Molecules, H2@Scale, and the Plastics Innovation Challenge are included, as are additional investments in cybersecurity required to strengthen and heighten protection of networks and information through ongoing monitoring, detection, and response.

Facilities and Infrastructure (NREL)
Funding ($K)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted
Facilities and Infrastructure (NREL)				
Operations and Maintenance	31,500	87,500	74,500	-13,000
Facility Management	37,500	42,500	32,500	-10,000
NREL Site-Wide Facility Support	28,000	0	0	0
Total, Facilities and Infrastructure (NREL)	**97,000**	**130,000**	**107,000**	**-23,000**

Explanation of Major Changes ($K)

	FY 2021 Request vs FY 2020 Enacted
Facilities and Infrastructure (NREL)	
Operations and Maintenance: The FY 2020 Enacted provided for infrastructure investments to build-out the NREL Flatirons Campus into a grid integration test center and increase flexible laboratory space at the South Table Mountain campus with the design and construction of a new research and innovation laboratory facility. The FY 2021 Request prioritizes reducing the backlog of deferred maintenance at the STM campus.	-13,000
Facility Management: The reduction in funding for facility management is a result of no FY 2021 ESIF infrastructure investments and moves the prorated share of site operating costs and utilities to indirect funding.	-10,000
Total, Facilities and Infrastructure (NREL)	**-23,000**

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), Site-Wide (SW) as well as overhead-funded investments in institutional GPP (IGPP).

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 small (<$20 million) projects to accommodate new research capabilities.

Major GPP activity:

- Renovate and refurbish high-priority laboratories at the NREL STM campus including renovations to laboratories and installing enhanced mechanical capacity at the Integrated Biorefinery Research Facility; laboratory and chilled water upgrades at the Field Test Laboratory Building; and widespread ventilation upgrades at the Science and Technology Facility and the Solar Energy Research Facility.

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:

- Replace 18-year old Dual-beam Cryogenic Focused Ion Beam (FIB) to maximize low temperature research critical to perovskites, battery and “soft matter’ research, membranes, structural materials, bioenergy and critical interfaces in support of the Electrons-to-Molecules and the Plastics Innovation Challenge.
- Acquire Electron-to-Molecules Analytical Suite of inline and continuous (at one second intervals) analytical tools that examine products from electrochemical reactions to more accurately link catalyst reactant conditions for chemical reactions in support of the Electrons-to-Molecules and H2@Scale initiatives.
- Purchase Ultrafast Broadband Transient Absorption Microscopy to detect and visualize the movement of charges, energy, and spin states in nanoscale systems such as novel photovoltaic absorbers, fuel-forming photocatalysts, light-emitting diodes, and quantum storage systems to support manufacturing of high efficiency photovoltaics such as perovskites and efforts in quantum information science, neuromorphic computing, and advanced concepts for low energy devices.

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 2021 Request ensures 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.

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, shipping/receiving, facility and space planning, facility condition assessment inspections, and database management of DOE’s Facilities Information Management System.

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
$87,500,000	**$74,500,000**	**-$13,000,000**
• GPP and GPE investments expand the Flatirons campus and adds a new research innovation laboratory on the STM Campus.	• GPP and GPE investments expand capabilities and refurbish laboratories at the STM Campus.	• Prioritizes continued STM Campus laboratory and equipment investments.
• Maintains operational readiness for M&R activities and keeps funding within the DOE control standard of two to four percent of RPV.	• M&R funding enables continuation of the DOE control standard of two to four percent of RPV.	• M&R ensures suitable condition, as facilities and equipment age, for research activities at NREL.
• Maintains operational readiness for S&S activities.	• Maintains operational readiness for S&S activities, with increased investments in cybersecurity.	• Maintains operational readiness for S&S activities, with increased investments in cybersecurity.
• Realigns NREL Site-Wide Facility Support within Operations and Maintenance.	• Continues NREL Site-Wide Facility Support FY 2020 realignment within Operations and Maintenance.	• No significant change.

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. The FY 2021 request reflects implementation of a new research-readiness efficiency-charge for users of the ESIF and moves the prorated share of site operating costs and utilities to indirect funding.

ESIF is a unique national asset that provides 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 energy systems design and 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 2021 request provides the last year of a four-year refresh/upgrade.

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

ESIF investments fund a user program (e.g., user outreach, engagement, and education; development of calls for proposals; conduct of technical peer reviews of proposals; scheduling of R&D projects, and reporting on ESIF status and progress); maintain the safety envelope of the ESIF; and provide technical support to research activities. Funding also implements Integrated Safety Management, Environmental Management, and Hazard Management requirements within the ESIF; maintains, repairs, and modifies connection for SCADA, laboratory 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.

ESIF investments also fund HPC refresh/upgrade and expansion; HPC operations, HPC cybersecurity, HPC user operations, data center operations, and HPC project management/scheduling.

Facility Management

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
$42,500,000	**$32,500,000**	**-$10,000,000**
• Provides for the third year of a four-year refresh/upgrade of the HPC.	• Provides for the last year of a four-year refresh/upgrade of the HPC and continued investments in HPC equipment and operations.	• Completes HPC refresh/upgrade.
	• Implements new research-readiness efficiency-charge for users of the ESIF.	• Implements new research-readiness efficiency-charge for users of the ESIF.
• Provides for energy system security and resilience to ensure that activities at ESIF meet all cybersecurity requirements and needs of users.	• Provides for energy system security and resilience to ensure that activities at ESIF meet all cybersecurity requirements and needs of users.	• Completes current investments in energy security and resilience visualization.
• Provides for utilities, building operations, and routine maintenance.	• Moves prorated share of site operating costs and utilities to indirect funding.	• Moves prorated share of site operating costs and utilities to indirect funding.
• Provides for systems engineers, area supervisors, health and safety personnel, and management for ESIF research activities.	• Provides for systems engineers, area supervisors, health and safety personnel, and management for ESIF research activities.	• No significant change.
• Provides for experimental connections and enhanced data collection.	• Provides for experimental connections and enhanced data collection.	• No significant change.
• Provides additional investments in energy security and resilience visualization.		• Energy security and resilience visualization project completes in FY 2020.

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

	Total	Prior Years	FY 2019 Enacted	FY 2019 Actuals	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted
Capital Operating Expenses Summary (including Major Items of Equipment (MIE))							
Capital Equipment > $500K (including MIE)	n/a	n/a	7,468	3,900	10,080	8,360	-1,720
Minor Construction	0	0	9,300	9,300	40,010	30,050	-9,960
Total, Capital Operating Expenses	**n/a**	**n/a**	**16,768**	**13,200**	**50,090**	**38,410**	**-11,680**
Capital Equipment > $500K (including MIE)							
Total Non-MIE Capital Equipment	n/a	n/a	2,468	904	0	0	0
HPC Eagle E-Cell	5,000	0	5,000	0	0	0	0
Automated Fabric Cutting and Manufacturing Validation Equipment	630	0	0	630	0	0	0
Environmental Atomic Force Microscope	700	0	0	700	0	0	0
Advanced Ultrafast System for Optical Biophysics and Kinetics	710	0	0	710	0	0	0
SMB Advanced Chromatographic Separations Laboratory	956	0	0	956	0	0	0
Beyond Megawatt-Scale Fast Charging Station	7,700	0	0	0	7,700	0	-7,700
X-Ray Photoelectron Spectroscopy (XPS)	2,380	0	0	0	2,380	0	-2,380
Dual Beam Cryogenic Focused Ion Beam (FIB)	3,190	0	0	0	0	3,185	+3,185
Electron to Molecules Analytical Suite	2,080	0	0	0	0	2,075	+2,075
Ultrafast Broadband Transient Absorption Microscopy	1,200	0	0	0	0	1,200	+1,200
Polymer Synthesis and Characterization Equipment	1,000	0	0	0	0	1,000	+1,000
Direct Detector for Transmission Electron Microscopy (TEM)	900	0	0	0	0	900	+900
Total, Capital Equipment (including MIE)	**n/a**	**n/a**	**7,468**	**3,900**	**10,080**	**8,360**	**-1,720**

	Total	Prior Years	FY 2019 Enacted	FY 2019 Actuals	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted
Total Direct Funded Minor Construction Projects (TEC <$5M)	n/a	n/a	9,300	9,300	8,800	18,850	+10,050
Enhanced Grid/Energy Systems Control Center (DF)	10,500	0	0	0	10,500	0	-10,500
Research and Innovation Laboratory (DF)	19,510	0	0	0	19,510	0	-19,510
Flatirons Campus Water Line Project (IF)	12,400	0	0	0	1,200	11,200	+10,000
Total, Minor Construction Projects	**n/a**	**n/a**	**9,300**	**9,300**	**40,010**	**30,050**	**-9,960**
Total, Capital Summary	**n/a**	**n/a**	**16,768**	**13,200**	**50,090**	**38,410**	**-11,680**

Minor Construction Projects ($K)

Facilities & Infrastructure Operations & Maintenance	
Flatirons Campus Water Line Project NREL Flatirons Campus	
Type:	Minor Construction (Indirect-funded)
Total Estimated Cost:	$12,400
Construction Design:	$ 1,200
Project Start:	FY 2020
Design Complete:	FY 2020
Construction Complete:	FY 2022
Project Description:	This project provides an onsite water system enabling a safe, reliable, and secure connection to a municipal water supply and upgrades existing sanitary sewer facilities. Currently, water supply on the campus is truck-delivered multiple times each week and stored onsite for drinking purposes and fire suppression. The infrastructure investments include a water pipeline to supply municipal water to the campus; storage tanks for fire suppression and domestic water demands; a wastewater collection and treatment system to manage effluent from the sanitary sewer system; and associated appurtenances including, electrical, controls, pumps, fire hydrants, and valves. The water system project ensures long-term beneficial impacts to public safety and asset protection by mitigating fire risk and ensuring compliance with National Fire Protection Association (NFPA) requirements as the Flatirons campus continues to expand.
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) • Procure water rights and/or easements for 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 (Project management; independent testing/inspection, commissioning, and other third-party services; technical oversight during design and construction
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 2019 Actual Cost	FY 2019 Planned Cost	FY 2020 Planned Cost	FY 2021 Planned Cost
National Renewable Energy Laboratory	14, 581	11,272	11,283	16,605
Total, Direct-Funded Maintenance and Repair	**14,581**	**11,272**	**11,283**	**16,605**

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

	FY 2019 Actual Cost	FY 2019 Planned Cost	FY 2020 Planned Cost	FY 2021 Planned Cost
National Renewable Energy Laboratory	0	0	0	0
Total, Indirect-Funded Maintenance and Repair	**0**	0	**0**	**0**

Report on FY 2019 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 2019 to the amount planned for FY 2019, including Congressionally-directed changes.

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

	FY 2019 Actual Cost	FY 2019 Planned Cost
National Renewable Energy Laboratory	14, 581	11,272
Total, Maintenance and Repair	**14, 581**	**11,272**

The Planned Cost is an estimate developed at the beginning of the year and is a minimum target amount. The driver of the actual to planned cost variance is additional focus on priority maintenance and repair projects in FY19.

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

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted
Protective Forces	3,100	3,100	3,100	0
Physical Security Systems	750	750	750	0
Information Security	500	500	500	0
Cybersecurity	9,380	5,200	7,200	+2,000
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	**14,900**	**10,720**	**12,720**	**+2,000**

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

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted
Basic	0	0	0	0
Applied	1,408,415	1,204,964	471,514	-733,450
Development	444,154	801,918	166,440	-635,478
Subtotal, R&D	1,852,569	2,006,882	637,954	-1,368,928
Equipment	8,089	10,781	4,807	-5,974
Construction	10,073	36,267	29,881	-6,386
Total, R&D	**1,870,731**	**2,053,930**	**672,642**	**-1,381,288**

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

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted
Vehicles Technologies				
SBIR	9,788	10,450	2,269	(8,181)
STTR	1,608	1,470	319	(1,151)
Bioenergy Technologies				
SBIR	7,232	8,178	1,424	(6,754)
STTR	1,017	1,150	200	(950)
Hydrogen and Fuel Cell Technologies				
SBIR	3,735	3,984	1,333	(2,651)
STTR	645	560	187	(373)
Solar Energy				
SBIR	8,308	8,768	2,125	(6,643)
STTR	308	1,233	299	(934)
Wind Energy				
SBIR	2,793	2,546	701	(1,845)
STTR	200	358	99	(259)
Water Power				
SBIR	3,483	4,447	1,440	(3,007)
STTR	92	625	203	(422)
Geothermal Technologies				
SBIR	2,688	3,520	832	(2,688)
STTR	378	495	117	(378)
Advanced Manufacturing				
SBIR	7,752	11,072	3,008	(8,064)
STTR	2,468	1,557	423	(1,134)
Building Technologies				
SBIR	5,757	6,567	1,344	(5,223)
STTR	617	923	189	(734)
Total, SBIR	51,536	59,532	14,476	(45,056)
Total, STTR	7,333	8,371	2,036	(6,335)

DEPARTMENT OF ENERGY
Funding by Site Detail
Energy Efficiency and Renewable Energy
(Dollars in Thousands)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request
Ames Laboratory			
Advanced Manufacturing	25,000	25,000	0
Vehicle Technologies	650	300	0
Hydrogen and Fuel Cells Technologies	686	830	0
Total Ames Laboratory	**26,336**	**26,130**	**0**
Argonne National Laboratory			
Bioenergy Technologies	10,218	10,218	2,500
Building Technologies	189	2,327	200
Advanced Manufacturing	3,120	2,206	667
Vehicle Technologies	58,000	39,700	16,000
Strategic Programs	0	1,650	200
Geothermal Technologies	51	25	0
Solar Energy Technologies	2,637	874	1,469
Water Power Technologies	791	727	307
Wind Energy Technologies	1,052	1,646	649
Hydrogen and Fuel Cells Technologies	5,399	6,539	2,500
Total Argonne National Laboratory	**81,457**	**65,912**	**24,492**
Brookhaven National Laboratory			
Bioenergy Technologies	1,000	0	0
Building Technologies	0	950	0
Vehicle Technologies	2,500	2,500	2,000
Geothermal Technologies	750	0	0
Hydrogen and Fuel Cells Technologies	996	1,206	0
Total Brookhaven National Laboratory	**5,246**	**4,656**	**2,000**
Golden Field Office			
Bioenergy Technologies	68,910	95,000	650
Building Technologies	54,885	37,000	13,900
State Energy Program Grants	2,900	1,600	0
Weatherization Assistance Program	355	1,115	0
Training and Technical Assistance	1,355	450	0
Weatherization and Intergovernmental Programs	4,610	3,165	0
Program Direction - Energy Efficiency and Renewable Energy	20,585	24,516	18,400
Advanced Manufacturing	77,000	272,699	69,330
Federal Energy Management Program	4,140	11,623	400
Vehicle Technologies	2,800	0	1,000
Geothermal Technologies	8,500	47,800	12,500
Solar Energy Technologies	139,759	75,865	15,500
Water Power Technologies	42,356	65,550	12,340
Wind Energy Technologies	20,845	35,000	225
Hydrogen and Fuel Cells Technologies	53,007	68,859	21,850
Total Golden Field Office	**497,397**	**737,077**	**166,095**
Idaho National Laboratory			
Bioenergy Technologies	16,627	16,371	3,950
Federal Energy Management Program	457	181	150
Vehicle Technologies	10,500	9,800	4,900
Geothermal Technologies	2,175	25	25
Water Power Technologies	1,301	834	574
Wind Energy Technologies	159	1,166	484
Hydrogen and Fuel Cells Technologies	5,442	6,591	1,200
Total Idaho National Laboratory	**36,661**	**34,968**	**11,283**

DEPARTMENT OF ENERGY
Funding by Site Detail
Energy Efficiency and Renewable Energy
(Dollars in Thousands)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request
Lawrence Berkeley National Laboratory			
Bioenergy Technologies	9,049	9,049	3,100
Building Technologies	31,718	44,784	8,400
State Energy Program Grants	357	875	0
Training and Technical Assistance	170	200	0
Weatherization and Intergovernmental Programs	527	1,075	0
Advanced Manufacturing	12,200	9,868	667
Federal Energy Management Program	4,685	4,020	600
Vehicle Technologies	14,500	13,500	4,250
Strategic Programs	2,750	2,050	1,000
Geothermal Technologies	11,492	4,130	775
Solar Energy Technologies	126	1,349	0
Wind Energy Technologies	1,675	1,674	1,063
Hydrogen and Fuel Cells Technologies	5,479	6,636	2,000
Total Lawrence Berkeley National Laboratory	**94,201**	**98,135**	**21,855**
Lawrence Livermore National Laboratory			
Bioenergy Technologies	707	700	150
Building Technologies	774	0	0
Advanced Manufacturing	5,200	5,200	4,000
Vehicle Technologies	3,800	3,800	1,000
Geothermal Technologies	1,475	25	25
Solar Energy Technologies	434	1,049	836
Wind Energy Technologies	771	1,327	546
Hydrogen and Fuel Cells Technologies	2,833	3,431	1,000
Total Lawrence Livermore National Laboratory	**15,994**	**15,532**	**7,557**
Los Alamos National Laboratory			
Bioenergy Technologies	7,422	7,422	1,950
Vehicle Technologies	350	600	0
Geothermal Technologies	1,436	25	25
Wind Energy Technologies	212	353	0
Hydrogen and Fuel Cells Technologies	5,741	6,954	1,500
Total Los Alamos National Laboratory	**15,161**	**15,354**	**3,475**
National Energy Technology Lab			
Bioenergy Technologies	311	505	150
Building Technologies	17,750	53,500	0
Program Direction - Energy Efficiency and Renewable Energy	11,345	10,928	0
Vehicle Technologies	128,000	185,100	6,500
Geothermal Technologies	30,000	30,000	0
Hydrogen and Fuel Cells Technologies	20	24	0
Total National Energy Technology Lab	**187,426**	**280,057**	**6,650**

DEPARTMENT OF ENERGY
Funding by Site Detail
Energy Efficiency and Renewable Energy
(Dollars in Thousands)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request
National Renewable Energy Laboratory			
Bioenergy Technologies	53,577	50,577	16,205
Building Technologies	15,764	31,437	4,000
State Energy Program Grants	1,050	1,475	0
Training and Technical Assistance	0	850	0
Weatherization and Intergovernmental Programs	1,050	2,325	0
Advanced Manufacturing	1,825	4,000	0
Federal Energy Management Program	8,636	6,739	2,600
Vehicle Technologies	38,000	20,200	9,200
Strategic Programs	5,250	6,150	3,200
Facilities and Infrastructure - NREL	97,000	130,000	107,000
Geothermal Technologies	9,111	1,800	425
Solar Energy Technologies	45,479	122,416	27,478
Water Power Technologies	19,976	15,838	7,538
Wind Energy Technologies	33,694	30,000	10,947
Hydrogen and Fuel Cells Technologies	14,493	17,555	4,000
Total National Renewable Energy Laboratory	**343,855**	**439,037**	**192,593**
Oak Ridge Institute for Science & Education			
Bioenergy Technologies	851	351	245
Building Technologies	2,150	650	0
State Energy Program Grants	0	450	0
Training and Technical Assistance	450	450	0
Weatherization and Intergovernmental Programs	450	900	0
Advanced Manufacturing	5,700	5,495	0
Federal Energy Management Program	167	325	0
Vehicle Technologies	900	0	0
Geothermal Technologies	200	600	125
Hydrogen and Fuel Cells Technologies	721	873	500
Total Oak Ridge Institute for Science & Education	**11,139**	**9,194**	**870**
Oak Ridge National Laboratory			
Bioenergy Technologies	13,381	13,381	3,900
Building Technologies	15,316	27,568	5,500
Weatherization and Intergovernmental Programs	1,025	1,550	0
Advanced Manufacturing	32,025	36,028	11,666
Federal Energy Management Program	2,382	6,052	1,150
Vehicle Technologies	52,000	29,500	12,800
Geothermal Technologies	4,133	1,025	25
Solar Energy Technologies	2,581	0	289
Water Power Technologies	6,273	6,985	2,300
Wind Energy Technologies	925	1,306	198
Hydrogen and Fuel Cells Technologies	2,609	3,160	1,000
Total Oak Ridge National Laboratory	**132,650**	**126,555**	**38,828**

DEPARTMENT OF ENERGY
Funding by Site Detail
Energy Efficiency and Renewable Energy
(Dollars in Thousands)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request
Pacific Northwest National Laboratory			
Bioenergy Technologies	17,921	17,350	3,500
Building Technologies	22,898	30,172	4,500
Weatherization and Intergovernmental Programs	60	0	0
Advanced Manufacturing	300	300	0
Federal Energy Management Program	4,788	4,839	1,300
Vehicle Technologies	14,500	13,300	7,250
Strategic Programs	250	50	100
Geothermal Technologies	3,985	725	25
Solar Energy Technologies	48	316	0
Water Power Technologies	15,565	12,411	4,957
Wind Energy Technologies	6,501	6,430	1,671
Hydrogen and Fuel Cells Technologies	4,904	5,940	1,500
Total Pacific Northwest National Laboratory	**91,720**	**91,833**	**24,803**
Sandia National Laboratories			
Bioenergy Technologies	7,613	7,113	1,975
Building Technologies	0	1,100	0
Vehicle Technologies	13,000	13,000	4,000
Strategic Programs	750	300	0
Geothermal Technologies	5,720	2,981	775
Solar Energy Technologies	10,918	6,179	6,797
Water Power Technologies	7,608	7,779	2,310
Wind Energy Technologies	7,254	8,769	3,647
Hydrogen and Fuel Cells Technologies	7,542	9,135	3,000
Total Sandia National Laboratories	**60,405**	**56,356**	**22,504**
Savannah River National Laboratory			
Hydrogen and Fuel Cells Technologies	1,344	1,628	500
Total Savannah River National Laboratory	**1,344**	**1,628**	**500**
SLAC National Accelerator Laboratory			
Building Technologies	0	567	0
Vehicle Technologies	4,500	5,200	1,500
Solar Energy Technologies	2,445	1,998	591
Hydrogen and Fuel Cells Technologies	50	61	50
Total SLAC National Accelerator Laboratory	**6,995**	**7,826**	**2,141**

DEPARTMENT OF ENERGY
Funding by Site Detail
Energy Efficiency and Renewable Energy
(Dollars in Thousands)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request
Washington Headquarters			
Bioenergy Technologies	18,413	31,463	6,225
Building Technologies	64,556	54,945	24,500
State Energy Program Grants	1,633	2,100	0
Weatherization Assistance Program	145	6,765	0
Weatherization and Intergovernmental Programs	1,778	8,865	0
Program Direction - Energy Efficiency and Renewable Energy	130,570	129,556	104,163
Advanced Manufacturing	157,630	34,204	8,270
Federal Energy Management Program	4,745	6,221	2,200
Vehicle Technologies	0	59,500	4,000
Strategic Programs	5,000	4,300	500
Geothermal Technologies	4,972	20,839	11,275
Solar Energy Technologies	42,073	69,954	14,040
Water Power Technologies	11,130	37,876	14,674
Wind Energy Technologies	18,912	16,329	2,670
Hydrogen and Fuel Cells Technologies	8,734	10,578	1,400
Energy Efficiency and Renewable Energy Programs	468,513	484,630	193,917
Rescission of Prior Year Balances	0	-70,723	0
Total Washington Headquarters	**468,513**	**413,907**	**193,917**
Grants			
State Energy Program Grants	49,000	56,000	0
Weatherization Assistance Program	253,500	297,120	0
Total Grants	**302,500**	**353,120**	**0**

Electricity

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Electricity
Proposed Appropriation Language

For Department of Energy expenses including the purchase, construction, and acquisition of plant and capital equipment, and other expenses necessary for electricity **[**delivery**]** 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, **[**$190,000,000**]** *$195,045,000*, to remain available until expended: *Provided*, That of such amount, **[**$18,000,000**]** *$19,645,000* shall be available until September 30, **[**2021**]** *2022*, for program direction. *(Energy and Water Development and Related Agencies Appropriations Act, 2020)*

Public Law Authorizations

- Public Law 95–91, "Department of Energy Organization Act", 1977
- Public Law 109-58, "Energy Policy Act of 2005"
- Public Law 110-140, "Energy Independence and Security Act, 2007"
- Public Law 114-94, "Fixing America's Surface Transportation Act", 2015

Electricity
($K)

FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request
156,000	190,000	195,045

Overview

The Office of Electricity (OE) leads the Department's efforts to strengthen, transform, and improve energy infrastructure so that consumers have access to secure and resilient sources of electricity. OE provides solutions to market, institutional, and operational failures that go beyond any one utility's ability to solve.[a] To accomplish this critical mission, OE works with private industry and Federal, State, Tribal, territorial, and regional governments on a variety of initiatives to modernize the electric grid.

Grid modernization is critical to achieving public policy objectives, sustaining economic growth, supporting environmental stewardship, and mitigating risks to secure the Nation. The goal for the future grid is to deliver reliable, affordable, and resilient electricity to consumers.

Within the next decade, proactive, coordinated, and innovative steps are needed to address four critical challenges:

- Increasing threats and risks to the security of energy infrastructure
- Changes in demand driven by population growth, adoption of more energy efficient technologies, dynamic economic conditions, and broader electrification
- Changes in the supply mix and location (centralized, distributed, and off-shore) of the Nation's generation portfolio
- Increasing variability and uncertainty from both supply and demand, including integration of variable renewables, more active consumer participation, and accommodating new technologies and techniques

Due to the critical role the electric grid plays across Federal, State, Tribal, territorial, and regional jurisdictions, OE programs work in an integrated manner in partnership with industry and other stakeholders, as well as other DOE offices, to enhance key characteristics of the U.S. electric transmission and distribution systems:

- Resilience—the ability to withstand and quickly recover from disruptions and maintain critical function
- Security—the ability to protect system assets and critical functions from unauthorized and undesirable actors
- Reliability—consistent and dependable delivery of high quality power
- Flexibility—the ability to accommodate changing supply and demand patterns and new technologies
- Affordability—more optimal deployment of assets to meet system needs and minimize costs
- Efficiency—low losses in electricity delivery and more optimal use of system assets

Timely action is needed to perform the research and development that facilitates industry in deploying a reliable electric power grid that supports the vitality of other critical sectors that depend on electricity, such as telecommunications, banking and finance, water, and public health and safety. A reliable and resilient power grid is critical to U.S. economic competitiveness and leadership.

Within the Request, OE funds:

- Research and Development (R&D)—pursuing research for technologies to improve grid reliability, resilience, efficiency, flexibility, and functionality
- Modeling and Analytics—developing core analytic, assessment, and engineering capabilities that can evolve as the technology and policy needs mature to support decision making within the Department and for stakeholders; analyses explore complex interdependencies among energy infrastructure systems, such as between electricity and natural gas systems

[a] Examples include wide-area visibility, identified from the 2003 Northeast blackout, and faster modeling and analysis, identified in the 2011 Southwest blackout.

- Institutional Support and Technical Assistance—building capacity in the industry and convening stakeholders to coordinate efforts to transform the electric grid; providing technical assistance to Federal, State, Tribal, territorial, and regional entities to improve policies, utility incentives, State laws, and programs that facilitate the modernization of the electric infrastructure
- Coordination of Federal Transmission Permits—streamlining permits, special use authorizations, and other approvals required under Federal law to site electric transmission facilities
- Coordination with the Power Marketing Administrations on advancing R&D solutions and Defense Critical Electric Infrastructure

The proposed investment continues to support OE's mission of security and resilience through four key priorities:

- North American Energy Resiliency Model: Working with the national laboratories and relevant stakeholders, develop an integrated North American Energy Resiliency Model (NAERM) to conduct planning and contingency analysis to address vulnerabilities in the North American energy system
- Megawatt Scale Grid Storage: pursue megawatt-scale storage capable of supporting voltage and frequency regulation, ramping, and energy management for bulk and distribution power systems
- Revolutionize Sensing Technology Utilization: pursue integration of high-fidelity, low-cost sensing technology for predictive and correlation modeling for electricity and interdependencies with oil and natural gas (ONG) systems
- Transmission: pursue electricity-related policy issues by carrying out statutory and executive requirements, while also providing policy design and analysis expertise to Federal, State, Tribal, territorial, and regional entities

Energy Storage Grand Challenge (ESGC): DOE is taking a holistic approach to accelerate the development, commercialization, and utilization of next-generation energy storage technologies. The Department integrated the existing disparate storage efforts from the Grid Modernization Initiative (GMI), Advanced Energy Storage Initiative (AESI), Beyond Batteries, and others into a the Energy Storage Grand Challenge, an integrated, comprehensive DOE-wide strategy. The ESGC will deploy the Department's extensive resources and expertise to address technology development, commercialization, manufacturing, valuation, and workforce challenges. The vision for the ESGC is to create and sustain global leadership in energy storage utilization and exports, with a secure domestic manufacturing supply chain that is independent of foreign sources of critical materials, by 2030.

OE's Energy Storage program's request supports grid-related ESGC objectives and other OE R&D efforts are also complementary to ESGC goals.

Grid Modernization Initiative and Grid Modernization Laboratory Consortium: The Grid Modernization Laboratory Consortium (GMLC) was established as a crosscutting strategic partnership between DOE and the national laboratories to bring together leading experts, technologies, and resources to collaborate on the goal of modernizing the Nation's grid. The benefits of the GMLC include more efficient use of resources; shared networks; improving learning and preservation of knowledge; enhanced lab coordination and collaboration; and regional perspective and relationships with local stakeholders and industry. One of the main components of the GMI portfolio is the Grid Modernization Lab Call, which is a comprehensive effort of eighty-eight projects that span over the course of three years managed by the national laboratories.[a]

Highlights and Major Changes in the FY 2021 Budget Request

Transmission Reliability and Resilience ($55,950,000; -$1,050,000) is focused on ensuring the reliability and resilience of the U.S. electric grid through early-stage and foundational R&D on measurement and control of the electricity system and risk assessment to address challenges across integrated energy systems. A critical aspect of the request is the full development of a dynamic integrated NAERM to allow the United States to conduct planning and contingency analyses that address vulnerabilities in the North American energy system. Building on lessons learned from the FY 2018 Puerto Rico work of creating a near-real-time model and efforts seeded in FY 2019, the Request supports assessment of cross-infrastructure interdependencies and contingencies in the North American energy system. NAERM will provide unique and ground-breaking national-scale energy planning and real-time situational awareness capabilities for rigorous and quantitative assessment, prediction, and improvement to ensure reliable and resilient energy delivery across multiple sectors, spanning

[a] https://www.netl.doe.gov/File Library/Business/solicitations/2016GMLabCall.pdf

multiple organizations and authorities, while considering a range of large-scale, emerging threats.[a] A Sensors and Data Analytics activity is also continued to develop and integrate high-fidelity, fast-acting sensing technologies, and advanced data analytics, to revolutionize their use in electric transmission systems for improved diagnosis, prediction, and determination of action during normal and extreme-event conditions.

Resilient Distribution Systems ($18,300,000; -$26,700,000) focuses on the development of innovative technologies, tools, and techniques to modernize the distribution portion of the electric delivery system. The reduction is primarily due to transitioning core capabilities of the DOE-developed Advanced Distribution Management System (ADMS) platform to industry for further development in response to industry needs and because no funding is provided in FY 2021 for the Coordinated Management of Microgrids and Networked Distributed Energy Resources (COMMANDER) National Testbed Laboratory, which was fully funded in FY 2020.

Energy Storage ($83,500,000; +$27,500,000) is designed to develop new and advanced technologies that will ensure the stability, reliability, and resilience of electricity infrastructure. The request supports the development of advanced power electronic architectures and topologies to address stranded energy, improve battery failure diagnostics, and integrated highly accurate state-of-charge and state-of-health monitoring of energy storage systems. The increase supports design and construction for an OE Grid Storage Launchpad (GSL) project aimed at accelerating materials development, testing, and independent evaluation of battery materials and battery systems for grid applications. The increase is offset by reductions for two congressionally directed projects that were fully funded in FY 2020.

Transformer Resilience and Advanced Components ($9,000,000; +$2,000,000) supports hardening, response, and restoration of electric infrastructure by addressing the unique challenges facing transformers and other critical grid components responsible for carrying and controlling electricity from where it is generated to where it is needed. TRAC will continue to address critical research needs for solid-state power substations (SSPS) with an emphasis on advanced materials, embedded sensors, and capabilities to evaluate prototype converter building blocks.

Defense Critical Energy Infrastructure (DCEI) Energy Mission Assurance ($1,650,000; +$1,650,000) will identify, evaluate, prioritize, and assist in developing executable strategies to strengthen the energy infrastructure systems that supply critical infrastructure needed to ensure government continuity following severe natural and manmade disasters. This is a proposed new activity in FY 2021 and will be coordinated with owners and users of DCEI.

Transmission Permitting and Technical Assistance ($7,000,000; no change) promotes a resilient and reliable electricity system by addressing key institutional issues through a collaborative process with federal, state, local, territorial, Tribal, regional, community, and industry decision makers. TPTA will work with experts around the country to advance methods and approaches addressing emerging challenges including incorporating resilience into planning processes, developing effective grid modernization strategies, evaluating myriad resource options, improving the coordination of planning and operations across the bulk power and distribution systems, and applying regulatory and business models that provide the appropriate incentives for building a resilient and efficient energy system.

FY 2019 Key Accomplishments

Stochastic Optimization for Grid Resilience: Lawrence Livermore National Laboratory (LLNL) developed a stochastic optimization technique that can better allocate black start resources (pre-outage) and develop restoration sequences (post-outage) to improve the resiliency of the electrical grid. By building a mathematical framework that accounts for uncertainty and explicitly incorporates the knowledge of system operators, the tool enables planners to efficiently plan system upgrades to improve the ability of the system to recover from outages.

Award for a New Rechargeable Battery Chemistry: A team from Sandia National Laboratories and the City University of New York Energy Institute was recognized with the 2019 Environmental Protection Agency/American Chemical Society Green Chemistry Award for their OE-funded work on the development of low-cost rechargeable zinc manganese oxide ($Zn\text{-}MnO_2$) batteries. The team developed a high voltage aqueous $Zn\text{-}MnO_2$ rechargeable battery operating at 2.8 volts

[a] Resilient systems (versus reliable) anticipate, withstand, and recover critical loss-of-supply resulting from low-probability, high-impact threats. Threats include, for example, natural disasters, coordinated cyber-physical attacks, and electromagnetic pulses due to nuclear detonation

without the use of expensive ion selective membranes. This new high-voltage aqueous battery is able to charge and discharge 20−100% of MnO_2's theoretical capacity of 308 mAh/g, showing a pathway for energy dense aqueous Zn-MnO_2 batteries for applications where cost, safety, and high energy density characteristics are paramount.

Award for an Innovative and Cheaper Battery: Dr. Michael Aziz and Roy Gordon of Harvard University were awarded the 2019 international Eni Energy Frontiers award.[a] Their OE-supported research into novel flow battery technologies resulted in a new kind of battery that is far cheaper and more innovative than others currently available.

Urban Resilience Pilot: A partnership project with the 100 Resilient Cities Organization, the City of New Orleans, and Entergy New Orleans used OE-funded microgrid R&D tools developed by DOE's national laboratories to conduct an in-depth analysis of microgrid designs to provide both resilience solutions (for extreme events) and blue-sky solutions (for normal operations). One outcome was an optimal microgrid design for resilience, energy efficiency, and sustainability that is under consideration for an approximately $100 million venture capital investment.

Electricity Industry Technology and Practices Innovation Challenge (EITPIC): OE launched the inaugural EITPIC in January 2019 to seek ideas from industry, academia, and other innovators for concepts that include technologies or solutions that can address existing or emerging vulnerabilities and threats to the electric sector or mitigate interdependencies between the electricity sector and other sectors. OE awarded over $300,000 to seven submissions tackling topics such as improving situational awareness in the power grid, incorporating technology such as augmented reality into grid operations, and improving the speed and quality of data analytics.

Enhancing the Energy Zones Mapping Tool's online, geospatial analysis capabilities: The Energy Zones Mapping Tool (EZMT) is a free public geospatial analysis tool that supports siting analyses for a variety of energy resources and linear corridors. In partnership with Argonne National Laboratory, suitability models were extended from the Eastern Interconnection to the full lower 48 states, including land-based and offshore wind, concentrating and photovoltaic solar, and corridor suitability. These user-adjustable models rapidly map areas that may be suitable for these technologies based on many siting criteria. Also, the ability to import and export analysis areas and corridors was added, which makes it easier to use the EZMT with other GIS systems and data. The EZMT has a large library of energy mapping data and recent updates to it include adding another transmission line layer, updating all the layers from the Energy Information Administration, and many other layer updates.

Improving Grid Reliability against Drought Effects: OE supported the Western Electricity Coordinating Council and the Electric Reliability Council of Texas in their long-term grid reliability planning. Using advanced modeling and analysis tools, drought-related risk to thermoelectric and hydroelectric plant operations was assessed. Additionally, grid expansion plans for new generation assets were developed that minimize system disruptions caused by an uncertain and changing water future.

[a] https://www.eni.com/en_IT/media/2019/07/eni-awards-innovation-in-energy-winners-of-the-eni-award-2019-announced#

Electricity
Funding by Congressional Control ($K)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted ($)	FY 2021 Request vs FY 2020 Enacted (%)
Transmission Reliability and Resilience	39,000	57,000	55,950	-1,050	-1.8%
Resilient Distribution Systems	40,000	45,000	18,300	-26,700	-59.3%
Energy Storage					
Research	46,000	55,000	43,500	-11,500	-20.9%
Construction: 20-OE-100 Grid Storage Launchpad	0	1,000	40,000	+39,000	+3,900.0%
Total, Energy Storage	46,000	56,000	83,500	+27,500	+49.1%
Transformer Resilience and Advanced Components	7,000	7,000	9,000	+2,000	+28.6%
DCEI Energy Mission Assurance	0	0	1,650	+1,650	N/A
Transmission Permitting and Technical Assistance	7,000	7,000	7,000	0	0.0%
Program Direction	17,000	18,000	19,645	+1,645	+9.1%
Total, Electricity	**156,000**	**190,000**	**195,045**	**+5,045**	**+2.7%**
Federal Full Time Equivalent Employees (FTEs)	**52**	**62**	**62**	**0**	**0.0%**
Additional FE FTEs at NETL supporting OE[a]	12	12	12	0	0.0%
Total OE-funded FTEs	64	74	74	0	0.0%

SBIR/STTR:

- FY 2019 Enacted: SBIR/STTR: $4,218
- FY 2020 Enacted: SBIR/STTR: $4,931
- FY 2021 Request: SBIR/STTR: $4,118

[a] OE funds FTEs at FE's National Energy Technology Laboratory who are FE employees, but support OE activities. The FTEs are in FE's FTE totals and are not included in the OE FTE totals shown on the "Federal Full Time Equivalent Employees (FTEs)" line.

Transmission Reliability and Resilience

Overview

The Transmission Reliability and Resilience (TRR) program provides the electric sector with the necessary tools and analyses to assess risks, inform decisions, and improve power system planning and performance including mitigating the risks of large-scale blackouts. The TRR program is focused on ensuring the reliability and resilience of the U.S. electric grid through early-stage and foundational research and development (R&D) concentrated on measurement and control of the electricity system, as well as model development and validation for assessing risks across integrated energy systems. TRR brings together energy stakeholders from government, industry, and academia to generate ideas and develop solutions to the Nation's energy infrastructure challenges.

The Federal Government's responsibilities for national defense, economic prosperity, and public health and safety across all States and territories demand a holistic perspective on energy infrastructure security that is separate from, but complementary to, those found at the individual company, State, tribal, and local levels. Understanding how the North American energy system as a whole would react to disruptions to one or more of its individual components is a vital part of the Nation's ability to protect the Nation's critical infrastructure and defense installations.

The development of an integrated North American Energy Resiliency Model (NAERM) will allow the United States to conduct planning and contingency analyses that address vulnerabilities in the North American energy system. The Request continues the development of a dynamic integrated NAERM to assess cross-infrastructure interdependencies and contingencies in the North American energy system in coordination with critical infrastructure Federal partners and stakeholders.

This capability will incorporate all relevant assets of the integrated bulk energy system and identify recommendations for infrastructure investments and improvements to be made by asset owners and operators that would improve resilience and mitigate risks associated with energy system interdependencies. The resulting model will also allow the exploration of sequences of events that create risk across critical infrastructure sectors and identification of key critical infrastructure interdependencies.

The NAERM will leverage previous national laboratory efforts to fully understand the resilience risks associated with operating the highly diversified, regionally isolated North American electric grid and associated fuel delivery systems. National laboratories including the Argonne, Idaho, Los Alamos, National Renewable Energy, Oak Ridge, Pacific Northwest, Lawrence Livermore, and Sandia National Laboratories, among others, have a long history of developing system-wide modeling and analysis tools. This national capability will provide:

- Tools to better assess all forms of electricity generation, gas, oil, and electricity transmission infrastructure at risk of being disrupted by all-hazards events;
- Contingency analysis models to determine the impacts that loss of assets can have on system-wide resilience and reliability;
- Tools to estimate impacts to and from interdependent infrastructure systems such as natural gas and electric generation; and
- Real-time situational awareness with automatic worst-case analysis to inform operational decision making.

The NAERM will improve analysis of the significant interdependencies that have evolved within the energy sector. The Federal Government will have the ability to better evaluate strategic opportunities for improving system performance through the deployment of certain types of infrastructure, for example, energy storage for frequency control. This and other features of the enhanced planning and analysis tool will inform national security investments and enhance decision making and the use of authorities to respond to grid security emergencies. Overall, the NAERM and associated tools will support several private and public efforts:

- Utilizing a systems perspective to compare and collectively plan for impacts across geographic and jurisdictional boundaries
- Systematically defining critical energy infrastructure criteria through a defensible and repeatable methodology at the State and local level

- Targeting collaboration on mitigations with the Department's Power Marketing Administrations and other energy infrastructure owners and operators to most effectively address national security concerns

Such a coordinated effort is essential for identifying the critical contingencies necessary for risk mitigation, establishing North American-wide consequences when multi-State disruptions occur, and most effectively managing the deployment of high-priority investments. The ability to analyze data and models, predict consequences, and prioritize infrastructure protection is a necessary prerequisite for enhancing the resilience of the North American energy sector.

Improving energy sector resilience requires an enhanced ability to deliver real-time information on the status of transmission system operations and infrastructure components. There is a growing need to improve monitoring and assessment to ensure that the Bulk Power Energy system remains reliable while improving the overall security and resilience. This is critical to improving the ability of owners and operators to rapidly identify and diagnose faults and failures and monitor the health of key system components to mitigate potential challenges, natural and man-made.

The Sensors and Data Analytics program, which begins in FY 2020 will develop and integrate high-fidelity, fast-acting sensing technologies, and advanced data analytics, to revolutionize their use in electric transmission systems for improved diagnosis, prediction, and determination of action during normal and extreme-event conditions. Advances in data analytics are needed to enable utilizing an increasing number of heterogeneous data sources to infer complex underlying dynamics, diagnose system behavior and abnormalities, and provide situational awareness for operators to make informed decisions. The outcome of Sensors and Data Analytics R&D will enable determining the state of the power system with greater speed, accuracy, and precision than ever before, as required to manage the increasing complexity of grid operations and assets and to monitor and manage the interconnected and interdependent effects among the Nation's critical infrastructures, all under increasing levels of threat conditions.

To date, the energy sector has adopted a number of techniques for accessing timely and accurate information on the status of energy systems. However, existing data feeds often do not provide the accuracy, speed, or level of detail needed to fully evaluate system stability. The deployment of sensing technology across the energy system can greatly enhance the sector's ability to gather and analyze critical information needed to rapidly identify infrastructure vulnerabilities. The sector can then increase its ability to mitigate disruptions to key infrastructure, or it can identify alternative pathways for energy delivery.

The advanced sensors capability will foster the development and integration of high-fidelity, low-cost sensing technologies, as well as the advanced data analytics needed to revolutionize the diagnosis, prediction, and mitigation of system disruption during steady state and extreme-event conditions.

DOE will continue leading Federal efforts to adopt a common approach across its national laboratory complex to strengthen partnerships with the energy industry and to promote the development and deployment of next-generation interoperable energy system sensors. This capability will enable the Grid Modernization Laboratory Consortium (GMLC) to:

- Deploy cost-effective sensors directly at critical assets to improve monitoring;
- Evaluate opportunities to improve phasor measurement units;
- Develop data analytics for asset health monitoring and anomaly detection;
- Utilize sensors to enhance distribution system resilience; and
- Improve situational awareness and system evaluation through providing data feeds to DOE initiatives including the NAERM.

Through this national capability, the Department and its partners will have access to the information needed to make proactive, informed decisions about the operation and security of key energy system assets across transmission energy systems. These next-generation monitoring tools and analytics will vastly enhance the ability of the energy sector to improve resilience.

TRR's mission manifests itself in several key areas:

- Advancing early-stage and foundational research in electric grid measurements, models, mathematics, and computation
- Developing and validating early-stage proof-of-concept tools intended to enable the electricity system operators and planners to improve reliability, resilience, and security of the system

- Enhancing risk-based quantification to improve methods and models used to study power system resilience, recovery, and restoration
- Transforming protective relaying approaches; these approaches will include efforts to improve system resilience against modern threats while enhancing recovery operations following natural events
- Producing a model that allows understanding of risks across critical infrastructure sectors and identifying key energy infrastructure interdependencies

TRR directly engages energy stakeholders and decision makers to disseminate research results and promote innovation, and risk-informed energy system decisions. TRR activities also focus on advancing university-based power systems research, helping ensure an enduring strategic national capability for innovation in this essential area.

Highlights of the FY 2021 Budget Request
The request supports TRR's goals to:

- Develop methods for validating power system models using real-time data (such as synchrophasor measurements) to support reliable grid operations and improve electrical power infrastructure security and resilience;
- Develop the next generation of mathematical and statistical algorithms for improvement of the security, reliability, and resilience of the electric power system, including interdependencies and failure analysis;
- Develop integrated risk-based, measurement-model approaches to improve detection, mitigation, and recovery/restoration from weather events and man-made attacks to the electric power system, and to enable the operation of degraded or damaged electricity systems while sustaining critical functionality;
- Research protective relaying approaches to improve system resilience against modern threats while enhancing recovery operations following natural disasters;
- Develop and test algorithmic methods to manage uncertainty associated with data, modeling, and model validation in a dynamic, probabilistic, and stochastic environment targeted to improve resilience, reliability, and security of the electric power system;
- Integrate real-time data into NAERM to provide situational awareness; and
- Develop high-fidelity sensing technologies and data analytics for transmission systems.

Phase I of NAERM (the static model) began in FY 2019 and continues through the FY 2020. As part of Phase I, the development team started developing tools to study the impact of changes in different infrastructures on the electric power system using planning data. Phase II of NAERM (the real-time model) starts in FY 2020 in parallel to Phase I, using real-time data for near-real-time study of the electric power system. As the software and tools become more mature, the development will focus more on fixing defects and enhancements of the user interface and other areas. As the result the request for FY 2021, the final year of funding for NAERM Phase II, is reduced relative to FY 2020.

The Request will continue supporting efforts to address the needs for new sensors and advanced data analysis techniques to enable successful realization of incipient failure detection schemes along with associated condition-based maintenance programs ubiquitously throughout the grid. The resultant early detection schemes will provide utilities and other stakeholders with sufficient warning time and specificity regarding the failure mechanism to enable predictive and prescriptive actions to prevent potentially disruptive, costly, and even catastrophic failures before they occur, with the ultimate objective of ensuring that electricity delivery to the Nation's critical facilities and services is uninterrupted under all circumstances.

The Request will continue supporting R&D on sensors and data analytics for transmission systems in the following areas:

- Development of fast-acting current and voltage sensors for detection of electrical abnormalities for fault detection and dynamic system protection (from power surges, over and under frequency, over and under voltages, harmonics, etc.) and could include phasor measurement units (PMUs) and novel transducers in place of traditional electromechanical-based instrument transformers (voltage transformers [VT] and current transformers [CT]). Electro-optic effect based VTs, magneto-optical effect based CTs, and all-optical transducer technologies, as well as derivative sensors for voltage and current, will be considered for development to achieve rapid, high-bandwidth, and low-latency electrical parameter measurements.

- Transmission system asset monitoring and fault diagnosis. This technical area will build on electrical parameter measurements for signatures of low-probability, high consequence events to enable actions that prevent large-scale failures and minimize impacts for increasing grid resilience. Additional R&D thrusts include sensor technology platforms that could include multiple non-electrical parameters (for example, temperature, pressure, motion and vibration, inclination, proximity, and tampering) for identification of faults and failures internal of the transmission system, optical- and wireless-sensing based devices that must be compatible with electrically energized components for asset monitoring, and remote monitoring using unmanned aerial vehicles instrumented with on-board sensing, imaging, or diagnostic or interrogation capabilities for wide area infrastructure monitoring.

The Request continues TRR's focus on developing early-stage algorithms, methods, and proof of concept tools to improve the resilience, reliability, and security of the electric grid.

Centers[a]

The Request includes DOE support for the potential start of a new university-based Engineering Research Center, which would be jointly funded by the National Science Foundation (NSF) and the Department. Through the new Center, DOE would seek to develop fundamental knowledge in different aspects of the Electric Power System, contributing to a reliable, resilient, and secure electric power grid, while educating a new generation of electric power and energy systems engineering leaders.

[a] Per the guidance on inclusion of centers in budget justifications in H.Rpt. 113–135, the House report for the FY 2014 Energy and Water Development appropriations.

Transmission Reliability and Resilience
Funding ($K)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted ($)	FY 2021 Request vs FY 2020 Enacted (%)
Transmission Reliability and Resilience	39,000	57,000	55,950	-1,050	-1.8%

SBIR/STTR:

- FY 2019 Enacted: SBIR/STTR $1,273
- FY 2020 Enacted: SBIR/STTR: $1,731
- FY 2021 Request: SBIR/STTR: $1,961

Transmission Reliability and Resilience
Explanation of Major Changes ($K)

	FY 2021 Request vs FY 2020 Enacted
• NAERM funding for the final year of Phase II is reduced as some of the major technology risk is addressed in FY 2020 and the development in FY 2021 focuses on enhancing the user interface and the expansion of real-time data/infrastructure models	**-1,050**
• Research support for synchrophasor-specific tools and technologies, including NASPI, was reduced	
• DOE support for the Center for Ultra-Wide-Area Resilient Electric Energy Transmission Networks (CURENT), an Engineering Research Center based at the University of Tennessee, was completed in FY 2020; the FY 2021 Request supports the potential start of a new university-based Engineering Research Center	

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Transmission Reliability and Resilience $57,000,000	**$55,950,000**	**-$1,050,000**
• Conduct research in protective relaying. These approaches will include efforts to improve system resilience against modern threats while enhancing recovery operations following natural disasters. • Continue technical support for NASPI to conduct information sharing and joint problem solving among utilities, vendors, universities, and the Federal Government. • Continue support for the university-led CURENT Engineering Research Center, in coordination with NSF • Continue exploring the mathematical and computational research to manage uncertainty, associated with data, modeling, and model validation • Continue co-funding with the National Science Foundation of development of the next generation of mathematical and statistical algorithms for improvement of the security, reliability, and resilience of the electric power system	• Continue conducting research in protective relaying. These approaches will include efforts to improve system resilience against modern threats while enhancing recovery operations following natural disasters • Continue technical support for NASPI to conduct information sharing and joint problem solving among utilities, vendors, universities, and the Federal Government • Initiate assessment of research needs for a new university-based engineering research center related to electric power systems in coordination with National Science Foundation (NSF) • Continue exploring the mathematical and computational research to manage uncertainty, associated with data, modeling, and model validation • Continue co-funding with the National Science Foundation of development of the next generation of mathematical and statistical algorithms for improvement of the security, reliability, and resilience of the electric power system	• Reduced support for synchrophasor-specific tools and technologies, including NASPI • DOE support for CURENT is completed in FY 2020

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
North American Energy Resiliency Model • Fully integrate dynamic critical infrastructure models for NAERM in coordination with critical infrastructure Federal partners • Initiate incorporation of real-time data into dynamic models for NAERM to provide situational awareness • Develop use cases for NAERM to study the impact of Electricity, Natural Gas, and Communication infrastructures on each other and develop plan to minimize the risk	*North American Energy Resiliency Model* • Continue supporting the incorporation of real-time data into dynamic models for NAERM to provide situational awareness • Develop use cases for NAERM to study the impact of electricity and other infrastructures on each other and develop plan to minimize the risk	*North American Energy Resiliency Model* • NAERM funding for the final year of Phase II is reduced as some of the major technology risk is addressed in FY 2020 and the development in FY 2021 focuses on the scalable expansion of real-time data/infrastructure models
Sensors and data analytics for transmission systems • Define performance requirements for novel voltage and current transducers, including PMUs, for transmission system power flow and grid state monitoring • Define performance requirements for sensor technology platforms for transmission system asset monitoring and fault diagnosis • Award new R&D projects for sensors and data analytics for the transmission system • Post-Event Analysis Coordination (PEAC) network supporting the synchronization and timing to Federal installations across the United States	*Sensors and data analytics for transmission systems* • Continue supporting existing projects and award new R&D projects for sensors and data analytics for the transmission system • Operational support and expansion of the PEAC network	

Resilient Distribution Systems

Overview

Resilient, reliable, and affordable electricity is a cornerstone for a strong economy and provides foundational support for communities to grow and attract new businesses. Today's electric grid is undergoing dramatic changes. While this provides new benefits and new opportunities, it also presents significant operational challenges to maintaining the safe and reliable delivery of affordable power to consumers. For the most part, the existing electrical distribution system—the infrastructure that takes power from the transmission system and delivers it to individual businesses and homes—was designed and built using engineering principles established over 100 years ago. Today, however, that same distribution system is being relied upon to perform in ways it was neither intended nor designed to do. As States, Tribes, municipalities, and local communities look for ways to increase resilience, integrate distributed energy resources, and provide consumers with more choices for managing their energy consumption, distribution system operations have become increasingly complex and in many cases are challenged to maintain safety and reliability. As the electricity distribution system continues to evolve and its complexity increases, these problems will continue to grow unless new technologies are developed that enable changes to the way the electric grid is operated. In order for utilities to maintain reliable and resilient operations, they need to have the tools and capabilities to perform dynamic protection and control across all distribution system assets.

The Resilient Distribution Systems (RDS) program focuses on addressing the challenges facing the electric power grid by developing the innovative technologies, tools, and techniques to enable industry to modernize the distribution portion of the electric delivery system. RDS pursues strategic investments in early-stage research and development of innovative technologies and practices that improve reliability, resilience, outage recovery, and operational efficiency, building upon previous and ongoing grid modernization efforts including the Grid Modernization Laboratory Consortium (GMLC).

The technological convergence of the electricity infrastructure with information and communication systems presents an enormous opportunity to improve overall system resilience and reliability through the integration of vast amounts of information/data from historically disparate systems. Information and communication technology advances have initiated opportunities to leverage increased data volumes as never before possible to begin addressing many distribution grid operation technical challenges, including increased demand and supply variability, bi-directional power flow, data management and security, interoperability between new and legacy technologies and devices, and the increasing interdependencies between distribution and transmission operations.

The focus of Advanced Distribution Management Systems (ADMS) early-stage research is to explore an innovative, new approach to the management and control of utility distribution grids. ADMS will enable a new level of visibility and control across a utility's entire service territory. Microgrid research investments have shown success in addressing reliability, resilience, and efficiency, particularly at the community level, and will continue to be a focus within the RDS program. New approaches and technologies will also be investigated, including Dynamic Controls and Communications (DC&C) research and development to enhance the Nation's electric distribution grid to harness flexibility across all distribution assets to withstand and recover from disruptions caused by extreme weather events and man-made events, as well as for normal operations.

Results from the RDS research in ADMS, microgrids, and DC&C will enable industry to strengthen the resilience of electrical infrastructure against adverse effects of future extreme weather phenomena and other unforeseen natural and man-made occurrences.

Highlights of the FY 2021 Budget Request

The request includes a limited investment in the development of an open-source ADMS application platform, known as GridAPPS-D. The primary focus of the Request will be to transition core capabilities of the DOE-developed ADMS platform to industry to maintain and further develop the core in response to industry needs.

Microgrid and Resilience Tools R&D activities will continue national laboratory foundational R&D in several areas:

- Development of resilient operations of networked microgrids (RONM) software will continue. Version 1 of RONM software with a single, integrated mathematical formulation of resilient distribution design and restoration control will be tested in FY 2021, via hardware-in-the-loop (HIL), on one utility partner's circuit with at least 1,000 nodes. Development of standard-based microgrid-to-microgrid communication and control to support an advanced concept of

operations that involves self-assembly of microgrids and collaborative autonomy operations of networked microgrids for abnormal operations and restoration.

- Continue development of resiliency, consequence-based, quantitative models for system resilience and apply the models to support cities, utilities, and military installations in resilience planning. The focus will be to apply the models to analyze microgrids, both at a military installation and the surrounding community. Results will be useful for the Department of Defense master planning process and improving cities' resilience (utilizing the 100 Resilient Cities network).
- Develop key microgrid building-blocks, such as switching, power conversion, control (voltage and power), dispatch, and interfacing, which can be readily integrated to form microgrids for all purposes. The concept addresses the key challenge of costly and lengthy customization required for microgrid designs and builds.
- Development of protection schemes for microgrids with high penetration of inverter-based resources and development of new microgrid fault location algorithms using real-time sensor data and analytics will continue for both singular and networked microgrids.

DC&C R&D activities will support priorities on grid resiliency and dynamically sourced grid support services to help harden and evolve critical distribution grid infrastructure. Activities will be supported in the following areas:

- Dynamic Controls: These activities will develop the theoretical basis for methods and tools to evolve from centralized command and control to a more decentralized but coordinated system. Economic-control theory hybrid work, developed in previous years and will continue to be tested in simulation relative to traditional control methods.
- Blockchain concepts will be explored through public private partnerships in academia and industry for the purposes of secure peer to peer transactions, high integrity distributed data stores, and secure computing platforms in untrusted environments.
- Grid Communications: R&D activities to develop low latency, resilient communications networks capable of adapting to extreme events and disruptions. Efforts on adaptive spectrum research and co-simulation of power and communications to enhance communications bandwidth for utility applications will be completed. Foundational efforts on advanced resilient grid communication networks concepts will be initiated.

OE coordinates with the Office of Energy Efficiency and Renewable Energy and other relevant DOE programs through the Grid Modernization Initiative and regular programmatic outreach to ensure the programs support complementary R&D and avoid duplication. Work in this area will continue to leverage and integrate energy storage, power electronics, systems controls and first of a kind technologies that could meet the technical needs of microgrids that can support various types of communities ranging from rural to islanded grids.

Support of R&D activities through the Grid Modernization Laboratory Consortium (GMLC) will continue.

Resilient Distribution Systems
Funding ($K)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted ($)	FY 2021 Request vs FY 2020 Enacted (%)
Resilient Distribution Systems	**40,000**	**45,000**	**18,300**	**-26,700**	**-59.3%**

SBIR/STTR:

- FY 2019 Enacted: SBIR/STTR: $1,313
- FY 2020 Enacted: SBIR/STTR: $1,359
- FY 2021 Request: SBIR/STTR: $560

Resilient Distribution Systems
Explanation of Major Changes ($K)

	FY 2021 Request vs FY 2020 Enacted
• Core capabilities of the DOE-developed ADMS platform will be transitioned to industry to maintain and to further develop the core in response to industry needs	**-26,700**
• The National Test Bed Laboratory for Coordinated Management of Microgrids and Networked Distributed Energy Resources (COMMANDER) was fully funded in FY 2020 and does not require additional support	
• Situational Awareness Network (SAN) activities are reduced to operational support, maintenance, and expansion	

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Resilient Distribution Systems $45,000,000	**$18,300,000**	**-$26,700,000**
• Demonstrate ADMS resiliency functions (fault location, isolation, and service restoration [FLISR], switch order management, and dynamic feeder reconfiguration) at the ADMS test bed at National Renewable Energy Laboratory • Conduct field trials of the use of the GridAPPS-D platform for developing and hosting applications in two utilities • Execute the transition plan and release the GridAPPS-D core capabilities in terms of software and documentation to industry for stewardship and continued development • Develop models for protection coordination and dynamic stability for integration into version 2 of the optimal design and operation (OD&O) tool • Validate the control solutions of the integrated micro energy management system/distribution management system, via field testing in two utility use cases • Further development of distribution system designs responsive to high resilience architecture requirements, including laminar coordination, which enables decentralized, resilient control • Blockchain and related distributed technology application to grid challenges involving local resilience and reliability markets, high integrity distributed data, and secure trusted computing platforms • Foundational research into "Serotinous Networks" capable of automatically re-establishing critical grid communications after extreme events	• Continue software development for resilient operations of networked microgrids (RONM) and Version 1 testing at utility hardware-in-loop (HIL) • Advance standard-based microgrid-to-microgrid communication and control that involves self-assembly of microgrids and collaborative autonomy operations • Continue development and application of consequence-based, quantitative models for system resilience applied to microgrids • Provide technical assistance on resilient microgrid implementation to critical defense facilities in meeting their mission-critical needs utilizing national laboratory expertise • Continue development of a key, standardized building-blocks with combined capabilities for power conversion and microgrid control functions • Develop protection schemes for microgrids with high penetration of inverter-based resources and develop new microgrid fault location algorithms using real-time sensor data and analytic • Conduct funding opportunity on highly resilient adaptive networks leveraging analysis and laboratory activities accomplished in FY 2020 • Initiate the development of a comprehensive communications planning toolkit	• Core capabilities of the DOE-developed ADMS platform will be transitioned to industry • COMMANDER National Test Bed Laboratory requirements are fully funded in FY 2020 • SAN activities reduced to operational support, maintenance, and expansion

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
• R&D efforts to develop methods to prioritize distribution system information flows based on dynamic control needs • Situational Awareness Network (SAN) supports the operation and maintenance for the Defense Critical Infrastructure Situational Awareness Network (DCISAN) • Implement the National Test Bed Laboratory for Coordinated Management of Microgrids and Networked Distributed Energy Resources (COMMANDER)	• Demonstrate the feasibility and benefits of resilience services utilizing Dynamic Control Source • Operation, maintenance, and expansion of the SAN	

Energy Storage

Overview

The Energy Storage program leads a national effort to ensure a more resilient and flexible North American power grid through increased deployment of bi-directional electrical energy storage. The electric power grid is the backbone of our modern economy and success of the grid has rested on two key principles: reasonably predictable load and a measure of control over generation. As the electric grid evolves to accommodate more distributed energy resources, new models and tools, such as energy storage, can help effectively manage these changes. Energy storage is an enabling element for this transition as it is a bi-directional flexible resource capable of providing a suite of grid services while improving the inherent resiliency of the grid.

The U.S. electric grid's installed electricity generation summer capacity of just over 1 terawatt (TW) (1,000 GW) has roughly 23 GW of energy storage, of which 22 GW is provided by large pumped hydro energy storage plants. Historically, less than one percent of installed generation capacity is provided by modular, flexible energy storage assets (such as batteries and flywheels) that offer the greatest potential for large scale deployment and operational flexibility. To make energy storage ubiquitous throughout the grid infrastructure, further research is needed in reducing the cost of energy storage systems, along with significant improvements in the safety and long term reliability of utility-scale energy storage systems. In addition, further research is needed in developing analytic models that can facilitate greater understanding of technical and economic benefits energy storage can provide to utilities and grid operators.

The Energy Storage program is designed to develop new and advanced technologies that will ensure the stability, reliability, and resilience of electricity infrastructure. The R&D program focuses on:

- Energy Storage Technology Development
  - Performing advanced research on the development of novel materials and system components to resolve key cost and performance challenges with respect to novel flow, lithium, sodium, zinc, and magnesium batteries, electrode materials, membranes, electrolytes, interconnects, and supporting power electronics and power conversion systems. These advanced battery and device technologies will lead to significant improvements in the cost and performance of energy storage systems that enable widespread deployment and support domestic manufacturing.
- Safety and Reliability
  - Continuing establishment of a scientifically derived knowledge base that will improve the understanding and predictability of energy storage systems and components and support fostering greater confidence in the safety and reliability of energy storage systems.
  - Improving the safety and reliability of energy storage technologies and their installation in close collaboration with fire departments, building managers, and other approval authorities.
- Energy Storage Analytics
  - Developing open source analytic tools for small and large utility customers and regulatory agencies to facilitate planning and implementation of energy storage in transmission and distribution infrastructure.
  - Supporting the development of open-source tools for optimal sizing, placement, and valuation of energy storage and develop performance protocols for rapid adaption of energy storage.
  - Designing and building advanced control systems to optimize fleets of diverse energy storage systems to supply existing and emerging grid services.

Highlights of the FY 2021 Budget Request

Grid energy storage is one of the key components for the development of a flexible and resilient electric grid infrastructure and the proposed OE research portfolio greatly advances the deployment of grid scale energy storage. The Request continues support for the program's core R&D agenda including materials research on the next generation of battery chemistries, development of new materials and new device technologies for efficient power conversion, improved safety and reliability of storage systems, development of optimal design and control architectures for energy storage integration, and development of open source models and software tools for system level energy storage planning and evaluation.

The research program builds on a long history of successful research, development, and deployment (RD&D) by the OE Energy Storage program. Advanced materials R&D is focused primarily on improving the cost and performance of earth abundant, domestically available battery chemistries for next generation flow batteries and advanced sodium- and zinc-

based systems. Materials research is aimed at improving the lifetime and performance of the chemistries and all critical cell components and moving these technologies toward practical prototypes that can achieve specific cost targets under $200 per kWh. Targeted R&D efforts in aqueous soluble organic redox flow batteries as well as sodium and zinc systems are coordinated in national programs that engage a cross-section of national laboratories, universities, and industry partners to meet ultimate performance objectives.

Lead-acid batteries, with an installed manufacturing capacity nearly an order of magnitude larger than lithium ion, represents a low cost, highly recyclable technology for some grid applications if new advances in materials and systems design can improve their durability. R&D efforts will focus on mitigating these degradation mechanisms. Additionally, R&D efforts will be initiated on novel storage technologies that can cost-effectively provide both longer discharge durations (12+ hours) than today's technologies as well as potential storage systems that may enable seasonal shifting of electrical energy usage.

Advanced materials device development efforts continue for lower-cost power electronics and power conversion systems that can represent up to 30% of an installed storage system's cost. The program will continue to develop and improve new wide-bandgap materials for power electronics and advanced dielectric materials for high voltage capacitors, and to improve the reliability of power convertors enabling lower-cost, higher-performance inverter technologies. R&D activities investigating new topologies for optimal control and safety of power electronics will continue, as well as the development of advanced power electronic architectures to address stranded energy, improve battery failure diagnostics, and integrate highly accurate state-of-charge and state-of-health monitoring of energy storage systems.

Safety and reliability of energy storage systems are critical for large-scale deployment of storage technologies into grid infrastructure and will continue to be an active R&D area in the program. The OE Energy Storage program continues to be the primary conduit between research and industry for energy storage safety and is enabling the establishment of strong safety standards. The program continues working closely with fire departments, building managers, and other approval authorities to understand the critical R&D needs of the end users, then conducting fundamental investigations into the broad range of mechanisms affecting the safety and reliability of energy storage systems, and then communicating and proliferating research products to standards development organizations such as the Institute of Electrical and Electronics Engineers (IEEE), National Fire Protection Association (NFPA), and UL. Establishing a referenceable database of energy storage degradation and expected lifetimes will continue to be a priority through energy storage reliability testing capabilities. This capability is aimed at long-term and accelerated testing methodologies to determine the expected lifetime of storage technologies when operated under grid duty cycles.

The scarcity of technical information on the economic performance of energy storage technologies continues to be a serious barrier to the wider-scale adoption of grid energy storage. The program's energy storage analytics focus has an established track record for providing analysis on performance of energy storage systems for a full range of grid application. The program will continue to support the development open source analytic tools for the electric utility industry to help ensure that the future North American electric grid has flexible and distributed resources to be reliable and resilient. The program will also continue to support the development of robust user tools for storage planning, operation, and evaluation. This entails open source software development for optimal sizing and placement, optimal control and coordination, cyber-threat analysis and protection, and techno-economic assessment. It is critical that these tools are validated on real-world storage deployments as increased fidelity of these analytical tools can greatly lower the barrier for acceptance by stakeholders by enabling them to fully understand how integrating storage into the grid can lower energy prices, secure their electrical supply, and solve a variety of challenges faced by specific localities across the United States. Providing technical assistance to states and regional stakeholders in the use of these analytical tools and how to safely install, integrate, and operate deployed energy storage systems will continue to be a vital element of the program. Furthermore, new electrical energy storage field evaluation projects that highlight the importance of energy storage to enhance the resiliency to defense critical infrastructures will be pursued. The data and experience from these projects will be used to develop and validate the North American Energy Resiliency Model (NAERM) by advancing the Nation's understanding of the strategic use and placement of energy storage systems, including batteries, within the energy sector.

This request also supports the OE Grid Storage Launchpad (GSL) construction project, which is aimed at accelerating materials development, testing, and independent evaluation of battery materials and battery systems for grid applications. FY 2020 and 2021 Project Engineering and Design (PED) funds are used to complete the DOE O 413.3B requirements in preparation for Critical Decision (CD)-2/3. FY 2021 construction funding will be used to initiate the design-build acquisition

strategy in which design and construction services are secured together. The GSL will focus on early-stage materials and prototype battery systems (less than 100 KW) to identify and solve issues before moving to larger-scale systems and will standardize grid performance testing across the spectrum of battery materials, battery systems, inverters, auxiliary power, and battery management systems under grid use-case conditions. The GSL will provide an objective national resource to report battery testing performance under grid conditions and will integrate and coordinate researchers from universities and national labs together to rapidly solve crosscutting science and technology challenges. The GSL will also develop new capabilities to rapidly scale-up new materials for grid scale storage, deliver dedicated state of the art characterization capabilities that do not exist, and conduct realistic testing of design options in a laboratory environment. The GSL will incorporate the energy storage reliability testing capability. The existing center is focused on determining the appropriate method to test currently available grid storage technologies; the GSL will also provide independent validation of the entire storage system, from materials and chemicals to battery modules and power electronics, and offer development solutions that can reduce the levelized cost of future systems.

Support of R&D activities through the Grid Modernization Laboratory Consortium (GMLC) will continue.

Energy Storage Grand Challenge (ESGC): DOE is taking a holistic approach to accelerate the development, commercialization, and utilization of next-generation energy storage technologies. The Department integrated the existing disparate storage efforts from the Grid Modernization Initiative (GMI), Advanced Energy Storage Initiative (AESI), Beyond Batteries (BB), and others into a the Energy Storage Grand Challenge, an integrated, comprehensive DOE-wide strategy. The ESGC will deploy the Department's extensive resources and expertise to address technology development, commercialization, manufacturing, valuation, and workforce challenges. The vision for the ESGC is to create and sustain global leadership in energy storage utilization and exports, with a secure domestic manufacturing supply chain that is independent of foreign sources of critical materials, by 2030.

OE’s Energy Storage program’s request supports grid-related ESGC objectives and other OE R&D efforts are also complementary to ESGC goals.

Energy Storage
Funding ($K)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted ($)	FY 2021 Request vs FY 2020 Enacted (%)
Energy Storage					
Research	46,000	55,000	43,500	-11,500	-20.9%
Construction	0	1,000	40,000	+39,000	+3,900.0%
Total, Energy Storage	**46,000**	**56,000**	**83,500**	**+27,500**	**+49.1%**

SBIR/STTR:

- FY 2019 Enacted: SBIR/STTR: $1,389
- FY 2020 Enacted: SBIR/STTR: $1,618
- FY 2021 Request: SBIR/STTR: $1,310

Energy Storage
Explanation of Major Changes ($K)

	FY 2021 Request vs FY 2020 Enacted
Research	
• Supports deployment and validation of longer term (6+ hour) storage applications for defense critical infrastructures	**-11,500**
• Supports deployment of electrical energy storage systems for rural co-operatives	
• Expanded R&D efforts on lead-acid batteries for grid storage applications	
Construction	
• The FY 2021 request completes design funding and provides initial construction funding, which will be used to initiate a design-build acquisition strategy where design and construction services are secured together.	**+39,000**
Total, Energy Storage	**+27,500**

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Request
Research $55,000,000	**$43,500,000**	**-$11,500,000**
• Demonstrate a 2 kW prototype stack of the novel aqueous soluble organic flow battery technology capable of achieving 200 mA/cm² with a projected 1 MW/4 MWh system cost of less than $225 per kWh • Demonstrate large format (300 Ah) zinc-manganese dioxide batteries with an energy density of 150 Wh/L with a projected cell level costs below $100 per kWh • Continued development of sodium batteries capable of achieving less than $100 per kWh • Develop new power electronics and power converter topologies for efficient coupling between batteries and power electronics for improved power conversion optimized for aqueous batteries including flow batteries and zinc-based batteries • Develop control strategies and architectures for distributed control of energy storage for different control functions including grid stability, economic dispatch, and system reliability and safety • Validate novel control algorithms for enhanced battery lifetime for enhanced reliability and safety • Continue development of open source software tools for optimal sizing, location, and valuation of grid scale energy storage • Support validation of 3–4 new electrical energy storage field evaluation projects that highlight the regional diversity of storage applications	• Demonstrate a 5 kW prototype of a novel aqueous soluble organic flow battery technology capable of achieving 400 mA/cm² with a projected 1 MW/4 MWh system cost of less than $200 per kWh • Demonstrate large format (300 Ah) zinc-manganese dioxide batteries with an energy density of 150 Wh/L with projected cell level costs below $50 per kWh when produced in volume • Demonstrate performance and long-term stability of sodium batteries technologies (sodium-ion and sodium metal halide) in greater than 5 Ah prototypical formats capable of achieving less than $100 per kWh when produced at scale • Continue research and development of new power electronics and power converter topologies for efficient coupling between batteries and power electronics for improved power conversion optimized for aqueous batteries including flow batteries and zinc-based batteries • Migrate novel control strategies and architectures for distributed control of energy storage from R&D to industry for improved grid stability, economic dispatch, and system reliability and safety • Expand reliability testing of new battery chemistry under defined grid use cases and develop comprehensive reliability metric for grid scale storage systems • Disseminate open source software tools and validated analytical models for optimal sizing, location, and operation of grid scale energy storage	• Supports deployment and validation of longer term (6+ hour) storage applications for defense critical infrastructures • Supports deployment of electrical energy storage systems for rural co-operatives • Expanded R&D efforts on lead-acid batteries for grid storage applications

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Request
• Develop and share analytical models validated through these field trials within the stakeholder community through technical reports, presentations, and journal publications	• Support installation, integration, and validation of at least 3 new electrical energy storage projects that highlight longer term (6+ hour) storage applications for defense critical infrastructures • Support installation, integration, and validation of at least 2 new electrical energy storage projects aimed at improving resiliency and operational efficiency of rural co-operatives • Expand R&D efforts on lead-acid batteries as potential grid scale energy storage solutions	
Construction $1,000,000	**$40,000,000**	**+$39,000,000**
• Perform DOE O 413.3B requirements in preparation for CD 2/3	• Complete DOE O 413.3B requirements and the design-build acquisition strategy in which design and construction services are secured together	• The increase completes PED funding and provides initial construction funding

Construction Projects Summary ($K)

	Total Project Cost (TPC)	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted
20-OE-100 Grid Storage Launchpad					
Total Estimated Cost (TEC)	75,000[a]	0	1,000	40,000	+39,000
Other Project Costs (OPC)	2,000[b]	1,000	0	0	0
TPC	77,000[a]	1,000	1,000	40,000	+39,000

[a] This project has not received CD-2 approval; therefore, preliminary cost estimates are shown for TEC and TPC.
[b] OPC is funded through laboratory overhead.

20-OE-100, Grid Storage Launchpad
Pacific Northwest National Laboratory, Richland, Washington
Project is for Design and Construction

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

Summary: The FY 2021 Request for the Grid Storage Launchpad (GSL) will be used to initiate the design-build acquisition strategy in which design and construction services are secured together for a new building and associated infrastructure that will consolidate existing grid energy storage research capabilities at PNNL with new characterization, validation and independent testing capabilities for next generation grid scale energy storage materials under grid operating conditions. With a design-build acquisition strategy, design and construction services overlap to ensure effective constructability is factored into the design. This project has a preliminary total project cost (TPC) range of $57,000,000 to $77,000,000 based on a preliminary total estimated cost (TEC) range of $55,000,000 to $75,000,000 and $2,000,000 of other project costs (OPC). The most recent DOE Order 413.3B Critical Decision (CD) is CD-1, Approve Alternative Selection and Cost Range, and was approved on August 21, 2019.

A Federal Project Director with level II certification is assigned to the project.

The scope of this project is to design and construct a facility and associated infrastructure to consolidate existing materials development research and new characterization and testing capabilities focused on grid scale energy storage research. The facility is needed to house critical research capabilities devoted to accelerated materials development, testing and independent validation of storage materials and systems for grid applications. These early stage validation and testing capabilities are not readily available in the private sector. The GSL will also complement current industry efforts by developing standardized grid testing protocols that the entire stakeholder community can use for performance validation of storage technologies. Finally, the GSL will provide new, dedicated capabilities—such as the in-operando storage characterization capability—that are critical to accelerate materials development and does not exist in industry.

Significant Changes: This construction project data sheet (CPDS) does not include a new start for FY 2021.

- Activities leading to CD-1 were initiated after CD-0 approval.
- CD-1 was approved on August 21, 2019.
- An Analysis of Alternatives was conducted by a DOE cross-program team and Pacific Northwest Site Office to consider a wide range of laboratory site and site mission achievement alternatives. The analysis was independently reviewed and resulted in selection of a preferred alternative to construct a new facility at the Pacific Northwest National Laboratory.
- FY 2020 PED funding is being used by to perform the DOE O 413.3B requirements for CD-2/3.
- The data sheet includes funding for design and construction services starting in FY 2021.

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 2020	11/30/2018	3Q FY 2019	1Q FY 2020	4Q FY 2020	1Q FY 2021	TBD	N/A	TBD
FY 2021 [a]	11/30/2018	7/9/2019	8/21/2019	4Q FY 2021	4Q FY 2022	4Q FY 2021	N/A	1Q FY 2026[b]

[a] This project will be requesting a combined CD-2/3 approval as part of the tailoring strategy associated with the Acquisition Strategy. This project is pre-CD-2 and the schedule estimates are preliminary.
[b] Includes 12 months of schedule contingency for risk mitigation.

Fiscal Year	Performance Baseline Validation
FY 2020	4Q FY 2020
FY 2021	4Q FY 2021[a]

CD-0 – Approve Mission Need for a construction project with a conceptual scope and cost range
Conceptual Design Complete – Estimated/actual date the conceptual design will be/was complete
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
CD-3 – Approve Start of Construction
D&D Complete – Completion of decontamination and decommissioning (D&D) work
CD-4 – Approve Start of Operations or Project Closeout

Project Cost History

(Dollars in Thousands)

Fiscal Year	TEC, Design	TEC, Construction	TEC, Total	OPC, Except D&D[b]	OPC, D&D	OPC, Total[b]	TPC
FY 2020	5,000	TBD	TBD	1,000	N/A	1,000	6,000
FY 2021[a]	5,000	70,000	75,000	2,000	N/A	2,000	77,000

2. Project Scope and Justification

Scope

The scope is for the design and construction of a new capital asset at PNNL, including utilities and infrastructure capabilities, capable of the development and testing of new materials for grid energy storage. A facility is needed to consolidate, modernize and expand critical research capabilities that will enable accelerated materials development, testing and independent validation of battery materials and systems for grid applications and complementary technologies. The GSL project design is intended to lead to construction and turnover of facilities and infrastructure that will provide nominally 60,000–90,000 gross square feet of wet chemistry, instrumentation, and computational space in approximately 35 laboratory modules along with workstations for approximately 105 research and support staff.

The Pacific Northwest National Laboratory (PNNL) has a shortage of onsite institutional laboratory space. The GSL offers relief from the shortage by providing modern agile research space that not only enables the missions of today but is readily adaptable to the needs of tomorrow. Consolidation of this research community also benefits related and ongoing work for other programs likely resulting in synergic and complementary outcomes. The analysis of alternatives considered several alternatives including construction of a new structure at PNNL, renovation of existing space at PNNL, moving the capability to another national laboratory, and the status quo.

Justification

America's security, economy, and sustained global leadership depend on a secure and resilient power grid. Through a mix of technology and policy solutions and in partnership with the private and public sectors, OE harnesses innovation for a stronger, more resilient North American energy system and a path forward to energy independence.

OE's Advanced Grid Research and Development Division invests in next-generation technologies to support OE's mission of ensuring a secure, resilient flow of power to the Nation. The OE Advanced Grid Research and Development Division works closely with the private and public sectors to ensure the Nation's critical energy infrastructure is secure and able to recover

[a] This project is pre-CD-2 and the funding estimates are preliminary. The funding estimates provided are based on the upper end of the TEC and TPC ranges.
[b] Other project costs (OPC) are funded through laboratory overhead.

rapidly from disruptions. A major enabler for critical energy infrastructure is megawatt-scale energy storage capable of supporting regulation, ramping, and energy management for bulk and distribution power systems. Storage activities include collaboration with other DOE offices through the Energy Storage Grand Challenge (ESGC) to investigate and integrate new technologies for advancing megawatt-scale storage with added resilience and control capabilities and working with the national laboratories to identify and pursue capabilities in flow batteries for grid scale energy storage.

Assuring grid security and resilience will require greater grid flexibility and the deployment of grid assets, like energy storage, that can buffer increased variable supply and demand efficiently. Development of grid-scale energy storage, at levels to ensure the required resiliency and reliability of the future U.S. power grid, will require the development of new technologies that are more cost effective, safer, and durable. To help accomplish this goal, OE proposes the development of a Grid Storage Launchpad to enhance critical research capabilities for the development and testing of new grid energy storage materials. GSL development will help maintain U.S. R&D leadership in energy storage through validation, acceleration, and collaboration. The GSL will enable independent validation of next-generation grid energy storage materials and systems under realistic grid operating conditions. From benchtop to systems, the GSL will de-risk and accelerate new technology maturation by propagating rigorous grid-performance requirements to all stages of storage development. By linking the DOE and storage R&D communities in a new collaboration facility, the GSL will lower barriers to solving key crosscutting challenges.

The GSL will provide a holistic set of storage development capabilities that does not exist in industry and is not currently accessible to the general R&D community. The GSL will promulgate rigorous grid-performance requirements throughout the R&D development cycle—from basic materials synthesis to testing of near-commercial prototypes—in order to accelerate the development lifetime and ensure continuous validation of new technologies. Current commercial capabilities, focused on later stage prototyping of known storage architectures and device testing, lack the GSL's planned ability to validate new grid-storage technologies at smaller scales and earlier technology maturity stages. The GSL will complement current industry efforts by developing standardized grid testing protocols that the entire stakeholder community can use for performance validation of storage technologies. Finally, the GSL will provide for new, dedicated capabilities, such as an in-operando storage characterization capability, that are critical to accelerate materials development and do not exist in industry. The GSL will also enable broader collaboration across DOE, university, and industry R&D communities than potential proprietary commercial efforts. Because the GSL offers a transformational approach for the accelerated validation of grid-storage technologies, DOE stewardship is critical to ensure open access to these capabilities to enable U.S. leadership in gird-storage technologies.

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

Key Performance Parameters (KPPs)

The KPPs constitute the definition of project completion and are a prerequisite for approval of CD-4, Project Completion. Threshold KPPs, the minimum acceptable performance that the project must achieve, and Objective KPPs, the desired project performance, will be established at CD-2. This project is pre-CD-2.

3. Financial Schedule

(Dollars in Thousands)

	Budget Authority (Appropriations)	Obligations	Costs
Total Estimated Cost (TEC)			
Design			
FY 2020	1,000	1,000	500
FY 2021	4,000	4,000	4,500
Total, Design[a]	5,000	5,000	5,000

[a] PED funding is being used by the Project to perform the DOE O 413.3B requirements for CD-2/3.

(Dollars in Thousands)

	Budget Authority (Appropriations)	Obligations	Costs
Construction			
FY 2021	36,000	36,000	5,000
FY 2022	34,000	34,000	30,000
FY 2023	…	…	20,000
FY 2024	…	…	15,000
Total, Construction	70,000	70,000	70,000
Total Estimated Cost (TEC)			
FY 2020	1,000	1,000	500
FY 2021	40,000	40,000	9,500
FY 2022	34,000	34,000	30,000
FY 2023	…	…	20,000
FY 2024	…	…	15,000
Total, TEC[a]	**75,000**	**75,000**	**75,000**
Other Project Costs (OPC)			
FY 2019	1,000	1,000	1,000
FY 2024	1,000	1,000	1,000
Total, OPC[ab]	**2,000**	**2,000**	**2,000**
Total Project Costs (TPC)			
FY 2019	1,000	1,000	1,000
FY 2020	1,000	1,000	500
FY 2021	40,000	40,000	9,500
FY 2022	34,000	34,000	30,000
FY 2023	…	…	20,000
FY 2024	1,000	1,000	16,000
Grand Total[a]	**77,000**	**77,000**	**77,000**

4. Details of Project Cost Estimate

(Dollars in Thousands)

	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
Total Estimated Cost (TEC)			
Design			
Design	4,000	4,500	N/A
Contingency	1,000	500	N/A
Total, Design	5,000	5,000	N/A

[a] This project is pre-CD-2 and the funding estimates are preliminary. The funding estimates provided are based on the upper end of the TEC and TPC ranges.

[b] Other Project Costs (OPC) are funded through laboratory overhead.

(Dollars in Thousands)

	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
Construction			
Construction	58,100	…	N/A
Contingency	11,900	…	N/A
Total Construction	70,000	…	N/A
Total, TEC[a]	**75,000**	**5,000**	**N/A**
Contingency, TEC	*12,900*	*500*	*N/A*
Other Project Cost (OPC)			
OPC except D&D			
Conceptual Planning	…	100	N/A
Conceptual Design	1,000	900	N/A
Other OPC Costs	1,000	…	N/A
Total, OPC[ab]	**2,000**	**1,000**	**N/A**
Total Project Cost[a]	**77,000**	**6,000**	**N/A**
Total Contingency (TEC+OPC)	*12,900*	*500*	*N/A*

5. Schedule of Appropriations Requests

(dollars in thousands)

Request Year	Type	FY 2019	FY 2020	FY 2021	FY 2022	FY 2023	FY 2024	Total
FY 2020	TEC	…	5,000	…	…	…	…	5,000
	OPC	1,000	…	…	…	…	…	1,000
	TPC	1,000	5,000	…	…	…	…	6,000
FY 2021	TEC[a]	…	1,000	40,000	34,000	…	…	75,000
	OPC[ab]	1,000	…	…	…	…	1,000	2,000
	TPC[a]	1,000	1,000	40,000	34,000	…	1,000	77,000

6. Related Operations and Maintenance Funding Requirements

Start of Operation or Beneficial Occupancy (fiscal quarter or date)	1Q FY 2026[c]
Expected Useful Life (number of years)	50
Expected Future Start of D&D of this capital asset (fiscal quarter)	1Q FY 2076

[a] This project is pre-CD-2 and the funding estimates are preliminary. The funding estimates provided are based on the upper end of the TEC and TPC ranges.

[b] Other Project Costs (OPC) are funded through laboratory overhead.

[c] Schedules are estimates and are based on early completion dates. The schedule baseline with contingency will be established at CD-2.

Related Funding Requirements
(Budget Authority in Millions of Dollars)

	Annual Costs		Life Cycle Costs	
	Previous Total Estimate	Current Total Estimate[a]	Previous Total Estimate	Current Total Estimate
Operations and Maintenance	N/A	0.9	N/A	44.8

7. D&D Information

This project will be providing a new facility and does not include demolition of an existing facility. Construction of the new facility enables the reduction of Federal work from Battelle and leased space.

	Square Feet
New area being constructed by this project at Pacific Northwest National Laboratory	60000–90,000[b]
Area of D&D in this project at Pacific Northwest National Laboratory	None
Area at PNNL to be transferred, sold, and/or D&D outside the project, including area previously "banked"	None
Area of D&D in this project at other sites	None
Area at other sites to be transferred, sold, and/or D&D outside the project, including area previously "banked"	None
Total area eliminated	None

8. Acquisition Approach

The PNNL Management and Operating (M&O) contractor, Battelle Memorial Institute, will perform the acquisition activities for this Project, with oversight provided by the Pacific Northwest Site Office. Various acquisition approaches and project delivery methods were evaluated prior to achieving CD-1. A design/build best value technical qualification approach was selected as the best method to deliver the Grid Storage Launchpad facility. The contract will be competitively selected based on demonstrated competence and qualifications to perform the required services at a fair and negotiated maximum price.

[a] Operations and Maintenance cost based on the Life Cycle Cost Analysis associated with the Analysis of Alternatives. FIMS data for similar type facilities on the PNNL campus was used to estimate the annual value.
[b] Project is pre-CD-2. Specific KPPs will be established with the program office during CD-2 approval process.

Transformer Resilience and Advanced Components

Overview

The Transformer Resilience and Advanced Components (TRAC) program supports hardening, response, and restoration of electric infrastructure by addressing the unique challenges facing transformers, critical components, and other grid hardware technologies responsible for carrying, controlling, and converting electricity from where it is generated to where it is needed. As the electric power system evolves and the threat environment changes, early-stage R&D can help power-system stakeholders understand the physical impact these changes have on vital grid components, address fundamental performance limits, and identify new requirement, functions, and features necessary to enable a modernized grid that is more resilient and secure. Research in advanced power electronics, materials, and sensors will provide the fundamental physical capabilities and enhancements in next-generation grid hardware required to accommodate a rapidly changing power system, ensure all-hazards resilience to a more complex threat environment, and enable new grid architectures and operating paradigms. Program activities will ultimately address the need for real and reactive power flow control, facilitate the integration of grid-scale energy storage, and increase system efficiency, stability, and resilience.

Transformers, power lines, and substation equipment are often exposed to the elements and are vulnerable to an increasing number of natural and man-made threats. To enhance the security, reliability, and resilience of the electric power system, the next-generation of these grid hardware technologies will need to be designed and built to withstand and rapidly recover from the impact of extreme terrestrial or space weather events, electrical disturbances, equipment failures, accidents and deliberate attacks, and other unknowns. Other important characteristics include flexibility and adaptability to address the wide range of designs and specifications across these critical assets, facilitating interchangeability and sharing in emergency situations as highlighted in the July 2017 National Academies Report, *Enhancing the Resilience of the Nation's Electricity System*.[a] Additionally, greater deployment of distributed energy resources introduce new stresses from reverse power flows, increased harmonics, and challenges with control and protection coordination that can impact the reliability and lifetimes of current grid hardware, requiring new and expanded capabilities such as enhanced monitoring and embedded intelligence.

TRAC focuses on innovative designs, materials research, exploratory concepts (such as a high-voltage direct current backbone), and modeling and analysis to address the range of challenges associated with transformers and other grid components. Program activities, developed in close coordination with industry, aim to fill fundamental R&D gaps and encourage the adoption of new technologies and approaches. Next-generation solutions are urgently needed; the age of existing grid assets degrades their ability to withstand physical stresses and may result in higher failure rates that can lead to widespread outages and long restoration times. For example, failure of a large power transformer (LPT) (with 70% aged 25 years or older) can disrupt power to the equivalent of 500,000 homes and take over 12 months to procure, transport, and install a replacement. As a large percentage of these assets will be replaced in the near future, the timing is ripe for innovation to transition away from technologies that are outdated, expensive, less capable, and less resilient. Results of the TRAC program will help lay the foundation for the grid of the future by catalyzing advances in the underlying physical infrastructure.

Highlights of the FY 2021 Budget Request

TRAC will continue to address critical research needs for solid-state power substations (SSPS) with an emphasis on advanced materials, embedded intelligence for equipment monitoring, and capabilities to evaluate prototype converter building blocks.[b] The high voltage, high power, and high reliability requirements of grid applications present unique challenges for these technologies, especially when operating at higher frequencies. Greater utilization of high voltage power electronic converters within substations, including in hybrid and solid-state transformer applications, can provide power flow control capabilities and reactive power support, limit fault currents, and increase system reliability and resilience. Understanding the value and impact of these improved capabilities will benefit from high-fidelity modeling and simulation. Continued efforts in this cutting-edge technology concept can enable more flexible and adaptable designs that are interoperable with legacy systems, help reduce the criticality of substations, and facilitate integration of energy storage for enhanced resilience.

[a] https://www.nap.edu/catalog/24836/enhancing-the-resilience-of-the-nations-electricity-system

[b] https://energy.gov/oe/downloads/solid-state-power-substation-roadmapping-workshop-june-2017

Additionally, efforts will be pursued to establish a consortium of academics, vendors, national laboratories, other government agencies, and utilities to guide advancement of the SSPS vision.

Support of R&D activities through the Grid Modernization Laboratory Consortium (GMLC) will continue.

Transformer Resilience and Advanced Components
Funding ($K)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted ($)	FY 2021 Request vs FY 2020 Enacted (%)
Transformer Resilience and Advanced Components	**7,000**	**7,000**	**9,000**	**+2,000**	**+28.6%**

SBIR/STTR:

- FY 2019 Enacted: SBIR/STTR: $243
- FY 2020 Enacted: SBIR/STTR: $223
- FY 2021 Request: SBIR/STTR: $287

Transformer Resilience and Advanced Components
Explanation of Major Changes ($K)

	FY 2021 Request vs FY 2020 Enacted
• The request continues R&D of SSPS converter building blocks and expand efforts in evaluation and use case development for these novel technologies and concepts.	**+2,000**

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Transformer Resilience and Advanced Components **$7,000,000**	**$9,000,000**	**+$2,000,000**
• R&D of SSPS converter building blocks suitable for multiple grid applications, such as power flow controllers, hybrid transformers, and integration of energy storage • Continue applied materials research to address converter component limitations associated with the high voltage, high power, and high reliability requirements of the grid	• Establish modeling and testing capabilities to evaluate the performance and interoperability of SSPS building blocks • Continue applied materials research on converter components with an emphasis on packaging and embedded intelligence • Establish a consortium of diverse stakeholders around the SSPS vision to help guide technology development and maturation	• The increase reflects an expansion of efforts in evaluation and use case development for SSPS building blocks and associated concepts

Defense Critical Energy Infrastructure Energy Mission Assurance

Overview

The Defense Critical Energy Infrastructure (DCEI) Energy Mission Assurance program will identify, evaluate, prioritize, and assist in developing executable strategies to strengthen the energy infrastructure systems that supply critical infrastructure needed to ensure continuity of defense activities following severe natural and manmade disasters. Specifically, these investments will enable an increased confidence that necessary energy resources will be available to those locations designated by the Secretary of Energy as Defense Critical Infrastructure as codified by the 2015 Fixing America's Surface Transportation Act. These funds are necessary at a Federal level because the investments contemplated will be made for national security reasons and may be inconsistent with the responsibilities and regulatory frameworks of the utilities that otherwise supply energy resources to Defense Critical Facilities. Furthermore, these investments will be informed by DOE's Office of Intelligence and Counterintelligence in conjunction with the broader Intelligence Community, which is not available to traditional utility service providers at present.

Political, economic, and market forces drive efficiencies in our Nation's electric grid. Such efficiencies, however can have unintended consequences on the resilience of our Nation's Defense Critical Energy Infrastructure, which is targeted by adversaries. These funds will help mitigate such threats through a DCEI risk-management process and help identify strategic investments to help assure defense critical missions.

DCEI Energy Mission Assurance will capitalize on work led by DOE's Office of Electricity (OE) working with its Power Marketing Administrations, DOE's National Nuclear Security Administration, the Department of Homeland Security (DHS), the Department of Defense (DOD), the Army Corps of Engineers, the Bureau of Reclamation, and other energy infrastructure stakeholders, as appropriate. OE will provide technical assistance in design engineering, modeling, and analysis to help identify strategic investments in additional infrastructure to facilitate the mission of providing energy resources to Defense Critical Facilities.

Highlights of the FY 2021 Budget Request

The DCEI Energy Mission Assurance program's objective is to strengthen energy infrastructure systems for national security purposes.

Activities will be undertaken to begin to develop methodologies that improve the resiliency of providing electric power to Defense Critical Facilities, including development of electric power resiliency requirements and metrics for essential critical infrastructure nodes.

DCEI Energy Mission Assurance
Funding ($K)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted ($)	FY 2021 Request vs FY 2020 Enacted (%)
DCEI Energy Mission Assurance	**…**	**…**	**1,650**	**+1,650**	**N/A**

DCEI Energy Mission Assurance
Explanation of Major Changes ($K)

	FY 2021 Request vs FY 2020 Enacted
• This is a proposed new activity in FY 2021	+1,650

DCEI Energy Mission Assurance

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
DCEI Energy Mission Assurance $0	**$1,650,000**	**+$1,650,000**
	• Develop electric power resiliency requirements and metrics for essential critical infrastructure nodes • Develop electric power resiliency strategies and evaluation methodologies for Defense Critical Facilities • Identify and select at least one site for execution of a suite of site specific strategies	• This is a new budget line item to create strategies and identify requirements for resilient power systems for essential critical infrastructure nodes

Transmission Permitting and Technical Assistance

Overview

The mission of the Transmission Permitting and Technical Assistance (TPTA) program is to promote a resilient and reliable electricity system by addressing key institutional issues through a collaborative process with Federal, State, local, territorial, Tribal, regional, community, and industry decision makers.

TPTA's Technical Assistance program works with stakeholders to address emerging issues by enabling informed institutional decision-making that leads to prudent electric grid investment strategies and related practices. Decision makers are facing a complex set of issues affecting the planning and operating practices of the electric grid. Evolving Federal and State policies, the changing technology landscape, the emergence of new participants in the management of electricity, and the convergence of the electric grid with other infrastructures are key factors introducing increased levels of complexity and uncertainty in our grid management practices. In addition, the increasing interdependence between the electric grid and other key infrastructures, including natural gas, transportation, and communications, presents critical issues concerning fuel security and energy delivery reliability.

Integral to addressing this is TPTA's utilization of the Office of Electricity's North American Energy Resilience Model initiative, which is funded via the Transmission Reliability and Resilience program and can identify energy system interdependency risks, as well as potential infrastructure investments and risk mitigation strategies. TPTA works with the Power Marketing Administrations (PMAs) and other stakeholders to address these opportunities, especially those related to critical electric infrastructure investments, including Defense Critical Electric Infrastructure. Additionally, a key challenge is to establish effective institutional processes, particularly with regard to improved methods for planning and evaluation addressing the changing dynamics and uncertainties. TPTA's activities support the Administration's belief that the security and resilience of the Nation's energy system is of paramount importance.

TPTA also implements a number of legal authorities that seek to address grid reliability and security issues. TPTA assists the Secretary in timely responses to emergency circumstances resulting from an unexpected outage of grid assets in order to allow for reliable, uninterrupted provision of electric energy to citizens in such situations. TPTA issues Presidential permits and export authorization orders that facilitate U.S. border crossings of important international transmission line projects connecting the U.S. grid to reliable sources of power on the North American continent. TPTA implements a regulatory process intended to improve early coordination across Federal, State, and Tribal agencies and electricity providers for transmission lines that require multiple Federal authorizations, thereby facilitating more timely delivery of key electricity infrastructure. TPTA supports the Department's efforts to safeguard the integrity of critical electric infrastructure information provided to the Department in order to promote security of grid assets upon which the Nation relies. TPTA is also responsible for undertaking periodic transmission congestion, smart grid, and other congressionally mandated studies.

Highlights of the FY 2021 Budget Request

TPTA will continue to work closely with stakeholders to address emerging issues, particularly with regard to ensuring energy delivery within a changing energy landscape. A foundational part of TPTA's mission is to help States address key issues that will shape their respective programs, policies, and subsequent decisions on technological advancements associated with the energy infrastructure. Given the rapid advancement of technology and emerging complexity in planning and operating the energy infrastructure, State public utility commissions, energy offices, and legislative branches often lack the requisite experience, in-house experts, and resources to make fully informed decisions on approaches for addressing risks and formulating prudent policy and technology investment strategies.

TPTA is working with experts around the country, including the national laboratories and PMAs, to advance methods and approaches that can better address emerging challenges, including incorporating resilience into planning processes, developing effective grid modernization strategies, evaluating resource options, improving the coordination of planning and operations across the bulk power and distribution systems, and applying regulatory and business models that provide the appropriate incentives for building a resilient and efficient energy system. TPTA will provide support in these areas to State and other jurisdictional agencies seeking to advance their capabilities with respect to addressing these key challenges.

Work in these issue areas will result in the development of tools, reports, workshops, analyses, and interstate discussions that can help Federal, State, Tribal, territorial, and regional electricity officials make better informed decisions about their respective elements of the electricity system.

TPTA will also continue to carry out its regulatory responsibilities and evaluate regulatory reform to reduce the Federal burden associated with investing in our Nation's electricity infrastructure in several areas:

- Preparing and publishing DOE's annual Economic Dispatch Report, annual Transmission Data Review, biennial Smart Grid Systems Reports, and triennial national electric transmission congestion studies;
- Conducting environmental review and technical analyses needed for Federal authorization of transmission projects that cross U.S. international borders;
- Coordinating Federal permitting by other agencies of new transmission infrastructure that involves Federal authorizations, as required by Section 216(h) of the Federal Power Act;
- Supporting DOE efforts to implement E.O. 13807 "One Federal Decision" requirements in coordination with those found in Title 41 of the Fixing America's Surface Transportation (FAST) Act;
- Evaluating any new applications under Section 1222 of the Energy Policy Act of 2005, which authorizes DOE to participate in third-party-financed transmission projects within the Western Area Power Administration (WAPA) and the Southwestern Power Administration (SWPA) regions;
- Leading implementation of Section 215A of the Federal Power Act, which authorizes DOE to protect critical electric infrastructure information (CEII) from inappropriate release under the Freedom of information Act and other "sunshine" laws.
- Supporting the Secretary of Energy during electricity emergencies when implementing Section 202(c) of the Federal Power Act; and
- Facilitating the Electricity Advisory Committee, established in accordance with the provisions of the Federal Advisory Committee Act (FACA).

Transmission Permitting and Technical Assistance
Funding ($K)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted ($)	FY 2021 Request vs FY 2020 Enacted (%)
Transmission Permitting and Technical Assistance	**7,000**	**7,000**	**7,000**	**0**	**0.0%**

Transmission Permitting and Technical Assistance
Explanation of Major Changes ($K)

	FY 2021 Request vs FY 2020 Enacted
• Funding is proposed at the FY 2020 level	**0**

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Transmission Permitting and Technical Assistance **$7,000,000**	**$7,000,000**	**$0**
• Develop grid resilience tools and analyses to help State electricity officials promote prudent, strategic decision-making • Provide technical assistance to Federal, State, Tribal, territorial, and regional entities for current and future electricity-related issues • Continue to implement regulatory responsibilities and evaluate regulatory reform to reduce Federal burden • Support for technical assistance work to provide stakeholders an in-depth understanding of the resilience of the electricity and related infrastructure • Provide institutional support to potential infrastructure investments that addresses the vulnerabilities of the North American energy system	• Develop grid resilience tools and analyses to help State electricity officials promote prudent, strategic decision-making • Provide technical assistance to Federal, State, local, territorial, Tribal, and regional entities to address key challenges in the energy system • Continue to implement regulatory responsibilities and evaluate regulatory reform to reduce federal burden • Support for technical assistance work to provide stakeholders an in-depth understanding of the resilience of the electric grid and related infrastructure • Provide institutional support to potential critical electric infrastructure investments that address the vulnerabilities of the North American energy system	• Funding is proposed at the FY 2020 level

Program Direction

Overview

Program Direction provides for the costs associated with the Federal workforce, including salaries, benefits, travel, training, building occupancy, IT services, security clearance, and other related expenses. It also provides for the costs associated with contractor services that, under the direction of the Federal workforce, support the Office of Electricity (OE) mission.

Salaries and Benefits support Federal employees who provide executive management, programmatic oversight, and analysis for the effective implementation of the OE program. This includes staff at Headquarters and at the National Energy Technology Laboratory (NETL). While OE funds NETL staff within its budget, the NETL Federal employees are included within the full-time equivalent (FTE) total for the Fossil Energy Research and Development account.

Travel includes transportation, subsistence, and incidental expenses that allow OE to effectively manage research and development programs and projects in the field; to provide the Department's electricity-related outreach to regions, states, and tribes with regard to planning needs and issues, policies, siting protocols, and new energy facilities.

Support Services includes contractor support directed by the Federal staff to perform administrative tasks and provide analysis to management. These efforts include issue-oriented support on science, engineering, environment, and economics that benefit strategic planning; technology and market analysis to improve strategic and annual goals; development of management tools and analyses to improve overall office efficiency; assistance with communications and outreach to enhance OE's external communication and responsiveness to public needs; development of program-specific information tools that consolidate corporate knowledge, performance tracking and inventory data, improve accessibility to this information, and facilitate its use by the entire staff; and also may include support for post-doctoral fellows (such as American Association for the Advancement of Science [AAAS] fellows) and Intergovernmental Personnel Act (IPA) assignments.

Other Related Expenses includes corporate IT support (DOE's Energy Information Technology Services [EITS] desktop services) and working capital fund (WCF) expenses, such as rent, supplies, copying, graphics, mail, printing, and telephones. It also includes equipment upgrades and replacements, commercial credit card purchases using simplified acquisition procedures where possible, security clearance expenses, and other needs.

Program Direction
Funding ($K)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted ($)	FY 2021 Request vs FY 2020 Enacted (%)
Program Direction Summary					
Washington Headquarters					
Salaries and Benefits	8,565	9,789	10,972	+1,183	+12.1%
Travel	350	350	350	0	0.0%
Support Services	1,448	1,254	1,295	+41	+3.3%
Other Related Expenses	3,461	3,034	3,320	+286	+9.4%
Total, Washington Headquarters	**13,824**	**14,427**	**15,937**	**+1,510**	**+10.5%**
National Energy Technology Laboratory					
Salaries and Benefits	1,699	1,698	1,700	+2	+0.1%
Travel	180	180	180	0	0.0%
Support Services	370	371	371	0	0.0%
Other Related Expenses	927	1,324	1,457	+133	+10.0%
Total, National Energy Technology Laboratory	**3,176**	**3,573**	**3,708**	**+135**	**+3.8%**
Total Program Direction					
Salaries and Benefits	10,264	11,487	12,672	+1,185	+10.3%
Travel	530	530	530	0	0.0%
Support Services	1,818	1,625	1,666	+41	+2.5%
Other Related Expenses	4,388	4,358	4,777	+419	+9.6%
Total, Program Direction	**17,000**	**18,000**	**19,645**	**+1,645**	**+9.1%**
Federal FTEs	**52**	**62**	**62**	**0**	**0.0%**
Additional FE FTEs at NETL supporting OE[a]	12	12	12	0	0.0%
Total OE-funded FTEs	64	74	74	0	0.0%

[a] OE funds 12 FTEs at FE's National Energy Technology Laboratory who support OE activities. The 12 FTEs are in FE's FTE totals and are not included in the OE FTE totals shown on the "Federal FTEs" line.

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted ($)	FY 2021 Request vs FY 2020 Enacted (%)
Support Services and Other Related Expenses					
Support Services					
Technical Support	873	780	890	+110	+14.1%
Management Support	945	845	776	-69	-8.2%
Total, Support Services	**1,818**	**1,625**	**1,666**	**+41**	**+2.5%**
Other Related Expenses					
Other Services	1,606	1,444	1,593	+149	+10.3%
EITS Desktop Services	446	380	400	+20	+5.3%
WCF	2,336	2,534	2,784	+250	+9.9%
Total, Other Related Expenses	**4,388**	**4,358**	**4,777**	**+419**	**+9.6%**

Program Direction

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Program Direction $18,000,000	**$19,645,000**	**+$1,645,000**
Salaries and Benefits $11,487,000 • Salaries and Benefits support 74 FTEs at HQ and NETL that provide executive management, programmatic oversight, and analysis for the effective implementation of the OE program	**$12,672,000** • Salaries and Benefits support 74 FTEs at HQ and NETL that provide executive management, programmatic oversight, and analysis for the effective implementation of the OE program	**+$1,185,000** • Increase due to full-year funding of new FTEs hired late in FY 2020
Travel $530,000 • Travel includes transportation, subsistence, and incidental expenses that allow OE to effectively facilitate its mission	**$530,000** • Travel includes transportation, subsistence, and incidental expenses that allow OE to effectively facilitate its mission	**$0** • Unchanged

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Support Services $1,625,000 • Support Services includes contractor support directed by the Federal staff to perform administrative tasks and provide analysis to management. Support Services may include support for post-doctoral fellows and IPA assignments	**$1,666,000** • Support Services includes contractor support directed by the Federal staff to perform administrative tasks and provide analysis to management. Support Services may include support for post-doctoral fellows and IPA assignments	**+$41,000** • Increase in support services while Federal staff is being trained
Other Related Expenses $4,358,000 • Other Related Expenses includes EITS desktop services and WCF expense, such as rent, supplies, copying, graphics, mail, printing, and telephones. It also includes equipment upgrades and replacements, commercial credit card purchases using the simplified acquisition procedures to the maximum extent possible, security clearance expenses and other needs	**$4,777,000** • Other Related Expenses includes EITS desktop services and WCF expense, such as rent, supplies, copying, graphics, mail, printing, and telephones. It also includes equipment upgrades and replacements, commercial credit card purchases using the simplified acquisition procedures to the maximum extent possible, security clearance expenses and other needs	**+$419,000** • Other Related Expenses due to additional training, IT equipment and WCF expenses associated with the Federal FTEs hired in late FY 2020, and an increase in NETL's cost share

Electricity

Research and Development ($K)[a]

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted ($)	FY 2021 Request vs FY 2020 Enacted (%)
Basic	14,702	15,404	14,008	-1,396	-9.1%
Applied	75,110	67,881	54,527	-13,354	-19.7%
Development	45,933	70,584	61,480	-9,104	-12.9%
Total, R&D	135,745	153,869	130,015	-23,854	-15.5%
R&D-related construction	0	1,105	44,523	+43,418	+3,929.2%
Total, R&D and related facilities	135,745	154,974	174,538	+19,564	+12.6%

Electricity

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

	FY 2019 Enacted Transfer	FY 2020 Enacted Projected Transfer	FY 2021 Request Projected Transfer	FY 2021 Request vs FY 2020 Enacted ($)	FY 2021 Request vs FY 2020 Enacted (%)
Transmission Reliability and Resilience	1,273	1,731	1,961	+230	+13.3%
Resilient Distribution Systems	1,313	1,359	560	-799	-58.8%
Energy Storage	1,389	1,618	1,310	-308	-19.0%
Transformer Resilience and Advanced Components	243	223	287	+64	+28.7%
Total, SBIR/STTR	4,218	4,931	4,118	-813	-16.5%

[a] R&D reporting includes a proportional share of program direction funding in addition to direct R&D funding.

DEPARTMENT OF ENERGY
Funding by Site Detail
Electricity
(Dollars in Thousands)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request
Ames Laboratory			
Resilient Distribution Systems	75	0	0
Transformer Resilience and Advanced Components	450	0	0
Total Ames Laboratory	**525**	**0**	**0**
Argonne National Laboratory			
Transmission Reliability and Resilience	5,327	5,000	5,000
Resilient Distribution Systems	2,072	759	750
Energy Storage	525	0	0
Transmission Permitting and Technical Assistance	0	125	125
Total Argonne National Laboratory	**7,924**	**5,884**	**5,875**
Brookhaven National Laboratory			
Transmission Reliability and Resilience	1,400	500	500
Total Brookhaven National Laboratory	**1,400**	**500**	**500**
Idaho National Laboratory			
Transmission Reliability and Resilience	1,221	750	750
Resilient Distribution Systems	250	900	900
Energy Storage	38	0	0
Transformer Resilience and Advanced Components	861	300	300
Program Direction - Electricity	7	0	0
Total Idaho National Laboratory	**2,376**	**1,950**	**1,950**
Lawrence Berkeley National Laboratory			
Transmission Reliability and Resilience	1,844	250	250
Resilient Distribution Systems	1,060	460	450
Energy Storage	810	0	0
Transformer Resilience and Advanced Components	15	0	0
Transmission Permitting and Technical Assistance	743	1,330	1,330
Total Lawrence Berkeley National Laboratory	**4,472**	**2,040**	**2,030**
Lawrence Livermore National Laboratory			
Transmission Reliability and Resilience	4,593	1,750	1,750
Resilient Distribution Systems	2,030	1,750	1,750
Energy Storage	663	0	0
Total Lawrence Livermore National Laboratory	**7,285**	**3,500**	**3,500**
Los Alamos National Laboratory			
Transmission Reliability and Resilience	3,700	2,000	2,000
Resilient Distribution Systems	912	1,273	1,200
Total Los Alamos National Laboratory	**4,612**	**3,273**	**3,200**
National Energy Technology Lab			
Transformer Resilience and Advanced Components	25	2,500	4,500
Program Direction - Electricity	2,266	2,983	3,118
Total National Energy Technology Lab	**2,291**	**5,483**	**7,618**

DEPARTMENT OF ENERGY
Funding by Site Detail
Electricity
(Dollars in Thousands)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request
National Renewable Energy Laboratory			
Transmission Reliability and Resilience	660	2,500	2,500
Resilient Distribution Systems	2,470	3,351	1,600
Energy Storage	127	0	0
Transformer Resilience and Advanced Components	79	0	0
Transmission Permitting and Technical Assistance	85	280	280
Total National Renewable Energy Laboratory	**3,421**	**6,131**	**4,380**
Oak Ridge National Laboratory			
Transmission Reliability and Resilience	2,488	20,900	20,000
Resilient Distribution Systems	4,693	11,076	1,000
Energy Storage	4,525	3,500	4,000
Transformer Resilience and Advanced Components	2,525	3,000	3,000
Transmission Permitting and Technical Assistance	155	0	0
Total Oak Ridge National Laboratory	**14,386**	**38,476**	**28,000**
Pacific Northwest National Laboratory			
Transmission Reliability and Resilience	9,219	12,750	12,850
Resilient Distribution Systems	10,043	6,182	5,000
Energy Storage	16,624	15,000	16,000
Transformer Resilience and Advanced Components	340	0	0
DCEI Energy Mission Assurance	0	1,000	40,000
Transmission Permitting and Technical Assistance	1,373	600	600
Total Pacific Northwest National Laboratory	**37,599**	**35,532**	**74,450**
Sandia National Laboratories			
Transmission Reliability and Resilience	3,812	2,500	2,500
Resilient Distribution Systems	4,379	2,100	2,100
Energy Storage	20,156	20,500	21,000
Transformer Resilience and Advanced Components	525	525	550
Transmission Permitting and Technical Assistance	388	100	100
Total Sandia National Laboratories	**29,260**	**25,725**	**26,250**
Savannah River National Laboratory			
Transmission Reliability and Resilience	125	0	0
Resilient Distribution Systems	125	0	0
Transformer Resilience and Advanced Components	125	0	0
Total Savannah River National Laboratory	**375**	**0**	**0**
SLAC National Accelerator Laboratory			
Transmission Reliability and Resilience	400	0	0
Resilient Distribution Systems	1,175	500	0
Energy Storage	100	0	0
Total SLAC National Accelerator Laboratory	**1,675**	**500**	**0**
Southwestern Power Administration Office			
Resilient Distribution Systems	0	6,750	2,250
Total Southwestern Power Administration Office	**0**	**6,750**	**2,250**

DEPARTMENT OF ENERGY
Funding by Site Detail
Electricity
(Dollars in Thousands)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request
Washington Headquarters			
Transmission Reliability and Resilience	237	300	300
Resilient Distribution Systems	648	450	200
Energy Storage	361	300	300
Transformer Resilience and Advanced Components	812	432	322
DCEI Energy Mission Assurance	0	0	825
Transmission Permitting and Technical Assistance	2,547	3,315	3,315
Program Direction - Electricity	13,967	14,320	15,831
Total Washington Headquarters	**18,572**	**19,117**	**21,093**
Western Area Power Administration Office			
Transmission Reliability and Resilience	250	0	0
Resilient Distribution Systems	350	0	0
Transformer Resilience and Advanced Components	150	0	0
Total Western Area Power Administration Office	**750**	**0**	**0**
Grants			
Transmission Reliability and Resilience	3,720	7,781	7,542
Resilient Distribution Systems	8,864	9,143	668
Energy Storage	1,871	10,362	1,416
Transformer Resilience and Advanced Components	1,093	243	328
Transmission Permitting and Technical Assistance	1,710	1,250	1,250
Program Direction - Electricity	760	697	696
Total Grants	**18,018**	**29,476**	**11,900**
Undesignated LPI			
Transmission Reliability and Resilience	4	19	8
Resilient Distribution Systems	854	306	432
Energy Storage	200	5,338	784
DCEI Energy Mission Assurance	0	0	825
Total Undesignated LPI	**1,057**	**5,663**	**2,049**

Cybersecurity, Energy Security, and Emergency Response

Cybersecurity, Energy Security, and Emergency Response

Cybersecurity, Energy Security, and Emergency Response
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 sector cybersecurity, energy security, and emergency response 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, **[**$156,000,000**]** *$184,621,000*, to remain available until expended: Provided, That of such amount, [$13,000,000] *$11,521,000* shall be available until September 30, **[**2021**]** *2022*, for program direction. *(Energy and Water Development and Related Agencies Appropriations Act, 2020.)*

Public Law Authorizations
Public Law 95–91, "Department of Energy Organization Act", 1977
Public Law 109-58, "Energy Policy Act of 2005"
Public Law 110-140, "Energy Independence and Security Act, 2007"
Public Law 114-94, "Fixing America's Surface Transportation Act", 2015

Cybersecurity, Energy Security, and Emergency Response
($K)

FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY2020 Enacted
120,000	156,000	184,621	28,621

Overview

With the release of the Office of the Director of National Intelligence's Worldwide Threat Assessment in February 2019, the risk to the U.S. energy infrastructure is highlighted. The Assessment stated Russia is "staging cyber attack assets to allow it to disrupt or damage U.S. civilian and military infrastructure during a crisis."[a] It said Russia now "has the ability to execute cyber attacks in the United States that generate localized, temporary disruptive effects on critical infrastructure—such as disrupting an electrical distribution network for at least a few hours."[b] Since March 2016, Russian government cyber actors have targeted multiple U.S. government entities and critical American energy, nuclear, and manufacturing sectors. In addition, China has the ability to launch a cyberattack causing localized, temporary disruptive effects on critical infrastructure – including disruptions to natural gas pipelines that could last for days and weeks. The increasingly sophisticated cybersecurity exploit capabilities of our adversaries, coupled with changes to the cyber-physical control of our Nation's energy systems, have made it extremely challenging for the energy sector to stay ahead of a fast-evolving risk landscape.

The Department of Energy's (DOE's) Office of Cybersecurity, Energy Security, and Emergency Response (CESER) leads the Department's efforts to secure U.S. energy infrastructure against all hazards, reduce the risks of and impacts from cyber events and other disruptive events, and assist with restoration activities. CESER is the Office responsible for DOE's responsibilities as lead agency for Emergency Support Function #12 (Energy), or ESF #12, under the National Response Framework, and is the Energy Sector-Specific Agency for national efforts to enhance the preparedness, resiliency, and recovery of the U.S. energy infrastructure from all threats and hazards.

Due to the critical role the energy sector plays across Federal, State, and local jurisdictions, CESER programs work in an integrated manner in partnership with industry and other stakeholders, as well as other DOE offices and other federal agencies, to enhance the resilience (the ability to withstand and quickly recover from disruptions and maintain critical function) and security (the ability to reduce risks in the protection system assets and critical functions from unauthorized access and actions) of the U.S. energy infrastructure. Reliable, resilient, and secure energy infrastructure is critical to U.S. economic competiveness, innovation, and leadership.

Within the appropriation, CESER funds:

- Research and Development (R&D) to deliver game-changing tools and technologies that help utilities secure and reduce risks to today's energy infrastructure from advanced cyber threats and design next-generation systems that are built from inception to automatically detect, reject, and withstand cyber incidents, regardless of the threat.
- Public and private-sector partnerships to strengthen the energy sector's cybersecurity posture, leveraging DOE-supported tools, guidelines, outreach, training, and technical assistance.
- Emergency preparedness and response, supporting the energy sector, to pursue enhancements to national efforts, in cooperation with public and private-sector stakeholders, for preparedness, resilience, and recovery of U.S. energy infrastructure from all threats and hazards.

Highlights and Major Changes in the FY 2021 Budget Request

- **Cybersecurity for Energy Delivery Systems (CEDS)** ($103,100,000; +$8,100,000) seeks to accelerate and expand efforts to strengthen the energy infrastructure against cyber threats and mitigate vulnerabilities. Working closely with the energy sector and our government partners, the request focuses on enhancing the speed and effectiveness of threat and vulnerability information sharing, including bi-directional machine-to-machine information sharing, and accelerating game-changing R&D to mitigate cyber incidents in today's systems and to develop next-generation resilient

[a] https://www.dni.gov/files/ODNI/documents/2019-ATA-SFR---SSCI.pdf
[b] https://www.dni.gov/files/ODNI/documents/2019-ATA-SFR---SSCI.pdf

energy delivery systems while developing analyses to quantify the resulting relative risk reduction. For instance, research could accelerate development of artificial intelligence (AI) techniques for critical energy delivery infrastructure, such as machine learning using data generated by the underlying physical process of energy delivery as well as data generated by the cyber-systems that control that physical process, to provide for an automatic response to cyber-attack. Such AI techniques might allow for energy delivery systems or components, such as generation plants, to automatically adapt operations and survive a cyber-attack that would otherwise disrupt energy delivery. The increase from the FY 2020 appropriation is supporting the acceleration of research and development initiatives in particular for the Cybersecurity for the Operational Technology Environment (CyOTE™) building upon the initial pilot activities which includes $15,000,000 to test and analyze the scalability of technology and vendor neutral approaches. This type approach includes the secure cloud storage and access controls to ensure DOE has access controls capabilities which are designed to limit access to data based on individual energy sector company's data-sharing. The CEDS request includes $20,000,000 for the application of state-of-the-art capabilities including the continued development and operation of the Cyber Analytics Tools and Techniques 2.0 (CATT™ 2.0) program, which is designed to provide the energy sector with situational awareness and actionable information to support discovery and mitigation of advance cyber threats to the U.S. energy infrastructure enriched with classified threat information and unique analytical tradecraft owned by the U.S. Government. The capabilities will include the ability to pre-process data to filter redundant data, anonymize/de-anonymize, and tag data from different sources into a standardized format for CATT™ analytics. Establishment of a national physical energy system and component testing capability designed specifically to look at the vulnerabilities of the energy sector from threats such as electromagnetic pulses (EMP) and geomagnetic disturbances (GMD).

- **Infrastructure Security and Energy Restoration (ISER)** ($70,000,000; +$22,000,000) coordinates a national effort to secure U.S. energy infrastructure against all hazards, reduce impacts from disruptive events, and assist industry with restoration activities. ISER delivers critical capabilities including energy sector emergency response and recovery (including emergency response of a cyber nature); near-real-time situational awareness and information sharing about the status of the energy systems to improve risk management; analysis of evolving threats and hazards to energy infrastructure; and technical assistance that incorporates exercises in order to strengthen Federal, regional, State, local, tribal, and territorial (SLTT) abilities to work together to prepare for and mitigate the effects of an energy sector emergency. By working with the SLTT energy community to plan and develop mitigations, the Nation's energy systems will become more secure and resilient.

FY 2019 Key Accomplishments

Emergency Response: In 2019, CESER's Infrastructure Security and Emergency Response (ISER) division led successful responses to multiple catastrophic hurricanes and typhoons – including Hurricane Dorian and Typhoon Bualoi – supported National Special Security Events, and monitored major wildfires. CESER's Emergency Support Function #12 (ESF#12) team was activated for 79 days in 2019 and played an integral role in restoration, recovery, and energy security efforts in at least six states.

Enhanced Energy Sector Situational Awareness Capabilities: CESER continues to enhance the capabilities of ISER's situational awareness platform, EAGLE-I™. In FY 2019, DOE worked with state partners to further improve EAGLE-I™ coverage, by importing power outage information directly from South Carolina's Palmetto system and by automatically importing outage information posted by the Florida State Emergency Operations Center during incidents, such as a hurricane. DOE also implemented an outage override tool to allow deployed DOE responders to add the latest information directly from utilities or state partners for areas not covered by EAGLE-I™ or when automated feeds are not working. Finally, DOE released a call for proposals to the DOE National Laboratories for new capabilities to incorporate into EAGLE-I™ that will provide enhanced situational awareness and support interagency, industry, state, local, tribal, and territorial partners with incident preparedness and response.

Cyber Testing for Industrial Control Systems (CyTRICS™): CESER continued to formalize the CyTRICS™ program through the establishment of a strategic program plan that includes three pillars: governance, test operations, and analytics and information sharing. DOE has been leveraging its National Laboratories, with Idaho National Laboratory being the technical lead laboratory and conducting test operations, Sandia National Laboratory and Lawrence Livermore National Laboratories bringing their unique expertise and capabilities to support testing, and Pacific Northwest National Laboratory as the data repository for test results and threat analytics. CESER has started testing equipment, developed a test operations manual, is working with energy sector owners and operators on developing a risk-based prioritization methodology that takes into

account defense critical electric infrastructure and national critical functions, and has started discussions with critical industrial control system (ICS) vendor developing a partnership to advance this effort together through a coordinated vulnerability disclosure program for the energy sector.

Center for EMP/GMD Simulation, Modeling, Analysis, Research, and Testing (CE-SMART): While risk management activities for both electromagnetic pulse (EMP) threats and geomagnetic disturbance (GMD) hazards have been important to DOE for years, this past year saw a renewed focus on these topics, working closely with industry and government partners. ISER staff were heavily engaged in the development and implementation of Executive Order 13865, "Coordinating National Resilience to Electromagnetic Pulses," dated March 26, 2019, working closely with partners across the interagency. This included identification of critical energy sector assets, systems, and networks (with their respective architectures) and the national critical functions they support, all to assist prioritized application of protective measures and new designs. DOE continues to lead the development of unclassified waveforms in conjunction with our industry partners that can be used in the design of protective systems. Progress has also been made on the design and approach for several pilots to test different devices for the protection of large transformers from the effects of large GMD from solar storms. Several reports were finalized and released to help share the results of past studies to industry and government partners to improve their risk management decisions.

Clear Path VII Exercise: DOE's most recent exercise, Clear Path VII, took place in Memphis, Tennessee, in April 2019. This iteration examined the energy sector's response and restoration roles, responsibilities, plans, and procedures following a major earthquake along the New Madrid Seismic Zone. The exercise brought together more than 160 individuals from more than 80 organizations representing Federal and State governments; the electricity and oil and natural gas subsectors; the transportation, water, and communications sectors.

State, Local, Tribal, and Territorial Capacity Building for Energy Security: CESER released guidance and tools with National Association of Regulatory Utility Commissioners that enable state public utility commissioners to understand and assess the maturity of utilities' cybersecurity risk management practices. Working with National Association of State Energy Officials, CESER established an energy security accelerator to guide energy security planning and coordination in U.S. territories and remote communities of Alaska and hosted statewide and multi-state workshops to test emergency planning and response capabilities for natural gas and fuel supply disruptions caused by natural disaster or cyber intrusion. To institutionalize the fundamentals of energy security planning and provide new and continued learning for state energy security planners and emergency responders, CESER outlined an online training framework that will go live in 2020. With American Public Power Association, CESER facilitated a storm preparedness and resilience workshop in the U.S. Virgin Islands for the municipal power authority and local stakeholders to improve preparedness and resilience measures made since the 2017 hurricane season.

CEDS supports research and development of new tools and technologies to enhance situational awareness and cybersecurity of critical energy infrastructure, through research partnerships that engage universities, national laboratories, energy asset owners and operators, and suppliers, focused on the innovation of cybersecurity technologies that will be useful, and used throughout the energy sector. Each research partnership, whether led by industry, academia or national laboratories, is expected to establish a clear path toward industry acceptance and transition to practice of the research results, from the earliest stages of the research. The CEDS R&D Program supports promising energy sector cybersecurity technologies through annual competitive solicitations by providing federal funding and oversight. Here are a few FY 2019 key accomplishments:

- **Software Defined Radio (SDR)**: As of early 2019, Schweitzer Engineering Laboratories' (SEL's) versatile radio platform is now a commercially available product from SEL. This radio platform supports strong passwords, event and device access logging, and advanced encryption and authentication, while offering data throughput that is 3-4 times faster than conventional radios.
- **Cyber-Attack Detection and Accommodation for Energy Delivery Systems**: General Electric has validated the Cyber-Attack Detection and Accommodation technology with the simulation in the loop (SIL) environment containing Global Detection (GD). The plant model was based on 7FA.05 gas turbine and was evaluated under conditions of a sensor bias injection attack under otherwise normal operation. Then the system was tested in off-nominal conditions, that is, outside those used for training the algorithm. Environmental conditions such as

temperature, pressure, humidity and compressor/turbine efficiency were modified and the sensor bias attack was detected.

- **Autonomous Tools for Attack Surface Reduction**: Iowa State University (ISU) performed the field deployment and testing of their Attack Surface Reduction technology. ISU researchers and Cedar Falls Utilities (CFU) engineers have worked collaboratively to successfully implement and test Security information and event management (SIEM)-based Intrusion Detection System (IDS) at the CFU Control Center and a substation.
- **Enabling Situational Awareness Project**: The Pacific Northwest National Laboratory (PNNL) "Enabling Situational Awareness" project has developed a cybersecurity situation awareness visualization dashboard to bridge the communication gap between transmission control room operators and cybersecurity professionals during cyber events. The project successfully deployed the visualization dashboard for the final hands-on usability testing at Western Area Power Administration's (WAPA) training facilities in Lakewood, CO, and Folsom, CA.

Anonymization Tool for Operational Technology (OT) Data Analysis: As part of CESER, the Cyber Analytic Tools and Techniques™ 2.0 (CATT™ 2.0) program team was tasked with finding a solution to address the risk of inadvertently exposing analysts to sensitive information in volumes of utility company network data shared with DOE. The CATT™ 2.0 team defined two kinds of information of specific interest: EII – Entity identifiable information and DII – Device identifiable information. The CATT™ 2.0 team began searching for existing technologies to anonymize and de-anonymize the sensitive data. Through an Expression of Interest publication it was determined many available tools are tightly coupled to a service offering, with only a few able to stand alone. The testing process revealed that, of the tools able to stand-alone, for the ones within this test complement, system configuration and data issues make them unworkable as a CATT™ 2.0 solution. Idaho National Laboratory developed a tool specifically to address the gap identified in commercial anonymization tools for CATT™ 2.0.

Cybersecurity for Operational Technology Environments (CyOTE™): The CESER supported CyOTE™ program developed analytic tools and procedures to receive, store and analyze partner utility data in the initial CyOTE™ pilot. The analysis lead to the processes for identifying anomalous behavior on Operational Technology (OT) networks to provide increased situational awareness and identify potential vulnerabilities.

Cybersecurity, Energy Security, and Emergency Response
Funding by Congressional Control ($K)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted	% Change FY 2021 Request vs FY 2020 Enacted
Cybersecurity for Energy Delivery Systems	89,500	95,000	103,100	+8,100	+9%
Infrastructure Security and Energy Restoration	19,000	48,000	70,000	+22,000	+46%
Program Direction	11,500	13,000	11,521	-1,479	-12%
Total, Cybersecurity, Energy Security, and Emergency Response	**120,000**	**156,000**	**184,621**	**+28,621**	**+19%**
Federal Full Time Equivalent Employees (FTEs)	**25**	**27**	**43**	**+16**	**+59%**
Additional FE FTEs at NETL supporting CESER[a]	9	9	9	0	0
Total CESER-funded FTEs	34	36	52	+16	+44%

SBIR/STTR:

- FY 2019 Enacted: SBIR/STTR: $1,607
- FY 2020 Enacted: SBIR/STTR: $1,169
- FY 2021 Request: SBIR/STTR: $2,060

[a] CESER funds FTEs at FE's National Energy Technology Laboratory who are FE employees, but support CESER activities. The FTEs are in FE's FTE totals and are not included in the CESER's FTE totals shown on the "Federal Full Time Equivalent Employees (FTEs)" line.

Cybersecurity for Energy Delivery Systems

Overview

The Nation's energy infrastructure is a major cyberattack target for malicious external actors. Over the past decade, the frequency and sophistication of cyber-attacks have increased as adversaries advanced their tactics from scanning to reconnaissance to full compromise of critical energy control systems. Given the Nation's growing dependence on electricity and fuels and increasing interdependencies with communication systems and other critical infrastructures, a major attack could cause wide-ranging national security and economic impacts. Cyber risks from operator error, software upgrades, and equipment failures have also grown as the Nation's electricity and fuel delivery systems have become more complex and interdependent. As a result, energy cybersecurity and resilience are among the Nation's most urgent security challenges.

The 2015 and 2016 cyber-attacks on the Ukraine electrical distribution system demonstrated the vulnerability of power grids to cyber events and the advanced capabilities of our cyber adversaries. The 2015 attack knocked out power to 225,000 customers for several hours. Attackers used spear phishing emails to gain initial access to utility information technology (IT) networks. The hackers then went undetected for nine months as they stole credentials using keystroke loggers, identified hosts and devices, and hijacked the supervisory control and data acquisition (SCADA) data management system (DMS) to systematically open breakers and cause a power outage. The attackers' ability to perform long-term reconnaissance operations and execute a highly synchronized, multistate, multisite attack represents a step change in sophistication and intent. Subsequent cyber-attacks targeting U.S. energy systems have shared some traits with those seen during the Ukraine events.

Securing and managing cyber risk to operating systems within the energy sector and ensuring reliable energy delivery is a major challenge for the U.S. and our global partners. The dramatic increase across multiple attack vectors, such as probes, innovative social engineering, and malware exploits, has strained the financial, technical, and human resources of energy companies as they continuously adjust to manage a new risk paradigm. The rapid pace of technology and market changes is also transforming the energy business. Grid modernization is introducing new technologies to better manage increasingly complex transmission and distribution systems. Advanced information and communications technologies that improve reliability, increase situational awareness, enhance asset management, and speed recovery from unplanned outages are being widely deployed by companies throughout the sector. While benefits of these new cyber-based systems have been clearly demonstrated, they also increase the cyber-attack surface and require innovative cyber risk management approaches and continuous monitoring to ensure appropriate levels of risk management and security. Simply put, the rapid pace of change in the cyber-physical control of energy systems, coupled with the advancing cyber exploit capabilities of our adversaries, have made it extremely challenging for the energy sector to stay ahead of the escalating cyber risk landscape they face.

The *National Cyber Strategy*[a] of the United States demonstrates the Administration's commitment to strengthening our Nation's cybersecurity capabilities, specifically working in partnership with the private sector to secure critical infrastructure. DOE has been collaborating with the energy sector for nearly two decades in a voluntary public-private partnership to identify and mitigate physical and cyber risks to energy systems. Through this partnership, DOE has earned the trust of energy companies and helped accelerate the mutual exchange of information and deployment of new technology, tools, and best practices to improve security and resilience. The Cybersecurity, Energy Security, and Emergency Response (CESER) office aligns all activities with the Administration's *National Cyber Strategy.*

The *National Cyber Strategy* prioritizes risk-reduction activities across seven key areas, which include national security and energy and power. The CESER activities closely aligns to the Secure Critical Infrastructure section of Pillar I – Protecting the American People, the Homeland, and the American Way of Life, Prioritize Actions According to Identified National Risks, which states:

> The Federal Government will work with the private sector to manage risks to critical infrastructure at the greatest risk. The Administration will develop a comprehensive understanding of national risk by identifying national critical functions and will mature our cybersecurity offerings and engagements to better manage those national risks.

[a] https://www.energy.gov/sites/prod/files/2018/10/f57/National-Cyber-Strategy.pdf

The CESER office activities also advance the goals of the *U.S. Department of Energy (DOE) Strategic Plan 2014-2018.*[a] In particular, with the Strategic Objective 2, titled "Support a more economically competitive, environmentally responsible, secure and resilient U.S. energy infrastructure."

The Budget Request for CEDS focuses on two key activities:

- Enhancing the speed and effectiveness of threat and vulnerability information sharing, including bi-directional machine-to-machine information sharing; and
- Accelerating game-changing R&D to mitigate cyber incidents in today's systems and to develop next-generation resilient energy delivery systems while developing analyses to quantify the resulting relative risk reduction.

CEDS supports a R&D portfolio to address the energy sector's key technology challenges as described in the *National Cyber Strategy*. National laboratory participation in CEDS research projects also ensures critical skill sets remain current and sustains core capabilities to strengthen the continuous development of future energy delivery systems. CEDS efforts engage energy sector stakeholders from the earliest stages and align with initiatives and requirements outlined in the Roadmap to Achieve Energy Delivery Systems Cybersecurity[b] to ensure that CEDS is addressing the identified problem sets and needs. This approach enables the continuous transition of long-term innovative early-stage research from the national laboratories and academia into capabilities that the energy sector and supporting private sector entities can put into practice or incorporate into their product roadmaps to reduce cyber risk. The dynamic threat landscape, continuous advances in energy delivery system technologies, and the use of legacy devices in ways not previously envisioned underscore the importance of this continuous transition.

Research will accelerate development of artificial intelligence (AI) techniques for critical energy delivery infrastructure security, such as machine learning using data generated by the underlying physical process of energy delivery as well as data generated by the cyber-systems that control that physical process, to provide for an automatic response to cyber-attack. Such AI techniques will be designed to allow for energy delivery systems or components, such as generation plants or network servers, to automatically adapt operations and survive a cyber-attack that would otherwise disrupt energy delivery. R&D in the area of AI aligns with the Administration's priorities articulated in the *National Cyber Strategy*.

Highlights of the FY 2021 Budget Request

The request reflects the critical need to accelerate and expand efforts to strengthen the energy infrastructure against cyber threats and mitigate vulnerabilities. Working closely with the energy sector and our government partners, the request focuses on the following key areas:

- **Strengthen Energy Sector Cybersecurity Preparedness ($35 Million)**

  DOE strengthens the energy sector's cybersecurity posture through public and private sector partnerships that leverage DOE-supported tools, guidelines, outreach, training, and technical assistance. To inform programmatic activities in this space, DOE maintains a constant connection with industry through close coordination with the CEO-led Electricity Subsector Coordinating Council (ESCC) and Oil and Natural Gas Subsector Coordinating Council (ONG SCC).

  - ✓ **The Advanced Threat Mitigation ($20 Million)** initiative supports the application of state-of-the-art capabilities including the continued development and operation of the Cyber Analytics Tools and Techniques 2.0 (CATT™ 2.0) and Cybersecurity for the Operational Technology Environment (CyOTE™) experiences and concepts. This initiative also includes supporting cybersecurity projects that use advanced and emerging technologies to protect and secure the energy delivery systems. This initiative will use the latest available technology and architecture and innovative partnerships with the energy sector to promote enhanced cyber protection for the sector. The CATT™ initiative will continue to address both IT and OT infrastructure, and is designed to provide the energy sector with situational awareness and actionable information to support discovery and mitigation of advanced cyber threats to U.S.

[a] U.S. Department of Energy (DOE) Strategic Plan 2014-2018: https://www.energy.gov/sites/prod/files/2014/04/f14/2014_dept_energy_strategic_plan.pdf

[b] https://www.energy.gov/sites/prod/files/Energy%20Delivery%20Systems%20Cybersecurity%20Roadmap_finalweb.pdf

energy infrastructure enriched with classified threat information unique analytical tradecraft owned by the U.S. Government. The vision is to dramatically increase the footprint across the energy sector infrastructure and to gain a higher level of threat detection capability. The request will allow for near-real-time capability for energy owners and operators to voluntarily share cyber threat data, analyze this data, and receive machine-to-machine mitigation measures. The program will continue developing an advanced information sharing model—advancing technology, policy, and partnerships—to improve speed, reduce cost, and increase industry participation.

- ✓ **The Cybersecurity for the Operational Technology (OT) Environment Pilot ($15 Million)** continues to monitor utility data in the complex OT environment to identify malicious actions using an efficient approach that manages data by exception. The request expands the CyOTE™ approach to include additional utilities and apply the results and lessons learned from the OT pilot. While the current Cybersecurity Risk Information Sharing Program (CRISP) program monitors IT networks, CyOTE™ aims to design an industry-led approach for collecting and sharing OT data, which will be enhanced by special insights from the U.S. Intelligence Community and DOE national laboratories to deliver actionable information to utility operators.

- **Accelerate game-changing R&D of Energy Delivery Systems Able to Survive a Cyber-Attack ($38.1 Million)**

  CESER's R&D portfolio will deliver game-changing tools and technologies that help utilities secure today's energy infrastructure from advanced cyber threats and design next-generation future systems that are built from the start to automatically detect, reject, and withstand cyber incidents, regardless of the threat. The Department will continue to develop continuous monitoring tools and secure control system communications.

  - The request supports a competitive solicitation for energy sector-led R&D to redesign their current communication architecture to survive a cyber-attack, placing the energy sector's cyber-defender at an advantage by using operational data and the physics of energy delivery to research, develop, and demonstrate tools and technologies that prevent, detect, and mitigate cyber incidents in today's and tomorrow's energy delivery systems. The proposed solicitation will focus on energy delivery communication infrastructure. Resulting projects from the subject solicitation could impact the entire sector or specific facilities/systems depending on the applicant's approach. For instance, power grid components such as power plants or protective relays could use physics to automatically detect a cyber-attack, identify compromised sensors, and use the remaining trustworthy sensors to sustain critical functions. This approach avoids malware and malicious command impacts through managing by exception: recognizing and rejecting actions that would cause harmful departures from normal grid operations. Power systems or Oil and Natural Gas (ONG) delivery systems or devices could automatically detect a cyber-attack and shift to a simpler control system, part of a redundant architecture that sustains critical functions while the cyber-attack is isolated and eradicated. Specific technical approaches demonstrating AI will be advanced through this research in alignment with the *National Cyber Strategy*.
  - The request supports a competitive solicitation that will refine fully functional prototypes of cybersecurity solutions initially developed through research and demonstration partnerships under the CEDS R&D program. These deployments will reduce cyber risk for energy sector entities that provide power to military and government facilities while accelerating the transition of cybersecurity solutions to operational environments throughout the energy sector.
  - The request will support the Grid Modernization Laboratory Consortium (GMLC) initiatives. CESER has a central role in the Department's plan for integration of cybersecurity activities across the Department of Energy, and coordinates with other DOE offices through the GMLC to engage our leading experts and resources at DOE National Laboratories to collaborate on the goal of modernizing the Nation's electric grid. GMLC employs an integrated approach to ensure that DOE-funded studies and research and development are efficiently coordinated to reap the greatest return for the taxpayer dollar.
  - The request supports the university collaborations focused on advanced energy sector cybersecurity R&D. Project activities will integrate rigorous academic approaches with real-world expertise. Academic R&D is an important aspect of the CEDS portfolio because it involves technology-focused activities that, when combined with industry guidance, results in real-world, impactful solutions, as well as helping to train and develop the next generation of cybersecurity specialists.

- The R&D focus areas include early-stage technologies such as those that:
    - Focus on data and physics to redesign the architecture presently being used that exposes the energy grid to cyber threats. For instance, develop near-term actionable strategies for mitigation of physical consequences that might result from cyber-attack by using technology, design modifications, or operational considerations to protect national critical infrastructure, such as the transmission system and energy delivery operational communications platforms.
    - Prevent a cyber-incident by decreasing the cyber-attack surface of energy delivery systems and components, blocking attempted misuse of the energy delivery system at every level, or decreasing the risk posed by malicious functionality.
    - Detect a cyber-incident by providing for real-time continuous cybersecurity situational awareness at all energy delivery system levels that recognizes attempts to execute either unwanted functionality that the energy delivery system was not designed to support or anomalous behavior within an energy delivery system's functionality.
    - Mitigate a cyber-incident by distinguishing a disruption of energy delivery resulting from a cyber incident, from a disruption resulting from a different cause, characterizing the extent and consequences of a cyber incident to support response actions and providing for automated response.
    - Advance cyber resilience by designing cybersecurity into emerging power system device for future grid scenarios from the start or designing power systems and components to automatically recognize, and reject, attempted misuse.
- **Establish a National Physical Energy System and Component Testing Capability ($30 Million)**

Historically, DOE and the National Nuclear Security Administration (NNSA) have led efforts to understand the effects of electromagnetic radiation on a variety of components. As a result, DOE and its laboratories have made progress in leveraging other research to investigate electromagnetic pulse (EMP) effects on energy system components. However, there are several areas where significant advancements in assessment techniques could improve our understanding of EMP impacts to energy systems. The ability to perform the full assessment process (particularly testing at scale of energized large power transformers) does not reside within one single entity and will require a partnership with various subject matter experts, equipment manufacturers, national laboratories, and academia. To meet this need, CEDS will establish a national physical energy system and component testing capability, designed specifically to look at the vulnerabilities of the energy sector from threats such as EMP and geomagnetic disturbances (GMD).

Cybersecurity for Energy Delivery Systems
Funding ($K)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted ($)	FY 2021 Request vs FY 2020 Enacted (%)
Cybersecurity for Energy Delivery Systems	**89,500**	**95,000**	**103,100**	**+8,100**	**+9%**

SBIR/STTR:

- FY 2019 Enacted: SBIR/STTR $1,793
- FY 2020 Enacted: SBIR/STTR: $1,305
- FY 2021 Request: SBIR/STTR: $2,298

Cybersecurity for Energy Delivery Systems
Explanation of Major Changes ($K)

	FY 2021 Request vs FY 2020 Enacted
• The FY 2020 Congressionally-directed DarkNet project to secure communications based on optical fibers and develop communication technologies to secure existing networks is fully funded. No additional funding is required.	**-10,000**
• The FY 2020 Congressionally-directed Consequence-driven Cyber-informed Engineering project primarily to improve consequence prioritization process to simplify and isolate automated systems and remove vulnerabilities is fully funded. No additional funding is required.	**-10,000**
• The $6,000,000 provided in FY 2020 to develop cyber and cyber-physical solutions for advanced control concepts for distribution and municipal utility companies is one-time funding that is not continued in FY 2021. No additional funding is required.	**-6,000**
• R&D led FOA to develop innovative cybersecurity solutions for the next generation tools and technologies.	**+22,000**
• A greater focus on the demonstration of fully functional prototypes of CEDS solutions at energy sector entities that provide power to military and government installations.	**+12,100**
Total, Cybersecurity for Energy Delivery Systems	**+8,100**

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Cybersecurity for Energy Delivery Systems **$95,000,000**	**$103,100,000**	**+8,100,000**
• Continue the Advanced Threat Mitigation initiatives supporting cybersecurity projects that use advanced and emerging technologies to protect and secure the energy delivery systems. The program is creating advanced capabilities that align with the Agency Priority Goal, "Identify, contain, and defeat cyber threats to our Nation's energy delivery systems through a shared understanding between industry and government of adversarial techniques to mitigate energy sector cyber-attacks." ✓ Continue the CATT™ effort to develop an advanced information sharing secure platform ♦ Advance technology, policy, and partnerships to improve speed, reduce cost, and engage additional industry participants ✓ Implement the expansion of the CyOTE™ approach to other utilities and apply the results of the OT pilot ✓ Continue the Cybersecurity Capability Maturity Model (C2M2) to improve transparency, cybersecurity preparedness and provide a better understanding of the cybersecurity capabilities, gaps and challenges facing utilities.	• Continue the Advanced Threat Mitigation initiatives supporting cybersecurity projects that use advanced and emerging technologies to protect and secure the energy delivery systems. The program is creating advanced capabilities that align with the Agency Priority Goal, "Identify, contain, and defeat cyber threats to our Nation's energy delivery systems through a shared understanding between industry and government of adversarial techniques to mitigate energy sector cyber-attacks." ✓ Implement CATT™ initiatives to additional utilities to broaden the base to operationalize lessons learned ✓ Continue to develop and deploy analytics for emerging adversary tools, techniques and procedures under CyOTE™. ✓ Continue the Cybersecurity Capability Maturity Model (C2M2) to improve transparency, cybersecurity preparedness and provide a better understanding of the cybersecurity capabilities, gaps and challenges facing utilities.	

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
• Continue to advance game-changing R&D by focusing on two key activities: ✓ Issue a competitive Funding Opportunity Announcement (FOA) for University-based R&D of scalable cyber-physical platforms for resilient and secure electric power systems that are flexible, modular, self-healing and autonomous. ✓ Support GMLC initiatives	• Advance game-changing R&D by focusing on five key activities: ✓ Issue Industry-led partnership competitive Funding Opportunity Announcement (FOA) ✓ Support a competitive solicitation to refine fully functional prototypes of cybersecurity solutions ✓ Sponsor university collaboration focused on advanced energy sector cybersecurity R&D ✓ Support GMLC initiatives	• An industry-coordinated FOA will be issued to develop innovative cybersecurity solutions for next generation tools and technologies. • A greater focus on the demonstration of fully functional prototypes of CEDS solutions at energy sector entities that provide power to military and government installations.
• Create a national laboratory partnership to address at-scale understanding of energy component function during events including EMP and GMD	• Continue to support national laboratory partnership to address at-scale understanding of energy component function during events including EMP and GMD	
• *New and Emerging Threats*: Establish a national physical energy system and component testing capability in partnership with industry, designed specifically to look at the vulnerabilities of the energy sector from threats such as EMP and GMD	• *New and Emerging Threats*: Continue to support testing of new components using the national physical energy system and component testing capability in partnership with industry, designed specifically to look at the vulnerabilities of the energy sector from threats such as EMP and GMD	• Continue to support the National Physical Energy System and Component Testing Capability for capability expansion, as well as testing of new systems and components.

Infrastructure Security and Energy Restoration

Overview

The Infrastructure Security and Energy Restoration (ISER) program coordinates a national effort to secure U.S. energy infrastructure against all hazards, reduce impacts from disruptive events, and assist industry with restoration activities. ISER works closely with the electricity and oil and natural gas industries; other Federal agencies; State, Local, Tribal, and Territorial (SLTT) communities; and DOE's national laboratories to advance national energy security and prepare for, respond to, and recover from evolving threats and events.

ISER is responsible for executing DOE's Energy Sector Specific Agency (SSA) and Emergency Support Function-12 (ESF #12) (Energy) roles and providing DOE's support to the Infrastructure Systems Recovery Support Function.[a] ISER also serves as the point of entry for energy private sector partners when collaborating with DOE and the Federal Government on critical infrastructure protection, energy security, and emergency response.

To meet its mission and support its stakeholders, ISER delivers critical capabilities including energy sector emergency response and recovery to all hazards (including emergency response of a cyber nature); near-real-time situational awareness and information sharing about the status of the energy systems to improve risk management; analysis of evolving threats and hazards to energy infrastructure; and technical assistance that incorporates exercises in order to strengthen Federal, regional, State, tribal, and territorial abilities to work together to prepare for and mitigate the effects of an energy sector emergency.

Highlights of the FY 2021 Budget Request

The budget request supports the National Cyber Strategy and energy sector security and resilience in coordination with our government and industry partners in the delivery of emergency response coordination, energy sector situational awareness, and cyber preparedness and incident coordination as stipulated in the 2015 Fixing America's Surface Transportation (FAST) Act, as well as by seeding public-private partnerships at national laboratories to advance the Department and its partners' efforts to prepare for, mitigate, respond to, and recover from all threats and hazards facing the U.S. energy sector.

Expand Emergency Support Function 12 Capacity ($6.5 Million): In FY 2021, ISER will continue to maintain and improve its ability to support industry and the interagency during major events, such as hurricanes, wildfires, and cyber-attacks, and will develop subject-specific training for responders that they can utilize and draw upon when responding to events. We will focus on expanding familiarity with and capability to support remote location responses, educating responders to changing energy sector interdependencies, and expanding access to available subject matter expertise across DOE.

Improve Energy Sector Situational Awareness Capabilities ($11 Million): ISER is home to EAGLE-I™, the Federal Government's situational awareness tool for national power outages. ISER will expand the current configuration of EAGLE-I and work to ensure its continued usefulness as a collaborative platform for historic and real time data collection, integration, and curation across the public and private sectors. EAGLE-I™ will leverage cloud infrastructure to scale implementation for facilitated access to existing models and data sets expanding its capabilities and value to response partners. EAGLE-I™ will incorporate machine learning for all-hazards event characterization and consequence analysis (including cyber and natural disaster). It will take advantage of high-performance computing and artificial intelligence technologies to analyze large data sets (such as historical outages and infrastructure interdependencies), which will improve energy sector impact prediction capabilities.

Ensure Energy Sector Cybersecurity Coordination and Preparedness ($14.5 Million): ISER will continue to build a coordinated emergency management response effort for cyber events, as identified in Presidential Policy Directive 41 (PPD-41) and the FAST Act, as part of its all-hazards approach to incident response for the energy sector using the CESER risks and hazards approach. ISER continues to improve and enhance the DOE-wide cyber incident response plan developed in FY 2018 to use all available resources in supporting response and preparation for cyber events. During FY 2021, ISER will leverage participation in both industry-focused cyber exercises (Liberty Eclipse) and internally focused, no-notice cyber exercises to identify improvements to policies, procedures, and capabilities. ISER will continue working with Department of Homeland

[a] The Infrastructure Systems Recovery Support Function is described at https://www.fema.gov/pdf/recoveryframework/infrastructure_system_rsf.pdf.

Security (DHS) to proactively connect energy companies to DHS response teams before a disaster, which should enable more rapid response to cyber incidents, and will work toward the goal of obtaining pre-approved requests for technical assistance from the most critical U.S. utilities. ISER will also expand its CyberForce competition to support development of the energy sector's cyber defense workforce Nation-wide in support of the Administration's Executive Order 13870 America's Cybersecurity Workforce.

Maintain and Develop Cyber Operation Tools ($20.6 Million): Cybersecurity for Energy Delivery Systems (CEDS) funding in FY 2019 and prior developed operational tools that are now being moved to implementation, deployment, or both within ISER. Along with maintaining previously developed tools, ISER will continue to evolve the operational capabilities available before and during cyber events. ISER will seek to use technologies to accelerate response and recovery by maintaining situational awareness and enabling operations in degraded states. By developing technology to support cybersecurity personnel, including energy sector operators and engineers, ISER will bolster the Nation's defense of critical energy systems.

Cybersecurity Testing for Resilience and Control Systems ($9.8 Million): The Cybersecurity Testing for Resilience and Control Systems (CyTRICS™) program serves as a central capability for DOE's efforts to increase energy sector cybersecurity and reliability through testing and enumeration of critical components to identify embedded cyber vulnerabilities across. Analysis of test results will identify systemic and supply chain risks and vulnerabilities to the sector by correlating collected test data and enriching it with other data sources and methods. DOE will collaborate with other Federal partners, national laboratories, and industry to identify key energy sector industrial control systems components and apply a targeted, collaborative approach to these efforts.

Continue engagement with SLTT Entities ($7.6 Million): When a major disaster strikes, the restoration of energy systems depends on the planning and coordinated response effectiveness of local, State, multi-State, tribal, territorial, and national responses. In FY 2021, the SLTT Energy Assurance program will continue to support technical assistance engagement for coordinated risk analysis and planning with States and territories that improves preparedness for all hazards, including hurricanes, fuel emergencies, and cyber events. With additional funding in this area, ISER will pilot the creation of a data hub for SLTT energy assurance technical assistance and workforce development. In past years, DOE has provided grants and technical assistance to States to develop and refine energy assurance plans, build in-house expertise on infrastructure interdependencies and vulnerabilities, and address new technologies and challenges such as cybersecurity. However, these efforts quickly become outdated, while energy sector threats continue to evolve and grow.[a] By ensuring plans, tools, and trained personnel are in place prior to catastrophic events, DOE can help to alleviate challenges faced during Federal response support during events such as Hurricane Katrina and Superstorm Sandy, and serve as a standing resource for securing energy infrastructure.

[a] National Association of State Energy Officials, "Energy Assurance Planning," accessed June 6, 2018, http://www.naseo.org/energyassurance.

Infrastructure Security and Energy Restoration
Funding ($K)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted ($)	FY 2021 Request vs FY 2020 Enacted (%)
Infrastructure Security and Energy Restoration	**19,000**	**48,000**	**70,000**	**+22,000**	**+46%**

Infrastructure Security and Energy Restoration
Explanation of Major Changes ($K)

	FY 2021 Request vs FY 2020 Enacted
• CESER will leverage participation in both industry-focused cyber exercises (Liberty Eclipse) and internally focused, no-notice cyber exercises to identify improvements to policies, procedures, and capabilities. CESER will also expand its CyberForce competition, CyberStrike, and the Presidential Cyber Competition to support development of the energy sector's cyber defense workforce Nation-wide in support of the Administration's Executive Order 13870 America's Cybersecurity Workforce.	**+2,600**
• CESER will continue to develop and enhance the EAGLE-I™ platform including incorporating additional products and tools to support incident preparedness, response and recovery across the energy sector. CESER will also continue to fund predicative modeling and tools, such as predicted restoration timelines and remote sensing to provide damage assessments to further improve response efforts.	**+3,800**
• Continue funding and expansion of cyber operational tools that were transitioned from CEDS in FY 2019 to provide situational awareness and support incident response. Continued support for cyber preparedness activities and funding to support analysis and subject matter expertise during cyber incident response.	**+15,600**
Total, Infrastructure Security and Energy Restoration	**+22,000**

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Infrastructure Security and Energy Restoration **$48,000,000**	**$70,000,000**	**+$22,000,000**

• *ESF 12 Responsibilities*: Maintain cadre of trained volunteer emergency responders, focusing efforts on:
  • Expanding capabilities internally and for response partners to support energy issues in remote locations and to address changing hazards
  • Educating responders to evolving adversarial threats and energy sector interdependencies
  • Expanding access to available DOE subject matter expertise, including from DOE's Power Marketing Administrations
	• *ESF 12 Responsibilities*: Maintain and expand cadre of trained volunteer emergency responders, focusing efforts on:
	  • Expanding regionalization of emergency response cadre to ensure established regional relationships and understanding
	  • Develop critical incident response responder team to provide initial support challenging incidents and incidents in remote locations
	  • Educating responders to evolving adversarial threats and energy sector interdependencies
	  • Maintain availability of DOE to provide subject matter expertise, from DOE's Power Marketing Administrations
		• In FY 2021, CESER will expand the regionalization of ESF 12 responders across all regions following a successful test in FY 2020. The regionalization ensures responders have established relationships with regional and state counterparts and enables DOE to better respond to multiple simultaneous incidents
		• In addition to standard initial and refresher all-hazards training for ESF 12 responders, in FY 2021 CESER will implement a module to provide ESF 12 responders training on responding during a cyber incident, where ESF 12 responder are deployed to support consequence management

• *SSA Responsibilities*: Continue work with the ESCC and ONGSCC to identify gaps for addressing cyber, physical, and supply chain risks
  • Support owners and operators of critical infrastructure at greatest risk (Section 9 of E.O. 13686) to pilot new capabilities for energy security
	• *SSA Responsibilities*: Work with the ESCC and ONGSCC to identify gaps for addressing cyber, physical, and supply chain risks
	  • Fund the development of a new physical security program to address continued threats to critical energy infrastructure, including pipelines and Defense Electric Critical Infrastructure.
	  • Support owners and operators of critical infrastructure at greatest risk (Section 9 of E.O. 13686) to pilot new capabilities for energy security
	  • Support continue development of plans for use of Grid Security Emergency Orders
		• To address continuing and evolving physical threats to critical energy infrastructure, including pipelines and Defense Electric Critical Infrastructure, in FY 2021, CESER will implement a physical security program to ensure understanding of the threat, potential impacts, and to develop best practices for mitigation
		• Continue to support development of plans for use of Grid Security Emergency Orders

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted

• *Exercises, Competitions and Workshops*: Conduct *Clear Path VIII* and *Liberty Eclipse II* with a focus on the connection between internal and external emergency response of a cyber nature
  • Host CyberForce energy sector cyber defense competition and CyberStrike workshops, which provide hands-on lessons learned from the 2015 cyber-attack on the Ukrainian grid
	• *Exercises, Competitions and Workshops*: Conduct *Clear Path IX* and *Liberty Eclipse III* with a focus on the connection between emergency response of a cyber nature and consequence management
	  • Continue to Host CyberForce energy sector cyber defense competition and CyberStrike workshops
	  • Support the Presidential Operations Technology Cyber Competition
		• Continue to support the Presidential Operations Technology Cyber Competition

• *Situational Awareness and Emergency Response Tools*: Expand EAGLE-I™ functionality and maintain its status as the Federal source for near-real-time situational awareness of energy infrastructure
  • Improve State and local government tools to better prepare for a coordinated response requiring Federal support
	• *Situational Awareness and Emergency Response Tools*: Enhance EAGLE-I™ to expand near real-time situational awareness capabilities and make it platform for integration energy infrastructure situational awareness tools
	  • Support development, operationalization, and integration of modeling and tools, such as predicted power outage restoration timelines and remote sensing to provide damage assessments to further improve response efforts
		• To support interagency, state, local, tribal, and territorial, and industry partner to prepare and respond to incidents, CESER will develop and operationalizing new modeling and tools. These tools will help minimize impacts to energy infrastructure and enable faster restoration post-incident. CESER will also continue to integrate existing tools and models into the EAGLE-I™ platform for broader availability

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted

• *Emergency Response of a Cyber Nature*: Exercise application of an effective, timely, and coordinated cyber event management capability
  • Expand engagement with industry to include technical assistance agreements with the most critical electric utilities to enable rapid response to cyber incidents
  • Grow operation and testing of research and development results with partners to add capabilities to the energy sector for better cyber response
	• *Emergency Response of a Cyber Nature*: application of an effective, timely, and coordinated cyber incident management capability
	  • Expand engagement with industry to include technical assistance agreements with the most critical electric utilities to enable rapid response to cyber incidents
	  • Continued support for cyber preparedness activities and funding to support analysis and subject matter expertise during cyber incident response.
	  • Grow operation and testing of research and development results with partners to add capabilities to the energy sector for better cyber response
		• Continue to develop and mature capabilities to support emergency response of a cyber nature for cyber incidents affecting or potentially affecting the energy sector, including proving subject matter expertise and technical support.
		
		• Build on existing learning from analysis and testing in FY 2020 to identify new issues and areas to focus efforts in FY 2021.

Program Direction

Overview

Program Direction provides for the costs associated with the Federal workforce, including salaries, benefits, travel, training, and other related expenses. It also provides for the costs associated with contractor services that, under the direction of the Federal workforce, support the Office of Cybersecurity, Energy Security, and Emergency Response (CESER) mission.

Salaries and Benefits support Federal employees who provide executive management, programmatic oversight, and analysis for the effective implementation of the CESER program. This includes staff at Headquarters and at the National Energy Technology Laboratory (NETL) to support the overall mission of CESER in the Infrastructure Security & Energy Restoration (ISER) and Cybersecurity for Energy Delivery Systems (CEDS) Divisions. While CESER funds NETL staff within its budget, the NETL Federal employees are included within the full-time equivalent (FTE) total for the Fossil Energy Research and Development account.

CESER Federal staff provide oversight for a wide range of cyber and emergency response functions and programs. These include guiding a multi-million dollar R&D program; staffing and managing the Department's all hazard energy sector emergency response function; training and coordinating a cadre of more than 100 volunteer energy sector emergency responders; overseeing annual programs of energy sector exercises, workshops, interagency and industry engagement, and coordination with states and localities before and during emergencies; and the development of reports and analyses on threats and hazards to the energy sector. Increased need is seen in the area of cyber preparedness and incident response. Federal staff also support crosscutting functions, including budgeting, procurement, contracting, and human resources.

When Presidential Disaster Declarations are activated, CESER staff are called upon under the National Response Framework, to provide trained staff support for Federal Emergency Management Agency (FEMA) Emergency Support Function 12 (ESF-12) mission. Some of these trained responders may be ordinarily employed in other parts of DOE, such as the Office of Energy Efficiency and Renewable Energy or the Power Marketing Administrations. During these activations, CESER is reimbursed by FEMA for overtime expenses; CESER responders', base pay is funded from this CESER Program Direction budget. In FY 2019, trained responders were activated for 79 days. These frequent activations are projected to continue into FY 2020 and FY 2021.

Specifically, the Infrastructure Security and Energy Restoration's (ISER's) staffing efforts will continue to focus on the building on the core capabilities of emergency response and recovery programs addressing both natural and man-made disasters, in order to meet the Department of Energy's (DOE's) statutory responsibilities included in the Fixing America's Surface Transportation Act of 2015, Presidential priorities including cyberwork force for operational technology and industrial control systems; Electromagnetic Pulse (EMP) and Geomagnetic Disturbance (GMD); and DOE's Sector Specific Agency responsibilities included in the National Response Framework, Emergency Support Function (ESF #12).

The goal of accelerating advances in cybersecurity capacity to address current and future capabilities gaps in the energy sector to fulfill the mission of CESER in support of the Administration's priorities are being addressed by the Cybersecurity for Energy Delivery Systems (CEDS). CEDS' staffing efforts will focus on building and maintaining program and project management aligned with existing initiatives underway such as Cybersecurity Analytical Tools and Techniques (CATT™) and Cybersecurity for Operational Technology (CyOTE™) and existing research and development investments.

Travel includes transportation, subsistence, and incidental expenses that allow CESER to effectively deliver on its mission. Major drivers of travel include the need to oversee R&D programs and projects in the field; attend industry, interagency and regional state government energy sector emergency response coordination meetings; and conduct emergency response training for responders in conjunction with Department of Homeland Security (DHS) regional response centers. FEMA reimburses DOE for all travel associated with a Presidential Disaster Declaration.

Support Services includes contractor support directed by the Federal staff to perform administrative tasks and provide analysis to management and may also include support for post-doctoral fellows (such as American Association for the Advancement of Science [AAAS] fellows) and Intergovernmental Personnel Act (IPA) assignments.

Other Related Expenses includes equipment upgrades and replacements, office furniture, commercial credit card purchases using simplified acquisition procedures when possible, and other needs.

Highlights of the FY 2021 Budget Request

The budget request supports 16 additional FTEs to support mission critical work.

Program Direction Funding ($K)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted ($)	FY 2021 Request vs FY 2020 Enacted (%)
Program Direction Summary					
Washington Headquarters					
Salaries and Benefits	4,586	4,951	5,980	+1,029	+21%
Travel	250	250	347	+97	+39%
Support Services	1,743	1,378	1,430	+52	+4%
Other Related Expenses	2,021	3,521	876	-2,645	-75%
Total, Washington Headquarters	**8,600**	**10,100**	**8,633**	**-1,467**	**-15%**
National Energy Technology Laboratory					
Salaries and Benefits	1,258	1,258	1,282	+24	+2%
Travel	120	120	120	0	0%
Support Services	438	438	438	0	0%
Other Related Expenses	1,084	1,084	1,048	-36	-3%
Total, National Energy Technology Laboratory	**2,900**	**2,900**	**2,888**	**-12**	**-0%**
Total Program Direction					
Salaries and Benefits	5,844	6,209	7,262	+1,053	+17%
Travel	370	370	467	+97	+26%
Support Services	2,181	1,816	1,848	+52	+2%
Other Related Expenses	3,105	4,605	1,944	-2,661	-58%
Total, Program Direction	**11,500**	**13,000**	**11,521**	**-1,479**	**-11%**
Federal FTEs	**25**	**27**	**43**	**+16**	**+59%**
Additional FE FTEs at NETL supporting CESER[a]	9	9	9	0	0%
Total CESER-funded FTEs	34	36	52	+16	+44%

[a] CESER funds 9 FTEs at FE's National Energy Technology Laboratory who support CESER activities. The 9 FTEs are in FE's FTE totals and are not included in the CESER FTE totals shown on the "Federal FTEs" line.

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted ($)	FY 2021 Request vs FY 2020 Enacted (%)
Support Services and Other Related Expenses					
Support Services					
Technical Support	1,047	872	1,160	+288	+33%
Management Support	1,134	944	688	-256	-27%
Total, Support Services	**2,181**	**1,816**	**1,848**	**+32**	**+2%**
Other Related Expenses					
Other Services	1,182	2,682	721	-1,961	-73%
EITS Desktop Services	223	223	223	0	0%
WCF	1,700	1,700	1,000	-700	-41%
Total, Other Related Expenses	**3,105**	**4,605**	**1,944**	**-2,661**	**-58%**

Program Direction

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Program Direction $13,000,000	**$11,521,000**	**-$1,479,000**
Salaries and Benefits $6,209,000 • Salaries and benefits support 34 FTEs at HQ and NETL that provide executive management, programmatic oversight, and analysis for the effective implementation of the CESER program	**$7,262,000** • Salaries and benefits support 36 FTEs at HQ and 9 FTEs at NETL that provide executive management, programmatic oversight, and analysis for the effective implementation of the CESER program	**+$1,053,000** • Salaries and Benefits increase is due to 16 additional FTEs in 2020. This will allow CESER to decrease reliance on contractual service and facilitating better project management due to the increase request of the program.
Travel $370,000 • Travel includes transportation, subsistence, and incidental expenses that allow CESER to effectively facilitate its mission	**$467,000** • Travel includes transportation, subsistence, and incidental expenses that allow CESER to effectively facilitate its mission	**+$97,000** • Increase due to the addition of 16 new FTE's

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Support Services $1,816,000 • Support Services includes contractor support directed by the federal staff to provide analysis to management • Support Services may include support for post-doctoral fellows and Intergovernmental Personnel Act (IPA) assignments	**$1,848,000** • Support Services includes contractor support directed by the federal staff to provide analysis to management • Support Services may include support for post-doctoral fellows and IPA assignments	**+$32,000** • Support Service increases are due to normal contractual increases that are outlined in the Contracts
Other Related Expenses $4,605,000 • Other Related Expenses includes equipment upgrades and replacements, office furniture, minor construction, commercial credit card purchases using simplified acquisition procedures when possible, and other needs	**$1,924,000** • Other Related Expenses includes equipment upgrades and replacements, office furniture, minor construction, commercial credit card purchases using simplified acquisition procedures when possible, and other needs	**-$2,661,000** • Decrease due to the use of planned carryover to fund training, office equipment, construction, WCF, and other related expenses

Cybersecurity, Energy Security, and Emergency Response

Research and Development ($K)[ab]

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted ($)	FY 2021 Request vs FY 2020 Enacted (%)
Basic	989	1,308	2,304	+996	+76%
Applied	36,284	18,742	33,010	+14,268	+76%
Development	11,859	15,691	27,637	+11,946	+76%
Total, R&D	49,132	35,741	62,951	+27,210	+76%

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

	FY 2019 Enacted Transfer	FY 2020 Enacted Projected Transfer	FY 2021 Request Projected Transfer	FY 2021 Request vs FY 2020 Enacted ($)	FY 2021 Request vs FY 2020 Enacted (%)
Cybersecurity for Energy Delivery Systems	1,793	1,305	2,298	+993	+76%

[a] R&D reporting includes a proportional share of program direction funding in addition to direct R&D funding.

[b] The R&D Programs are approximately structured as follows: 2-4% basic, 52-74% applied, 24-44% development. Generally, technical readiness levels (TRL) 1-2 is basic research, 2-5 is applied research, 5-8 is development, and 8-9 is demonstration/commercialization. The TRLs vary between specific R&D projects in a portfolio.

DEPARTMENT OF ENERGY
Funding by Site Detail
Cybersecurity, Energy Security and Emergency Response (CESER)
(Dollars in Thousands)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request
Argonne National Laboratory			
Cybersecurity for Energy Delivery Systems	150	900	1,062
Infrastructure Security and Energy Restoration	1,865	5,000	5,898
Total Argonne National Laboratory	**2,015**	**5,900**	**6,960**
Idaho National Laboratory			
Cybersecurity for Energy Delivery Systems	13,000	3,000	3,539
Infrastructure Security and Energy Restoration	250	7,000	8,258
Total Idaho National Laboratory	**13,250**	**10,000**	**11,797**
Lawrence Berkeley National Laboratory			
Cybersecurity for Energy Delivery Systems	1,700	0	0
Total Lawrence Berkeley National Laboratory	**1,700**	**0**	**0**
Lawrence Livermore National Laboratory			
Cybersecurity for Energy Delivery Systems	2,400	2,600	3,067
Infrastructure Security and Energy Restoration	350	4,000	4,719
Total Lawrence Livermore National Laboratory	**2,750**	**6,600**	**7,786**
Los Alamos National Laboratory			
Cybersecurity for Energy Delivery Systems	1,000	0	0
Infrastructure Security and Energy Restoration	500	2,500	2,949
Total Los Alamos National Laboratory	**1,500**	**2,500**	**2,949**
National Energy Technology Lab			
Cybersecurity for Energy Delivery Systems	32,070	50,900	60,636
Infrastructure Security and Energy Restoration	1,400	5,250	6,193
Program Direction - CESER	2,984	2,802	3,305
Total National Energy Technology Lab	**36,454**	**58,952**	**70,135**
National Renewable Energy Laboratory			
Infrastructure Security and Energy Restoration	50	4,000	4,719
Total National Renewable Energy Laboratory	**50**	**4,000**	**4,719**
Oak Ridge Institute for Science & Education			
Infrastructure Security and Energy Restoration	210	1,600	1,887
Total Oak Ridge Institute for Science & Education	**210**	**1,600**	**1,887**
Oak Ridge National Laboratory			
Cybersecurity for Energy Delivery Systems	10,800	1,300	1,534
Infrastructure Security and Energy Restoration	2,950	5,500	6,488
Total Oak Ridge National Laboratory	**13,750**	**6,800**	**8,022**
Pacific Northwest National Laboratory			
Cybersecurity for Energy Delivery Systems	6,050	3,300	3,893
Infrastructure Security and Energy Restoration	425	3,500	4,129
Total Pacific Northwest National Laboratory	**6,475**	**6,800**	**8,022**

DEPARTMENT OF ENERGY
Funding by Site Detail
Cybersecurity, Energy Security and Emergency Response (CESER)
(Dollars in Thousands)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request
Richland Operations Office			
Infrastructure Security and Energy Restoration	1,415	3,000	3,539
Total Richland Operations Office	**1,415**	**3,000**	**3,539**
Sandia National Laboratories			
Cybersecurity for Energy Delivery Systems	1,600	1,800	2,123
Infrastructure Security and Energy Restoration	1,125	11,150	13,154
Total Sandia National Laboratories	**2,725**	**12,950**	**15,277**
Savannah River Operations Office			
Infrastructure Security and Energy Restoration	400	5,000	5,898
Total Savannah River Operations Office	**400**	**5,000**	**5,898**
Washington Headquarters			
Cybersecurity for Energy Delivery Systems	20,575	10,700	12,623
Infrastructure Security and Energy Restoration	8,060	11,500	13,566
Program Direction - CESER	8,516	8,698	10,261
Total Washington Headquarters	**37,151**	**30,898**	**36,450**
Western Area Power Administration Office			
Cybersecurity for Energy Delivery Systems	155	0	0
Infrastructure Security and Energy Restoration	0	1,000	1,180
Total Western Area Power Administration Office	**155**	**1,000**	**1,180**

Power Marketing Administrations

Power Marketing Administrations

Power Marketing Administrations

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Southeastern Power Administration

Southeastern Power Administration

Southeastern Power Administration
Proposed Appropriation Language

For expenses necessary for operation and maintenance of power transmission facilities and for marketing electric power and energy, including transmission wheeling and ancillary services, pursuant to section 5 of the Flood Control Act of 1944 (16 U.S.C. 825s), as applied to the southeastern power area, [$6,597,000] *$7,246,000*, including official reception and representation expenses in an amount not to exceed $1,500, to remain available until expended: *Provided,* That notwithstanding 31 U.S.C. 3302 and section 5 of the Flood Control Act of 1944, up to [$6,597,000] *$7,246,000*, collected by the Southeastern Power Administration from the sale of power and related services shall be credited to this account as discretionary offsetting collections, to remain available until expended for the sole purpose of funding the annual expenses of the Southeastern Power Administration: *Provided further,* That the sum herein appropriated for annual expenses shall be reduced as collections are received during the fiscal year so as to result in a final fiscal year [2020] *2021* appropriation estimated at not more than $0: *Provided further,* That, notwithstanding 31 U.S.C. 3302, up to [$56,000,000] *$71,238,000* collected by the Southeastern Power Administration pursuant to the Flood Control Act of 1944 to recover purchase power and wheeling expenses shall be credited to this account as offsetting collections, to remain available until expended for the sole purpose of making purchase power and wheeling expenditures: *Provided further,* That for purposes of this appropriation, annual expenses means expenditures that are generally recovered in the same year that they are incurred (excluding purchase power and wheeling expenses). *(Energy and Water Development and Related Agencies Appropriations Act, 2020.)*

Explanation of Changes

No changes.

Public Law Authorizations:

Public Law 78-534, Flood Control Act of 1944
Public Law 95-91, DOE Organization Act of 1977, Section 302
Public Law 101-1-1, Title III, Continuing Fund (amended 1989)
Public Law 102-486, Energy Policy Act of 1992

Southeastern Power Administration

Funding ($K)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted
Gross	75,324	77,301	96,647	19,346
Offsets	-75,324	-77,301	-96,647	-19,346
Net BA	0	0	0	0

Overview

Southeastern Power Administration (Southeastern or SEPA) exists to carry out the functions assigned by the Flood Control Act of 1944: to market the electric power and energy generated by the Federal reservoir projects to public bodies and cooperatives in the southeastern United States in a professional, innovative, customer-oriented manner, while continuing to meet the challenges of an ever-changing electric utility environment through continuous improvement. Southeastern provides 475 public power customers with 3,392 megawatts of hydroelectric capacity from 22 Federal multipurpose projects, operated by the U.S. Army Corps of Engineers (Corps) at cost based rates.

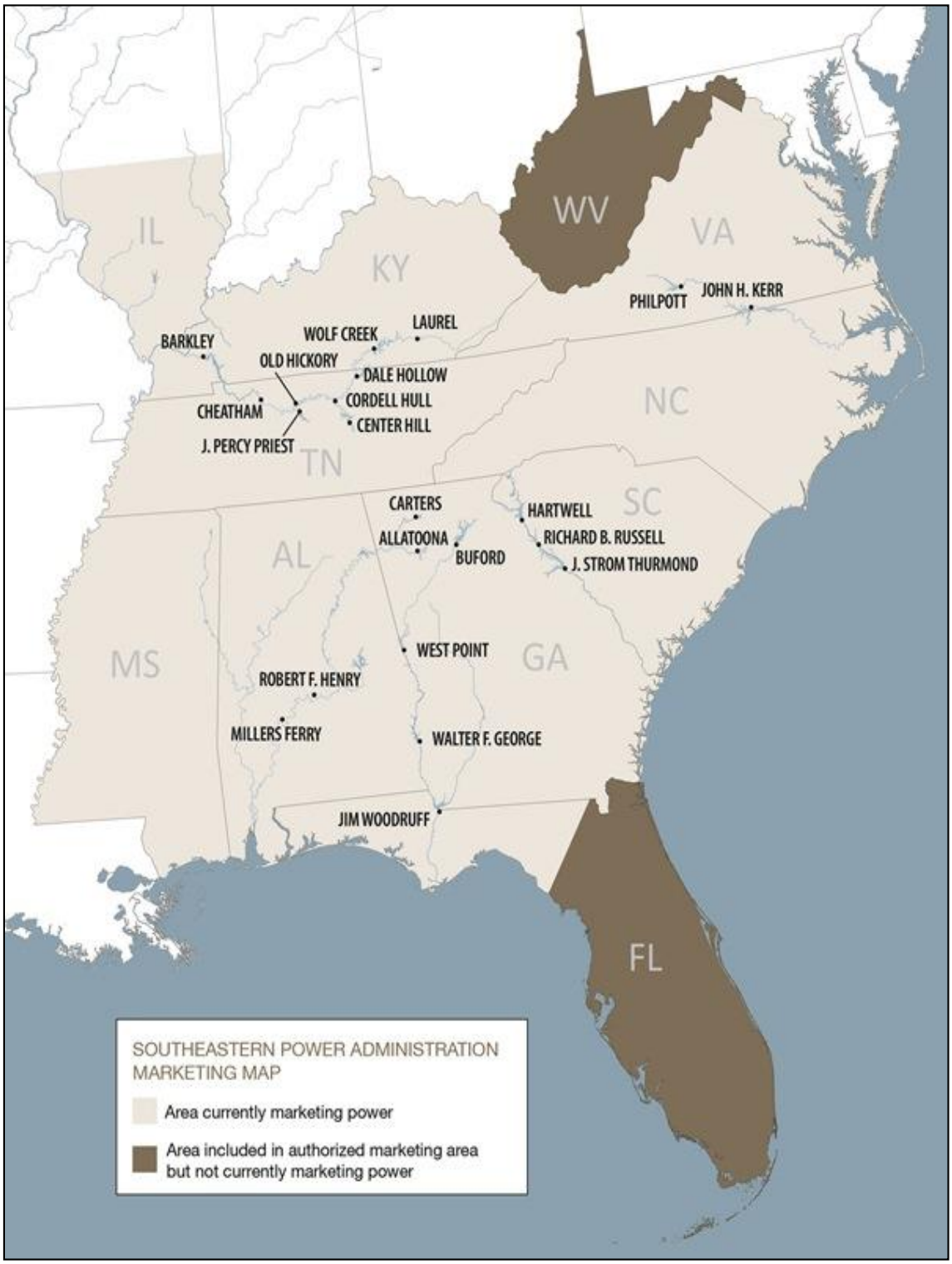
Annually, Southeastern produces an average of 7,613 gigawatt-hours of clean renewable hydroelectric energy. Southeastern maintains and upgrades its energy infrastructure to ensure reliable and efficient delivery of Federal power. Southeastern promotes energy efficiency, renewable energy, and sound management of the dispatch and distribution of Federal hydroelectric power resources in the southeastern United States while also meeting national utility performance standards and balancing the diverse interests of other water resource stakeholders. This budget submission enables Southeastern to promote the effective management of hydroelectric resources.

Program Direction supports day-to-day agency operation and Purchase Power and Wheeling supports acquisition of replacement and pumping power along with contractually-required transmission services. Consistent with the authority provided in the FY 2010 Energy and Water Appropriations, the FY 2021 Budget provides funding for annual expenses (Program Direction) through discretionary offsetting collections derived from power receipts collected to recover those expenses.

Highlights and Major Changes in the FY 2021 Budget Request

Southeastern's request for FY 2021 increases Purchase Power and Wheeling (+$14.697 million), reflecting changes in transmission rates and rainfall estimates, and increases Program Direction (+$ 4.649 million) based on more accurate cost estimates. The FY 2021 budget request includes a proposal to change SEPA's statutory rate structure requirement from cost recovery to a market based structure. The FY 2021 budget request also seeks authority for Southeastern to purchase or construct a new headquarters facility.

Service Area Map



Southeastern Power Administration
Funding by Congressional Control ($K)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted ($)	FY 2021 Request vs FY 2020 Enacted (%)
Southeastern Power Administration					
Purchase Power and Wheeling (PPW)	68,824	70,704	85,401	14,697	21%
Program Direction (PD)	6,500	6,597	11,246	4,649	70%
Subtotal, Southeastern Power Administration	**75,324**	**77,301**	**96,647**	19,346	25%
Offsetting Collections, PPW	-55,000	-56,000	-71,238	-15,238	27%
Alternative Financing, PPW	-13,824	-14,704	-14,163	541	-4%
Offsetting Collections, Annual Expenses, PD	-6,500	-6,597	-7,246	-649	10%
Alternative Financing, PD	0	0	-4,000	-4,000	100%
Total, Southeastern Power Administration	**0**	**0**	**0**	0	0%
Federal FTEs	**44**	**44**	**44**	0	0

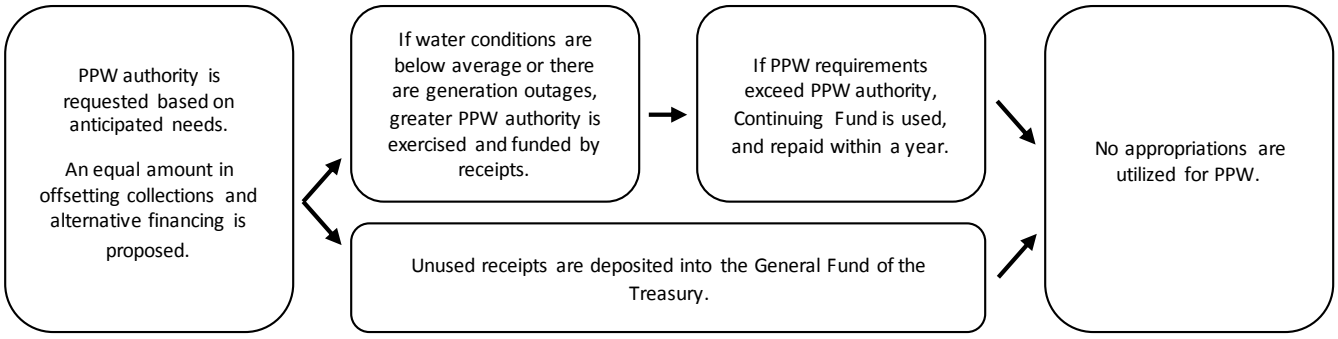
Purchase Power and Wheeling

Overview

The mission of Purchase Power and Wheeling (PPW) is to provide funding for acquisition of transmission services, ancillary services for the system, pumping energy for the Richard B. Russell and Carters Pumped Storage units, and support of the Jim Woodruff Project. Southeastern must purchase power on the open market when its Federal generating assets cannot provide enough power to fulfill its contracts with its customers.

Additionally, because Southeastern does not own or operate any transmission infrastructure, transmission expenses are based on contracts with area transmission providers to deliver specified amounts of Federal power from the hydropower projects to Federal power customers. Southeastern has access to a continuing fund for emergency expenses necessary to ensure continuity of service. Southeastern has implemented a plan to repay any Purchase Power and Wheeling expenditures made through the Continuing Fund within one year.

The FY 2021 request uses customer receipts and net billing to pay for purchase power and wheeling expenses at no cost to the Federal Treasury. Some customers, acting independently or in partnerships, acquire replacement power and transmission services directly from suppliers. Southeastern will continue to assist its customers by arranging funding for these activities through alternative financing instruments, as needed.



Highlights of the FY 2021 Budget Request

The PPW subprogram supports Southeastern's mission to market and deliver reliable, cost-based hydroelectric power and related services. PPW enables Southeastern to wheel Federal power to preference customers, purchase replacement power, and acquire pumping energy to maximize the efficiency and benefits of Southeastern's hydropower resources. Power and services are marketed at rates designed to provide recovery of expenses and Federal investment, as established by law. The FY 2021 budget request includes a proposal to change SEPA's statutory rate structure requirement from cost recovery to a market based structure.

Purchase Power & Wheeling
Funding ($K)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted ($)
Purchase Power				
Replacement Power	3,797	3,797	8,778	4,981
Russell Project pumping power	11,584	10,250	12,704	2,454
Carters Project pumping power	9,439	8,964	13,823	4,859
Jim Woodruff Project support	2,600	2,600	2,600	0
Total, Purchase Power	27,420	25,611	37,905	12,294
Wheeling				
Wheeling service charges	36,664	40,353	42,756	2,403
Ancillary Services	4,740	4,740	4,740	0
Total, Wheeling	41,404	45,093	47,496	2,403
Total, Purchase Power and Wheeling	68,824	70,704	85,401	14,697
Alternative Financing				
Net Billing	-13,824	-14,704	-14,163	541
Subtotal, Purchase Power and Wheeling	55,000	56,000	71,238	15,238
Offsetting Collections Realized	-55,000	-56,000	-71,238	-15,238
Total, Purchase Power and Wheeling Budget Authority	**0**	**0**	**0**	**0**

Southeastern Power Administration
Purchase Power and Wheeling
($K)

Activities, Milestones, and Explanation of Changes ($K)

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Purchase Power and Wheeling $70,704	**$85,401**	**+$14,697**
Purchase Power $25,611	**$37,905**	**+$12,294**
• On-Peak Replacement Power, purchased to meet contract minimum service in drought conditions. • Off-Peak Pumping Power, purchased to supplement stream flow energy demand. • Jim Woodruff System Generating Support required for high river flows at low head plant.	• Continuing activities from prior year.	• The increase reflects anticipated needs based on projected market prices.
Wheeling $45,093	**$47,496**	**+$2,403**
• Transmission expenses based on contracts with area transmission providers to deliver specified amounts of Federal power from the hydropower projects to Federal power customers.	• Continued funding supports ongoing activities.	• The increase is due to variations in transmission rates.

Program Direction

Overview

Program Direction provides the Federal staffing resources and associated costs required to provide overall direction and execution of the Southeastern Power Administration. Provision is made for negotiation and administration of transmission and power contracts, collections of revenues, accounting and budget activities, development of wholesale power rates, amortization of the Federal power investment, energy efficiency and competitiveness programs, investigation and planning of proposed water resources projects, scheduling and dispatch of power generation, scheduling storage and release of water, administration of contractual operation requirements, and determination of methods of operating generating plants individually and in coordination with others to obtain maximum allowable utilization of resources.

Highlights of the FY 2021 Budget Request

The FY 2021 Budget Request provides for the continuation of Southeastern's activities related to Program Direction at the level necessary to meet mission requirements. In FY 2021, Southeastern is seeking authority to purchase or construct a new headquarters in order to reduce future annual expenses and the rate impact to its customers.

Program Direction Funding ($K)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted ($)
Program Direction Summary				
Southeastern Power Administration				
Salaries and Benefits	4,800	4,800	5,500	700
Travel	105	100	50	-50
Support Services	5	3	0	-3
Other Related Expenses	1,590	1,694	5,696	4,002
Subtotal, Southeastern Power Administration	**6,500**	**6,597**	**11,246**	4,649
Offsetting Collections (annual expenses)	-6,500	-6,597	-7,246	-649
Alternative Financing, PD	0	0	-4,000	-4,000
Total, Program Direction	**0**	**0**	**0**	0
Federal FTEs	**44**	**44**	**44**	**0**
Support Services and Other Related Expenses				
Support Services				
Management and Professional Support Services	5	3	0	-3
Total, Support Services	**5**	**3**	**0**	-3
Other Related Expenses				
Training	20	20	21	1
Communications, Utilities, Misc.	177	202	209	7
Equipment	81	68	129	61
Maintenance Agreements	175	171	430	259
Land and Structures	0	0	4,000	4,000
Rent to GSA	352	352	0	-352
Rent to Others	0	0	0	0
Tuition	10	47	48	1
Contract Services	400	456	472	16

Audit of Financial Statements	246	251	257	6
Supplies and Materials	77	71	73	2
Working Capital Fund	47	48	49	1
Printing and Reproduction	5	8	8	0
Total, Other Related Expenses	**1,590**	**1,694**	**5,696**	4,002

Program Direction ($K)

Activities, Milestones, and Explanation of Changes ($K)

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Program Direction $6,597	**$11,246**	**+$4,649**
Salaries and Benefits $4,800	**$5,500**	**+$700**
The funding supports Federal salaries and benefits for 44 FTEs who market Federal hydropower, promote energy efficiency and renewable energy, administrative support, and workloads in cyber-security and operational reliability. These estimates are derived from the current year budgeted salaries, plus cost-of-living adjustments, promotions, within-grade increases, overtime, DOE-cascading performance awards, and retirement payouts for unused leave.	Continue funding support for Federal salaries and benefits for 44 FTEs.	Continue funding support for Federal salaries and benefits including the recruiting and retaining of FTEs.
Travel $100	**$50**	**-$50**
Funding supports transportation and per diem expenses incurred for preference customer meetings, relocation expenses for new FTEs, contract negotiations, rate forums, Congressional hearings, site visits, and operations meetings with industry organizations.	Continued funding supports ongoing activities.	Continued greater use of conference calls, webinar sessions, internet training, and video conferencing.
Support Services $3	**$0**	**-$3**
Funding supports preference customers' efforts in support of the Energy Policy Act of 2005.	Continue funding for co-sponsored training support for municipal and cooperative utilities.	Reduced customer participation in program funding.
Other Related Expenses $1,694	**$5,696**	**+$4,002**

Additional Tables

Revenue and Receipts ($K)

	FY 2019 Actual	FY 2020 Estimate	FY 2021 Estimate	FY 2022 Estimate	FY 2023 Estimate	FY 2024 Estimate	FY 2025 Estimate
Gross Revenues	304,474	305,757	307,304	316,235	317,951	319,752	321,644
Net Billing (Credited as an Offsetting Receipt)	-13,562	-14,704	-14,163	-14,352	-14,551	-14,760	-14,979
Total Cash Receipts	290,912	291,053	293,141	301,883	303,400	304,992	306,665
Use of Offsetting Collections to fund PPW	-41,500	-56,000	-71,238	-72,681	-74,198	-75,790	-77,463
Use of Offsetting Collections to fund Annual Expenses	-6,500	-6,597	-7,246	-7,383	-7,521	-7,647	-7,887
Total Receipts, net use of Offsetting Collections	242,912	228,456	214,657	221,819	221,681	221,555	221,315
Cumberland Rehabilitation	-52,480	-25,000	-25,000	-25,000	-25,000	-25,000	-25,000
GA-AL-SC Rehabilitation	-9,410	-10,000	-10,000	-15,000	-15,000	-15,000	-1,500
Kerr-Philpott Rehabilitation	-155	-4,000	-3,000	-5,000	-5,000	-5,000	-5,000
Jim Woodruff	-428	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000
Accts Rec Yearly Difference	2509	0	0	0	0	0	0
Total Proprietary Receipts	182,948	188,456	175,657	175,819	175,681	175,555	188,815
Percent of Sales to Preference Customers	99%	99%	99%	99%	99%	99%	99%
Energy Sales and Power Marketed (megawatt-hours)	9,125,689	5,587,740	5,587,740	5,587,740	5,587,740	5,587,740	5,587,740

Alternative Financing

2019	Transmission	Purchase Power	Offsetting Collections	Net Billing	Appropriated Funds
Jim Woodruff System	310	2,013	-1,842	-481	0
Kerr-Philpott System	9,054	4	-9,058	0	0
GA-AL-SC System	26,883	7,041	-30,516	-3,408	0
Cumberland System	9,757	0	-84	-9,673	0
	46,004	9,058	-41,500	-13,562	0

2020	Transmission	Purchase Power	Offsetting Collections	Net Billing	Appropriated Funds
Jim Woodruff System	336	2,600	-2,236	-700	0
Kerr-Philpott System	9,185	0	-9,185	0	0
GA-AL-SC System	26,343	22,492	-44,504	-4,331	0
Cumberland System	9,748	0	-75	-9,673	0
	45,612	25,092	-56,000	-14,704	0

2021	Transmission	Purchase Power	Offsetting Collections	Net Billing	Appropriated Funds
Jim Woodruff System	336	2,600	-2,236	-700	0
Kerr-Philpott System	9,994	0	-9,994	0	0
GA-AL-SC System	27,418	35,305	-58,933	-3,790	0
Cumberland System	9,748	0	-75	-9,673	0
	47,496	37,905	-71,238	-14,163	0

Power Marketed, Wheeled, or Exchanged by Project

Project	State	Plants	Installed Capacity (KW)	FY 2019 Estimated Power (GWH)	FY 2020 Estimated Power (GWH)	FY 2021 Estimated Power (GWH)
Kerr-Philpott System				293	293	293
John H. Kerr	VA-NC	1	291,000			
Philpott	VA	1	15,000			
Georgia-Alabama-South Carolina System				2,508	2,508	2,508
Allatoona	GA	1	82,000			
Buford	GA	1	127,000			
Carters	GA	1	600,000			
J. Strom Thurmond	GA-SC	1	364,000			
Walter F. George	GA-AL	1	160,000			
Hartwell	GA-SC	1	424,000			
R. F. Henry	AL	1	82,000			
Millers Ferry	AL	1	90,000			
West Point	GA-AL	1	87,000			
Richard B. Russell	GA-SC	1	656,000			
Jim Woodruff Project	FL-GA	1	43,500	148	148	148
Cumberland System				2,481	2,481	2,481
Barkley	KY	1	130,000			
Center Hill	TN	1	135,000			
Cheatham	TN	1	36,000			
Cordell Hull	TN	1	99,900			
Dale Hollow	TN	1	54,000			
Old Hickory	TN	1	103,752			
J. Percy Priest	TN	1	28,000			
Wolf Creek	TN	1	270,000			
Laurel	TN	1	61,000			
Total Power Marketed		22	3,939,152	5,430	5,430	5,430

System Statistics

	FY 2019 Actual	FY 2020 Estimate	FY 2021 Estimate
Generating Capacity:			
Nameplate Capacity (KW)	3,939,152	3,939,152	3,939,152
Peak Capacity (KW) [a]	4,330,000	4,330,000	4,330,000
Generating Stations			
Generating Projects (Number)	22	22	22
Available Energy			
Energy from Stream-flow (MWH)	8,763,810	4,685,000	4,685,000
Energy generated from Pumping (MWH)	361,210	745,100	745,100
Energy Purchased for Replacement (MWH)	669	157,640	157,640
Total, Energy available for marketing [b] (MWH)	9,125,689	5,587,740	5,587,740

[a] Southeastern markets capacity based on nameplate plus an overload factor. NERC requires that Southeastern keep a portion of the capacity in reserve for emergency purposes and to cover losses.

[b] Gross amount. Transmission losses are deducted from this amount to estimate the amount of energy marketed.

DEPARTMENT OF ENERGY
Funding by Site Detail
Southeastern Power Administration
(Dollars in Thousands)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request
Southeastern Power Administration Office			
Purchase Power and Wheeling - SEPA	68,824	70,704	85,401
Program Direction - SEPA	6,500	6,597	11,246
Total Southeastern Power Administration Office	**75,324**	**77,301**	**96,647**

Southwestern Power Administration

Southwestern Power Administration

Southwestern Power Administration
Proposed Appropriation Language

For expenses necessary for operation and maintenance of power transmission facilities and for marketing electric power and energy, for construction and acquisition of transmission lines, substations and appurtenant facilities, and for administrative expenses, including official reception and representation expenses in an amount not to exceed $1,500 in carrying out section 5 of the Flood Control Act of 1944 (16 U.S.C. 825s), as applied to the Southwestern Power Administration, [$47,775,000]*$47,540,000* to remain available until expended: Provided, That notwithstanding 31 U.S.C. 3302 and section 5 of the Flood Control Act of 1944 (16 U.S.C. 825s), up to [$37,375,000]*$37,140,000* collected by the Southwestern Power Administration from the sale of power and related services shall be credited to this account as discretionary offsetting collections, to remain available until expended, for the sole purpose of funding the annual expenses of the Southwestern Power Administration: Provided further, That the sum herein appropriated for annual expenses shall be reduced as collections are received during the fiscal year so as to result in a final fiscal year [2020]*2021* appropriation estimated at not more than $10,400,000: Provided further, That, notwithstanding 31 U.S.C. 3302, up to [$43,000,000]*$70,000,000* collected by the Southwestern Power Administration pursuant to the Flood Control Act of 1944 to recover purchase power and wheeling expenses shall be credited to this account as offsetting collections, to remain available until expended for the sole purpose of making purchase power and wheeling expenditures: Provided further, That for purposes of this appropriation, annual expenses means expenditures that are generally recovered in the same year that they are incurred (excluding purchase power and wheeling expenses). (Energy and Water Development and Related Agencies Appropriations Act, 2020.)

Explanation of Changes

No changes.

Public Law Authorizations

Southwestern Power Administration:

- P.L. 78-534, Section 5, Flood Control Act of 1944
- P.L. 95–91, Section 302, DOE Organization Act of 1977
- P.L. 100-71, Supplemental Appropriations Act, 1987
- P.L. 101–101, Title III, Continuing Fund (amended 1989)
- P.L. 102-486, Section 721, Energy Policy Act of 1992
- P.L. 108-447, Appropriations Act, FY 2005
- P.L. 111-85, Appropriations Act, FY 2010

Southwestern Power Administration
Overview

($K)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted
Gross	126,876	131,863	157,194	25,331
Offsets	-116,476	-121,463	-146,794	-25,331
Net BA	10,400	10,400	10,400	0

Overview

Southwestern Power Administration's (Southwestern) mission is to market and reliably deliver Federal hydroelectric power, with preference to public bodies and cooperatives. This is accomplished by maximizing the use of Federal assets to repay the Federal investment, participating with other water resource users in an effort to balance diverse interests with power needs within broad parameters set by the U.S. Army Corps of Engineers (Corps), and implementing public policy.

Southwestern markets and delivers power at wholesale rates to 78 municipal utilities, 21 rural electric cooperatives, and 3 military installations in the six states of Arkansas, Kansas, Louisiana, Missouri, Oklahoma, and Texas. In turn, these customers distribute that power to approximately 10 million end users in the six-state area. To integrate the operation of the Federal hydroelectric generating plants and to transmit power from 24 multi-purpose Corps dams to customers, Southwestern operates and maintains 1,380 miles of high-voltage transmission lines, 26 substations/switchyards, and 51 microwave and very high frequency (VHF) radio sites. Southwestern is headquartered in Tulsa, Oklahoma, and has maintenance facilities in Gore, Oklahoma; Jonesboro, Arkansas; and Springfield, Missouri. In addition, around-the-clock power scheduling and dispatching are conducted by staff in Southwestern's Operations Center located in southwest Missouri.

Southwestern participates in the Southwest Power Pool (SPP) Regional Transmission Organization (RTO) and the Midcontinent Independent System Operator (MISO) RTO, which reinforces Southwestern's role as part of the Nation's interconnected generation and transmission system. In participation with the RTOs, Southwestern works on regional and interregional transmission policy initiatives in response to the evolution of the electric utility industry. Furthermore, Southwestern coordinates its varied utility activities in conjunction with a broader group of stakeholders. As the demand for the transmission of power increases across regional and interregional footprints, maintaining and improving the Nation's energy infrastructure through improvements, replacements, interconnections, and coordination with the RTOs in Southwestern's marketing area has become more critical than ever. Southwestern assures the efficient and reliable delivery of Federal hydropower, thus fulfilling energy security for the present as well as for future generations.

Southwestern's marketing services and delivery capability provide for recovery of all annual operating costs, including the Corps' hydropower related costs, and for repayment of taxpayer investment in all assets and facilities that support the Federal hydropower program. Hydroelectric power is a domestic energy source that helps America achieve energy dominance and provides American jobs. Southwestern markets an average of 5,570 gigawatt-hours of clean renewable hydroelectric energy annually.

Southwestern will use the following strategies to fulfill its mission:

- Market and deliver, at the lowest possible cost, all available Federal hydropower generated at the Corps multipurpose projects and work with the Corps, States, cooperatives, and municipalities to meet its statutory requirements while balancing the interests of other water users.

- Maintain infrastructure and modernize systems to increase the reliability, efficiency, and use of Federal assets. This will be accomplished using appropriations; Federal power receipts; and alternative financing arrangements, which include net billing, bill crediting, and/or reimbursable authority (customer advances).[1]
- Conduct annual power repayment studies to ensure power rates are sufficient to repay all annual operating costs and the Federal investment with interest.
- Meet Southwestern's 1200-hour peaking power contractual obligations with necessary purchase power and wheeling using Federal power receipts; alternative financing arrangements, which include net billing, bill crediting, and/or reimbursable authority (customer advances); and the Continuing Fund as necessary in periods of below-average hydropower generation.
- Operate the transmission system efficiently to support the Nation's integrated power grid and engage in transmission policy initiatives within the RTOs in Southwestern's marketing area to respond effectively to the evolution of the electric utility industry.
- Meet requirements for Southwestern's compliance with the latest North American Electric Reliability Corporation (NERC) standards.
- Bolster Southwestern's cyber and physical security postures using best-available technologies and in cooperation with DOE and industry partners to protect the Federal transmission system and the Nation's power grid. Ongoing assessments, realigning vacant positions, investments in the cyber and physical security programs, and infrastructure protection improvements enable Southwestern to continue to provide a safe and reliable product. Southwestern will continue to emphasize security, both cyber and physical, as an agency priority.

External factors that present potential impacts to the overall achievement of the programs' strategic goals include weather, natural disasters, NERC reliability standards, industry deregulation, physical and cybersecurity, changing electric industry organizational structure, interconnections, open access, the uncertainty of sustainable funding resources, competing uses' demand for the limited water resource, and other unforeseen requirements. More specifically:

- The bulk of Southwestern's transmission infrastructure is approximately 60 years old and requires ongoing maintenance and replacement while concurrently balancing changing and increasing demands for availability.
- Industry efforts to improve the reliability of the Nation's power grid are placing more requirements on Southwestern's workforce to implement mandatory reliability standards.
- The potential for malicious physical and cyber-attacks on Southwestern's assets remains a primary concern. These attacks, cyber and physical, on a utility's operation would threaten electric system reliability and potentially result in large scale power outages.
- As more of Southwestern's employees retire or leave Federal service, Southwestern must compete with the rest of the electric utility industry to attract and retain the quality workforce needed to provide a reliable power supply and transmission service.
- Southwestern is increasingly challenged by more complex transmission policy developments including intricate energy and capacity markets, transmission planning processes, and technical rate structures; the deployment of new technologies such as renewables and distributed generation; and heightening emissions and environmental restrictions.
- The Corps water resources projects from which Southwestern markets the hydropower are all multi-purpose. As the demand for water for other purposes increases, energy generation and operating capacity of the hydropower units can be impacted by loss of water storage and availability as well as required operational changes.

[1] Southwestern's authority to use net billing and bill crediting is inherent in the authority provided by the Flood Control Act of 1944 and has been affirmed by the Comptroller General. Honorable Secretary of the Interior B-125127 (February 14, 1956). This allows Southwestern to accept goods and services in lieu of payment.

Highlights of the FY 2021 Budget Request

Southwestern requests a net appropriation of $10.4 million for FY 2021. Southwestern's appropriation consists of four subprograms: Operations and Maintenance, Construction, Purchase Power and Wheeling, and Program Direction. Southwestern utilizes a variety of financing methods including appropriations, Federal power receipts, and alternative financing arrangements, which include net billing, bill crediting, and/or reimbursable authority (customer advances).

Priority is placed on maintenance, upgrades, physical and cybersecurity, compliance, and cost containment.

Consistent with the FY 2018, FY 2019, and FY 2020 Budget Requests; the FY 2021 Budget Request includes the proposal that the Federal government be authorized to sell the transmission assets of Southwestern. The FY 2021 Budget Request also includes a proposal to change Southwestern's statutory rate structure requirement from cost recovery to a market-based structure.

Service Area Map

Southwestern Power Administration
Funding by Congressional Control ($K)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted ($)	FY 2021 Request vs FY 2020 Enacted (%)
Operation and Maintenance					
Operations and Maintenance (O&M)	17,006	13,639	13,292	-347	-2.5%
Construction (CN)	16,875	15,067	13,267	-1,800	-11.9%
Purchase Power and Wheeling (PPW)	60,000	68,000	95,000	+27,000	+39.7%
Program Direction (PD)	32,995	35,157	35,635	+478	+1.4%
Subtotal, Operation and Maintenance	126,876	131,863	157,194	+25,331	+19.2%
Offsetting Collections, O&M	-5,707	-5,908	-5,657	+251	-4.2%
Offsetting Collections, PD	-29,695	-31,467	-31,483	-16	+0.1%
Offsetting Collections, PPW	-50,000	-43,000	-70,000	-27,000	+62.8%
Alternative Financing, O&M	-8,894	-6,018	-5,635	+383	-6.4%
Alternative Financing, CN	-12,180	-10,070	-8,167	+1,903	-18.9%
Alternative Financing, PD	0	0	-852	-852	+100%
Alternative Financing, PPW	-10,000	-25,000	-25,000	0	0%
Net Budget Authority, Operation and Maintenance	10,400	10,400	10,400	0	0%
Federal FTEs	194	194	194	0	0

Operation and Maintenance
Explanation of Major Changes ($K)

	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Operations and Maintenance: The decrease in the operations and maintenance subprogram reflects reduction in communications replacements.	**-347**
Construction: The decrease in the construction subprogram reflects reduction in communication towers and radio replacements.	**-1,800**
Purchase Power and Wheeling: The increase in system support reflects the anticipated needs based on projected market prices and severe drought hydrologic conditions. It is important for Southwestern to maintain Purchase Power and Wheeling (PPW) funding authority at a level that allows for timely response to severe drought conditions that can develop rapidly (in a matter of months) in Southwestern's region. Access to funding via spending authority from offsetting collections and utilizing alternative financing provides Southwestern PPW funding options to best plan for and respond to varied hydrologic conditions, such as periods of drought or low water conditions, as well as operational impacts, such as hydropower unit outages for major rehabilitation. This increase reflects anticipated needs for periods of drought or low water conditions.	**+27,000**
Program Direction: The increase in the program direction subprogram reflects aggressive recruiting to fill several technical hard to fill positions, back-filling retirees, and filling succession planning positions for knowledge transfer. Increases in travel reflect transmission policy related efforts, water resource activities, and field maintenance crew travel expenses. Also, increase in support services for projected contractual cost of living adjustments.	**+478**
Total, Southwestern, Operation and Maintenance	**+25,331**

Operations and Maintenance
Funding ($K)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted ($)
Operations and Maintenance (O&M)				
Power Marketing	4,200	200	200	0
Operations	7,893	8,217	8,178	-39
Maintenance	3,088	3,834	3,550	-284
Capitalized Moveable Equipment	1,825	1,388	1,364	-24
Subtotal, Operations and Maintenance	**17,006**	**13,639**	**13,292**	**-347**
Offsetting Collections (annual expenses)	-5,707	-5,908	-5,657	+251
Alternative Financing	-8,894	-6,018	-5,635	+383
Total, Operations and Maintenance	**2,405**	**1,713**	**2,000**	**+287**

Southwestern Power Administration
Operations and Maintenance

Description

The activities of the Operations and Maintenance (O&M) subprogram are critical components in maintaining the reliability of the Federal power system, which is part of the Nation's interconnected generation and transmission system. By marketing and delivering hydroelectric energy, Southwestern makes a meaningful contribution of clean, safe, reliable, affordable, and secure renewable hydroelectric energy to our Nation. The Energy Policy Act (EPACT) and the Department of Energy (DOE) and Administration's policies emphasize its significant contribution to the Nation's past, current, and future energy supply; and identify Southwestern's important role in meeting electricity demand by supplying hydroelectric energy to its customers. These laws and policies emphasize the need to repair, maintain, and improve generation facilities to ensure safety, security, and reliability of the Nation's energy infrastructure.

Southwestern's planned O&M projects are subject to change due to unanticipated equipment failure, customer needs, and weather conditions. The realities of maintaining a complex interconnected electric power system periodically require unforeseen reprioritizations of planned projects. All projects share the commonality of maintaining, repairing, and improving the aging infrastructure to ensure the reliability of the Federal power system. Southwestern will continue to maintain infrastructure and modernize systems to increase the reliability, efficiency, and use of Federal assets. This will be accomplished using appropriations; offsetting collections; and alternative financing arrangements, which include net billing, bill crediting, and/or reimbursable authority (customer advances) wherein Southwestern may accept work or services in lieu of payment.[2]

The budget request includes a proposal to authorize the Federal government to sell the transmission assets of Southwestern. Until such time as this proposal is enacted, Southwestern will continue its plans for operating, maintaining, and replacing equipment.

Southwestern will continue to strengthen cyber and physical security postures using strong and proven technologies that are part of the Continuous Diagnostics and Mitigation (CDM) program. The CDM program provides capabilities and tools to identify cybersecurity risks on an ongoing basis, prioritize these risks based on potential impacts, and enable cybersecurity personnel to mitigate the most significant problems first. In addition to CDM, Southwestern continues to look for other technologies that can be leveraged to ensure compliance with the Federal Information Security Management Act (FISMA) and North American Energy Reliability Corporation (NERC) Critical Infrastructure Protection (CIP) Standards to protect the Federal transmission system and the Nation's power grid.

[2] Southwestern's authority to use net billing and bill crediting is inherent in the authority provided by the Flood Control Act of 1944 and has been affirmed by the Comptroller General. Honorable Secretary of the Interior B-125127 (February 14, 1956).

Power Marketing

The Power Marketing activity funds technical and economic studies to support Southwestern's transmission planning, water resources management, and communication functions. Technical and economic studies provide data to analyze and evaluate the impacts of proposed operational changes and decision-making based on cost-benefit analysis. Funding is also required for Southwestern's coordination with the RTOs and to provide regional power restoration assistance to other non-hydropower generation sources during electric power grid emergencies. The National Electric Transmission Congestion Study identified constraints in the Nation's interconnected electrical grid which could impede power flows. Studies to identify any constraints on Southwestern's system will continue to be conducted. These studies show how the marketing and delivery of power is operationally impacted. The funding level for this activity is derived from Southwestern's engineering plan, negotiated architect/engineering contracts, and the number of studies required per year.

Operations

The Operations activity funds communication functions associated with the dispatch and delivery of power; environmental, safety, and health activities; and other transmission activity costs such as physical security, cybersecurity, and day-to-day power dispatch functions. The Operations activity includes three subactivities:

Communications

This subactivity funds telemetering improvements, technical support to protect cyber infrastructure, an e-tagging system that electronically schedules power for customers, load forecasting, digital test equipment, the radio frequency spectrum fee, and supplies and materials. The telemetering improvements include replacement of obsolete power and energy accounting equipment and modification of existing remote terminal units that improve the reliability of the power system, specifically in the areas of monitoring and control. Funding is required for upgrades that enable Southwestern to meet the goals of the EPACT and NERC by replacing aging infrastructure while assuring reliability and continuing to coordinate with the RTOs in its marketing area. The funding level for communications maintenance is derived from maintenance history, the age of equipment, expected life span, annual diagnostic maintenance testing, and historical pricing information.

Environmental, Safety, and Health

This subactivity funds environmental activities including waste disposal and clean-up of transformers, grounding and drainage, cultural resource reviews, and environmental assessments for threatened and endangered species such as the American Burying Beetle, various endangered bats, the Leopard Darter, and Interior Least Tern. Additionally, Southwestern may have environmental activities it performs as a Consulting Agency or participating agency resulting from a Biological Opinion or Biological Assessment, or as a participant on an interagency committee or working group. This subactivity also funds property transfers, wetland assessments, environmental library access, Toxic Substance Control Act and Resource Conservation Recovery Act compliance, contractor services, and requirements of the Environmental Protection Program as identified in DOE Order 450.1. The Safety and Health Program activities require funding for aviation safety, industrial hygiene, medical examinations, medical officer, wellness program, safety equipment, and first aid equipment and supplies.

Other Transmission

This subactivity funds physical security, field utility costs, and day-to-day power expenses of the dispatch center and the Alternate Control Center.

Maintenance

The Maintenance activity funds routine repair, maintenance, and improvement of Southwestern's substations/switchyards and high-voltage transmission lines and ensures delivery of reliable, efficient, and clean power to its customers. Southwestern's initial facilities, which were built approximately 60 years ago, are constantly evaluated. The funding level is based on analysis derived from age of equipment, risk of failure, life-cycle of equipment, and field crew evaluation. Internal and external factors include obsolescence of technology and unavailability of replacement parts. This budget request reflects Southwestern's assessment of the funding required to ensure continued reliability of the Federal power system and to fulfill the NERC operational criteria. By replacing aging equipment and removing constraints that impede power flows, Southwestern ensures the provision of a reliable Federal transmission system. The maintenance activity includes two subactivities:

Substation Maintenance

This subactivity funds power circuit breakers, disconnect switches, instrument transformers, protective relays and related equipment, computer aided drafting and design, revenue meters, vehicle maintenance, fuel, and other equipment to reliably perform general maintenance projects. Southwestern maintains the Federal power system in compliance with the regional electric reliability council and NERC requirements. The funding level for this subactivity is derived from an internal maintenance information system, which includes age and condition of the existing equipment.

Transmission Line Maintenance

This subactivity funds the purchase and maintenance of wood and steel structures, crossarms and braces, right-of-way (ROW) clearing, herbicide application, aerial patrol of the transmission system to identify maintenance needs, routine vehicle repair and maintenance, tractors, equipment, and fuel. The number of steel or wood poles and crossarms and high-voltage insulators replaced is derived from internal maintenance information system criteria. Emphasis has been placed on ROW clearing since NERC identified improper/insufficient ROW clearing as a major factor in potential blackouts. The funding level is appropriate for the number of structures and components to be replaced and the miles of ROW to be cleared as set forth by Southwestern's maintenance plan for meeting the goals of the EPACT and NERC to maintain a reliable transmission system.

Capitalized Moveable Equipment

This activity funds the replacement of vehicles, tractor-trailers, and heavy equipment used for the maintenance and repair of the transmission system and facilities. These vehicles and equipment have exceeded their useful lives and require high levels of maintenance. The vehicle cost estimates are derived from General Services Administration (GSA) pricing schedules.

Operations and Maintenance

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Operations and Maintenance $13,639,000	**$13,292,000**	**-$347,000**
Power Marketing $200,000	**$200,000**	**$0**
• The Power Marketing activity funds the technical and economic studies to support transmission planning.	• The Power Marketing activity funds the technical and economic studies to support transmission planning.	• No change.
Operations $8,217,000	**$8,178,000**	**-$39,000**
Communications ($6,573,000) • This subactivity funds telemetering improvements, technical support to protect cyber infrastructure, SCADA/EMS system maintenance, load forecasting, and digital testing equipment.	*Communications ($5,408,000)* • This subactivity funds telemetering improvements, technical support to protect cyber infrastructure, SCADA/EMS system maintenance, load forecasting, and digital testing equipment.	*Communications (-$1,165,000)* • The decrease reflects completion of the mobile radio system replacement.
Environmental, Safety, and Health ($903,000) • The subactivity funds environmental, safety, and health services.	*Environmental, Safety, and Health ($2,050,000)* • The subactivity funds environmental, safety, and health services.	*Environmental, Safety, and Health (+$1,147,000)* • The increase reflects a cultural resources archeological survey on Southwestern's transmission lines.
Other Transmission ($741,000) • The subactivity funds physical security, field utility costs, and day to day expenses of the dispatch center.	*Other Transmission ($720,000)* • The subactivity funds physical security, field utility costs, and day to day expenses of the dispatch center.	*Other Transmission (-$21,000)* • The decrease reflects a small reduction in planned service agreements for security.

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Maintenance $3,834,000	**$3,550,000**	**-$284,000**
Substation ($2,298,000) • This subactivity funds all equipment, parts, and materials for the operation of high voltage substations.	*Substation ($2,001,000)* • This subactivity funds all equipment, parts, and materials for the operation of high voltage substations.	*Substation (-297,000)* • The decrease reflects substation grounding and drainage improvements.
Transmission Line Maintenance ($1,536,000) • This subactivity funds all equipment, parts, and materials for the operation of the high voltage transmission system.	*Transmission Line Maintenance ($1,549,000)* This subactivity funds all equipment, parts, and materials for the operation of the high voltage transmission system. Also, vegetation management contracts.	*Transmission Line Maintenance (+$13,000)* • The increase reflects the change in the number of miles planned to be cleared by vegetation management contract.
Capitalized Moveable Equipment $1,388,000	**$1,364,000**	**-$24,000**
This activity funds the replacement of vehicles, tractor-trailers, and heavy equipment used for the maintenance and repair of the transmission system and facilities.	• This activity funds the replacement of vehicles, tractor-trailers, and heavy equipment used for the maintenance and repair of the transmission system and facilities.	• The decrease reflects the estimated replacement cost of the heavy equipment and utility trucks being purchased.

Construction
Funding ($K)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted ($)
Construction				
Transmission System				
Substation Upgrades	1,896	1,933	0	-1,933
Communication Upgrades	4,579	4,412	2,980	-1,432
Transmission Upgrades	10,400	8,722	10,287	+1,565
Subtotal, Construction	**16,875**	**15,067**	**13,267**	**-1,800**
Alternative Financing	-12,180	-10,070	-8,167	+1,903
Total, Construction	**4,695**	**4,997**	**5,100**	**+103**

Southwestern Power Administration
Construction

Description

The activities of the Construction subprogram enable Southwestern to market and deliver Federal hydropower in the most reliable, safe, efficient, and cost-effective manner to meet the operational criteria required by the North American Electric Reliability Corporation while avoiding transmission infrastructure deterioration. Southwestern's planned construction projects are subject to change based on unanticipated equipment failure, customer needs, and weather conditions. The realities of maintaining a complex interconnected power system include unforeseen priority projects which arise periodically, causing a reprioritization of planned projects. All projects share the commonality of replacing aging infrastructure necessary to maintain the reliability of the Federal power system.

Southwestern will continue to maintain infrastructure and modernize systems to increase the reliability, efficiency, and use of Federal assets. This will be accomplished using appropriations and alternative financing arrangements, which include net billing, bill crediting, and/or reimbursable authority (customer advances).[3]

The budget request includes a proposal to authorize the Federal government to sell the transmission assets of Southwestern. Until such time as this proposal is enacted, Southwestern will continue current plans for construction, maintenance, and equipment upgrades.

Transmission System

This activity funds current construction projects that require expansion of, or additions to, existing facilities. Southwestern ensures system reliability by replacing aging equipment and removing constraints that limit power flows. The projects outlined below address Southwestern's efforts to reduce the risk of extended service outages, avoid more costly replacements in the future, and support the increased transmission system usage. The funding level for this activity is derived from internal and external management decisions and field crew observations. System age, risk of equipment failure, life-cycles, obsolescence of technology and unavailability of spare parts, cost, and demand for more capacity are also considered in these budgeting decisions. These variables are assessed and incorporated into Southwestern's ten-year construction plan. The transmission activity includes three subactivities:

Substation Upgrades

This subactivity funds the construction and upgrade of the substations and the components necessary to provide improved system reliability and reduce future maintenance and equipment costs. Southwestern owns and operates 26 substation/switching stations. Many of these facilities were designed and constructed over 60 years ago. The equipment which will be replaced or upgraded includes power transformers, circuit breakers, and control equipment, as well as the structural components necessary to sustain reliable power delivery and support a stable, flexible interconnected power grid.

Communication Upgrades

This subactivity funds all communication equipment planned to provide improved system reliability and reduce future maintenance and equipment costs. This subactivity also provides funding for microwave radios and microwave tower additions, replacements, and modifications that will increase the reliability of communications with generating plants and substations. The communication system provides for the transfer of voice and data traffic to allow monitoring and control of power system generation and transmission assets.

[3] Southwestern's authority to use net billing and bill crediting is inherent in the authority provided by the Flood Control Act of 1944 and has been affirmed by the Comptroller General. Honorable Secretary of the Interior B-125127 (February 14, 1956).

Transmission Upgrades

This subactivity funds transmission system upgrades. Much of the conductor, optical ground wire (OPGW), and static wire on Southwestern's transmission lines has reached the end of its original assumed service life. With this assumed service life, approximately 20 to 30 miles of transmission line, including the conductor, OPGW, static wire, and structures, will need to be replaced each year. As Southwestern replaces the conductor, Southwestern will use the opportunity to increase line capacity where practical to accommodate increased loads in the region.

Spectrum Relocation

The Commercial Spectrum Enhancement Act of 2004 (CSEA, Title II of P.L. 108-494) created the Spectrum Relocation Fund (SRF) to streamline the relocation of Federal systems from existing spectrum bands and accommodate commercial use by facilitating reimbursement of relocation costs to affected agencies. Southwestern has received $42.8 million in spectrum relocation funds, as approved by the Office of Management and Budget, and as reported to the Congress. Southwestern has completed 100 percent of the tower installation project and anticipates completing antenna and radio installation and obtaining comparable capability by the end of 2022. These mandatory funds will remain available until expended, and Southwestern will return any amounts received in excess of actual relocation costs to the SRF. Spectrum relocation activities were funded from spectrum auction proceeds; thus, no funding is requested in this subactivity.

Construction

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Construction $15,067,000	**$13,267,000**	**-$1,800,000**
Transmission System $15,067,000	**$13,267,000**	**-$1,800,000**
Substation Upgrades ($1,933,000) • Funding is requested for Power Circuit Breakers at Clarksville; Disconnect Switches at New Madrid and Weleetka; Grounding and Drainage Projects at Malden and Piggott; and Instrument Transformers at various locations.	*Substation Upgrades ($0)* • No planned transformer replacements in FY 2021.	*Substation Upgrades (-$1,933,000)* • The decrease is due to no planned transformer replacements in FY 2021.
Communication Upgrades ($4,412,000) • This subactivity funds all communication equipment additions and replacements. Projects include microwave equipment between Nixa, Selmore, and Hercules. Also, Microwave Tower Replacement at White Oak.	*Communication Upgrades ($2,980,000)* • This subactivity funds all communication equipment additions and upgrades. Projects include microwave equipment, fiber terminal equipment upgrades, and microwave tower at Tulsa Headquarters.	*Communication Upgrades (-$1,432,000)* The decrease reflects one less tower replacement planned for FY 2021.
Transmission Upgrades ($8,722,000) • Rebuild portions of Line 3001, 15.1 miles due to age, condition and electrical loading of the conductor.	*Transmission Upgrades ($10,287,000)* • Rebuild structures from Clarksville to Structure 87TC, 15.15 miles and Reconductor Dardanelle Dam to structure 39, Line 3001C, phase one (west side), 8.66 miles.	*Transmission Upgrades (+$1,565,000)* • The increase in the construction subprogram reflects the use of a composite conductor on the steel structures for Line 3001C phase one. This product is lighter and will prevent the need to replace the steel towers.

Purchase Power and Wheeling
Funding ($K)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted
Purchase Power and Wheeling				
System Support	56,500	64,500	91,500	+27,000
Other Contractual Services	3,500	3,500	3,500	0
Subtotal, Purchase Power and Wheeling	**60,000**	**68,000**	**95,000**	**+27,000**
Offsetting Collections (PPW)	-50,000	-43,000	-70,000	-27,000
Alternative Financing	-10,000	-25,000	-25,000	0
Total, Purchase Power and Wheeling	**0**	**0**	**0**	**0**

Southwestern Power Administration
Purchase Power and Wheeling

Description

The Purchase Power and Wheeling (PPW) subprogram provides for the purchase of energy to meet peaking power contractual obligations and the delivery of Federal power. Except for contractual arrangements pertaining to a few electrically-isolated hydropower projects, Southwestern's power sales contracts provide for 1200-hours of peaking power per year delivered from its interconnected system of hydropower projects. At times, due to below average water conditions or hydropower unit outages, Southwestern must purchase power when the hydropower projects cannot produce enough to fulfill its 1200-hour contract obligations. Blending purchased power with the Federal hydropower provides a reliable product while ensuring contract fulfillment occurs.

Southwestern assesses its purchase power needs based on hydrologic conditions and anticipated hydropower unit outages. Hydrologic conditions can vary widely and change rapidly, such that purchase power needs are assessed at least seasonally and can change daily. Unit outages for major rehab and replacement work are known years in advance so that purchase power needs can be planned; however, forced outages or delays in units returning to service can cause sudden changes to anticipated purchase power needs. Power purchases are typically made through contractual arrangements but may also be made on the spot market when conditions are more severe than anticipated or otherwise unexpected. Delivery of purchase power to Southwestern's system is made via the SPP RTO or Southwestern's own transmission system.

Southwestern's budget request for the PPW subprogram reflects the maximum anticipated need to ensure adequate funding to fulfill its 1,200-hour peaking power contractual obligations considering volatile market prices, unknown forced generation outages, and all but the most severe hydrological conditions. Southwestern will continue to use offsetting collections and alternative financing arrangements, which include net billing, bill crediting, and/or reimbursable authority (customer advances), to fund this subprogram. When hydropower generation falls significantly below normal due to severe drought conditions or major outages, Southwestern will utilize the Continuing Fund for emergency PPW expenses.

Southwestern employs a risk mitigation strategy to ensure continuous operations during periods of significant drought. The strategy involves maintaining an unobligated reserve balance of funds from receipts credited as offsetting collection for PPW, in order to respond to rapid-developing severe drought conditions. Any receipts retained are available until expended and are available only for PPW expenses. As of the end of FY 2019, Southwestern's PPW reserve balance was $86 million. Customers will provide other power resources and/or purchases for the remainder of their firm loads.

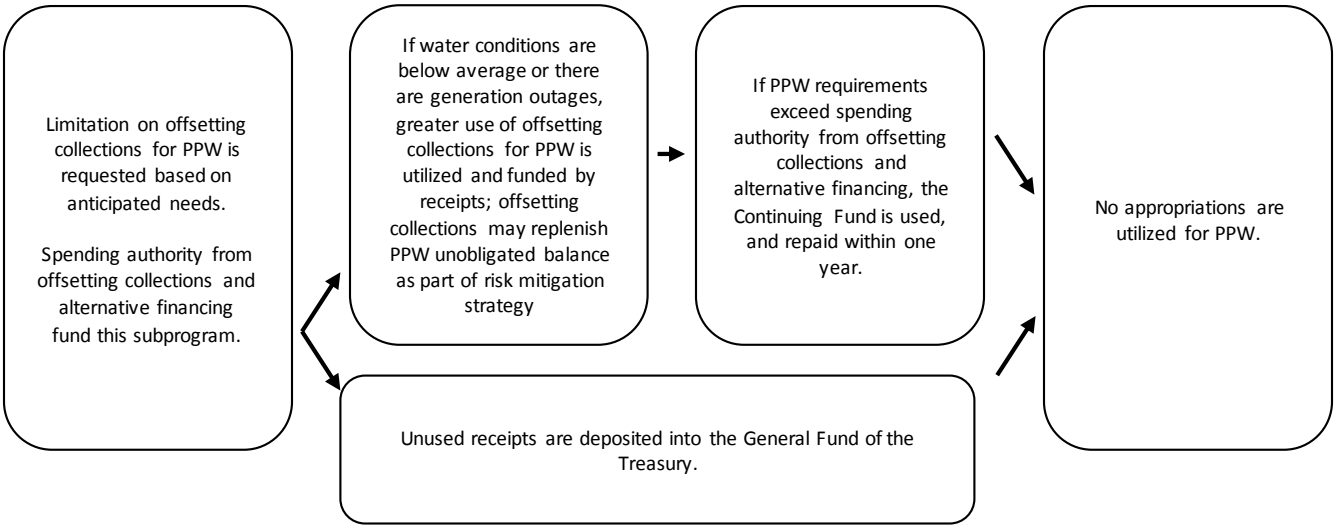
The activities of the PPW subprogram provide for the purchase of power that helps fulfill limited peaking power contractual obligations, thereby ensuring the marketability of the Federal hydropower resource and repayment of the Federal investment. This subprogram also provides for wheeling services that deliver Federal power to optimize the operation of the hydropower facilities marketed by Southwestern. This subprogram enhances the reliability of the electrical transmission grid. PPW includes two activities:

System Support

This activity funds Southwestern's purchase power requirements needed to fulfill all 1200-hour contractual peaking power obligations with customers. System support requirements depend on the conditions of the interconnected system of hydropower projects which is affected by weather, unit operational condition, power market prices (which can be volatile), and limited availability of energy banks. In prior years, inadequate funding for PPW and hydrological fluctuations required multiple requests to access the Continuing Fund to ensure sufficient funding was available to fulfill Southwestern's 1200-hour peaking power contractual obligations. In FY 2001, Southwestern requested, and Congress enacted, authority to use Federal power receipts that recover purchase power and wheeling expenses (offsetting collections) to fund its PPW program (up to a specified limit). The use of this authority will be largely dependent upon the hydrological conditions realized during the fiscal year. Under average conditions, less than half of the limit requested will be collected and used. Since the rates Southwestern charges its customers are based on full cost recovery, Southwestern has a built-in incentive to minimize expenditures for purchase power. The spending authority from offsetting collections supports proactive strategies and ensures greater flexibility when Southwestern experiences low water conditions, hydropower unit outages, and/or volatile power market prices, and will decrease dependence on the Continuing Fund under all but the most severe hydrological conditions.

Other Contractual Services

This activity funds other contractual services that provide for wheeling associated with the purchase of transmission service to meet limited peaking power obligations and for the integration of projects for the delivery of Federal power. The funding level is derived from contractual wheeling requirements. The FY 2021 funding request reflects the projected cost for wheeling services based on contractual pricing and delivery terms.



Purchase Power and Wheeling

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Purchase Power and Wheeling $68,000,000	**$95,000,000**	**+$27,000,000**
System Support $64,500,000	*$91,500,000*	*+$27,000,000*
• This activity funds purchase power requirement needed to fulfill all 1200-hour contractual peaking power obligations with customers.	• This activity funds purchase power requirement needed to fulfill all 1200-hour contractual peaking power obligations with customers.	• The overall increase in system support reflects maximum anticipated needs based on projected market prices and severe drought hydrologic conditions.
Other Contractual Services $3,500,000	*$3,500,000*	*+$0*
• Contractual services for wheeling associated with the purchase of transmission service.	• Contractual services for wheeling associated with the purchase of transmission service.	• Funding request remains the same.

Program Direction Funding ($K)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted ($)
Southwestern Power Administration				
Salaries and Benefits	23,311	25,157	25,238	+81
Travel	1,372	1,561	1,710	+149
Support Services	3,867	3,983	4,037	+54
Other Related Expenses	4,445	4,456	4,650	+194
Subtotal, Southwestern Power Administration	**32,995**	**35,157**	**35,635**	**+478**
Offsetting Collections (annual expenses)	-29,695	-31,467	-31,483	-16
Alternative Financing	0	0	-852	-852
Total, Program Direction	**3,300**	**3,690**	**3,300**	**-390**
Federal FTEs	194	194	194	0
Support Services				
Management Support				
Engineering and Technical Services	0	0	2,624	+2,624
Technical Support				
Management and Professional Support Services	3,867	3,983	1,413	-2,570
Total Support Services	3,867	3,983	4,037	+54
Total, Support Services	**3,867**	**3,983**	**4,037**	**+54**
Other Related Expenses				
Rent to Others	882	889	852	-37
Communication, Utilities, Misc.	390	966	937	-29
EITS	0	34	36	+2
Printing and Reproduction	115	76	76	0
Other Services	1,085	719	719	0
Training	285	185	190	+5
Power Marketing Liaison	178	140	140	0
Financial Audit	545	400	430	+30

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted ($)
Supplies and Materials	250	150	170	+20
Equipment	465	450	450	0
Working Capital Fund	250	447	650	+203
Total, Other Related Expenses	**4,445**	**4,456**	**4,650**	**+194**

Program Direction

Overview

Southwestern's Program Direction subprogram ensures continued reliability of the Federal power system by utilizing Federal staffing resources and associated funds required to provide overall direction and execution of Southwestern's Operation and Maintenance Program.

The Program Direction subprogram supports DOE's and Southwestern's missions by providing compensation and all related expenses for its workforce, including those employees that operate and maintain Southwestern's high-voltage interconnected transmission system and associated facilities; those that plan, design, and supervise the construction of replacements, upgrades, and additions (capital investments) to the transmission facilities; those that market the power and energy produced to repay annual expenses and capital investment; those that perform cyber and physical security roles; and those that administratively support these functions.

Southwestern will use available programs and develop new strategies to hire and train the next generation of engineers, cyber and physical security specialists, power system dispatchers, high voltage electricians, and linemen. These initiatives will address the shortage of these valuable resources because of retirement trends, and the ever-expanding demands on the electric utility industry, such as compliance with NERC and FISMA standards.

Southwestern trains all employees on a continuing basis in occupational safety and health regulations, policies, and procedures to keep the safety culture strong. Accidents are always reviewed to ensure lessons are learned and proper work protocol is in place.

Program Direction is mainly funded from offsetting collections. Other funding utilized for Program Direction is appropriations and if necessary alternative financing arrangements.

Highlights of the FY 2021 Budget Request

The FY 2021 Budget Request's funding level for salaries is derived from the current year budgeted salaries, projected cost-of-living adjustments, promotions, and within-grade increases. The funding level for benefits is derived from a percentage of budgeted salaries.

Program Direction

Activities and Explanation of Changes

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Program Direction $35,157,000	**$35,635,000**	**+$478,000**
Salaries and Benefits $25,157,000	*$25,238,000*	*+$81,000*
• The FY 2020 level supports 194 Federal employees: 54 percent of the employees are GS; salaries of the remaining 46 percent (craft workers and power system dispatchers) are determined through union negotiations and wage surveys. This activity also includes overtime, awards, relocation, workers' compensation, recruitment bonuses, retention pay, and advanced in-hire rates. By the end of FY 2020, approximately 24 percent of Southwestern's staff will be eligible for optional retirement. Southwestern will continue to invest in its employees, emphasizing strong development programs, completing skills gap analyses, and pursuing aggressive recruitment and retention efforts.	• The FY 2021 level supports 194 Federal employees: 54 percent of the employees are GS; salaries of the remaining 46 percent (craft workers and power system dispatchers) are determined through union negotiations and wage surveys. This activity also includes overtime, awards, relocation, workers' compensation, recruitment bonuses, retention pay, and advanced in-hire rates. By the end of FY 2021, approximately 28 percent of Southwestern's staff will be eligible for optional retirement. Southwestern will continue to invest in its employees, emphasizing strong development programs, completing skills gap analyses, and pursuing aggressive recruitment and retention efforts.	• The increase in Salaries and Benefits reflects aggressive recruiting to fill several technical hard to fill positions, back-filling retirees, and filling succession planning positions for knowledge transfer.
Travel $1,561,000	*$1,710,000*	*+$149,000*
• This activity funds all related travel and per diem expenses for mission-related travel to maintain the integrity and reliability of Southwestern's geographically dispersed power system. The funding level for this activity is primarily derived from the daily requirement of the field maintenance personnel to maintain 1,380 miles of transmission lines, 26 substations/switchyards, 51 microwave/radio sites, communication equipment, and the Supervisory Control and Data Acquisition network. Travel for the performance of general and administrative functions is also included.	• This activity funds all related travel and per diem expenses for mission-related travel to maintain the integrity and reliability of Southwestern's geographically dispersed power system. The funding level for this activity is primarily derived from the daily requirement of the field maintenance personnel to maintain 1,380 miles of transmission lines, 26 substations/switchyards, 51 microwave/radio sites, communication equipment, and the Supervisory Control and Data Acquisition network. Travel for the performance of general and administrative functions is also included.	• The increase in travel reflects transmission policy related efforts, water resource activities, and field maintenance crew travel.

FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Support Services $3,983,000	*$4,037,000*	*+$54,000*
• This activity funds contracted management support services including information technology, E-government, and administrative/records management support. The funding level for this activity is derived from the most recent negotiated contract for support services essential to achieve Southwestern's mission.	• This activity funds contracted management support services including information technology, E-Government, and administrative/records management support. The funding level for this activity is derived from the most recent negotiated contract for support services essential to achieve Southwestern's mission.	• Increase reflects projected contractual cost-of-living increase.
Other Related Expenses $4,456,000	*$4,650,000*	*+$194,000*
• This activity funds rental space, facility security, the financial audit, services of the Power Marketing Liaison Office, the Human Resources Shared Service Center (HRSSC), the working capital fund, technology refresh in the areas of personal computers, hardware and software, printing and reproduction, and training and tuition fees in support of workforce planning and required training to meet the NERC emergency operations requirement. Rental space costs assume the GSA inflation factor. Other costs are based on the historical usage and actual cost of similar items.	• This activity funds rental space, facility security, the financial audit, services of the Power Marketing Liaison Office, the Human Resources Shared Service Center (HRSSC), the working capital fund, technology refresh in the areas of personal computers, hardware and software, printing and reproduction, and training and tuition fees in support of workforce planning and required training to meet the NERC emergency operations requirement. Rental space costs assume the GSA inflation factor. Other costs are based on the historical usage and actual cost of similar items.	• The increase reflects additional costs of the HRSSC, Information Technology service agreements, and the Working Capital Fund.

Southwestern Power Administration
Revenues and Receipts

	FY 2018 Actual	FY 2019 Actual	FY 2020 Estimate	FY 2021 Estimate	FY 2022 Estimate	FY 2023 Estimate	FY 2024 Estimate	FY 2025 Estimate
Gross Revenues								
Sale and Transmission of Electric Energy	186,305	214,312	198,610	198,610	198,610	198,610	198,610	198,610
Up to Potential Revenues, if needed[4]			29,726	56,726	56,726	56,726	56,726	56,726
Total, Gross Revenues	186,305	214,312	228,336	255,336	255,336	255,336	255,336	255,336
Alternative Financing Credited as an Offsetting Receipt, Net Billing/Bill Crediting	-121,141	-136,804	-141,500	-141,700	-140,600	-140,200	-139,400	-138,700
Offsetting Collections, Southwestern Annual Expenses (Net Zero)	-18,888[5]	-35,402	-37,375	-37,140	-38,193	-38,680	-39,440	-40,098
Offsetting Collections, Purchase Power and Wheeling ('up to' ceiling)[6]	-40,000	-36,000	-43,000	-70,000	-70,000	-70,000	-70,000	-70,000
Total Proprietary Receipts	6,276	6,106	6,461	6,496	6,543	6,456	6,496	6,538
Percent of Sales to Preference Customers	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Energy Sales from Power Marketed (billions of kilowatt hours)	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4

[4] Southwestern has the ability to adjust its revenues to ensure full recovery of purchase power expenses, by making limited adjustments as allowed for within its current rates and/or through the annual power repayment studies and rates change process if a more substantial adjustment is needed.

[5] FY 2018 annual expenses were less than previous and estimated future years resulting from the use of prior year balances to offset the request.

[6] FY 2019 amount enacted for the limit on PPW offsetting collections was $50 million. The actual amount collected in FY 2019 was $36.0 million. For FY 2020 through FY 2025, the estimated amount of offsetting collections for PPW is equivalent to the "up to" amount enacted (FY2020) or requested in the budget (FY 2021-2025). The PPW offsetting collections limit requested (when matched with PPW receipts), along with alternative financing used for PPW, could potentially fund a drought for one year or replenish unobligated balances after a drought has occurred. This will also allow funding to be collected in case the drought persists for more than a year.

Southwestern Power Administration
Estimate of Offsetting Collections for Reimbursable Work and Work for Others[7]

	(Dollars in Thousands)		
	FY 2019	FY 2020	FY 2021
Offsetting Collections for Reimbursable Work [8]			
Alternative Financing			
Operations and Maintenance	8,894	6,018	5,635
Construction	12,180	10,070	8,167
Purchase Power and Wheeling (PPW)	10,000	25,000	25,000
Program Direction	0	0	852
Subtotal, Alternative Financing	31,074	41,088	39,654
Offsetting Collections not anticipated for obligation in budget year	0	0	0
Subtotal, Offsetting Collections for Reimbursable Work	**31,074**	**41,088**	**39,654**
Offsetting Collections for Reimbursable Work-for-Others [9]	**19,926**	**9,912**	**11,346**
Total, Offsetting Collections for Reimbursable	**51,000**	**51,000**	**51,000**

[7]Southwestern received permanent non-Federal reimbursable authority pursuant to 16 USC 825s-4. Table is shown for transparency purposes.

[8]Southwestern relies significantly on alternative financing arrangements with customers to finance much of its direct mission work on a reimbursable basis.

[9] Southwestern utilizes various forms of Federal and non-Federal reimbursable agreements. Work-for-Others agreements include interconnection requests, system upgrades for reliability, and relocation of structures for State and Federal highways.

Southwestern Power Administration
System Statistics

	FY 2019 Actuals	FY 2020 Estimate	FY 2021 Estimate	FY 2022 Estimate	FY 2023 Estimate	FY 2024 Estimate	FY 2025 Estimate
Generating Capacity (kilowatts)							
Installed Capacity	2,173,500	2,173,500	2,193,500	2,193,500	2,193,500	2,193,500	2,193,500
Marketed Capacity	2,058,500	2,058,500	2,058,500	2,058,500	2,058,500	2,058,500	2,058,500
Generating Stations							
Generating Projects (Number)	24	24	24	24	24	24	24
Substations/Switchyards (Number)	26	26	26	26	26	26	26
Substations/Switchyards (kVA Capacity)	1,026,900	1,026,900	1,026,900	1,026,900	1,026,900	1,026,900	1,026,900
Available Energy[10] (Megawatt-hours)							
Energy Generated	7,201,004	4,928,700	4,905,700	5,105,900	5,168,200	5,168,200	5,168,200
Energy Received	197,057	335,700	303,000	314,500	252,200	252,200	252,200
Total, Energy Available for Marketing	7,398,061	5,264,400	5,208,700	5,420,400	5,420,400	5,420,400	5,420,400
Transmission Lines (Circuit-Miles)							
161-KV	1,117	1,117	1,117	1,117	1,117	1,117	1,117
138-KV	164	164	164	164	164	164	164
69-KV	99	99	99	99	99	99	99
Total, Transmission Lines	1,380	1,380	1,380	1,380	1,380	1,380	1,380

[10] Available Energy: actual data is gross; estimated data comes from Southwestern's 2019 power repayment studies.

Power Marketed, Wheeled, or Exchanged by Project

	State	Number of Plants	Installed Capacity (kW)	Marketed Capacity (kW)	FY 2019 Actual Energy (GWh)	FY 2020 Estimated Energy (GWh)	FY 2021 Estimated Energy (GWh)	FY 2022 Estimated Energy (GWh)	FY 2023 Estimated Energy (GWh	FY 2024 Estimated Energy (GWh)	FY 2025 Estimated Energy (GWh)
Power Marketed											
Interconnected											
System	Missouri	4	470,000	666,754	2,381	1,703	1,684	1,753	1,753	1,753	1,753
	Arkansas	9	1,037,050	366,849	1,337	956	946	986	986	986	986
	Oklahoma	7	514,100	404,798	1,473	1,054	1,042	1,086	1,086	1,086	1,086
	Texas	2	113,000	277,750	926	662	655	683	683	683	683
	Louisiana	0	0	138,876	484	346	342	357	357	357	357
	Kansas	0	0	144,161	547	391	387	403	403	403	403
Subtotals		22	2,134,150	1,999,188	7,148	5,112	5,056	5,268	5,268	5,268	5,268
Isolated:											
Robert D. Willis Project											
Sam Rayburn Project											
50% to Texas		2	59,350	29,675	125	76	76	76	76	76	76
50% to Louisiana		0	0	29,675	125	76	76	76	76	76	76
Subtotals		2	59,350	59,350	250	152	152	152	152	152	152
Total, Power Marketed[11]		24	2,193,500	2,058,538	7,398	5,264	5,208	5,420	5,420	5,420	5,420
Power Wheeled/Exchanged											
Wheeled (MW)					434	684	504	497	503	503	503
Exchanged (GWh)					0	0	0	0	0	0	0

[11] Total, Power Marketed: actual energy data is the energy delivered and therefore net of losses and other non-marketed energy; estimated data comes from Southwestern's 2019 power repayment studies.

DEPARTMENT OF ENERGY
Funding by Site Detail
Southwestern Power Administration Operation
(Dollars in Thousands)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request
Southwestern Power Administration Office			
Operation And Maintenance - SWPA	17,006	13,639	13,292
Construction - SWPA	16,875	15,067	13,267
Purchase Power And Wheeling - SWPA	60,000	68,000	95,000
Program Direction - SWPA	32,995	35,157	35,635
Total Southwestern Power Administration Office	**126,876**	**131,863**	**157,194**

Western Area Power Administration

Western Area Power Administration

Construction, Rehabilitation, Operation and Maintenance
Western Area Power Administration
Proposed Appropriation Language

For carrying out the functions authorized by title III, section 302(a)(1)(E) of the Act of August 4, 1977 (42 U.S.C. 7152), and other related activities including conservation and renewable resources programs as authorized, [$262,959,000] *$259,126,000*, including official reception and representation expenses in an amount not to exceed $1,500, to remain available until expended, of which [$262,959,000] *$259,126,000* shall be derived from the Department of the Interior Reclamation Fund: Provided, That notwithstanding 31 U.S.C. 3302, section 5 of the Flood Control Act of 1944 (16 U.S.C. 825s), and section 1 of the Interior Department Appropriation Act, 1939 (43 U.S.C. 392a), up to [$173,587,000] *$169,754,000* collected by the Western Area Power Administration from the sale of power and related services shall be credited to this account as discretionary offsetting collections, to remain available until expended, for the sole purpose of funding the annual expenses of the Western Area Power Administration: Provided further, That the sum herein appropriated for annual expenses shall be reduced as collections are received during the fiscal year so as to result in a final fiscal year [2020] *2021* appropriation estimated at not more than $89,372,000 of which $89,372,000 is derived from the Reclamation Fund: Provided further, That notwithstanding 31 U.S.C. 3302, up to [$227,000,000] *$227,043,000* collected by the Western Area Power Administration pursuant to the Flood Control Act of 1944 and the Reclamation Project Act of 1939 to recover purchase power and wheeling expenses shall be credited to this account as offsetting collections, to remain available until expended for the sole purpose of making purchase power and wheeling expenditures: Provided further, That for purposes of this appropriation, annual expenses means expenditures that are generally recovered in the same year that they are incurred (excluding purchase power and wheeling expenses). [Provided further, That of the unobligated balances from prior year appropriations available under this heading, $176,000 is hereby permanently cancelled.] (Energy and Water Development and Related Agencies Appropriations Act, 2020.)

Explanation of Changes

There is no change in the appropriation language.

Public Law Authorizations

P.L. 57-161, "The Reclamation Act of 1902"
P.L. 78-534, "Flood Control Act of 1944"
P.L. 95-91, "Department of Energy Organization Act" (1977)
P.L. 102-486, "Energy Policy Act of 1992"
P.L. 66-389, "Sundry Civil Appropriations Act" (1922)
P.L. 76-260, "Reclamation Project Act of 1939"
P.L. 80-790, "Emergency Fund Act of 1948"
P.L. 102-575, "Reclamation Projects Authorization and Adjustment Act of 1992"
"Economy Act" of 1932, as amended (41 stat. 613)
"Interior Department Appropriation Act of 1928" (44 Stat. 957)
P.L. 70-642, "Boulder Canyon Project Act" (1928)
P.L. 75-756, "Boulder Canyon Project Adjustment Act" (1940)
P.L. 98-381, "Hoover Power Plant Act of 1984"
P.L. 75-529, "The Fort Peck Project Act of 1938"
P.L. 84-484, "The Colorado River Storage Project Act of 1956"
P.L. 90-537, "The Colorado River Basin Project Act of 1968"
The Act of June 18, 1954 (68 Stat. 255)
P.L. No 111-5, "American Recovery and Reinvestment Act of 2009"

Falcon and Amistad Operating and Maintenance Fund
Proposed Appropriation Language

For operation, maintenance, and emergency costs for the hydroelectric facilities at the Falcon and Amistad Dams, [$3,160,000] *$5,776,000*, to remain available until expended, and to be derived from the Falcon and Amistad Operating and Maintenance Fund of the Western Area Power Administration, as provided in section 2 of the Act of June 18, 1954 (68 Stat. 255): Provided, That notwithstanding the provisions of that Act and of 31 U.S.C. 3302, up to [$2,932,000] *$5,548,000* collected by the Western Area Power Administration from the sale of power and related services from the Falcon and Amistad Dams shall be credited to this account as discretionary offsetting collections, to remain available until expended for the sole purpose of funding the annual expenses of the hydroelectric facilities of these Dams and associated Western Area Power Administration activities: Provided further, That the sum herein appropriated for annual expenses shall be reduced as collections are received during the fiscal year so as to result in a final fiscal year [2020] *2021* appropriation estimated at not more than $228,000: Provided further, That for purposes of this appropriation, annual expenses means expenditures that are generally recovered in the same year that they are incurred: Provided further, That for fiscal year [2020] *2021*, the Administrator of the Western Area Power Administration may accept up to [$1,187,000] *$1,526,000* in funds contributed by United States power customers of the Falcon and Amistad Dams for deposit into the Falcon and Amistad Operating and Maintenance Fund, and such funds shall be available for the purpose for which contributed in like manner as if said sums had been specifically appropriated for such purpose: Provided further, That any such funds shall be available without further appropriation and without fiscal year limitation for use by the Commissioner of the United States Section of the International Boundary and Water Commission for the sole purpose of operating, maintaining, repairing, rehabilitating, replacing, or upgrading the hydroelectric facilities at these Dams in accordance with agreements reached between the Administrator, Commissioner, and the power customers. (Energy and Water Development and Related Agencies Appropriations Act, 2020.)

Explanation of Changes

There is no change in the appropriation language.

Public Law Authorizations
P.L. 103-236, "Foreign Relations Authorization Act, Fiscal Years 1994 and 1995"
The Act of June 18, 1954 (68 Stat. 255)

Western Area Power Administration
Funding ($K)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted
Gross	1,102,514	1,157,256	1,175,542	+18,286
Offsets	-1,012,914	-1,110,632	-1,107,342	+3,290
Net BA	**89,600**	**46,624**	**68,200**	**+21,576**

Overview

Western Area Power Administration (WAPA) continues to support the Department of Energy (DOE) priorities for a resilient, reliable and secure North American electricity system.

WAPA's mission is to market and reliably deliver cost-based Federal hydroelectric power. WAPA markets power in 15 central and western states from Federally-owned power plants operated primarily by the U.S. Army Corps of Engineers, U.S. Bureau of Reclamation and the Department of State's International Boundary and Water Commission. WAPA operates and maintains a high-voltage, integrated transmission system, including approximately 17,000 circuit-miles of high-voltage transmission lines, more than 300 substations/switchyards and associated power system controls, and communication and electrical facilities.

WAPA serves a diverse group of nearly 700 wholesale customers, including more than two dozen military installations, DOE National labs, municipalities, cooperatives, public utility and irrigation districts, Federal and state agencies and Native American tribes. In turn, WAPA's customers provide service to millions of retail consumers.

WAPA's base program is funded through three appropriation accounts: 1) the Construction, Rehabilitation, Operation and Maintenance Account (CROM); 2) Falcon and Amistad Operating and Maintenance Fund; and 3) Colorado River Basins Power Marketing Fund (CRBPMF). Within these three accounts, there are seven subprograms; four in the CROM Account, one in the Falcon and Amistad Operating and Maintenance Fund and two in CRBPMF.

Highlights and Major Changes in the FY 2021 Budget Request

The FY 2021 budget request includes:

- A proposal to authorize the Federal government to sell the transmission assets of WAPA.
- A proposal to change WAPA's statutory rate structure requirement from cost recovery to a market based structure that takes into consideration rates charged by comparable utilities and could result in faster recoupment of the taxpayer investment.
- A proposal to repeal the $3.25 billion borrowing authority managed by WAPA's Transmission Infrastructure Program (TIP).

Western Area Power Administration
Funding by Congressional Control ($K)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted ($)	FY 2021 Request vs FY 2020 Enacted (%)
Construction, Rehabilitation, Operation and Maintenance (CROM)					
Operation and Maintenance	77,056	72,176	77,874	+5,698	+8%
Construction and Rehabilitation	32,632	45,887	26,251	-19,636	-43%
Purchase Power and Wheeling	486,396	515,769	520,933	+5,164	+1%
Program Direction	238,483	250,091	253,575	+3,484	+1%
Subtotal, CROM Program	834,567	883,923	878,633	-5,290	-1%
Alternative Financing					
Operation and Maintenance	-7,758	-6,600	-6,297	+303	-5%
Construction and Rehabilitation	-27,077	-39,922	-20,353	+19,569	-49%
Purchase Power and Wheeling	-260,954	-288,769	-293,890	-5,121	+2%
Program Direction	-39,136	-44,719	-48,546	-3,827	+9%
Subtotal, Alternative Financing	-334,925	-380,010	-369,086	+10,924	-3%
Offsetting Collections from Colorado River Dam Fund					
Operation and Maintenance	-1,455	-1,415	-1,868	-453	+32%
Program Direction	-7,603	-7,539	-6,510	+1,029	-14%
Subtotal, Offsetting Collections from Colorado River Dam Fund	-9,058	-8,954	-8,378	+576	-6%
Offsetting Collections, annual Operation and Maintenance and Program Direction					
Operation and Maintenance	-25,009	-24,445	-24,744	-299	+1%
Program Direction	-150,761	-149,142	-145,010	+4,132	-3%
Subtotal, Offsetting Collections, annual Operation and Maintenance and Program Direction	-175,770	-173,587	-169,754	+3,833	-2%
Offsetting Collections, Purchase Power and Wheeling	-225,442	-227,000	-227,043	-43	0%
Use of Prior Year Balances					
Annual Operation and Maintenance	0	-1,000	-2,200	-1,200	+120%
Annual Program Direction	0	-4,000	-12,800	-8,800	+220%
Subtotal, Use of Prior Year Balances	0	-5,000	-15,000	-10,000	+200%
Subtotal, CROM	**89,372**	**89,372**	**89,372**	**+0**	**0%**
Rescission of Prior Year Balances	0	-176	0	+176	-100%
Total, CROM	**89,372**	**89,196**	**89,372**	**+176**	**0%**

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted ($)	FY 2021 Request vs FY 2020 Enacted (%)
Federal FTEs	**1,177**	**1,210**	**1,216**	**+6**	**0%**
Falcon and Amistad Operating and Maintenance Fund	4,440	5,647	7,302	+1,655	+29%
Offsetting Collections, annual Operation and Maintenance	-1,340	-2,932	-5,548	-2,616	+89%
Use of Prior Year Balances	-2,500	-1,300	0	+1,300	-100%
Alternative Financing	-372	-1,187	-1,526	-339	+29%
Total, Falcon and Amistad	**228**	**228**	**228**	**0**	**0%**
Federal FTEs	**0**	**0**	**0**	**0**	**0%**
Colorado River Basins Power Marketing Fund (CRBPMF)	220,337	220,244	245,047	+24,803	+11%
Offsetting Collections	-220,337	-263,044	-266,447	-3,403	+1%
Total, CRBPMF	**0**	**-42,800**	**-21,400**	**+21,400**	**-50%**
Federal FTEs	**280**	**296**	**294**	**-2**	**-1%**
Transmission Infrastructure Program Fund (TIP)	43,170	47,442	44,560	-2,882	-6%
Advance Funding	-4,500	-4,300	-2,025	+2,275	-53%
Offsetting Collections	-38,670	-43,142	-42,535	+607	-1%
Total TIP	**0**	**0**	**0**	**0**	**0%**
Federal FTEs	**4**	**15**	**11**	**-4**	**-27%**
Total, Western Area Power Administration	**89,600**	**46,624**	**68,200**	**+21,576**	**+46%**
Federal FTEs	**1,461**	**1,521**	**1,521**	**0**	**0%**

Construction, Rehabilitation, Operation and Maintenance
Western Area Power Administration
Funding ($K)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request
Gross	834,567	883,923	878,633
Offsets	-745,195	-794,551	-789,261
Subtotal	**89,372**	**89,372**	**89,372**
Rescission of prior year balances	0	-176	0
Net BA	**89,372**	**89,196**	**89,372**

Overview

WAPA markets and delivers reliable, cost-based Federal hydroelectric power and related services. WAPA's marketing efforts and delivery capability provide for recovery of annual operational costs, including the generating agencies' hydropower related costs, and repayment of taxpayer investment in the Federal hydropower program. WAPA repays the Federal investment for which it is responsible within the timeframes established by law and regulations.

WAPA's Construction, Rehabilitation, Operation and Maintenance Account (CROM) is comprised of four subprograms:

- Operation and Maintenance
- Construction and Rehabilitation
- Purchase Power and Wheeling
- Program Direction

WAPA's subprograms are funded using a variety of financing methods including appropriations, alternative financing (primarily customer advances), and use of receipt authorities.

Highlights of the FY 2021 Budget Request

The FY 2021 budget request includes:

- A proposal to authorize the Federal government to sell the transmission assets of WAPA.
- A proposal to change WAPA's statutory rate structure requirement from cost recovery to a market based structure that takes into consideration rates charged by comparable utilities and could result in faster recoupment of the taxpayer investment.

Operation and Maintenance
Funding ($K)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted ($)	FY 2021 Request vs FY 2020 Enacted (%)
Operation and Maintenance					
Regular Operation and Maintenance	34,715	33,923	35,586	+1,663	+5%
Replacements and Additions	42,341	38,253	42,288	+4,035	+11%
Total, Operation and Maintenance	**77,056**	**72,176**	**77,874**	**+5,698**	**+8%**
Alternative Financing	-7,758	-6,600	-6,297	+303	-5%
Use of Receipts from Colorado River Dam Fund	-1,455	-1,415	-1,868	-453	+32%
Offsetting Collections	-25,009	-24,445	-24,744	-299	+1%
Use of Prior Year Balances	0	-1,000	-2,200	-1,200	+120%
Total, Operation and Maintenance (Budget Authority)	**42,834**	**38,716**	**42,765**	**+4,049**	**+10%**

Description
The Operation and Maintenance (O&M) subprogram provides the supplies, materials and equipment necessary for WAPA to continue to deliver on its mission of providing reliable, resilient domestic energy to 40 million Americans across its 15 state footprint.

Regular Operation and Maintenance
Supplies and materials necessary to respond to routine and emergency situations across WAPA's 17,000 miles of high-voltage interconnected transmission system will be purchased. This includes miscellaneous equipment and software used for power billing, transmission planning, e-tagging, and energy scheduling, as well as supplies and materials such as wood poles (individual pole replacement only; excludes whole line replacements), instrument transformers, meters, relays, etc. Additionally, cyber and physical security audits and monitoring as well as grid operations and monitoring are provided through this activity, which is funded primarily through offsetting collections and alternative customer financing.

Replacements and Additions
WAPA's planned replacements and additions activity is based on cyber and physical security audits, assessments of condition and criticality of equipment, maintenance and frequency of problems on individual items of equipment, availability of replacement parts, safety of the public and WAPA's personnel, environmental concerns and an orderly work plan. Cost estimates are based on an analysis of system operation and maintenance requirements and concerns, customer-coordinated work plans, actual costs of recent similar projects, and bottom-up budgeting techniques. Planned activity is detailed by category below.

Cyber and Physical Security
Investments in the hardening of the transmission grid against increasing foreign and domestic threats include firewalls, cybersecurity upgrades, encryptors for operations offices, security equipment such as perimeter intrusion detection devices, card readers and associated software, security cameras and recording devices at various sites throughout WAPA's service area. These investments in cyber, physical security, and grid technology improvements rely primarily on appropriated funds.

Electrical Equipment
Electrical equipment, such as circuit breakers, transformers, relays, batteries and chargers, reactors, meters, buses, surge arresters, capacitor banks and disconnect switches, will replace obsolete equipment at facilities throughout WAPA's 15-state area. Test equipment used by maintenance crews, such as metering and relaying test sets, pentameters, Ohm testers, oil dielectric testers, battery load testers, and specialized communication and environmental control test equipment is also included. Also included in this request is funding for WAPA's wood pole replacement program. This is a continuing program to replace aging wood transmission line structures, line hardware, and repair damaged conductors and static wires. Many of WAPA's wood transmission line structures were built in the 1950's and 1960's, with the facilities reaching ages in excess of recommended lifespan. Due to age, woodpecker damage, vibratory fatigue, and general deterioration, the system requires constant maintenance upgrades and repairs in order to eliminate the weak links and improve the reliability to our customers.

Communications Equipment
Key to system reliability, replacement of aged or obsolete remote terminal units (RTU), telephone systems, microwave and mobile radio systems with new generation digital radio and fiber optic systems continues. Manufacturers are discontinuing support of obsolete time domain multiplexing (TDM) digital technology equipment in favor of newer packet/internet protocol (IP) based technology as the industry transitions to packet-based networks. WAPA continues with its migration plans to incorporate packet technologies as the current TDM based equipment reaches its end-of-life. Manufacturers have discontinued support of the digital mobile radio equipment WAPA is operating due to obsolescence; this equipment is being replaced with new digital mobile radio technology equipment now and will continue for the next several years.

WAPA's communication systems are currently comprised of approximately 20 percent fiber optics, 70 percent fixed radio, and 10 percent mobile radio. WAPA currently has 1,193 radio frequency authorizations in the fixed radio bands, all of which are digital. This funding will not be used to replace equipment impacted by the Spectrum Relocation initiative.

In addition, WAPA will continue to upgrade its existing supervisory control and data acquisition (SCADA) systems which control WAPA's electric power system. These hardware and software upgrades improve grid reliability by allowing the main SCADA computer to communicate with RTUs in over 300 substations across WAPA's territory, thus allowing the power system dispatcher to operate a device in any of these substations to rapidly make changes in response to electric power industry requirements or system emergencies.

Spectrum Relocation Equipment

The Commercial Spectrum Enhancement Act (CSEA, Title II of P.L. 108-494) of 2004, created the Spectrum Relocation Fund (SRF) to streamline the relocation of Federal systems from specific radio spectrum bands. These spectrum bands will accommodate commercial users and the SRF will facilitate reimbursement to affected agencies for relocation costs. The Federal Communications Commission has allocated this spectrum for Advanced Wireless Services. Funds have been made available to agencies from the crediting of auction receipts to the SRF during FY 2007 and system relocation efforts commenced. WAPA received $108.2 million for this effort. This amount included WAPA's estimated relocation costs, as approved by the Office of Management and Budget, and as reported to the Congress by the Department of Commerce in December 2005. Since receipt of these funds, WAPA has completed all design work including radio path analysis, tower load analysis, communication building upgrades and replacements, acquiring radio frequency authorizations, and all communication equipment purchases. Final communication equipment installation has been completed. Final system clean-up activities and acceptance testing will be completed in FY 2020. WAPA anticipates returning approximately $16 million received in excess of actual relocation costs to the SRF. No appropriations are being requested for this activity.

Capitalized Movable Equipment

The majority of these funds will be used to purchase and lease the fleet of standard and specialized vehicles required for WAPA's O&M activities. Although WAPA prefers to lease its vehicles from GSA, GSA cannot always provide the necessary specialized vehicles, especially in the Upper Great Plains Region and the Desert Southwest Region, where they must be equipped for extreme weather and terrain conditions. In these instances, WAPA is forced to purchase its specialized vehicles. All sedans, vans, SUVs, and light trucks are leased from GSA**.** WAPA replaces government-owned vehicles according to the Federal Management Regulations guidelines, the same guidelines used by GSA. Other capitalized movable equipment in this estimate includes substation test equipment, brush chipper, map board replacement, information technology equipment such as server and router replacements, LAN upgrades, network equipment replacements, storage upgrades, upgrades to WAPA's power system simulator equipment for training purposes, auto-CAD workstation replacements, and helicopter equipment replacements that add value to the helicopter or extend the service life, such as engine, rotor blades, avionics, airframe, and other major components.

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Operation and Maintenance			
$77,056,000	**$72,176,000**	**$77,874,000**	**+$5,698,000**
Regular O&M ($34,715,000) The continuing maintenance of WAPA's transmission system at or above industry standards supports DOE and WAPA missions by minimizing sudden failure, unplanned outages, and possible regional power system disruptions. The request is based on projected work plans for activities funded from this account. Estimates are based on historical data of actual supplies needed to operate and maintain the transmission system and recent procurement of similar items. This request also includes approximately $153,000 for appropriated O&M annual expenses that are required to fund WAPA's Salinity and Levee non-reimbursable power systems. The request includes approximately $1,455,000 for activities in the Boulder Canyon Project, funded directly through receipts from the Colorado River Dam.	*Regular O&M ($33,923,000)* The continuing maintenance of WAPA's transmission system at or above industry standards supports DOE and WAPA missions by minimizing sudden failure, unplanned outages, and possible regional power system disruptions. The request is based on projected work plans for activities funded from this account. Estimates are based on historical data of actual supplies needed to operate and maintain the transmission system and recent procurement of similar items. This request also includes approximately $123,000 for appropriated O&M annual expenses that are required to fund WAPA's Salinity and Levee non-reimbursable power systems. The request includes approximately $1,415,000 for activities in the Boulder Canyon Project, funded through receipts from the Colorado River Dam.	*Regular O&M ($35,586,000)* The continuing maintenance of WAPA's transmission system at or above industry standards supports DOE and WAPA missions by minimizing sudden failure, unplanned outages, and possible regional power system disruptions. The request is based on projected work plans for activities funded from this account. Estimates are based on historical data of actual supplies needed to operate and maintain the transmission system and recent procurement of similar items. This request also includes approximately $137,000 for appropriated O&M annual expenses that are required to fund WAPA's Salinity and Levee non-reimbursable power systems. The request includes approximately $1,868,000 for activities in the Boulder Canyon Project, funded through receipts from the Colorado River Dam.	*Regular O&M (+$1,663,000)* Regular O&M increases above inflation are largely driven by Vegetation management and power system operations.
Replacements and Additions ($42,341,000) Replacement needs are based on age, reliability, and safety of equipment, customer-coordinated review, cost	*Replacements and Additions ($38,253,000)* Replacement needs are based on age, reliability, and safety of equipment, customer-coordinated review, cost	*Replacements and Additions ($42,288,000)* Replacement needs are based on age, reliability, and safety of equipment, customer-coordinated review, cost	*Replacements and Additions (+$4,035,000)* Replacements and Additions increases reflect year to year fluctuations in the equipment replacement cycle and are

FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
analysis of rebuild versus replacement, availability of replacement parts, and obsolescence of diagnostic maintenance tools. Estimates are determined using actual costs of similar items.	analysis of rebuild versus replacement, availability of replacement parts, and obsolescence of diagnostic maintenance tools. Estimates are determined using actual costs of similar items.	analysis of rebuild versus replacement, availability of replacement parts, and obsolescence of diagnostic maintenance tools. Estimates are determined using actual costs of similar items.	largely driven by communications, transmission line and movable equipment replacements.

Construction and Rehabilitation
Funding ($K)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted ($)	FY 2021 Request vs FY 2020 Enacted (%)
Construction and Rehabilitation					
Transmission Lines and Terminal Facilities	20,091	27,599	13,722	-13,877	-50%
Substations	8,725	14,825	2,727	-12,098	-82%
Other	3,816	3,463	9,802	+6,339	+183%
Subtotal, Construction and Rehabilitation	**32,632**	**45,887**	**26,251**	**-19,636**	**-43%**
Alternative Financing	-27,077	-39,922	-20,353	+19,569	-49%
Total, Construction and Rehabilitation	**5,555**	**5,965**	**5,898**	**-67**	**-1%**

Construction, Rehabilitation, Operation and Maintenance
Construction and Rehabilitation

Description
The Construction and Rehabilitation (C&R) subprogram supports WAPA's mission to deliver reliable, clean Federal hydroelectric power by emphasizing the replacement, upgrade, and modernization of the electrical system infrastructure to bring continued reliability, improved connectivity, and increased resilience, flexibility and capability to the power grid.

Financing of the FY 2021 C&R budget, planned at $26.3 million, will continue to rely heavily on voluntary stakeholder participation in alternative methods for capital financing. Approximately 78 percent of the program funding, or $20.4 million, will be required from stakeholders, requiring significant partnering efforts.

WAPA has initiated a formalized asset management program to capture data uniformly and systematically on condition, consequences of failure data, and other relevant asset information. The improvements to WAPA's current asset management practices include stronger, more objective data driven evidence, risk-informed priority and decision making, and greater transparency to stakeholders in the allocation of limited resources.

The request incorporates the most current information to identify and schedule necessary C&R projects. WAPA assigns priority to those situations that pose the highest risk to compliance, system reliability, and economic impact to WAPA and its customers, while meeting the mandates for open access to our transmission system. When conditions change, WAPA shifts funding as necessary to ensure the highest program priorities continue to be met to maintain the reliability and integrity of WAPA's power transmission system.

All replacement and rehabilitation plans are coordinated with stakeholders to help establish the timing and scope of work at specific substations. When upgrades or additional capacity are required, WAPA actively pursues partnering with neighboring utilities to jointly finance activities, resulting in cost savings and increased efficiencies for participants.

Unless otherwise provided by law, all C&R costs are recovered from ratepayers with interest over the useful life of the asset providing a revenue stream to the U.S. Treasury. In rare cases, where a C&R project is abandoned, costs are still recovered, but may be expensed.

The FY 2021 budget request continues to include a proposal to authorize the Federal government to sell the transmission assets of WAPA. Until such time as this proposal is enacted, WAPA will continue its plans for construction, maintenance, and equipment upgrades.

Transmission Lines and Terminal Facilities
WAPA's 17,000 circuit-mile transmission infrastructure was primarily constructed in the 1940s through 1960s. Thousands of miles of transmission line already exceed their design life. For FY 2021, there is continued focus on replacement and upgrade of deteriorating and inadequate infrastructure across WAPA's service area using alternative financing, with continued emphasis on deteriorating transmission lines in the Parker-Davis systems in Arizona. In addition, activities are underway to address voltage support problems in the Colorado front-range, impacts of growing loads in the Pick-Sloan Missouri Basin service territory, and reliability or compliance concerns in northern California.

Substations
WAPA owns and operates more than 300 substations across its 15-state service territory. Many of these facilities were designed and constructed more than 50 years ago. As substation equipment (such as power transformers, circuit breakers, and control equipment) ages, maintenance costs increase, replacement parts become unavailable, risk of outages increase, and system reliability declines. The normal service life for power transformers and circuit breakers is 40 years and 35 years, respectively. This activity funds the construction, replacement, or upgrade of the substations and its components necessary to sustain reliable power delivery and support a stable, flexible interconnected power grid.

Other

The Other category includes C&R activities not otherwise included in the Substations or Transmission Lines and Terminal Facilities categories. These include communication system equipment and other miscellaneous projects covering items like construction or major rehabilitation of maintenance facilities, access roads, and facility decommissioning and removal costs.

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Construction and Rehabilitation			
$32,632,000	**$45,887,000**	**$26,251,000**	**-$19,636,000**
Transmission and Terminal Facilities ($20,091,000) • Continue rehabilitation and construction required on WAPA's transmission lines and terminal facilities to cost-effectively market and deliver clean renewable Federal hydropower and promote a strong record of reliability and safety. • Address additional system reliability risk and operational problems. • Appropriations ($2,234,000) provide for the following projects in FY 2019: o Dome Tap – Gila (AZ) 161-kV T-line rebuild of a deteriorating 7.6-mile segment to increase reliability, improve safety, and reduce maintenance costs o Gila-Wellton Mohawk Interstate 8 Crossings (AZ) rebuild of 13-mile segment to comply with NERC standards, improve safety at interstate crossings, improve life span of the transmission line, and reduce maintenance costs	*Transmission and Terminal Facilities ($27,599,000)* • Continue rehabilitation and construction required on WAPA's transmission lines and terminal facilities to cost-effectively market and deliver clean renewable Federal hydropower and promote a strong record of reliability and safety. • Address additional system reliability risk and operational problems. • Appropriations ($5,021,000) are requested for the following projects in FY 2020: o Dome Tap-Gila (AZ) 161-kV T-line rebuild of a deteriorating 7.6-mile segment to increase reliability, improve safety, and reduce maintenance costs o Kofa-Dome Tap (AZ) 161-kV rebuild of a 7.3-mile segment to comply with NERC standards and improve the engineered life span of the transmission line	*Transmission and Terminal Facilities ($13,722,000)* • Continue rehabilitation and construction required on WAPA's transmission lines and terminal facilities to cost-effectively market and deliver clean renewable Federal hydropower and promote a strong record of reliability and safety. • Address additional system reliability risk and operational problems. • Appropriations ($5,898,000) are requested for the following projects in FY 2021: o Parker-Bouse (AZ) construct 15-mile segment of 230-kV double circuit transmission line and upgrade equipment at Bouse substation to improve reliability of service, improve safety, and reduce ongoing maintenance costs • Alternative financing ($7,824,000) sought for the following projects in FY 2021: o Parker-Bouse (AZ) construct 15-mile segment of 230-kV double circuit transmission line	*Transmission and Terminal Facilities (-$13,877,000)* • The decrease in transmission line work reflects the year to year fluctuation in the timing of capital investments while maintaining a continued focus on upgrading and replacing aging and inadequate infrastructure to improve reliability and safety and reduce maintenance costs.

FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
○ Kofa-Dome Tap (AZ) 161-kV rebuild of a 7.3-mile segment to comply with NERC standards and improve the engineered life span of the transmission line ○ Gila-Knob (AZ) 161-kV transmission line re-route of 2-mile segment in advance of neighboring utility 500-kV transmission line build ○ Lovell-Yellowtail (MT) rebuild of 15-miles of two 115-kV transmission lines and deteriorating structures to increase reliability and reduce maintenance costs ○ Snowy Range-Laramie (WY) construction of a new 1.5-mile 115-kV double circuit transmission line to mitigate low voltage to comply with FERC and NERC standards ○ Groton South-Ordway (SD) 115-kV reconductoring on an aging 15-mile transmission line to increase reliability and reduce maintenance costs • Alternative financing ($17,857,000) provide for the following projects in FY 2019: ○ Estes-Flatiron (CO) transmission line rebuild to improve reliability and accessibility of the	• Alternative financing ($22,578,000) sought for the following projects in FY 2020: ○ Bouse-Kofa (AZ) rebuild of a 44.3 miles of 161-kV transmission line to comply with NERC standards, increase reliability and reduce maintenance costs ○ Groton South-Ordway (SD) 115-kV reconductoring on an aging 15-mile transmission line to increase reliability and reduce maintenance costs ○ Lovell-Yellowtail (MT) rebuild of 15-miles of two 115-kV transmission lines and deteriorating structures to increase reliability and reduce maintenance costs ○ Headgate Rock-Parker (CA and AZ) 116-kV double circuit rebuild and relocation of 16-miles of deteriorating transmission line and structures to improve reliability of service, improve safety, and reduce maintenance costs	and upgrade equipment at Bouse substation to improve reliability of service, improve safety, and reduce ongoing maintenance costs	

FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
deteriorating 17-mile transmission line serving the city of Estes Park, CO o Cottonwood-Olinda (CA) substation rating upgrade of relays on two transmission lines to match new conductor and increase transfer capacity and eliminate potential NERC standard violation o Keswick-Airport and Airport-Cottonwood (CA) 230-kV transmission line reconductoring to increase transfer capacity and improve maintenance flexibility on 20.15-miles of existing single circuit line o Headgate Rock-Parker (CA and AZ) 116-kV double circuit rebuild and relocation of 16-miles of deteriorating transmission line and structures to improve reliability of service, improve safety, and reduce maintenance costs			
Substations ($8,725,000) • Continue construction, modification, and rehabilitation of WAPA's substations to ensure power system reliability and stability.	*Substations ($14,825,000)* • Continue construction, modification, and rehabilitation of WAPA's substations to ensure power system reliability and stability. • Address additional system reliability risk and operational problems.	*Substations ($2,727,000)* • Continue construction, modification, and rehabilitation of WAPA's substations to ensure power system reliability and stability. • Address additional system reliability risk and operational problems.	*Substations (-$12,098,000)* • The decrease in substation work reflects the year to year fluctuation in the timing of capital investments while maintaining a continued focus on replacing aging and deteriorating equipment and facilities to provide for system

FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
• Address additional system reliability risk and operational problems. • Appropriations ($3,296,000) provide for the following projects in FY 2019: o Devil's Lake Substation (ND) transformer replacement due to age (60+ years) and deteriorating conditions which could result in catastrophic failure, reliability, and customer outages o Gila Substation (AZ) 69-kV yard rebuild to improve reliability and safety of deteriorating facilities, and reduce rising maintenance costs and outage risk impacting the Parker-Davis, Salinity Control Project, and Colorado River Front Work and Levee system o Watertown Unit substations (SD) replacement of two aging (40+ years) unit substations to provide reliable station service power for critical operation and maintenance facilities o Fargo Substation (ND) control panel replacement for 115-kV and lower voltage equipment to improve reliability and maintenance o Sioux City 2 Substation (IA) transformer replacement is	• Appropriations ($210,000) requested for the following projects in FY 2020: o Watertown Unit substations (SD) replacement of two aging (40+ years) unit substations to provide reliable station service power for critical operation and maintenance facilities • Alternative financing ($14,615,000) sought for the following projects in FY 2020: o Carr Substation (CA) motor operated disconnect switch replacements to improve system reliability and mitigate risk of customer outages o Devil's Lake Substation (ND) transformer replacement due to age (60+ years) and deteriorating conditions which could result in catastrophic failure, reliability, and customer outages o Elverta Substation (CA) station service transformer installation to improve system reliability and mitigate risk of customer outages o Grand Forks Substation (ND) replacement of all 230, 115, 69, and 12.47-kV control panels for improved reliability, and construction of a new control building to house the control	• Appropriations ($0) are not requested for projects in FY 2021 • Alternative financing ($2,727,000) sought for the following projects in FY 2021: o Fort Thompson Substation (SD) transformer replacement due to age (50+ years) and high consequence of failure which could result in catastrophic failure, reliability, and customer outages o Maurine Substation (SD) aging (manufactured in 1962 and in service for 50+ years) transformer replacement to ensure reliability and mitigate risk of catastrophic failure o Sand Creek Tap (WY) installation of 3 breaker ring bus (power circuit breakers and line relays) to sectionalize the Erie-Hoyt-Willowby 115-kV transmission line and to increase reliability and reduce maintenance costs o Sioux City 2 Substation (IA) transformer replacement is needed due to deteriorating conditions creating an environmental hazard and will provide for increased reliability	reliability, increased capacity, and anticipated future needs.

FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
needed due to deteriorating conditions creating an environmental hazard and will provide for increased reliability and load growth • Alternative financing ($5,429,000) sought for the following projects in FY 2019: ○ Martin Substation (SD) 115-kV oil breakers, control panels, and relay replacements to increase reliability ○ Keswick, Airport, and Cottonwood substations (CA) rating upgrades to improve capacity and operational and maintenance flexibility ○ Folsom Substation (CA) transformer installation to eliminate a single point of failure and provide operation and maintenance flexibility ○ Maurine Substation (SD) aging (manufactured in 1962 and in service for 40+ years) transformer replacement to ensure reliability and mitigate risk of catastrophic failure ○ Grand Forks Substation (ND) replacement of all 230, 115, 69, and 12.47-kV control panels for improved reliability, and construction of a new control building to house the control	panels and comply with current safety regulations ○ Gregory Substation (SD) expansion and equipment replacement including breakers, transformer, disconnect switches, instrument transformers and relay to mitigate the risk of catastrophic failure and customer outages ○ Jamestown Substation (ND) aging (60+ years) transformer replacement to increase reliability and mitigate risk of catastrophic failure ○ Maurine Substation (SD) aging (manufactured in 1962 and in service for 40+ years) transformer replacement to ensure reliability and mitigate risk of catastrophic failure ○ Pole Creek Tap (WY) installation of line circuit breakers and line relays to sectionalize the Archer-Stegall 115-kV transmission line and to increase reliability and reduce maintenance costs ○ Roseville Substation (CA) replacement of 230-kV voltage transformers to improve system reliability and mitigate risk of customer outages ○ Sioux City 2 Substation (IA) transformer replacement is		

FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
panels and comply with current safety regulations ○ Mount Vernon Substation (SD) transformer and oil breaker replacement due to age and deteriorating conditions which could result in reliability and outage conditions as well as environmental impacts ○ Fargo Substation (ND) control panel replacement for 115-kV and lower voltage equipment to increase reliability and reduce maintenance costs	needed due to deteriorating conditions creating an environmental hazard and will provide for increased reliability		
Other ($3,816,000) • Appropriations ($25,000) provide for the following projects in FY 2019: ○ Crossman Peak microwave facility to increase reliability of service on the WAPA microwave backbone from Phoenix to the Hoover substation in AZ • Alternative financing ($3,791,000) sought for the following projects in FY 2019: ○ Replacement of existing overhead ground wire with optical fiber ground wire for continued system improvements for the Pick-Sloan Missouri Basin Program ○ Substation service upgrades at eight substations in CA to	*Other ($3,463,000)* • Appropriations ($734,000) requested for the following projects in FY 2020: ○ Substation service upgrades at eight substations in CA to mitigate safety hazards and increase reliability • Alternative financing ($2,729,000) sought for the following projects in FY 2020: ○ Renovate Fargo (ND) line crew building to modernize the data, communication and electrical systems and improve the efficiency of the heating and cooling systems ○ Replace Sioux Falls (SD) maintenance building (60+ years old) with new building for crew,	*Other ($9,802,000)* • Appropriations ($0) are not requested for projects in FY 2021 • Alternative financing ($9,802,000) sought for the following projects in FY 2021: ○ Devils Lake Substation (ND) cold storage building will house critical equipment and materials to enable WAPA to better manage supply levels and be more efficient in maintenance and response to emergencies ○ Gila Substation (AZ) maintenance building replacement will provide climate controlled crew meeting and workstation/workshop space, and vehicle/equipment	*Other (+$6,339,000)* • The increase in other investments reflects the year to year fluctuation in the timing of capital investments while maintaining a continued focus on replacing aging and deteriorating equipment and facilities to provide for system reliability, increased capacity, and anticipated future needs.

FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
mitigate safety hazards and increase reliability ○ Replace Sioux Falls (SD) maintenance building (60+ years old) with new building for crew, shop, vehicles, and equipment/materials storage ○ Bismarck maintenance facility (ND) addition of a 60' x 100' cold storage building to house critical vehicles and equipment required for maintenance activities ○ Rapid City Substation (SD) maintenance building replacement (40+ years old) will accommodate crew quarters, shop areas, house vehicles, and provide equipment storage and enable WAPA to be more efficient in maintenance and response to emergencies	shop, vehicles, and equipment/materials storage	storage to increase efficiency and reduce maintenance costs ○ Rapid City Substation (SD) maintenance building replacement (40+ years old) will accommodate crew quarters, shop areas, house vehicles, and provide equipment storage and enable WAPA to be more efficient in maintenance and response to emergencies ○ Substation service upgrades at Tracy substation (CA) to mitigate safety hazards and increase reliability	

Purchase Power and Wheeling
Funding ($K)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted ($)	FY 2021 Request vs FY 2020 Enacted (%)
Purchase Power and Wheeling					
Central Valley	299,752	293,804	318,508	+24,704	+8%
Pick-Sloan Missouri Basin and other Programs	186,644	221,965	202,425	-19,540	-9%
Subtotal, Purchase Power and Wheeling	**486,396**	**515,769**	**520,933**	**+5,164**	**+1%**
Alternative Financing Needed	-260,954	-288,769	-293,890	-5,121	+2%
Offsetting Collections	-225,442	-227,000	-227,043	-43	0%
Total, Purchase Power and Wheeling (New Budget Authority)	**0**	**0**	**0**	**0**	**0%**

Construction, Rehabilitation, Operation & Mainenance
Purchase Power and Wheeling

Description

The Purchase Power and Wheeling subprogram continues to support WAPA's marketing efforts and delivery capability which spans a 1.3 million square mile area serving a diverse group of several hundred wholesale customers, including municipalities, cooperatives, public utility and irrigation districts, Federal and state agencies and Native American tribes. No appropriated budget authority is necessary.

For a historical perspective, WAPAs Purchase Power and Wheeling subprogram is highly variable; it is affected by reservoir storage levels, annual and long-term drought conditions, downstream flow concerns due to icing, flooding, environmental, health and safety, recreation, irrigation and navigation requirements. To illustrate the extent of the variability, WAPA Purchase Power and Wheeling costs during FY 2008, an adverse water year, were nearly $600 million; whereas in FY 2016, a much improved water year, costs were half that at just over $300 million. Year-to-year changes can be extensive, and during long-term drought scenarios the increased purchase power requirements can last several years. The FY 2021 budget request reflects anticipated requirements utilizing current information on hydro conditions, generation, contractual commitments, and power pricing.

WAPA has implemented a Purchase Power and Wheeling risk mitigation strategy to ensure continuous operations during periods of significant drought. The strategy was developed consistent with existing authorities, and with the participation and support of WAPA power customers. Under this approach, WAPA retains receipts from the recovery of purchase power and wheeling expenses within the 'up to' amount specified by Congress. The receipts retained are available until expended, and are available only for purchase power and wheeling expenses. As of the end of FY 2019, WAPA's PPW reserve balance was $362 million. Since inception, the full cost of the PPW program has been included in the rate setting process. Through this process, and utilizing interim rate adjusting capabilities, all PPW costs are fully recovered through WAPA's rates.

Central Valley Project

WAPA continues to deliver on its contractual power commitments to customers under the Central Valley Project's Post 2004 Marketing Plan. The budget request assumes current full load service customers will continue to choose service from WAPA through "Custom Product" contractual agreements. WAPA also purchases power to support variable resource customers on a pass-thru basis. If project net generation is not sufficient, WAPA may also purchase to support project use load, First Preference Customer load, and sub-control area reserve requirements. As part of the Order 741, FERC promulgated guidance requiring RTO/ISOs to take physical title/ownership to the energy bought/sold in their respective markets, making it necessary for WAPA to acknowledge that customers receive the financial, and not the physical benefit of their Federal power allocations. In order to provide service in the state, WAPA is voluntarily participating in the California greenhouse gas cap-and-trade program which became effective January 1, 2013.

Pick-Sloan Missouri Basin and Other Programs

The budget request continues to support long-term firm power commitments to customers of the eastern and western divisions of the Pick-Sloan Missouri Basin Program, the Fryingpan-Arkansas Project, and the Parker-Davis Project commensurate with the levels of average firm hydroelectric energy marketed by WAPA. The request also provides transmission support for the Pacific Northwest-Southwest Intertie Project. The total program estimates shown are based primarily on market pricing of short term firm energy, negotiated transmission rates, and WAPA and generating agency's forecasts.

Purchase Power and Wheeling

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Central Valley Project			
Program Requirements ($299,752,000) The Purchase Power and Wheeling subprogram supports WAPA's power marketing effort by providing for power purchases to firm the variable hydropower resource and securing transmission services as necessary to meet its contractual power delivery obligations.	*Program Requirements ($293,804,000)* The Purchase Power and Wheeling subprogram supports WAPA's power marketing effort by providing for power purchases to firm the variable hydropower resource and securing transmission services as necessary to meet its contractual power delivery obligations.	*Program Requirements ($318,508,000)* The Purchase Power and Wheeling subprogram continues to support WAPA's power marketing effort by providing for power purchases to firm the variable hydropower resource and securing transmission services as necessary to meet its contractual power delivery.	*Program Requirements (+$24,704,000)* Increase is attributed to anticipated purchase needs based on hydro generation estimates to meet contractual needs. Amounts are for offsetting collections and alternative financing; no direct appropriations are requested for this activity.
Alternative Financing (-$160,152,000) Contractual arrangements made with customers provide opportunities for alternative financing of the purchase power requirements. Alternative financing methods include net billing, bill crediting, energy exchanges, and direct customer funding.	*Alternative Financing (-$167,831,000)* Contractual arrangements made with customers provide opportunities for alternative financing of the purchase power requirements. Alternative financing methods include net billing, bill crediting, energy exchanges, and direct customer funding.	*Alternative Financing (-$196,235,000)* Contractual arrangements made with customers provide opportunities for alternative financing of the purchase power requirements. Alternative financing methods include net billing, bill crediting, energy exchanges, and direct customer funding.	*Alternative Financing (-$28,404,000)* Increase is attributed to increased load requirements at Lawrence Livermore Labs. Amounts are for alternative financing. No direct appropriations are requested for this activity.
Pick-Sloan Missouri Basin			
Program Requirements ($186,644,000) The Purchase Power and Wheeling subprogram continues to support WAPA's power marketing effort by providing for power purchases to firm the variable hydropower resource and securing transmission services as necessary to meet its contractual power delivery obligations.	*Program Requirements ($221,965,000)* The Purchase Power and Wheeling subprogram continues to support WAPA's power marketing effort by providing for power purchases to firm the variable hydropower resource and securing transmission services as necessary to meet its contractual power delivery obligations.	*Program Requirements ($202,425,000)* The Purchase Power and Wheeling subprogram continues to support WAPA's power marketing effort by providing for power purchases to firm the variable hydropower resource and securing transmission services as necessary to meet its contractual power delivery.	*Program Requirements (-$19,540,000)* Decrease is attributed to anticipated purchase needs based on hydro generation estimates to meet contractual needs. Amounts are for offsetting collections and alternative financing; no direct appropriations are requested for this activity.

FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Alternative Financing (-$100,802,000) Alternative financing methods negotiated with customers provide an offset to the total program receipt financing requirement. Alternative financing methods include net billing, bill crediting, energy exchanges, and direct customer funding.	*Alternative Financing (-$120,938,000)* Alternative financing methods negotiated with customers provide an offset to the total program receipt financing requirement. Alternative financing methods include net billing, bill crediting, energy exchanges, and direct customer funding.	*Alternative Financing (-$97,655,000)* Contractual arrangements made with customers provide opportunities for alternative financing of the purchase power requirements. Alternative financing methods include net billing, bill crediting, energy exchanges, and direct customer funding.	*Alternative Financing (+$23,283,000)* Decrease is attributed to WAPA's participation in markets (Southwest Power Pool). Amounts are for alternative financing. No direct appropriations are requested for this activity

Construction, Rehabilitation, Operation & Maintenance
Program Direction

Overview

WAPA's Program Direction subprogram provides compensation and all related expenses for its workforce, including those employees that operate and maintain WAPA's high-voltage interconnected transmission system and associated facilities; those that plan, design, and supervise the construction of replacements, upgrades and additions (capital investments) to the transmission facilities; those that market the power and energy produced to repay annual expenses and capital investment; and those that administratively support these functions.

The Program Direction subprogram supports DOE's and WAPA's mission of operating and maintaining a resilient and secure energy grid by attaining and developing a critical highly skilled workforce of engineers, dispatchers, linemen, power system operators, and high voltage electricians. The Program Direction subprogram also includes the administrative staff, including those positions that monitor, detect and deter physical and cyber-attacks on WAPA's infrastructure.

WAPA trains its employees on a continuing basis in occupational safety and health regulations, policies and procedures, and conducts safety meetings at employee, supervisory and management levels to keep the safety culture strong. Accidents are reviewed to ensure lessons are learned and proper work protocol is in place.

In consultation with its customers, WAPA reviews required replacements and upgrades to its existing infrastructure to sustain reliable power delivery to its customers and to contain annual maintenance expenses. The timing and scope of these replacements and upgrades are critical to assure that WAPA's facilities do not become the "weak link" in the interconnected system. WAPA pursues opportunities to join with neighboring utilities to jointly finance activities, which avoid redundant facilities and result in realized cost savings and/or increased efficiencies for all participants.

Program Direction
Funding ($K)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted ($)	FY 2021 Request vs FY 2020 Enacted (%)
Program Direction					
Salaries and Benefits	161,966	169,663	172,151	+2,488	+1%
Travel	10,573	11,540	10,658	-882	-8%
Support Services	31,786	33,417	31,811	-1,606	-5%
Other Related Expenses	34,158	35,471	38,955	+3,484	+10%
Total, Program Direction	**238,483**	**250,091**	**253,575**	**+3,484**	**+1%**
Use of Alternative Financing	-39,136	-44,719	-48,546	-3,827	+9%
Use of Receipts from Colorado River Dam Fund	-7,603	-7,539	-6,510	+1,029	-14%
Offsetting Collections, Other Expenses	-150,761	-149,142	-145,010	+4,132	-3%
Use of Prior Year Balances	0	-4,000	-12,800	-8,800	+220%
Total, Program Direction	**40,983**	**44,691**	**40,709**	**-3,982**	**-9%**
Federal FTEs	**1,177**	**1,210**	**1,216**	**+6**	**0%**
Support Services					
Technical Support					
Economic and Environmental Analysis	8,052	9,687	9,631	-56	-1%
Total, Technical Support	**8,052**	**9,687**	**9,631**	**-56**	**-1%**
Management Support					
Automated Data Processing	14,222	13,508	13,024	-484	-4%
Training and Education	1,910	3,338	3,416	+78	+2%
Reports and Analysis, Management and General Administrative Support	7,602	6,884	5,740	-1,144	-17%
Total Management Support	**23,734**	**23,730**	**22,180**	**-1,550**	**-7%**
Total, Support Services	**31,786**	**33,417**	**31,811**	**-1,606**	**-5%**
Other Related Expenses					

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted ($)	FY 2021 Request vs FY 2020 Enacted (%)
Rent to GSA	2,139	2,571	2,431	-140	-5%
Communication, Utilities, Misc.	5,921	5,576	6,832	+1,256	+23%
Printing and Reproduction	116	117	111	-6	-5%
Other Services	11,369	12,755	15,015	+2,260	+18%
Training	11	12	12	0	0%
Purchases from Gov. Accounts	1,045	1,285	1,544	+259	+20%
Operation and Maintenance of Equipment	5,575	5,926	4,785	-1,141	-19%
Supplies and Materials	2,612	2,260	2,077	-183	-8%
Equipment	2,995	2,335	3,681	+1,346	+58%
Working Capital Fund	2,375	2,634	2,467	-167	-6%
Total, Other Related Expenses	**34,158**	**35,471**	**38,955**	**+3,484**	**+10%**

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Program Direction $238,483,000	**$250,091,000**	**$253,575,000**	**+$3,484,000**
Salaries and Benefits $161,966,000	**$169,663,000**	**$172,151,000**	**+$2,488,000**
Salary and benefits provide for Federal employees who construct and replace, operate and maintain and secure, on a continuing basis, WAPA's high-voltage interconnected transmission system. Salary and benefits fund those FTEs assigned to this account, including those salaries determined through negotiations.	Salary and benefits provide for Federal employees who construct and replace, operate and maintain and secure, on a continuing basis, WAPA's high-voltage interconnected transmission system. Salary and benefits fund those FTEs assigned to this account, including those salaries determined through negotiations.	Salary and benefits funding is for Federal employees who construct and replace, operate and maintain and secure, on a continuing basis, WAPA's high-voltage interconnected transmission system.	The salary and benefits reflect inflationary factors; and journeymen negotiated salaries.
Travel $10,573,000	**$11,540,000**	**$10,658,000**	**-$882,000**
This activity funds all travel and related expenses associated with WAPA's mission-related operation and maintenance activities, and those functions that support them.	This activity funds all travel and related expenses associated with WAPA's mission-related operation and maintenance activities, and those functions that support them.	Request funds all travel and related expenses associated with WAPA's mission-related operation and maintenance activities, and those functions that support them.	Request reflects variabilities in scope and location associated with mission related operation and maintenance travel, and travel for cross-functional collaboration among various internal and external programs.
Support Services $31,786,000	**$33,417,000**	**$31,811,000**	**-$1,606,000**
Support Services funded in this category include information technology, job related training and education, engineering, miscellaneous advisory and reporting services, and general administrative support.	Support Services funded in this category include information technology, job related training and education, engineering, miscellaneous advisory and reporting services, and general administrative support.	Request funds information technology, job related training and education, engineering, miscellaneous advisory and reporting services, and general administrative support services.	Reduction reflects a decrease in advisory and general administrative service support.
Other Related Expenses $34,158,000	**$35,471,000**	**$38,955,000**	**+$3,484,000**
Other related expenses include rental space, utilities, supplies and materials,	Other related expenses include rental space, utilities, supplies and materials,	Request funds rental space, utilities, supplies and materials,	The increase is primarily attributable to communication and utility costs

FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
telecommunications, information technology modernization (data/network), printing and reproduction, training tuition, and DOE's Working Capital Fund distribution. Rental space costs assume the General Services Administration's (GSA) inflation factor. Other costs are based on historical usage and actual cost of similar items.	telecommunications, information technology modernization (data/network), printing and reproduction, training tuition, and DOE's Working Capital Fund distribution. Rental space costs assume the General Services Administration's (GSA) inflation factor. Other costs are based on historical usage and actual cost of similar items.	telecommunications, information technology modernization (data/network), printing and reproduction, training tuition, and DOE's Working Capital Fund distribution. Rental space costs assume the General Services Administration's (GSA) inflation factor. Other costs are based on historical usage and actual cost of similar items.	associated with operation of facilities and substations; other services for physical security, vegetation management, asset management support and equipment purchases, with offsetting decrease in operation and maintenance of equipment, and slight decrease in supplies and materials, GSA rental space, and distribution of DOE's Working Capital Fund.

Falcon and Amistad Operating and Maintenance Fund
Funding ($K)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted
Gross	4,440	5,647	7,302	+1,655
Offsets	-4,212	-5,419	-7,074	-1,655
Net BA	**228**	**228**	**228**	**0**

Overview

The Falcon and Amistad Operating and Maintenance fund (Maintenance Fund) was established in the Treasury of the United States as directed by the Foreign Relations Authorization Act, FYs 1994 and 1995. The Maintenance Fund is administered by WAPA's Administrator for use by the Commissioner of the U. S. Section of the International Boundary and Water Commission (IBWC) to defray administrative, O&M, replacement, and emergency costs for the hydroelectric facilities at the Falcon and Amistad Dams. IBWC owns and operates the U.S. portion of the projects, and Federal staff funded under this program continues to be allocated to the U.S. Section of IBWC by the Department of State. The Falcon and Amistad project supports WAPA's program goals by providing power to rural electric cooperatives through WAPA. With the exception of monies received from the Government of Mexico, all revenues collected from the sale of electric power generated at the Falcon and Amistad Dams are credited to the Maintenance Fund. Monies received from the Government of Mexico are credited to the General Fund of the U.S. Treasury. Revenues collected in excess of operating expenses are used to repay, with interest, the cost of replacements and original investments. Full funding will support 24-hour/day operation and maintenance of the two power plants to ensure response to ever-changing water conditions, customer demand, and continual coordination with operating personnel of the Government of Mexico.

Highlights of the FY 2021 Budget Request

In FY 2021, WAPA's request has been formulated to meet its power marketing and contractual power delivery obligations with continued high marks for reliability. Revenues collected from customers to recover the costs of the Federal Power Program will be sufficient to provide for FY 2021 planned expenses for the facilities operated by the IBWC. Also included in FY 2021 is the continuation of WAPA's request to allow for U.S. customer(s) of the Falcon and Amistad Dams to contribute funds for use by the IBWC in fulfilling their duties in accordance with agreements between WAPA, IBWC, and the power customers. This will allow work to be accomplished using customer advances/alternative financing, a funding mechanism used throughout WAPA under the Contributed Funds Act, 43 USC 395. The customer contributed funds are planned to predominantly assist in capitalized replacement projects.

In response to the Explanatory Statement accompanying the Energy and Water Development and Related Agencies Appropriations Act, 2018, WAPA, the IBWC, and the customer have collaboratively developed and submitted a work plan to the Appropriations committees to address immediate and future infrastructure needs for the Falcon and Amistad hydroelectric facilities. WAPA and the IBWC jointly briefed the House Energy and Water Development Committee on November 27, 2018. As part of the work plan implementation, WAPA will continue to work closely with IBWC and the stakeholder(s) to review progress and plan for future infrastructure needs.

Falcon and Amistad Operating and Maintenance Fund
Funding ($K)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted ($)	FY 2021 Request vs FY 2020 Enacted (%)
Western Area Power Administration					
Falcon and Amistad Operating and Maintenance Fund	4,440	5,647	7,302	+1,655	+29%
Subtotal, Falcon and Amistad Operating and Maintenance Fund	**4,440**	**5,647**	**7,302**	**+1,655**	**+29%**
Offsetting Collections	-1,340	-2,932	-5,548	-2,616	+89%
Use of Prior Year Balances	-2,500	-1,300	0	+1,300	-100%
Alternative Financing	-372	-1,187	-1,526	-339	+29%
Total, Falcon and Amistad Operating and Maintenance Fund	**228**	**228**	**228**	**0**	**0%**

Falcon and Amistad Operating and Maintenance Fund

Description

The Falcon and Amistad Project consists of two international dams located on the Rio Grande River between Texas and Mexico. The United States and Mexico operate separate hydroelectric power plants on each side of the Rio Grande River. The power plants are independent and legislatively severable from the international reservoir storage dams. The Operating and Maintenance Fund was established in the Treasury of the United States and is administered by WAPA's Administrator for use by the Commissioner of the U.S. Section of the IBWC to defray administrative, O&M, replacement, and emergency costs for the hydroelectric facilities at the Falcon and Amistad Dams.

IBWC

O&M

Activities include salaries and benefits for the approximately 40 positions of the U.S. Section of the IBWC who operate and maintain the two power plants on a 24-hour/day basis, planned maintenance activities, required safety services, and emergency response to flood operations and/or equipment failure. O&M includes inspection and service of the HVAC and air compressor system, fire suppression systems, elevators, self-contained breathing apparatus, recharge and hydro-testing of fire extinguishers, calibration of test equipment, rebuild of electric motors, and repair of obsolete equipment when replacement parts are no longer available. Travel, training, communications, utilities, printing, and office supplies and materials for the IBWC employees and technical advisors is also funded by the O&M activity. The request includes essential training for employees to comply with standards of the Interagency Commission on Dam Safety, Occupational and Health Administration, and the National Dam Safety Act.

Capital Investment

WAPA, the IBWC, and the customer have collaboratively developed a rehabilitation work plan to address immediate and future infrastructure needs for the hydroelectric facilities. Future infrastructure needs will be appropriately planned and categorized by all parties through regularly scheduled progress reviews.

WAPA

Marketing, Contract, Repayment Studies

This activity funds power marketing, administration of power contracts, and preparation of rate and repayment studies. Based on accurate studies, staff ensures power revenues are set at an appropriate level to recover annual expenses and meet repayment schedules.

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Falcon and Amistad Operating and Maintenance Fund $4,440,000	**$5,647,000**	**$7,302,000**	**+$1,655,000**
IBWC O&M ($3,810,000) This activity funds the salaries and benefits for those employees assigned to the U.S. Section of the IBWC who operate and maintain the two power plants, equipment inspections and maintenance services, and travel, training, communications, utilities, printing, and office supplies/materials for the IBWC employees and technical advisors.	*IBWC O&M ($4,177,000)* This activity funds the salaries and benefits for those employees assigned to the U.S. Section of the IBWC who operate and maintain the two power plants, equipment inspections and maintenance services, and travel, training, communications, utilities, printing, and office supplies/materials for the IBWC employees and technical advisors.	*IBWC O&M ($5,470,000)* This activity funds the salaries and benefits for those employees assigned to the U.S. Section of the IBWC who operate and maintain the two power plants, equipment inspections and maintenance services, and travel, training, communications, utilities, printing, and office supplies/materials for the IBWC employees and technical advisors.	*IBWC O&M (+$1,293,000)* The increase is attributed to projects in the 10-year O&M work plan that was developed to address recommendations in the U.S. Army Corps of Engineers inspection report completed in 2018. FY 2021 projects include sandblast and repaint of penstock unit 1 at Amistad, and circuit breaker test program at Falcon. Amounts are for offsetting collections; no direct appropriations are requested for this activity.
IBWC Capital Investment ($600,000) This activity funds capital investment activities at the Falcon and Amistad hydroelectric facilities.	*IBWC Capital Investment ($1,415,000)* This activity funds capital investment activities at the Falcon and Amistad hydroelectric facilities.	*IBWC Capital Investment ($1,754,000)* This activity funds capital investment activities at the Falcon and Amistad hydroelectric facilities.	*IBWC Capital Investment (+$339,000)* The increase is attributed to projects in the 10-year capital work plan that was developed to address recommendations in the U.S. Army Corps of Engineers inspection report completed in 2018. FY 2021 projects include corrosion repair in turbine pits 1 and 2 and replacement of wicket gate seals at Amistad, and retrofit of the overhead crane at Falcon.
WAPA Marketing, Contracts, Repayment ($30,000) This activity funds power marketing, administration of power contracts,	*WAPA Marketing, Contracts, Repayment ($55,000)* This activity funds power marketing, administration of power contracts,	*WAPA Marketing, Contracts, Repayment ($78,000)* This activity funds power marketing, administration of power contracts,	*WAPA Marketing, Contracts, Repayment (+$23,000)* The increase is attributed to new software utilized by WAPA for power repayment and rates systems. Amounts are for offsetting

FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
and preparation of rate and repayment studies.	and preparation of rate and repayment studies.	and preparation of rate and repayment studies.	collections; no direct appropriations are requested for this activity.

Colorado River Basins Power Marketing Fund
Funding ($K)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted
Gross	220,337	220,244	245,047	+24,803
Offsets	-220,337	-263,044	-266,447	-3,403
Net BA	**0**	**-42,800**	**-21,400**	**+21,400**

Overview

WAPA operates and maintains the transmission system for the projects funded in this account to ensure an adequate supply of reliable electric power in a clean and environmentally safe, cost-effective manner. The Colorado River Basins Power Marketing Fund Program (CRBPMF) is comprised of the Colorado River Storage Project, including the Dolores and Seedskadee and Olmsted Projects; and the Fort Peck Project. WAPA is responsible for construction, maintenance, and operation of facilities for transmitting and marketing the electrical energy generated in these power systems.

Highlights of the FY 2021 Budget Request

In FY 2021, WAPA's request has been formulated to meet its power marketing and contractual power delivery obligations with continued high marks for reliability. Revenues collected from customers to recover the costs of the Federal Power Program will be sufficient to provide for WAPA's FY 2021 planned expenses for the power systems in the CRBPMF.

Colorado River Basins Power Marketing Fund
Funding ($K)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted ($)	FY 2021 Request vs FY 2020 Enacted (%)
Colorado River Basins Power Marketing Fund					
Equipment, Contracts and Related Expenses					
Supplies, Materials and Services	12,304	11,947	13,330	+1,383	+12%
Purchase Power Costs	109,062	98,172	116,673	+18,501	+19%
Capitalized Equipment	19,838	19,104	15,449	-3,655	-19%
Interest/Transfers	5,000	5,500	3,368	-2,132	-39%
Generating Agency Activities	11,185	18,409	25,911	+7,502	+41%
Total, Equipment, Contracts and Related Expenses	**157,389**	**153,132**	**174,731**	**+21,599**	**+14%**
Program Direction	**62,948**	**67,112**	**70,316**	**+3,204**	**+5%**
Total, Operating Expenses from new authority	**220,337**	**220,244**	**245,047**	**+24,803**	**+11%**
Offsetting Collections Realized	-220,337	-263,044	-266,447	-3,403	+1%
Total, Obligational Authority	**0**	**-42,800**	**-21,400**	**+21,400**	**-50%**

Colorado River Basins Power Marketing Fund
Equipment, Contracts and Related Expenses

Description

WAPA's equipment, contracts and related expenses are necessary to operate and maintain this activity. Revenues from the sale of electric energy, capacity and transmission services replenish the fund and are available for expenditure for operation, maintenance, power billing and collection, program direction, purchase power and wheeling, interest, emergencies, and other power marketing expenses.

Supplies, Materials and Services

This activity funds the procurement of supplies, materials, and services necessary to respond to routine and emergency situations in the transmission system. Estimates are based on recent actual costs for supplies needed to maintain transmission system reliability. Reimbursements to the U.S. Army Corps of Engineers has been moved to a new Generating Agency Activities category.

Purchase Power Costs

This activity funds the procurement of electrical power, transmission capacity and wheeling services on the open market. The request anticipates the results of continued low-steady-flow tests conducted at Glen Canyon Dam, as required by the Glen Canyon Dam Environmental Impact Statement Record of Decision. Additionally, the request includes obligation authority to accommodate replacement power purchases for customers served by the Colorado River Storage Project. The replacement power purchases, a provision of the Salt Lake City Area Integrated Projects electric power contracts, are made at the request of power customers at times when WAPA lacks sufficient generation to meet its full contract commitment. The funds for the replacement power purchases are advanced by the requesting customers prior to the purchase.

Capitalized Equipment

This activity funds the procurement of capitalized equipment including circuit breakers, transformers, relays, switches, transmission line equipment, microwave, SCADA, and other communication and control equipment to assure reliable service to WAPA's customers. Replacement and upgrade of aged power system components are crucial to system reliability and transmission services.

Transmission line estimates include the purchase of poles, crossarms, conductors, fusion splicers, line switches, overhead ground wire and hardware for the continued transmission line rebuilds. This estimate includes line rebuilds with the anticipated completion of 10 miles a year.

Planned substation estimates include upgrades, replacement of breakers and circuit switches, and replacement of transformers, test equipment, as well as other aged equipment at various substations. WAPA cyclically replaces older electro-mechanical relays with microprocessor relays. The microprocessor relays assist in finding faults faster in order to more efficiently restore service to customers. Other miscellaneous items required for substation replacements include surge arrestors, batteries and chargers, and monitoring equipment.

Planned movable capitalized property estimates include replacements of special purpose trucks, replacement of generators to maintain the reliability and backup power to the communications system, and replacement of outdated test and recording equipment. Other estimates include the replacement of test equipment used to troubleshoot the new digital microwave radio system. Ongoing replacement is also planned for aging information technology support systems and routers. Other requests include funding for other minor enhancements that provide for the ease of maintenance, protection of equipment and materials, and environmental compliance.

Interest/Transfers
This activity funds interest payments to the U.S. Treasury. Estimates are based on Power Repayment Studies for the Projects funded in this account.

Generating Agency Activities
This activity funds the continuation of reimbursements to the U.S. Army Corps of Engineers for operation and maintenance of the Fort Peck Power Plant. Estimates are based on recent actual costs for supplies needed to maintain generating system reliability. In prior year budgets, this activity was included in the Supplies, Materials and Services category.

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Equipment, Contracts and Related Expenses $157,389,000	**$153,132,000**	**$174,731,000**	**+$21,599,000**
Supplies, Materials & Services ($12,304,000) This activity funds the procurement of supplies, materials, and services necessary to respond to routine and emergency situations in the transmission system. In prior budgets, Supplies, Materials and Services also captured Generating Agency activity. It is now being separated out and reported in Generating Agency Activities for transparency.	*Supplies, Materials & Services ($11,947,000)* This activity funds the procurement of supplies, materials, and services necessary to respond to routine and emergency situations in the transmission system. In prior budgets, Supplies, Materials and Services also captured Generating Agency activity. It is now separated out and reported in Generating Agency Activities for transparency.	*Supplies, Materials & Services ($13,330,000)* This activity funds the procurement of supplies, materials, and services necessary to respond to routine and emergency situations in the transmission system	*Supplies, Materials & Services (+1,383,000)* The increases in miscellaneous services, Federal Agency and non-capitalized durable equipment are partially offset with decreases in supplies & materials including IT capitalized hardware and software.
Purchase Power Costs ($109,062,000) This activity funds the procurement of electrical power, transmission capacity and wheeling services on the open market. Purchase power cost estimates are based on 24-month study factors including water cycle, snow pack and market rates.	*Purchase Power Costs ($98,172,000)* This activity funds the procurement of electrical power, transmission capacity and wheeling services on the open market. Purchase power cost estimates are based on 24-month study factors including water cycle, snow pack and market rates.	*Purchase Power Costs ($116,673,000)* This activity funds the procurement of electrical power, transmission capacity and wheeling services on the open market. Purchase power cost estimates are based on 24-month study factors including water cycle, snow pack and market rates.	*Purchase Power Costs (+$18,501,000)* The increase is primarily attributed to purchase power requirements and costs. Power wheeling expenses remain static.
Capitalized Equipment ($19,838,000) This activity funds the procurement of capitalized equipment including circuit breakers, transformers, relays, switches, transmission line equipment, microwave, SCADA, and other	*Capitalized Equipment ($19,104,000)* This activity funds the procurement of capitalized equipment including circuit breakers, transformers, relays, switches, transmission line equipment, microwave, SCADA, and other	*Capitalized Equipment ($15,449,000)* This activity funds the procurement of capitalized equipment including circuit breakers, transformers, relays, switches, transmission line equipment, microwave, SCADA, and other communication and	*Capitalized Equipment (-$3,655,000)* The decrease is attributable to reduction in replacement of fixed equipment.

FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
communication and control equipment to assure reliable service to WAPA's customers. In prior budgets, Capitalized Equipment also captured Generating Agency activity. It is now separated out and reported in Generating Agency Activities for transparency.	communication and control equipment to assure reliable service to WAPA's customers. In prior budgets, Capitalized Equipment also captured Generating Agency activity. It is now separated out and reported in Generating Agency Activities for transparency.	control equipment to assure reliable service to WAPA's customers.	
Interest/Transfers ($5,000,000) This activity funds interest payments to the U.S. Treasury. Estimates are based on Power Repayment Studies for the Projects funded in this account.	*Interest/Transfers ($5,500,000)* This activity funds interest payments to the U.S. Treasury. Estimates are based on Power Repayment Studies for the Projects funded in this account.	*Interest/Transfers ($3,368,000)* This activity funds interest payments to the U.S. Treasury. Estimates are based on Power Repayment Studies for the Projects funded in this account.	*Interest/Transfers (-$2,132,000)* The decrease in interest/transfers is due to reduction in unpaid interest-bearing portion of capital investments.
Generating Agency Activities ($11,185,000) In prior budgets, this activity was reported in Supplies, Materials & Services and Capitalized Equipment. It is now being reported in Generating Agency Activities for transparency. It funds the continuation of reimbursements to the U.S. Army Corps of Engineers operation and maintenance of the Fort Peck Power Plant.	*Generating Agency Activities ($18,409,000)* In prior budgets, this activity was reported in Supplies, Materials & Services and Capitalized Equipment. It is now being reported in Generating Agency Activities for transparency. It funds the continuation of reimbursements to the U.S. Army Corps of Engineers operation and maintenance of the Fort Peck Power Plant.	*Generating Agency Activities ($25,911,000)* This activity funds the continuation of reimbursements to the U.S. Army Corps of Engineers for operation and maintenance of the Fort Peck Power Plant.	Generating Agency Activities (+$7,502,000) The increase is primarily attributable to scheduled replacements for capitalized communication, substation equipment and maintenance of the Fort Peck Power Plant.

Colorado River Basins Power Marketing Fund
Program Direction

Overview

Program Direction provides the Federal staffing resources and associated costs required to provide overall direction and execution of the Colorado River Basins Power Marketing Fund. WAPA trains its employees on a continuing basis in occupational safety and health regulations, policies and procedures, and conducts safety meetings at employee, supervisory and management levels to keep the safety culture strong. Accidents are reviewed to ensure lessons are learned and proper work protocol is in place.

Highlights of the FY 2021 Budget Request

The FY 2021 request provides for the continuation of WAPA's revolving fund activities related to Program Direction at the level necessary to meet mission requirements. The requested level of 294 FTE are critical to WAPA's mission activities.

Colorado River Basins Power Marketing Fund
Program Direction
Funding ($K)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted ($)	FY 2021 Request vs FY 2020 Enacted (%)
Program Direction					
Salaries and Benefits	44,278	46,963	49,157	+2,194	+5%
Travel	3,276	3,268	3,396	+128	+4%
Support Services	6,981	7,678	7,091	-587	-8%
Other Related Expenses	8,413	9,203	10,672	+1,469	+16%
Total, Program Direction	**62,948**	**67,112**	**70,316**	**+3,204**	**+5%**
Federal FTEs	**280**	**296**	**294**	**-2**	**-1%**
Support Services					
Technical Support					
Engineering and Technical Services	2,388	1,448	1,573	+125	+9%
Total, Technical Support	2,388	1,448	1,573	+125	+9%
Management Support					
Automated Data Processing	1,964	3,304	2,749	-555	-17%
Training and Education	915	970	1,011	+41	+4%
Reports and Analyses Management and General Administrative Support	1,714	1,956	1,758	-198	-10%
Total, Management Support	**4,593**	**6,230**	**5,518**	**-712**	**-11%**
Total, Support Services	**6,981**	**7,678**	**7,091**	**-587**	**-8%**
Other Related Expenses					
Rent to GSA	536	723	694	-29	-4%
Communication, Utilities, Misc.	1,710	1,468	1,854	+386	+26%
Printing and Reproduction	30	24	24	0	0%
Other Services	2,247	3,067	4,046	+979	+32%
Training	15	13	15	+2	+15%

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted ($)	FY 2021 Request vs FY 2020 Enacted (%)
Purchases from Gov. Accounts	261	237	319	+82	+35%
Operation and Maintenance of Equipment	1,484	1,653	1,374	-279	-17%
Supplies and Materials	695	631	596	-35	-6%
Equipment	797	652	1,057	+405	+62%
Working Capital Fund	638	735	693	-42	-6%
Total, Other Related Expenses	**8,413**	**9,203**	**10,672**	**+1,469**	**+16%**

Colorado River Basins Power Marketing Fund
Program Direction

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Program Direction, $62,948,000	**$67,112,000**	**$70,316,000**	**+$3,204,000**
Salaries and Benefits $44,278,000	**$46,963,000**	**$49,157,000**	**+$2,194,000**
Salary and benefits supports a FY 2019 request level of 293 FTE. This includes General Schedule employees, as well as those salaries determined through negotiations. This activity provides for Federal employees who operate and maintain the Program's high-voltage integrated transmission system and associated facilities; plan, design, and supervise the replacement (capital investments) to the transmission facilities; and market the power and energy produced to repay annual expenses and capital investment.	Salary and benefits supports a FY 2020 request level of 296 FTE. This includes General Schedule employees, as well as those salaries determined through negotiations. This activity provides for Federal employees who operate and maintain the Program's high-voltage integrated transmission system and associated facilities; plan, design, and supervise the replacement (capital investments) to the transmission facilities; and market the power and energy produced to repay annual expenses and capital investment.	Salary and benefits supports a FY 2021 request level of 294 FTE. This includes General Schedule employees, as well as those salaries determined through negotiations. This activity provides for Federal employees who operate and maintain the Program's high-voltage integrated transmission system and associated facilities; plan, design, and supervise the replacement (capital investments) to the transmission facilities; and market the power and energy produced to repay annual expenses and capital investment.	The increase in salaries and benefits supports the 294 FTE charged to this account for planned capital investments. The salary and benefits reflect inflationary factors; OPM pay increase for engineers and journeymen negotiated salaries.
Travel $3,276,000	**$3,268,000**	**$3,396,000**	**+$128,000**
This activity funds personnel travel and per diem expenses for essential mission-related activities, including the maintenance of transmission facilities. The request includes estimates for the rent/lease of GSA vehicles and other transportation.	This activity funds personnel travel and per diem expenses for essential mission-related activities, including the maintenance of transmission facilities. The request includes estimates for the rent/lease of GSA vehicles and other transportation.	This activity funds personnel travel and per diem expenses for essential mission-related activities, including the maintenance of transmission facilities. The request includes estimates for the rent/lease of GSA vehicles and other transportation.	The increase supports mission related operation and maintenance travel as well as capturing inflationary factors.
Support Services $6,981,000	**$7,678,000**	**$7,091,000**	**-$587,000**
Support services funded in this category include automated data	Support services funded in this category include automated data processing	Support services funded in this category include information technology support,	The decrease is primarily driven by reduction in Management support of

FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
processing support, warehousing, computer-aided drafting/engineering, job related training and education, and general administrative support.	support, warehousing, computer-aided drafting/engineering, job related training and education, and general administrative support.	warehousing, computer-aided drafting/engineering, job related training and education, and general administrative support.	Automated Data Processing and Report and Analyses with minor offsets in Engineering & Technical services.
Other Related Expenses $8,413,000	**$9,203,000**	**$10,672,000**	**+$1,469,000**
Other related expenses include, but are not limited to, DOE's working capital fund distribution, space, utilities and miscellaneous charges, printing and reproduction, training tuition, maintenance of office equipment, supplies and materials, telecommunications, and office equipment to include computers.	Other related expenses include, but are not limited to, DOE's working capital fund distribution, space, utilities and miscellaneous charges, printing and reproduction, training tuition, maintenance of office equipment, supplies and materials, telecommunications, and office equipment to include computers.	Other related expenses include, but are not limited to, DOE's working capital fund distribution, space, utilities and miscellaneous charges, printing and reproduction, training tuition, maintenance of office equipment, supplies and materials, telecommunications, and office equipment to include computers.	The increase to this activity is primarily driven by contractual services, equipment, and communication & utilities. A reduction in operation and maintenance of information technology equipment and other miscellaneous items are partially offsetting.

Transmission Infrastructure Program
Funding ($K)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted
Net BA	**0**	**0**	**0**	**0**

Overview

WAPA established the Transmission Infrastructure Program (TIP) and Office to implement Title III, Section 301 of the Hoover Power Plant Act of 1984 as amended by the American Recovery and Reinvestment Act of 2009 (Recovery Act), which provided WAPA borrowing authority of up to $3.25 billion for the purposes of: (1) constructing, financing, facilitating, planning, operating, maintaining, or studying construction of new or upgraded electric power transmission lines and related facilities with at least one terminus within the area served by WAPA; and (2) delivering or facilitating the delivery of power generated by renewable energy resources constructed or reasonably expected to be constructed after the Recovery Act's date of enactment.

TIP is expected to be an administratively self-sustaining program that relies on funding arrangements with project developers. When developers seek technical assistance, WAPA collects funds from the project developers to support development of eligible projects and to cover the overhead and administrative costs of the program. Reimbursable or Advance Funding Agreements with project developers are required prior to initiating efforts to evaluate the technical and financial merits of a potential project to ensure the full cost of services delivered are paid by project beneficiaries. For projects that are approved for use of WAPA's borrowing authority, the authority to cover the full amount of the loan is apportioned at the outset and cash is borrowed periodically from the Departments of Treasury (Treasury) as needed. The debt is repaid according to the financial agreement terms and conditions of each project.

As mandated, the TIP program is completely separate and distinct from WAPA's power marketing program.
TIP has one project currently using the borrowing authority for a total of $91 million in loan authority obligated.
All administrative costs for TIP are offset by advanced financing and collections. WAPA is not requesting any new annual appropriated funds for TIP.

Highlights of the FY 2021 Budget Request

The FY 2021 budget request includes a proposal to repeal the $3.25 billion borrowing authority managed by the TIP program. Pending repeal, WAPA anticipates ongoing use of new borrowing authority as new projects are approved along with collaborations with Departmental programs as appropriate. Construction and project debt estimates are based on preliminary information provided by the Project Sponsors/Proponents.

Note: Values for TIP are based on early stages of project development, forecasts of current projects, estimates of future project development, and departmental collaboration, which are subject to change. While based on knowledge and experience to date, these estimates are to be regarded as non-binding representations that are determined by Project Sponsors/Proponents.

Transmission Infrastructure Program
Funding ($K)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted ($)	FY 2021 Request vs FY 2020 Enacted (%)
Mandatory, Direct Budget Authority					
New Borrowing Authority	1,025,000	725,000	960,000	+235,000	+32%
Use of Collections from Projects	4,470	4,800	5,000	+200	+4%
Collections from Projects	-4,470	-4,800	-5,000	-200	+4%
Total Mandatory	**1,025,000**	**725,000**	**960,000**	**+235,000**	**+40%**
Repayment of Borrowing Authority	-350,000	0	-200,000	-200,000	+100%
Federal FTEs (Mandatory)	**0**	**0**	**0**	**0**	**0%**
Discretionary, Reimbursable Budget Authority					
Program Direction	43,170	47,442	44,560	-2,882	-6%
Advance Funding	-4,500	-4,300	-2,025	+2,275	-53%
Offsetting Collections	-38,670	-43,142	-42,535	+607	-1%
Total Discretionary	**0**	**0**	**0**	**0**	**0**
Federal FTEs (Discretionary)	**4**	**15**	**11**	**-4**	**-27%**
-					
Total, Transmission Infrastructure Program					
Total, Federal FTEs	**4**	**15**	**11**	**-4**	**-27%**

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Direct Budget Authority $1,025,000,000	**$725,000,000**	**$960,000,000**	**+$235,000,000**
New Borrowing Authority $1,025,000,000	**$725,000,000**	**$960,000,000**	**+$235,000,000**
Estimated new projects approved for use of WAPA's borrowing authority.	Estimated new projects approved for use of WAPA's borrowing authority.	Estimated new projects approved for use of WAPA's borrowing authority.	The increase is due to higher estimates provided by potential Project Sponsors/Proponents.
Collections from Projects $4,470,000	**$4,800,000**	**$5,000,000**	**+$200,000**
Collections in this category are from excess capacity offtake from borrowing authority funded projects.	Collections in this category are from excess capacity offtake from borrowing authority funded projects.	Collections in this category are from excess capacity offtake from borrowing authority funded projects.	TIP estimates collecting $5 million in excess capacity from the ED5 energized line in FY 2021. These collections will all be obligated and used for costs associated with operating and maintaining those lines generating the capacity.
Repayment of Borrowing Authority -$350,000,000	**$0**	**-$200,000,000**	**-$200,000,000**
This activity represents repayments to Treasury from projects for principal.	This activity represents repayments to Treasury from projects for principal.	This activity represents repayments to Treasury from projects for principal.	Amounts are for repayment of cash drawn for current projects according to the terms of each projects' lending agreement as they are anticipated to move into long term financing.

Transmission Infrastructure Program
Program Direction

Overview

WAPA's TIP Program Direction subprogram provides compensation and all related expenses for its workforce, including those employees that are directly assigned to the program as project management, technical experts, finance and administration; those that provide expertise in land acquisition, engineering and environmental compliance; those that provide legal counsel; and those that administratively support these functions.

All TIP program direction costs are expected to be offset by customers over time, either through advanced funding agreements or offsetting collections. Advanced funding is provided to TIP from project applicants who use TIP's expertise in the development of their project. The advanced funding agreements fund federal and/or contract staff working on the development of a specific project. Other sources of funds include the overhead rate applied to each active project; service charges; interest rate differentials; and the advance collection of Project Proposal and Business Plan Proposal evaluation expenses. These collections offset the costs of administering the TIP program and provide a risk mitigation reserve.

The Program Direction subprogram supports DOE and WAPA missions, specifically in facilitating delivery of renewable energy resources to market.

Highlights of the FY 2021 Budget Request

In FY 2021 the TIP office will continue to recover programmatic expenses, and maintain a risk mitigation reserve.

Program Direction
Funding ($K)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	FY 2021 Request vs FY 2020 Enacted ($)	FY 2021 Request vs FY 2020 Enacted (%)
Transmission Infrastructure					
Salaries and Benefits	2,315	2,065	1,225	-840	-41%
Travel	120	106	60	-46	-43%
Support Services	1,997	2,166	756	-1,410	-65%
Other Related Expenses	38,738	43,105	42,519	-586	-1%
Subtotal, Program Direction	**43,170**	**47,442**	**44,560**	**-2,882**	**-6%**
Use of Offsetting Collections	-43,170	-47,442	-44,560	+2,882	-6%
Total, Program Direction	**0**	**0**	**0**	**0**	**0%**
Federal FTEs (Mandatory Direct)	**0**	**0**	**0**	**0**	**0%**
Federal FTEs (Discretionary Reimbursable)	**4**	**15**	**11**	**-4**	**-27%**
Federal FTEs (Total TIP)	**4**	**15**	**11**	**-4**	**-27%**
Technical Support Projects	1,809	1,982	358	-1,624	-82%
Total, Technical Support	1,809	1,982	358	-1,624	-82%
Management Support					
Financial Modeling	42	41	99	+58	+141%
Legal Policy and Review	146	143	299	+156	+109%
Total Management Support	188	184	398	+214	+116%
Total, Support Services	**1,997**	**2,166**	**756**	**-1,410**	**-65%**
Other Related Expenses					
Communications; utilities; miscellaneous charges	172	223	20	-203	-91%
Services from Non- Federal and Federal Sources	42	41	389	+348	+849%
Services from Loan Programs Office	3,221	2,209	0	-2,209	-100%
Supplies and materials	5	5	4	-1	-20%
Interest Payments	35,298	40,627	42,106	+1,479	+4%
Total, Other Related Expenses	**38,738**	**43,105**	**42,519**	**-586**	**-1%**

Program Direction

Activities and Explanation of Changes

FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Program Direction $43,170,000	**$47,442,000**	**$44,560,000**	**-$2,882,000**
Salaries and Benefits $2,315,000	**$2,065,000**	**$1,225,000**	**-$840,000**
Salary and benefits provide for Federal employees that are directly assigned to the TIP program as project management, technical experts, finance and administration; those that provide expertise in land acquisition, engineering and environmental compliance; those that provide legal counsel; and those that administratively support these functions. FTE assigned to this account charge TIP's mandatory as well as discretionary funding accounts.	Salary and benefits provide for Federal employees that are directly assigned to the TIP program as project management, technical experts, finance and administration; those that provide expertise in land acquisition, engineering and environmental compliance; those that provide legal counsel; and those that administratively support these functions. FTE assigned to this account charge TIP's mandatory as well as discretionary funding accounts.	Salary and benefits provide for Federal employees that are directly assigned to the TIP program as project management, technical experts, finance and administration; those that provide expertise in land acquisition, engineering and environmental compliance; those that provide legal counsel; and those that administratively support these functions. FTE assigned to this account charge TIP's mandatory as well as discretionary funding accounts.	The decrease of salaries and benefits is due to the reduction of direct and indirect support provided to this account to include the proportionate FTE. This decrease is slightly offset by inflationary factors.
Travel $120,000	**$106,000**	**$60,000**	**-$46,000**
Planned essential travel supports TIP's mission related activities. TIP supports efficient spending initiatives and is cognizant of travel costs associated with general program operations. TIP focuses on using alternative means to conduct meetings and training sessions where appropriate.	Planned essential travel supports TIP's mission related activities. TIP supports efficient spending initiatives and is cognizant of travel costs associated with general program operations. TIP focuses on using alternative means to conduct meetings and training sessions where appropriate.	Planned essential travel supports TIP's mission related activities. TIP supports efficient spending initiatives and is cognizant of travel costs associated with general program operations. TIP focuses on using alternative means to conduct meetings and training sessions where appropriate.	The decrease in travel reflects TIP's continued effort to use technological capabilities to decrease travel requirements, reduction of FTE, and also captures a slight offset for inflationary factors.

FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request	Explanation of Changes FY 2021 Request vs FY 2020 Enacted
Support Services $1,997,000	**$2,166,000**	**$756,000**	**-$1,410,000**
Support services funded in this category include technical support costs directly associated with TIP projects; to include Environmental, Lands, Engineering, and Project Management activities. Also within this category are costs to cover legal and financial support activities to include financial modeling, outside legal counsel for contract review, policy issues and legislative concerns.	Support services funded in this category include technical support costs directly associated with TIP projects; to include Environmental, Lands, Engineering, and Project Management activities. Also within this category are costs to cover legal and financial support activities to include financial modeling, outside legal counsel for contract review, policy issues and legislative concerns.	Support services funded in this category include technical support costs directly associated with TIP projects; to include Environmental, Lands, Engineering, and Project Management activities. Also within this category are costs to cover legal and financial support activities to include financial modeling, outside legal counsel for contract review, policy issues and legislative concerns.	The decrease in support services is due to the reduction for technical support associated with project management and stage of development of projects given revised work scope demands with an offset of management support in financial modeling and legal policy and review for underwriting capability.
Other Related Expenses $38,738,000	**$43,105,000**	**$42,519,000**	**-$586,000**
Other related expenses include communications, utilities, training, depreciation, WAPA overhead rates, supplies and materials, Loan Program Office (LPO) services, and interest loan payments.	Other related expenses include communications, utilities, training, depreciation, WAPA overhead rates, supplies and materials, and interest loan payments.	Other related expenses include communications, utilities, training, depreciation, WAPA overhead rates, supplies and materials, and interest loan payments.	The decrease reflects elimination of services from Loan Programs Office offset by services from Federal sources, anticipated loan interest payments and interest rate adjustment.

Estimate of Gross Revenues [1]

(Dollars in Thousands)

	FY 2019[2]	FY 2020	FY 2021
Boulder Canyon Project	71,046	85,076	96,849
Central Valley Project	261,446	407,398	412,784
Falcon-Amistad Project	3,446	10,691	11,628
Fryingpan-Arkansas Project	19,154	19,136	18,724
Pacific Northwest-Southwest Intertie Project	41,621	43,001	43,001
Parker-Davis Project	65,870	72,061	77,397
Pick-Sloan Missouri Basin Program	617,626	541,945	532,876
Provo River Project	286	464	465
Washoe Project	459	451	451
Salt Lake City Area Integrated Projects	225,844	182,131	182,199
Other	146,273	0	0
Total, Gross Revenues	**1,453,071**	**1,362,354**	**1,376,374**

[1] Amounts for FY 2020 and FY 2021 are based on the FY 2018 Final Power Repayment Studies (PRS).

[2] FY 2019 amounts are actuals from the preliminary annual financial reports. For Central Valley Project, FY 2019 amounts reported exclude contractual pass-through purchase power arrangements which are included in the PRS estimates. The 'Other' FY 2019 amounts shown represent WAPA activities reported in the financials that are not reimbursable through the power and transmission rate-setting process, and are not forecasted through the PRS.

Estimate of Proprietary Receipts

(Dollars in Thousands)

	FY 2019 Actual	FY 2020	FY 2021
Mandatory Receipts			
Falcon Amistad Maintenance Fund	1,522	2,000	2,000
Sale and Transmission of Electric Power, Falcon and Amistad Dams	800	0	0
Sale of Power and Other Utilities Not Otherwise Classified	10,447	30,000	30,000
Sale of Power–WAPA–Reclamation Fund	266,329	200,644	224,437
Total, Mandatory Receipts	**279,098**	**232,644**	**256,437**
Discretionary Receipts			
Offsetting Collections from the Recovery of Power Related Expenses – WAPA CROM	225,442	227,000	227,043
Less Purchase Power and Wheeling Expenses	-225,442	-227,000	-227,043
Subtotal, WAPA CROM Recovery of Power Related Expenses	0	0	0
Offsetting Collections from the Recovery of Annual Expenses – WAPA CROM	175,770	173,587	169,754
Less Operating and Maintenance expenses	-25,009	-24,445	-24,744
Less Program Direction Expenses	-150,761	-149,142	-145,010
Subtotal, WAPA CROM Recovery of Annual Expenses	0	0	0
Offsetting Collections from the recovery of power related expenses – Falcon and Amistad	1,340	2,932	5,548
Less Operating and Maintenance expenses	-1,340	-2,932	-5,548
Subtotal, Falcon and Amistad Recovery of Power Related Expenses	0	0	0
Total, Discretionary Receipts	**0**	**0**	**0**
Total, Proprietary Receipts	**279,098**	**232,644**	**256,437**

Western Area Power Administration
Estimate of Offsetting Collections for Reimbursable Work and Work-for-Others

(Dollars in Thousands)

	FY 2019	FY 2020	FY 2021
Construction, Rehabilitation, Operation and Maintenance (CROM)			
Offsetting Collections for Reimbursable Work [1]			
Alternative Financing			
Operations and Maintenance	7,758	6,600	6,297
Construction and Rehabilitation	27,077	39,922	20,353
Purchase Power and Wheeling (PPW)	260,954	288,769	293,890
Program Direction	39,136	44,719	48,546
Subtotal, Alternative Financing	334,925	380,010	369,086
Offsetting Collections not anticipated for obligation in budget year	35,002	122,357	2,936
Less PPW net billing, bill crediting, energy exchange	-248,985	-256,321	-233,400
Offsetting collections from Colorado River Dam Fund	9,058	8,954	8,378
Subtotal, Offsetting Collections for Reimbursable Work	**130,000**	**255,000**	**147,000**
Offsetting Collections for Reimbursable Work-for-Others [2]	**469,000**	**490,000**	**601,000**
Total, Offsetting Collections for Reimbursable	**599,000**	**745,000**	**748,000**

[1] WAPA relies significantly on alternative financing arrangements with customers to finance much of its direct mission work on a reimbursable basis.

[2] WAPA has partnering arrangements with many power customers and Federal agencies to perform electrical systems operations, maintenance, construction, purchase power, and transmission services on a reimbursable basis.

DEPARTMENT OF ENERGY
Funding by Site Detail
Western Area Power Administration
(Dollars in Thousands)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request
Western Area Power Administration Office			
System Operation And Maintenance - CROM	77,056	72,176	77,874
Construction And Rehabilitation - CROM	32,632	45,887	26,251
Program Direction - CROM	238,483	250,091	253,575
Total Western Area Power Administration Office	**348,171**	**368,154**	**357,700**

DEPARTMENT OF ENERGY
Funding by Site Detail
Colorado River Basins Power Marketing Fund Western
(Dollars in Thousands)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 Request
Western Area Power Administration Office			
Program Direction - Colorado River Basins Fund	62,948	67,112	70,316
Equipment, Contracts and Related Expenses - Colorado River Basins Fund	157,389	153,132	174,731
Colorado River Basins Power Marketing Fund (CRBPMF) Programs	220,337	220,244	245,047
Total Western Area Power Administration Office	**220,337**	**220,244**	**245,047**

Bonneville Power Administration

Bonneville Power Administration

Bonneville Power Administration (Bonneville, BPA)

Proposed Appropriations Language

Expenditures from the Bonneville Power Administration Fund, established pursuant to Public Law 93–454, are approved [for the Steigerwald Floodplain Restoration Project and, in addition,] for official reception and representation expenses in an amount not to exceed $5,000: *Provided*, That during fiscal year [2020] *2021*, no new direct loan obligations may be made[: Provided further, Expenditures from the Bonneville Power Administration Fund, established pursuant to Public Law 93–454 are authorized and approved, without fiscal year limitation, for the cost of current and future year purchases or payments of emissions expenses associated with Bonneville Power Administration power and transmission operations in states with clean energy programs: Provided further, This expenditure authorization is limited solely to Bonneville Power Administration's voluntary purchase or payments made in conjunction with state clean energy programs and is not a broader waiver of Bonneville Power Administration's sovereign immunity].

Explanation of Changes

The proposed appropriations language restricts new direct loans in FY 2021 as in FY 2020**.** This bill language is drafted consistent with the Credit Reform Act of 1990.

Please Note - The FY 2021 Bonneville Power Administration Congressional Budget submission includes FY 2020 budget estimates.

Bonneville operates under a business-type budget under the Government Corporation Control Act, 31 U.S.C 9101-10 and on the basis of the self-financing authority provided by the Federal Columbia River Transmission System Act of 1974 (Transmission Act) (Public Law 93-454). Bonneville has authority to borrow from the U.S. Treasury under the Transmission Act, the Pacific Northwest Electric Power Planning and Conservation Act of 1980 (Northwest Power Act) (Public Law 96-501) for acquisition of energy conservation, renewable and other power resources, investment in fish facilities, and other purposes, the American Recovery and Reinvestment Act of 2009 (Public Law 111-5), and other legislation. Authority to borrow from the U.S. Treasury is available to Bonneville on a permanent, revolving basis. The principal amount of U.S. Treasury borrowing outstanding at any time may not exceed $7.70 billion.[1] Bonneville finances its approximate $4.4 billion annual cost of operations and investments by primarily using its power and transmission revenues, and proceeds of borrowing from the U.S. Treasury.

This budget has been prepared in accordance with the Statutory Pay-As-You-Go Act (PAYGO) of 2010. Under PAYGO, all Bonneville budget estimates are treated as mandatory and are not subject to the discretionary caps included in the Budget Control Act of 2011. These estimates support activities that are separate from discretionary activities and accounts. Thus, any changes to Bonneville estimates cannot be used to affect any other budget categories, which have their own dollar caps. Because Bonneville's obligations are and will be incurred under pre-existing legislative authority, Bonneville is not subject to a "pay-as-you-go" test regarding its revision of current-law funding estimates.

[1] The outstanding principal amount of bonds issued by Bonneville to the U.S. Treasury can be found in tables BP-4A – 4D in the Additional Tables section.

Bonneville Power Administration

Funding Profile by Subprogram [1/]

(Accrued Expenditures in Thousands of Dollars)

	Fiscal Year			
	2019 Actual	2020 Original [/2]	2020 Revised [/2]	2021 Proposed
Capital Investment Obligations				
Associated Project Costs [3/]	199,661	238,000	238,000	256,000
Fish & Wildlife	22,313	47,266	47,266	47,266
Subtotal, Power Services	221,974	285,266	285,266	303,266
Transmission Services	192,077	479,172	468,765	474,305
Capital Equipment & Bond Premium	10,029	22,099	22,100	22,131
Total, Capital Obligations [3/]	424,080	786,537	776,131	799,703
Expensed and Other Obligations				
Expensed	2,967,978	2,867,867	2,920,710	2,978,229
Projects Funded in Advance [5/]	239,228	85,886	85,896	66,179
Total, Obligations	3,631,286	3,740,290	3,782,736	3,844,110
Capital Transfers (cash)	733,505	407,536	350,933	401,721
Bonneville Total (Oligations & Capital Transfers)	4,364,791	4,147,826	4,133,669	4,245,831
Bonneville Net Outlays	67,000	(166,596)	(163,159)	(110,068)
Full-time Equivalents (FTEs) [4/]	2,727	3,000	3,000	3,000

Public Law Authorizations include:

Bonneville Project Act of 1937, Public Law No. 75-329

Federal Columbia River Transmission System Act of 1974, Public Law No. 93-454

Regional Preference Act of 1964, Public Law No. 88-552

Flood Control Act of 1944, Public Law No. 78-543

Pacific Northwest Electric Power Planning and Conservation Act of 1980 (Northwest Power Act), Public Law No. 96-501

Outyear Funding Profile by Subprogram [1/]

(Accrued Expenditures in Thousands of Dollars)

	Fiscal Year			
	2022	2023	2024	2025
Capital Investment Obligations				
Associated Project Costs [3/]	281,000	300,000	306,000	313,000
Fish & Wildlife	43,000	43,000	40,000	40,000
Subtotal, Power Services	324,000	343,000	346,000	353,000
Transmission Services	467,952	507,078	525,439	486,964
Capital Equipment & Bond Premium	22,296	22,268	21,146	20,271
Total, Capital Obligations [3/]	814,248	872,345	892,585	860,235
Expensed and Other Obligations				
Expensed	3,087,062	3,158,028	3,219,149	3,298,778
Projects Funded in Advance [5/]	60,463	39,848	39,823	40,947
Total, Obligations	3,961,773	4,070,221	4,151,557	4,199,960
Capital Transfers (cash)	370,837	329,598	313,705	300,902
Bonneville Total (Oligations & Capital Transfers)	4,332,610	4,399,819	4,465,262	4,500,862
Bonneville Net Outlays	(32,690)	53,373	119,735	143,013
Full-time Equivalents (FTEs) [4/]	3,000	3,000	3,000	3,000

These notes are an integral part of this table.

1/ This budget has been prepared in accordance with PAYGO. Under PAYGO all Bonneville budget estimates are treated as mandatory and are not subject to the discretionary caps included in the Budget Control Act of 2011. These estimates support activities that are separate from discretionary activities and accounts. Thus, any changes to Bonneville estimates cannot be used to affect any other budget categories which have their own dollar caps. Because Bonneville's obligations are and will be incurred under pre-existing legislative authority, Bonneville is not subject to a "pay-as-you-go" test regarding its revision of current-law funding estimates.

2/ Original estimates reflect Bonneville's FY 2020 Congressional Budget Submission. Revised estimates, consistent with Bonneville's annual near-term funding review process, provide notification to the Administration and Congress of updated capital and expense funding levels for FY 2020. The BPA estimates in this budget are consistent with the 2018 final IPR. Please see https://www.bpa.gov/Finance/FinancialPublicProcesses/IPR/Pages/IPR-2018.aspx for further information.

3/ Includes infrastructure investments to address the long-term electric power related needs of the Northwest and significant changes affecting Bonneville's power and transmission markets.

4/ As of October 25, 2019 DOE HR staff has reported FY 2019 BPA's FTE usage at 2,727.

5/ In this instance, Projects Funded in Advance represents prepayment of Power customers' bills reimbursed by future credits and third party non-federal financing for Conservation initiatives.

Additional Notes

Capital funding levels reflect external factors such as the significant changes affecting West Coast power and transmission markets, along with planned infrastructure investments designed to address the long-term needs of the region.

Cumulative advance amortization payments as of the end of FY 2019 are $5,791 million.

Refer to 16 USC Chapters 12B, 12G, 12H, and Bonneville's other organic laws, including P.L. 100-371, Title III, Sec. 300, 102 Stat. 869, July 19, 1988, regarding Bonneville's ability to obligate funds.

Budget estimates included in this budget are subject to change due to rapidly changing economic and institutional conditions in the evolving electric utility industry.

Net Outlay estimates are based on current cost savings to date and anticipated cash management goals. They are expected to follow anticipated management decisions throughout the rate period that, along with actual market conditions, will impact revenues and expenses. Actual Net Outlays are volatile and are reported in Report on Budget Execution and Budgetary Resources (SF-133). Actual Net Outlays could differ from estimates due to changing market conditions, streamflow variability, continued restructuring of the electric industry, and other reasons.

Revenues, included in the Net Outlay formulation, are calculated consistent with cash management goals and assume a combination of adjustments. Assumed adjustments include the use of a combination of tools, including upcoming rate adjustment mechanisms, a net revenue risk adjustment, debt service refinancing strategies and/or short-term financial tools to manage net revenues and cash. Some of these potential tools will reduce costs rather than generate revenue, causing the same Net Outlay result. Adjustments for depreciation and 4(h)(10)(C) credits of the Northwest Power Act are also assumed.

FY 2019 Net Outlays are calculated using Bonneville’s audited actual revenue. FYs 2020 to 2025 Net Outlays are based on 2018 final IPR assumptions and an escalation factor from using the FY 2018 White Book Loads and Resources Report

FTE outyear data are estimates and may change. Bonneville is facing a dynamic and changing energy marketplace and operations while, at the same time, many of its employees are eligible to retire in the near future. It is important that Bonneville continue to attract and retain skilled individuals to meet the growing demands of a competitive and rapidly changing industry. Accordingly, FTE estimates may need to be adjusted in the future.

Amounts in tables and schedules may not add to totals due to rounding.

Major Outyear Considerations

Bonneville's outyear estimates reflect ongoing efforts to achieve its long-term mission and strategic direction. The outyear estimates are developed with consideration and support of Bonneville's multi-year performance targets that lay out the course for achieving Bonneville's long-term objectives. Outyear capital investment levels support Bonneville's infrastructure program, hydro efficiency program, and its fish and wildlife mitigation projects.

Bonneville continues to incorporate the various aspects of the Energy Policy Act of 2005 related to its business, in particular the energy supply, conservation, and new energy technologies for the future that are highlighted in the legislation.

Bonneville provides electric power services, transmission services, and acquires energy efficiency throughout the Pacific Northwest. Bonneville serves a 300,000 square mile area including Oregon, Washington, Idaho, western Montana, and small parts of eastern Montana, California, Nevada, Utah, and Wyoming with a population of about 14 million people. Bonneville markets the electric power produced from 31 federal hydro projects in the Pacific Northwest owned by the U.S. Army Corps of Engineers (Corps) and the U.S. Department of Interior, Bureau of Reclamation (Reclamation)—the hydro projects are known as Associated Projects. In addition to the Associated Projects, Bonneville also acquires power from non-federal generating resources, including the power from a nuclear power plant, Columbia Generating Station (CGS). Bonneville uses the power from its non-federal purchases and the federal projects, collectively the Federal Columbia River Power System (FCRPS), primarily to meet the Administrator's long term firm power sales contract obligations. Bonneville currently maintains and operates 15,209 circuit miles of transmission lines, 261 substations, and associated power system control and communications facilities over which this electric power is delivered. Bonneville has capital and similar leases for certain transmission facilities. Bonneville also supports the protection and enhancement of fish and wildlife, and promotes conservation and energy efficiency, as part of its efforts to preserve and balance the economic and environmental benefits of the FCRPS.

The organization of Bonneville's FY 2021 Budget reflects Bonneville's business services basis for utility enterprise activities. Bonneville's two major areas of activity on a consolidated budget and accounting basis are Power Services (PS) and Transmission Services (TS) and include their related administrative costs. Power Services activities include line items for Fish and Wildlife, Energy Efficiency, Residential Exchange Program (REP), Associated Projects Operations & Maintenance (O&M) Costs, and Northwest Power and Conservation Council (Planning Council or Council). Transmission Services activities include line items for engineering, operations, and maintenance for Bonneville's electric transmission system.

The mission of Bonneville is to create and deliver federal power and transmission services at the best value for its customers and constituents as it acts in concert with others to assure the Pacific Northwest has the following: (1) an adequate, efficient, economical, and reliable power supply; (2) an open access transmission system that is adequate for integrating and transmitting power from federal and non-federal generating units, providing service to Bonneville's customers, providing interregional interconnections, and maintaining electrical reliability and stability; and (3) mitigation of the impacts on fish and wildlife from the federally owned hydroelectric projects from which BPA markets power.

Bonneville's vision is to be an engine of the Northwest's economic prosperity and environmental sustainability by advancing a Northwest power and transmission system that is a national leader in providing high reliability, low rates consistent with sound business principles, responsible environmental stewardship, and accountability to the region, all through a commercially successful business. Bonneville pursues this vision consistent with its four core values of safety, trustworthy stewardship, collaborative relationships, and operational excellence.

Legislative History

The Bonneville Project Act of 1937 provides the statutory basis for Bonneville's power marketing responsibilities and authorities. In 1974, passage of the Federal Columbia River Transmission System Act (Transmission Act) applied provisions of the Government Corporation Control Act (31 U.S.C. §§ 9101-9110) to Bonneville. The Transmission Act provides Bonneville with "self-financing" authority, establishes the Bonneville Fund (a permanent, indefinite appropriation) allowing Bonneville to use its revenues from electric power and transmission ratepayers to fund all programs without further appropriation, and authorizes Bonneville to sell bonds to the U.S. Treasury. As of the end of FY 2019, Bonneville has revolving U.S. Treasury borrowing authority of $7.7 billion of which approximately $2.4 billion remains available to be drawn.

The 1980 enactment of the Pacific Northwest Electric Power Planning and Conservation Act (Northwest Power Act) expanded Bonneville's authorities, obligations, and responsibilities. The purposes of the act include the following: to encourage electric energy conservation to meet regional electric power loads placed on Bonneville; to develop renewable energy resources within the Pacific Northwest; to assure the Northwest an adequate, efficient, economical, and reliable power supply; to promote regional participation and planning; and to protect, mitigate, and enhance the fish and wildlife of the Columbia River and its tributaries. The Northwest Power Act also established a revised statutory framework for Bonneville's administrative rate-setting process and established judicial review of Bonneville's final actions in the U.S. Court of Appeals for the Ninth Circuit.

Strategic Direction

In early 2018, Bonneville released its 2018-2023 Strategic Plan which describes how it will operate in a commercially successful manner while meeting its statutory obligations. Bonneville developed this strategic plan after listening to customers and constituents express their interests in Bonneville's commercial viability and ability to meet those obligations. The strategic plan was developed at the point when Bonneville was midway through 20-year firm power sales contracts with its preference power customers. Those customers continue to evaluate how Bonneville will be positioned to meet their needs beyond the terms of their current contracts. The strategic plan is framed by these goals:

- Strengthen financial health
- Modernize assets and system operations
- Provide competitive power products and services
- Meet transmission customer needs efficiently and responsively

Financial Plan

Also in 2018, Bonneville completed its Financial Plan to complement the objective in the strategic plan to strengthen its financial health. The 2018 Financial Plan establishes a guiding framework for decision-making by defining the financial constraints within which Bonneville operates, and outlines objectives to establish Bonneville's financial health. The plan contains Bonneville's statutory obligations and authorities, financial policies and established practices, and financial health objectives.

Pursuant to the Financial Plan, Bonneville adopted two specific policies. The Financial Reserves Policy defines the level of financial reserves Bonneville and each business line should hold; how to build financial reserves when they fall below a prescribed level; and a process to consider repurposing financial reserves when they exceed a prescribed level. The policy provides a framework to ensure Bonneville maintains a minimum of 60 days cash on hand for each business line and 90 days for the Agency.

The Leverage Policy creates a strategy to reduce Bonneville's total debt compared to its assets in an effort to strengthen financial health and flexibility. Reducing debt will help Bonneville lower its interest costs, support its strong credit rating, maintain access to borrowing from the U.S. Treasury, and improve financial strength and flexibility.

Cost Management

Prior to each rate case, Bonneville conducts an Integrated Program Review (IPR) with customers and interested regional parties. The 2018 IPR examined all of Bonneville's cost categories attempting to bring program cost increases to below the level of inflation. This included categories of spending often considered inflexible, such as fish and wildlife and the operating costs of generating assets.

With the renewed focus from the strategic plan, the 2018 Integrated Program Review resulted in significant program cost reductions. Bonneville's final projected agency program costs for fiscal years 2020 and 2021 are $66 million lower per year compared to the BP-18 rate period, mostly due to cost reductions in Power Services. The final program costs achieve Bonneville's goal staying at or below the rate of inflation, and also exceed the goal decreasing Bonneville's costs in nominal terms.

Fiscal Year 2020 and 2021 Rates

BPA released the BP-20 Final Record of Decision on July 25, 2019, covering both power and transmission rates for Fiscal Years 2020 and 2021. FERC granted interim approval to the proposed rates on September 30, 2019. For the average base power rate, there was no increase from BP-18. The base power rate does not include the potential impact of the Financial Reserves Policy (FRP) surcharge for power. Consistent with the FRP that was implemented in the 2020 Power Rate Schedules and General Rate Schedule Provisions, BPA has notified Power customers that the FRP Surcharge has been triggered for the full amount of $30 million based on the end of FY 2019 results, and this will recover the full amount by the end of FY 2020. The surcharge means power customers will see a rate increase of 1% to 2%, depending on the product they receive. For transmission rates, the weighted average increase is 3.6 percent for the two-year rate period, consistent with the settlement agreed upon during the rate proceeding. The BP-20 rates will be in effect through September 30, 2021.

Program Performance

To validate and verify program performance, Bonneville conducts various internal and external reviews and audits. Bonneville conducts extensive reviews with regional stakeholders of both capital and expense programs. In addition,

Bonneville's programmatic activities are subject to review by Congress, the U.S. Government Accountability Office (GAO), the DOE's Inspector General, and other governmental entities. Bonneville's financial statements are audited annually by an independent external auditor. Bonneville has received unqualified audit opinions since the mid-1980s and no material weaknesses have been identified in controls over financial reporting.

Financial Mechanisms

Bonneville's program is treated as mandatory and nondiscretionary. Bonneville is "self-financed" from its own revenues and does not rely on annual appropriations from Congress. Under the Transmission Act, Bonneville funds the expense portion of its budget and repays the federal investment with revenues from electric power and transmission sales. Bonneville's revenues fluctuate for a variety of reasons, including in response to variations in market prices for fuels and stream flow in the Columbia River System caused by variations in weather conditions and fish mitigation needs. Through FY 2019, Bonneville has returned approximately $35.8 billion to the U.S. Treasury, of which about $3.8 billion was for payment of FCRPS operation and maintenance (O&M) and other costs, $16.2 billion for interest, and $15.7 billion for amortization of appropriations and bonds.

In the FY 2021 Budget, the term Bonneville "bonds" refers to the debt instruments under which Bonneville receives advances of funds from the U.S. Treasury. This reference is consistent with section 13(a) of the Transmission Act, which defines "bonds" as all bonds, notes, and other evidences of indebtedness issued and sold by Bonneville to the U.S. Treasury.

In May 2019, debt instruments issued by non-federal entities but secured by payment and other financial commitments provided by Bonneville received the following credit ratings: Moody's at Aa1 with a negative outlook, Standard & Poor's at AA- with a stable outlook, and Fitch at AA with a stable outlook.

Bonneville and the U.S. Treasury have a comprehensive banking arrangement that covers Bonneville's short- and long-term federal borrowings. This provides Bonneville with the ability to borrow from the U.S. Treasury to finance capital investments and, on a short-term basis, to cover Northwest Power Act-related operating expenses. This latter ability provides Bonneville with much needed liquidity to help manage within-year cash flow needs and mitigate risk. Access to this use of U.S. Treasury borrowing authority has been incorporated into and relied upon in Bonneville's rate-setting process.

U.S. Treasury Payments and Budget Overview

Bonneville's FY 2019 payment to the U.S. Treasury was approximately $1.1 billion. This was the 36th consecutive year that Bonneville made its scheduled payments to the U.S. Treasury on time and in full. The payment included $734 million in principal, which included $228 million in early retirement of higher interest rate U.S. Treasury debt, $232 million for interest, $56 million in irrigation assistance payments, and $41 million in pension and post-retirement benefits. Total credits associated with fish mitigation and recovery that are applied toward Bonneville's U.S. Treasury payment were about $98.2 million for FY 2019. These credits are established and applied under section 4(h)(10)(C) of the Northwest Power Act. The FYs 2020 and 2021 U.S. Treasury payments are currently estimated at $624 million and $689 million, respectively. The FY 2020 and 2021 4(h)(10)(C) credits are estimated to be $86.2 million and $86.9 million, respectively.

Estimates of interest and amortization levels for outyear U.S. Treasury payments are included in the FY 2020-2021 final transmission and power rates. Bond and Appropriations Interest will continue to be revised based on upcoming capital investments and debt management actions. These estimates may change due to revised capital investment plans and actual U.S. Treasury borrowing. In recent years, Bonneville has made amortization payments in excess of those scheduled in its FERC-approved rate filings resulting in a balance of advance repayment. The cumulative balance of advance amortization payments as of the end of FY 2019 was about $5,791 million.

Bonneville has direct funding arrangements to fund the power-related portion of O&M and capital investments at the Corps and Reclamation facilities as well as the O&M costs of the U.S. Fish and Wildlife Service Lower Snake River Compensation Plan facilities. Direct funded Associated Projects capital costs, which had been funded exclusively through appropriations to the Corps and Reclamation prior to the initiation of direct funding, are now funded primarily from the proceeds of bonds issued by Bonneville to the U.S. Treasury. Certain power prepayments have also been a source of funds for direct funding. Bonneville's aggregate direct funding provided for capital and O&M was $617.2 million in FY 2019.

Starting in FY 2014, Bonneville and Energy Northwest, the Washington state joint operating agency that owns and operates the Columbia Generating Station nuclear plant, have been working together to implement a new phase of integrated debt

management for their combined total debt portfolios. The debt service of these portfolios is borne by Bonneville and recovered from Bonneville ratepayers through Bonneville's rates. Energy Northwest-related debt, as refinanced under this effort, is called Regional Cooperation Debt.

An important component of Regional Cooperation Debt is the issuance of new bonds by Energy Northwest to refund outstanding bonds shortly before their maturities when substantial principal repayments are due. An equal amount of higher interest rate Federal debt will be repaid instead. The net effect of refunding Regional Cooperation Debt and prepaying higher interest rate federal obligations is that the weighted-average interest rate of Bonneville's overall debt portfolio has been and will be reduced. In addition, Bonneville's aggregate principal balance of debt outstanding (federal and non-federal) does not and will not increase by virtue of the Regional Cooperation Debt program.

In FY 2018, BPA proposed an extension of the Regional Cooperation Debt program. This would extend the program through 2030 and involve up to $3.5 billion of tax-exempt debt. This extension would be similar to the current Regional Cooperation Debt program in many ways but the proceeds could be used to prepay federal bonds or directly used for capital investments. The Energy Northwest Board approved this proposal on September 27, 2018.

Power Prepayment Program

Bonneville undertook a Power Prepayment Program in FY 2013 under which all Bonneville preference customers had an opportunity to submit formal offers to provide lump-sum payments to Bonneville as prepayments of a portion of their power purchases through September 30, 2028, the termination date of their current Long-Term Regional Dialogue Power Sales Contracts. Bonneville accepted power prepayments from four preference customers, as described below.

Upon Bonneville's receipt of the agreed-to, lump-sum prepayments, the selected preference customers became entitled to future portions of their electricity from Bonneville without further payment. The power prepayments are and will be recognized in the customers' future power bills from Bonneville as fixed, equal monthly prepayment credits. In effect, the amount of electricity that is prepaid may vary by month, depending on Bonneville's power rates and rate schedules that apply to electricity purchases by the prepaying customers in the related month. Because this is structured as a variable amount of prepayment and not as a fixed-price/fixed-amount type of prepayment, Bonneville maintains flexibility to establish rates for the electric power that is prepaid.

As a result of the FY 2013 Prepayment solicitation, Bonneville received $340 million in prepayments, which Bonneville is using to fund needed FCRPS investments. The aggregate prepayment credits are set at $2.55 million per month through FY 2028.

Depending on a variety of factors it is possible that Bonneville may seek to implement later phases of the Power Prepayment Program in connection with future FCRPS hydroelectric investment needs.

Asset Management

The foundation of Bonneville's value is the base of the generating resources from which it markets electricity, and Federal transmission assets it owns and operates. Bonneville utilizes an asset management strategy to apply best-practice industry standards to manage the lifecycle costs of Federal assets. This is central to maintaining the long-term value and reliability of the power and transmission systems. Achieving these objectives for power requires collaborative, long-term planning with Bonneville's Federal partners, the Corps and Reclamation. Through the Asset Investment Excellence Initiative, the three agencies are establishing a long term asset investment plan, applying prioritization tools to inform investment decisions to ensure the long term affordability and reliability of the hydropower assets.

Bonneville Power Administration operates within a complex environment that requires asset management tradeoffs. Our business decisions consider five dimensions of risk: financial, reliability, compliance, safety and environmental. Reliability and safety remain Transmission priorities. Transmission's asset management capability is continually maturing and its competencies will enable the modernization of assets to help BPA maintain competitive advantage in the marketplace, enable industry change and deliver on public responsibilities; as well as strengthen financial health through the management of lifecycle costs and asset value.

Infrastructure Investments

The FCRPS is one of the nation's largest nearly carbon-free power systems, and preserving and enhancing the value of the FCRPS for the future continues to be a major Bonneville focus. Bonneville's ongoing prioritization and execution of capital

investment in transmission and FCRPS generation assets is the foundation for delivering clean, low cost power to support the communities and economies of the region well into the future.

Bonneville has experienced significant growth within its balancing area in installed variable renewable generation, primarily in the form of wind generation. Since 2001, installed wind generation connected to Bonneville's transmission system has grown from 115 MW to 4,785 MW through September 2019. Of the 4,785 MW of connected wind, 2,766 MW is currently in Bonneville's Balancing Authority Area (BAA). Wind is a non-dispatchable source of energy, meaning it cannot be relied upon for capacity. As such the substantial increase results in uncertainties in balance between load and generation required for maintaining a reliable grid. Bonneville has implemented and continues to study operational tools for integrating variable resources more cost effectively and reliably. Since the peak of installed wind in September 2017, the reduction has been a result of wind plants leaving the Bonneville BAA. Although the amount of variable generation has been reduced, these projects are still physically connected to Bonneville's system and continue to impact daily operations. Off-setting the wind leaving Bonneville's BAA is the possibility that a large amount of utility scale solar photo-voltaic (PV) projects are being added to Bonneville's queue. There is currently just under 8 MW of solar generation integrated into the Bonneville BAA. Bonneville, however, is currently studying approximately 3,500 MW of solar interconnection requests. Solar, like wind, is a variable generation source, but its characteristics are different than wind. As such Bonneville will continue to study and manage this new generation type for operations and cost recovery.

Consistent with the FY 2018, FY 2019, and FY 2020 Budget Requests, the FY 2021 Budget Request maintains the proposal that the Federal government be authorized to sell the transmission assets of Bonneville.

Bonneville continues to assess needed infrastructure investments in the Pacific Northwest to meet transmission capacity and reliability needs and continues to support a competitive wholesale market in the Western Interconnection, which encompasses 14 western states, two Canadian provinces, and one Mexican state.

Bonneville has completed three major transmission lines since 2011 (i) the McNary-John Day 500kV line—completed in FY 2012 —adding 79 miles, (ii) the Big Eddy-Knight 500kV transmission line and substation project resumed construction in 2014 and was energized in November 2015, adding 28 miles, and (iii) the Central Ferry-Lower Monumental 500kV Reinforcement which began construction in May 2014 and was also energized in November 2015, adding 38 miles. Bonneville also completed the modernization of the Celilo Converter Station at the northern end of the 846-mile Pacific Direct Current Intertie. The station was energized in January 2016. Additionally, 265 miles of direct current line were upgraded to match the capacity of the station upgrade.

Bonneville signed two agreements to participate with two investor-owned utilities in the environmental work and permitting for another transmission project, the proposed Boardman-to-Hemingway 500kV line; the initial agreements were executed in FY 2012 and subsequently amended in FY 2018. Participation in this preliminary review keeps Bonneville's options open for serving its six southeast Idaho preference customers following the termination of legacy transmission service agreements. Bonneville has not made a decision to co-develop or purchase capacity in this project. On January 17, 2014, Public Law 113-76 was enacted, which provided Bonneville with expenditure authority approval to construct or participate in the construction of a transmission line to southeast Idaho, should Bonneville decide to continue pursuing that service arrangement.

On May 18, 2017, Bonneville announced its decision to not build the I-5 Corridor Reinforcement Project. Bonneville continues to work with constituents and stakeholders to study more cost effective options to mitigate the current transmission limitations along this path. Cumulative capitalized costs associated with this project of $130.0 million were reclassified in fiscal year 2017 from Construction work in progress to a Regulatory asset on the Combined Balance Sheets, as these costs are expected to be recovered through future rates, beginning in FY 2020.

Bonneville continues to evaluate additional transmission investments and alternative non-wires solutions across the Pacific Northwest to improve reliability and support both load and renewable generation needs.

Bonneville makes use of certain alternative capital financing mechanisms, in addition to or in lieu of the use of its U.S. Treasury borrowing authority, to sustain funding for its infrastructure investment requirements. These approaches include revenue and financial reserves financing some amount of transmission investments, or seeking, when feasible, third party financing sources. See the BP-5 Potential Third Party Financing Transparency table in the budget schedules section of this

document. This FY 2021 Budget contains $15 million of annual financial reserves financing in FY 2019 for transmission infrastructure capital, which is included under Projects Funded In Advance.

Bonneville plays a key role in advancing energy efficiency across the region consistent with its statutes, including developing and promoting related technologies, and exploring demand-side management opportunities.

Bonneville is making disciplined technology innovation investments and looking to apply new operational and market mechanisms that enhance the reliability, efficiency, and flexibility of system operations.

Revised Transmission Tariff

In 2018, Bonneville engaged in settlement discussions with transmission customers to reach consensus on terms and conditions for a new Bonneville transmission tariff as well as gain agreement from those customers to convert their current contracts to the new tariff when it becomes effective. Bonneville presented its need for a modernized tariff that can be modified over time so that the region can take advantage of opportunities in the rapidly changing industry as well as further its objectives for improving the agency's commercial performance. This resulted in a settlement package that includes a TC-20 Settlement Agreement on the tariff terms and conditions and a BP-20 Partial Transmission Rates Settlement Agreement that settles transmission and ancillary and control area services rates. Bonneville's Fiscal Year 2020 and 2021 rate decision included the transmission, and ancillary and control area services rates agreed upon in the settlement.

Grid Modernization

Bonneville continues a cross-agency grid modernization initiative. Bonneville's reliance on legacy systems and non-standard commercial practices are costly to maintain and have led to being conservative in its power and transmission operations, planning, and marketing.

Grid modernization involves improving and modernizing transmission and generation system visibility and controls, and increasing the electricity market skills of Bonneville employees. The grid modernization initiative focuses on five areas of effort:

- Operational modernization
- Commercial modernization
- Energy Imbalance Market implementation
- Mission critical information technology improvements
- Improvements to core business practices

Part of the grid modernization scope is Bonneville's evaluation of joining the Western Energy Imbalance Market (EIM) and enabling Federal and non-federal resources in its service area to access that market. Joining the EIM could optimize the day-to-day operation of the power system and leverage hydropower in a market increasingly driven by intermittent renewable resources. Bonneville conducted monthly public meetings to include its customers and regional constituents in its evaluation of the EIM as it signed a Western EIM Implementation Agreement with the California Independent System Operator that signals the beginning of work on projects that need to be completed before BPA could start EIM operations.

The Columbia River System Operations

The U.S. Army Corps of Engineers, Bureau of Reclamation and Bonneville Power Administration have announced their intent to prepare an environmental impact statement (EIS) on the Columbia River System operations (CRSO) and configurations for 14 federal projects in the interior Columbia Basin. In this Columbia River System Operations EIS, the three agencies will present a reasonable range of alternatives for long-term system operations and evaluate the potential environmental and socioeconomic impacts on flood risk management, irrigation, power generation, navigation, fish and wildlife, cultural resources and recreation.

The on-going action that requires evaluation under NEPA is the long-term coordinated management of the System projects. An underlying need to which the co-lead agencies are responding is reviewing and updating the management of the System, including evaluating measures to avoid, offset, or minimize impacts to resources affected by the management of the System in the context of new information and changed conditions in the Columbia River basin. In addition, the co-lead agencies are responding to the Opinion and Order issued by the U.S. District Court for the District of Oregon such that this EIS will evaluate how to insure that the prospective management of the System is not likely to jeopardize the continued

existence of any endangered species or threatened species or result in the destruction or adverse modification of designated critical habitat, including evaluating mitigation measures to address impacts to listed species. The EIS will evaluate actions within the co-lead agencies' current authorities, as well as certain actions that are not within the co-lead agencies' authorities, based on the District Court's observations about alternatives that could be considered and comments received during the scoping process. The EIS will also allow the co-lead agencies and the region to evaluate the costs, benefits and tradeoffs of various alternatives as part of reviewing and updating the management of the System.

Fish and Wildlife Program Overview

Bonneville is committed to funding its share of the region's efforts to protect and mitigate Columbia River Basin fish and wildlife. To the extent possible, Bonneville is integrating actions to protect species listed for protection under the Endangered Species Act (ESA) in response to the FCRPS Biological Opinions (BiOps), including the National Oceanic and Atmospheric Administration (NOAA) Fisheries Willamette River BiOp and the United States Fish and Wildlife Service's (USFWS) 2006 Libby Dam BiOp, with projects implemented consistent with the Council's Fish and Wildlife Program (Program). The Program, BiOps, and long-term agreements include prioritized strategies for mitigation actions to meet Bonneville's environmental compliance responsibilities under the ESA, Northwest Power Act, and other laws. Together, all of these efforts contribute to sustaining and advancing the region's resilience.

Included with the budget schedules section of this document is the current tabulation of Bonneville's fish and wildlife costs from FY 2009 through FY 2019.

The Columbia River Treaty

The U.S. Government reached consensus on a high level position for negotiations of the post-2024 future of the Columbia River Treaty in June 2015, and received authorization to negotiate with Canada on the Columbia River Treaty in October 2016. Government Affairs Canada notified the United States State Department in December 2017 of Canada's mandate to negotiate the Columbia River Treaty with the United States. Negotiations began in spring 2018 and continue to date. Both the U.S. Department of State and Canadian negotiators have discussed shared objectives and exchanged information on flood risk management, hydropower and ecosystem considerations. The United States and Canada postponed the ninth round of negotiations to modernize the Columbia River Treaty regime, which were originally scheduled for November 19-20, 2019 in Washington, D.C. The United States' negotiating team would like additional time to complete preparations, with the aim of maximizing the productivity of the bilateral discussions. The next round of negotiations is scheduled for March 2020.

Radio Spectrum Communications

Bonneville's wireless communication system is used to operate and control critical national transmission grid infrastructure in a reliable, secure, and safe manner. Bonneville's communication systems are designed to meet strict reliability/availability objectives required by NERC and Western Electricity Coordinating Council (WECC) standards. Concerning proper spectrum stewardship, Bonneville designs highly efficient radio systems that use minimal radio frequency (RF) channel bandwidths to meet critical mission needs. However, in certain circumstances, efficiently designed spectrum radio systems will require broad RF channels and/or lower state RF modulation schemes to meet existing and future requirements in order to meet operational and reliability/availability objectives.

In order to meet Bonneville's mission/operational requirements, RF communication equipment approved for system use goes through a rigorous evaluation and testing process. RF spectrum efficiency factors are considered during the evaluation/testing period. RF terminal equipment approved for use is normally purchased directly from vendors and is not typically supplied through a Request for Proposal process.

Bonneville's operational telecommunications and other capital equipment and systems are acquired using Bonneville's self-financing and procurement authorities. The Bonneville budget includes a system-wide electric reliability performance indicator, consistent with NERC rules, to track and evaluate performance.

Bonneville may share temporarily-available spare capacity on its RF communication system with other government agencies (both Federal and State), and with other electric utilities in the region whose power systems interconnect with Bonneville. Non-critical administrative traffic is typically supported by commercial carrier enterprises. However, to meet the North American Electric Reliability Corporation/Western Electricity Coordinating Council (NERC/WECC) electrical bulk transmission requirements, Bonneville exclusively operates highly critical transmission control traffic over its private

telecommunication system as Bonneville has no control over the reliability/availability of the commercial enterprise or on how quickly critical operational control circuits are restored to active service during an interruption.

For high capacity communication system applications, Bonneville considers and operates non-spectrum dependent alternatives such as fiber optic cable infrastructure systems.

During FY 2014, Bonneville began upgrading the Very High Frequency (VHF) land mobile system and installing a number of digital Synchronous Optical Network (SONET) rings typically consisting of fiber segments in combination with point-to-point microwave hops operating in the 4 GHz and 7/8 GHz bands. These various telecommunication systems operate within Bonneville's approximate 300,000 square mile regional utility service territory (Oregon, Washington, Idaho, western Montana) with the majority of the RF infrastructure located in low population-rural areas.

The FCRPS hydroelectric projects, owned by the Corps and Reclamation, also utilize federal radio spectrum to preserve very high operational telecommunications and power system reliability.

In FY 2014, Bonneville completed work costing approximately $40 million, funded through the Spectrum Relocation Fund, to relocate its operational telecommunication systems from the 1710-55 MHz radio spectrum bands to alternative federal radio spectrum bands, part of the AWS-1 Federal Spectrum Relocation. In accordance with Federal law, Bonneville plans to return the approximately $8.2 million of excess funds to the U.S. Treasury, via the Spectrum Relocation Fund, as soon as the National Telecommunications and Information Administration (NTIA) officially notifies the Federal Communications Commission (FCC) that the DOE relocation effort is complete.

Bonneville began participating in a new spectrum relocation effort in FY 2015 to relocate its operational telecommunication systems from the 1755-80 MHz radio spectrum bands. The NTIA has approved and, in July 2014, web-posted federal agency relocation plans, including the Bonneville relocation plan. The FCC held an auction of this spectrum on November 13, 2014. Bonneville received an additional $5.2 million from the Spectrum Relocation Fund on July 29, 2015 to fully pay for this new relocation effort, including, as in the prior relocation, the purchase and installation of new digital radio equipment. Bonneville received obligational authority to proceed with this relocation effort by apportionment on July 24, 2015.

Bonneville has worked to complete its move off of 1755-80 MHz in two stages. First, Bonneville moved off of the old federal frequencies and "retuned" to new alternate federal frequencies in the band segment of 1780-1850 MHz which is above the highest frequency that is involved in the auction. Three hops federal frequency moves/retuning were completed as of 6/7/2017. The last remaining path, Happy Camp to Hilltop in northern California near the Oregon California Border, was moved/retuned, and as of 7/31/2018, Bonneville was off of the AWS-3 radio frequencies, meeting the commitment date promised to the NTIA. Bonneville still has additional work remaining to finish the construction related to the AWS-3 relocations. Bonneville will use the SRF relocation funds until the AWS-3 relocation work is completed and closed out. Second, Bonneville will complete its move of these four microwave hops to 7GHz-8GHz. This will take additional time because two of four hops require building construction to complete the work. AWS-3 funds will need to be retained by Bonneville at least through FY 2022 to complete construction of two communications buildings. Construction at the Glass Butte site may not occur until FY 2021. The construction of the new control house at Richland Substation is on a similar timeline as the Glass Butte project. The building construction will likely occur in FY 2020 with cutovers to the new radio equipment and retirement of old radio equipment likely concluding in FY 2021. Bonneville will assure that "comparable capability" has been achieved for these four AWS-3 relocated Bonneville operational telecommunication hops.

Educational Activities

Bonneville is a supporter of science, technology, engineering, and math (collectively known as "STEM") education programs. These programs provide support and encouragement to middle and high school students to study the sciences in school and to pursue careers in these fields. Working with Bonneville employees as volunteer ambassadors, the Bonneville education program provides value-added presentations, curricula, and activities to K-12 schools that enhance the learning experience for students and teachers, and extend awareness of the value of the region's hydroelectric system to future generations. As a regional leader in STEM education, Bonneville also proudly supports and organizes an award-winning Science Bowl. Bonneville also sponsors Science Fair competitions for students in Washington State, as well as a First Robotics tournament championship.

Budget Estimates and Planning

This FY 2021 Budget proposes estimated accrued expenditures of $2,978 million for operating expenses, $66 million for Projects Funded in Advance (PFIA), $800 million for capital investments, and $402 million for capital transfers in FY 2021.

The estimated spending levels in this budget are still subject to change to accommodate competitive dynamics in the region's energy markets, debt management strategies, continuing changes in the electric industry, and other factors.

This FY 2021 Budget includes capital and expense estimates based on final approved spending proposals from Bonneville's 2018 final Integrated Program Review (IPR). FY 2019 costs are based on Bonneville's FY 2019 audited financial statements. Consistent with the FY 2020 Budget Request, the FY 2021 Budget Request maintains the proposal that the Federal government be authorized to sell the transmission assets of Bonneville. The FY 2021 budget request also includes a proposal to change BPA's statutory rate structure requirements from cost recovery to a market based structure that takes into consideration rates charged by comparable utilities and which could allow for faster recoupment of the taxpayer investment.

Capital investment levels reflect Bonneville's capital asset management process and external factors such as changes affecting the West Coast power and transmission markets, along with planned infrastructure investments designed to address the long-term needs of the region and national energy security goals.

Bonneville utilizes a structured capital project selection process requiring submission of a standardized business case for review. Each business case consists of a description of the project, a clear statement of objectives, description and mitigation of risks, and a rigorous analysis of project costs and benefits including a status quo assumption and preferred alternatives. In addition, both annual and end-of-project targets are set for each project covering cost, scope, and schedule. Progress reports on these targets are provided to Bonneville's senior executives at least quarterly.

The FYs 2020-2025 revenue estimates in this budget, included in the Net Outlay formulation, are calculated consistent with cash management goals. The revenue estimates reflect assumed adjustments, which include the use of a combination of tools, including upcoming rate adjustment mechanisms, reduced cost estimates, a net revenue risk adjustment, debt management strategies, and/or short-term financial tools to manage net revenues and cash. The revenue estimates also include depreciation and U.S. Treasury repayment credit assumptions. These U.S. Treasury repayment credits offset, among other things, Bonneville's fish and wildlife program costs allocable to the non-power project purposes of the FCRPS, as provided under section 4(h)(10)(C) of the Northwest Power Act.

Overview of Detailed Justifications

In Bonneville's Detailed Justification Summaries, accrued expenditure is the basis of presenting Bonneville's program funding levels in the power and transmission rate making processes and the basis upon which Bonneville managers control their resources to provide products and services. Accrued expenditures relate period costs to period performance. Traditional budget obligation requirements for Bonneville's budget are assumed on the Program and Financing Summary Schedule prepared in accordance with Office of Management & Budget Circular A-11.

The organization of Bonneville's FY 2021 Budget and these performance summaries reflect Bonneville's business services basis for its utility enterprise activities. Bonneville's major areas of activity on a consolidated budget and accounting basis include power and transmission, with administrative costs included. Power Services includes line items for Fish and Wildlife, Energy Efficiency, Residential Exchange Program, Associated Projects O&M Costs, and the Northwest Power Council. Environmental activities are shown in the relevant Power Services and Transmission Services sections, as are reimbursable costs. Bonneville's interest expense, pension and post-retirement benefits, and capital transfers to the U.S. Treasury are shown by program.

The first section of performance summaries, Capital Investments, includes accrued expenditures for investments in electric utility and general plant associated with the FCRPS generation and transmission services, fish and wildlife, and capital equipment. These capital investments are estimated to require budget obligations and expected use of $800 million in bonds to be issued and sold to the U.S. Treasury in FY 2021.

The near-term forecast of capital funding levels has undergone an extensive internal review as a result of Bonneville's development of asset management plans. These plans encompass project cost management initiatives, capital investment assessments, and categorization of capital projects to be funded based on risk and other factors. Consistent with

Bonneville's near-term asset planning process and Bonneville's standard operating budget process, this FY 2021 Budget includes updated capital investment levels for FY 2020. Utilizing this review process helps Bonneville in its efforts as a participant in wholesale energy markets. Bonneville will continue to work with the Corps and Reclamation to optimize the mix of projects.

The second section of Bonneville's performance summaries, entitled Annual Operating Expenses, includes accrued expenditures for services and program activities financed by power sales revenues, transmission sales revenues, and projects funded in advance. For FY 2021, budget expense obligations are estimated at $2,978 million. The total program requirements of all Bonneville programs include estimated budget obligations of $4,246 million in FY 2021.

Evidence and Analysis in the Budget

Bonneville has undertaken several initiatives and processes to determine appropriate budget expenditures.

Bonneville's Integrated Program Review (IPR) process allows interested parties to see all relevant FCRPS expense and capital spending level estimates in the same forum. In addition, Bonneville's IPR process allows interested parties to review and comment on Bonneville's Strategic Asset Management Plans (SAMPs) and 10-year capital forecasts. The IPR occurs every two years, or just prior to each rate case, and provides participants with an opportunity to review and comment on Bonneville's program level estimates prior to spending levels being set for inclusion in rate cases. BPA concluded the 2018 IPR in summer 2018, which reviewed spending plans for the FY 2020 and 2021 rate period.

Bonneville is focused on institutionalizing operational excellence – continuous improvement that produces more efficient and effective ways to deliver on Bonneville's mission and vision. In FY 2017, the Business Transformation Office (BTO) was implemented in order to ensure that Bonneville's transformational initiatives, including its Key Strategic Initiatives (KSIs), are executed in the most efficient manner, from a time, cost and resource perspective. Over the next few years, Bonneville will focus on its single KSI Grid Modernization effort. Grid Modernization is a set of projects to advance the way BPA markets and operates the federal power and transmission systems, so that Bonneville can benefit from new technology and emerging market opportunities. It includes new state awareness tools, digital technologies and process automation to help us identify additional capacity, increase revenues and improve reliability. This work is critical to ensuring BPA's long-term commercial success and competitiveness. This effort is intended to unlock hydropower and transmission capacity. Today, BPA holds back a couple hundred megawatts of hydropower in reserve every hour because we have limited visibility into what is actually happening on our system in real-time. We also hold out transmission capacity because of this uncertainty. Grid modernization will give us the tools and system visibility we need to reduce the uncertainty, unlock capacity and increase revenues.

Judicial and Regulatory Activity

The Energy Policy Act of 2005 authorized the Federal Energy Regulatory Commission (FERC) to approve and enforce mandatory electric reliability standards with which users, owners, and operators of the bulk electric power system, including Bonneville, are required to comply. These standards became enforceable on June 18, 2007, and compliance is monitored by the North American Electric Regulatory Corporation (NERC) and the regional reliability organizations.

Power Services - Capital
Funding Schedule by Activity

Funding ($K)

	FY 2019 Actual	FY 2020 Estimate	FY 2021 Estimate	FY 2021 vs FY 2020 $	FY 2021 vs FY 2020 %
Power Services – Capital					
Associated Project Costs	199,661	238,000	256,000	18,000	7.6%
Fish & Wildlife	22,313	47,266	47,266	0	0.0%
Total, Power Services – Capital	**221,974**	**285,266**	**303,266**	**18,000**	**6.3%**

Outyears ($K)

	FY 2021 Estimate	FY 2022 Estimate	FY 2023 Estimate	FY 2024 Estimate	FY 2025 Estimate
Power Services – Capital					
Associated Project Costs	256,000	281,000	300,000	306,000	313,000
Fish & Wildlife	47,266	43,000	43,000	40,000	40,000
Total, Power Services - Capital	**303,266**	**324,000**	**343,000**	**346,000**	**353,000**

Program Overview

Associated Project Costs provide for direct funding of additions, improvements, and replacements of existing Reclamation and Corps hydroelectric projects in the Pacific Northwest. The FCRPS hydro projects produce a large portion of the electric power that is marketed by Bonneville.

Maintaining the availability and increasing the efficiency of the FCRPS is critical to ensuring that the region has an adequate, efficient, economic, and reliable power supply. The FCRPS represents about 80 percent of Bonneville's firm power supply and includes 31 operating federal hydroelectric projects with over 200 generating units. These projects have an average age of about 50 years, with some that exceed 60 years of age. Through direct funding and the cooperation of the Corps and Reclamation, Bonneville uses its U.S. Treasury borrowing authority and other sources to make investments needed to restore generation availability and improve efficiency, reducing demand on Corps and Reclamation appropriations for power-related investments.

Since the beginning of Direct Funding in 1997, BPA has invested over $2 Billion in Direct Capital in the Federal Columbia River Power System with the goal of maximizing system value for the region and its stakeholders. Ongoing analysis with its operating partners, the Army Corps of Engineers and the Bureau of Reclamation, has identified ongoing investment needs for the foreseeable future in order to maintain the health of the hydro system.

These planned investments, included in the FY 2021 Budget estimates, will maintain the generation performance of the FCRPS. Moving forward with the cost-effective opportunities to expand the generation and to preserve and enhance the capability of the FCRPS is a smart, economic, and environmentally beneficial decision when compared to purchasing power from the wholesale power market to serve growing Pacific Northwest electricity needs of BPA customers.

Fish and wildlife capital costs incurred by Bonneville are directed at activities that mitigate Columbia River Basin fish and wildlife resources. Bonneville uses capital to fund projects designed to increase juvenile and adult fish passage through the federal hydrosystem, to increase fish production and survival through construction of hatchery, acclimation and fish monitoring facilities, and to increase wildlife and resident fish populations through land acquisitions and associated habitat maintenance. These capital projects support both Northwest Power Act and ESA priorities and are integrated with the Program in order to efficiently meet Bonneville's responsibilities under the Northwest Power Act and other statutes to mitigate federal hydrosystem impacts to Columbia River Basin fish and wildlife.

Bonneville implements such projects consistent with the Pacific Northwest Electric Power Planning Council's (Council) Columbia Basin Fish and Wildlife Program and the purposes of the Northwest Power Act. Under the Northwest Power Act, the Council must develop a Program that protects, mitigates, and enhances Columbia River Basin fish and wildlife affected by the federal and non-federal hydroelectric projects in the basin while assuring the Pacific Northwest an adequate, efficient, economical, and reliable power supply. The Program, the FCRPS BiOp, other BiOps, and Bonneville's long-term agreements include prioritized strategies for mitigation actions and projects to meet Bonneville's responsibilities under the Northwest Power Act, the ESA, the Federal Clean Water Act, and other laws. When issues arise that potentially trigger the *in lieu* provision of the Northwest Power Act, which prohibits Bonneville from funding mitigation that other entities are authorized or required to undertake, Bonneville works with the Council and the regional fish and wildlife managers, customers, and tribes, as appropriate, to ensure ratepayers fund only appropriate mitigation.

Most projects recommended by the Council also undergo independent scientific review as directed by the 1996 Energy and Water Appropriations Act, which added section 4(h)(10)(D) to the Northwest Power Act. As a result, the Council appoints an Independent Scientific Review Panel (ISRP) "to review a sufficient number of projects" proposed to be funded through Bonneville's annual fish and wildlife budget "to adequately ensure that the list of prioritized projects recommended is consistent with the Program." The Northwest Power Act further states that "in making its recommendations to Bonneville, the Planning Council shall consider the impact of ocean conditions on fish and wildlife populations; and shall determine whether the projects employ cost effective measures to achieve program objectives." Today, most mitigation projects funded by Bonneville receive ISRP review as part of the Council recommendation process. The Council uses a multi-year project review cycle during which the ISRP reviews categories of projects grouped together.

To comply with the ESA, Bonneville funds capital investment actions to avoid jeopardizing listed species. Guidance for those actions is found in the most recent BiOp issued by NOAA in 2019 and the USFWS BiOp in 2006/2010.

- In February 2006, USFWS issued a BiOp for Libby Dam on the Kootenai River for white sturgeon and bull trout. A subsequent Settlement Agreement between USFWS and the Center for Biological Diversity was memorialized by modifying the BiOp in 2008. Additional consultation is occurring as part of the larger USFWS bull trout consultation.
- In 2010 USFWS designated critical habitat for bull trout (following USFWS's issuance in 2000 of a BiOp for FCRPS impacts on bull trout). The Action Agencies (Corps, Reclamation, and Bonneville) are preparing a biological assessment covering FCRPS operational effects on bull trout and designated bull trout critical habitat.
- In May 2008, NOAA issued an FCRPS BiOp for 13 listed species of salmon and steelhead, supplemented in a 2010 Supplemental BiOp that incorporated the Action Agencies' Adaptive Management Implementation Plan, and further supplemented in a 2014 Supplemental BiOp. On January 17, 2014, NOAA released its 2014 Supplemental BiOp. In May 2016, the Federal District Court for the District of Oregon invalidated the BiOp on numerous grounds and found that the Corps and Reclamation violated the National Environmental Policy Act (NEPA) when they issued decision documents to implement the BiOp. The court ordered NOAA to complete a new BiOp by December 31, 2018, and ordered the Corps and Reclamation to complete a NEPA process in 2021. In an order issued April 3, 2017, the court ordered additional spill beginning in 2018 and continuing through the BiOp remand period; this order was upheld by the Ninth Circuit Court of Appeals on April 2, 2018. NOAA issued an interim BiOp March 2019 and the Action Agencies are now in consultations with NOAA on the next BiOp.
- In July 2008, USFWS and NOAA issued Willamette River BiOps to address impacts from 13 federal dams on salmon, steelhead, Oregon chub, and bull trout. Implementation of a BiOp measure related to hatchery fish in the McKenzie River was the subject of litigation in Federal District Court. The Action Agencies are currently engaged in discussions with NOAA related to BiOp implementation for downstream passage and for hatchery consultations.

Under these collective BiOps, the Action Agencies have committed to implement hydro, habitat, hatchery, and other actions throughout the Columbia River Basin to address impacts stemming from the operation of the federal hydro-electric dams on ESA-listed fish, and to ensure that operations of the federal dams do not jeopardize the continued existence of the ESA listed species or adversely modify their designated critical habitat.

The Action Agencies also signed the 2008 Columbia Basin Fish Accords (Fish Accords or Accords) with five Northwest Tribes and the states of Idaho and Montana. In 2009, an agreement was signed with the state of Washington and federal agencies (the state of Washington Estuary agreement). And in 2012, the Action Agencies signed an agreement with the Kalispel Tribe of Indians covering Albeni Falls Dam and FCRPS operations. Wildlife settlement agreements have been signed with the states of Oregon and Idaho to help complete mitigation for the flooding and inundation caused by the construction of FCRPS dams operating in those states. These Fish Accords and settlements complement the BiOps and provide firm commitments to prioritize mitigation actions and secure funding over the life of the agreements.

In October 2018, BPA and its federal partners Corps and Reclamation signed extension agreements with current Accords partners, namely certain states and tribes, to extend the Columbia Basin Fish Accords (2018 Fish Accord extensions). The existing agreements expired September 30, 2018, and were extended from October 2018 until September 30, 2022, at the latest. The extension agreements commit nearly $450 million for fish and wildlife protection and mitigation, which is likely to result in future expenses or regulatory assets.

As noted above, BiOps, 2018 Fish Accord extensions, and wildlife settlement commitments are integrated along with other projects and implemented through the Program under the Northwest Power Act. They provide the basis for the Bonneville Fish and Wildlife Program's planned capital investment.

Accomplishments

- The BP-20 - Rate Case final record of decision was released July 25, 2019. FERC granted interim approval to proposed rates on September 30, 2019.

- 63,608 acres improved by various means via channel work, controlled burns, planting, removing invasive, restoring wetlands & floodplains, controlling erosion, no-till farming, etc.
- 731 miles of channels added, instream complexity improved, fenced, planted, noxious/invasive weeds removed
- 85,649 acres protected by land purchase or lease
- 36 miles of riparian habitat protected due to land purchase or lease
- 220 miles of habitat accessed due to instream passage improvements via removing diversions, dams, mine tailings, and installing fish passage structures screens
- 3,319 acre-feet/year of water protected due to installing fish screens
- 256,222 acre-feet of water improved due to protection & conservation via acquiring land and water, installing wells, pipelines, sprinklers, etc.
- 110 miles of stream improved due to protection & conservation via acquiring land and water, installing wells, pipelines, sprinklers, etc.
- Completed draft tube bulkhead refurbishment at John Day Dam
- Completed Hills Creek spillway gate rehabilitation, and digital governor replacements at Willamette Plants
- Completed powerhouse DC emergency lighting system installation at Libby Dam
- Completed DC and preferred AC upgrade at Chief Joseph Dam
- Completed unit 3 stator and cooler replacement at Dworshak Dam
- Completed powerhouse bridge crane skew control at McNary Dam
- Completed bridge crane rehabilitation at Little Goose Dam
- Completed bridge crane rehabilitation at Lower Granite Dam
- Completed breaker replacements at Lower Monumental Dam
- Completed turbine runner replacement at Palisades Dam
- Completed Units 8 and 9 governor replacements at Minidoka Dam

Explanation of Changes

Bonneville's budget includes $303.3 million in FY 2021 for Power Services capital, which is a 6.3 percent increase from the FY 2020 forecasted level. The FY 2021 level reflects additional cost management efforts while continuing to align with BPA's strategic asset management plans which focus on the need for investment in the hydroelectric system assets and investments necessary to implement the BiOps, 2018 Fish Accord extensions, and other Columbia Basin Fish and Wildlife activities.

The FY 2021 budget increases the levels for Associated Projects (+$18 million) while maintaining the same funding level for Fish & Wildlife, relative to FY 2020.

Strategic Management

Bonneville markets available electric power while supporting the achievement of its vital responsibilities for fish and wildlife, energy efficiency, renewable resources, and low-cost power in the Pacific Northwest region. Bonneville will continue to implement the following strategies to serve the region:

1. Bonneville coordinates its power operational activities with the Corps, Reclamation, NERC, regional electric reliability councils, its customers, and other stakeholders to provide the most efficient use of federal assets.
2. Ongoing work with the Corps and Reclamation is focused on improving the reliability of the FCRPS, increasing its generation efficiency, and optimizing hydro facility operation.
3. Bonneville is committed to funding efforts to protect listed fish and wildlife species in the Columbia Basin under the ESA and working closely with the Council, regional fisheries managers, and other federal agencies to prioritize and manage projects to mitigate fish and wildlife affected by the FCRPS.
4. Bonneville's utility customers have been, and continue to be, a critical part of Bonneville's collaborative efforts to promote and foster the efficient use of energy.
5. Bonneville has assisted with a DOE Wind Power crosscutting initiative to strengthen energy security.

The following external factors present the most significant risk and impact to overall achievement of the strategies listed above:

1. Continually changing regional economic and institutional conditions;
2. Competitive dynamics; and
3. Ongoing changes in the electric industry.

Associated Projects

Overview

Bonneville will work with both the Corps and Reclamation to reach mutual agreement on budgeting and scheduling capital improvement projects that are cost-effective and provide system or site-specific enhancements, increase system reliability, or provide generation efficiencies.

The work is focused on improving the reliability of the FCRPS and on increasing its generation efficiency or capacity through turbine runner replacements, optimizing hydro facility operation, and new unit construction. Also, limited investments may be made in joint-use facilities that are beneficial to both the FCRPS operations and to other Corps and Reclamation project purposes.

Corps of Engineers Projects

($K)		
FY 2019 Actual	**FY 2020 Estimate**	**FY 2021 Estimate**
160,790	123,071	117,963

Bonneville Dam:

- FY 2019. Completed powerhouse 2 roof replacement. Continued generator step up (GSU) transformer instrumentation, main unit breaker and station service reconfiguration, control room fire protection upgrades, oil water separator improvements, and tailrace gantry crane rehabilitation. Began generator fire protection.
- FY 2020. Complete GSU transformer instrumentation. Continue main unit breaker and station service reconfiguration, control room fire protection upgrades, oil water separator improvements, tailrace gantry crane rehabilitation, and generator fire protection projects.
- FY 2021. Complete control room fire protection upgrades and oil water separator improvements. Continue main unit breaker station service reconfiguration, tailrace gantry crane rehabilitation and generator fire protection projects.

John Day Dam:

- FY 2019. Completed station service transformer replacements and 500kV disconnect replacement. Continued emergency gantry crane replacement and SQ board replacement. Began powerhouse roof replacement, control room fire protection upgrades and trash rack crane replacement.
- FY 2020. Complete emergency gantry crane replacement. Continue heating, ventilating, air conditioning (HVAC) system upgrade, emergency gantry crane replacement, SQ board replacement, powerhouse roof replacement and trash rack crane replacement.
- FY 2021. Complete trash rack crane replacement. Continue HVAC system upgrade, emergency gantry crane replacement, SQ board replacement, and powerhouse roof replacement.

The Dalles Dam:

- FY 2019. Completed SR panel replacement. Continued transformer replacements, and fish unit breaker replacements.
- FY 2020. Complete fish unit breaker replacements. Continue transformer replacements. Begin emergency gantry crane rehabilitation.
- FY 2021. Complete transformer replacements. Continue emergency gantry crane rehabilitation.

Willamette Plants:

- FY 2019. Completed Foster bridge crane rehabilitation, Detroit spillway gate rehabilitation and turbine platform installations in the Willamette Valley. Continued Generic Data Acquisition and Control System (GDACS) installation across the Willamette Valley, intake gantry crane replacement at Big Cliff, and electrical reliability upgrades at Foster. Began fire detection, HVAC and life safety improvements at Dexter.
- FY 2020. Complete GDACS installation across the Willamette Valley, and Big Cliff intake gantry crane replacement. Continue electrical reliability upgrades at Foster, and fire detection, HVAC and life safety improvements at Dexter. Begin Dexter intake gantry crane and transformer replacements at Detroit.

- FY 2021. Continue electrical reliability upgrades at Foster, intake gantry crane at Dexter, and fire detection, HVAC and life safety improvements at Dexter. Continue transformer replacements at Detroit. Begin turbine and generator rehabilitation at Foster and main unit breakers and electric reliability upgrades at Green Peter.

Albeni Falls Dam:
- FY 2019. Completed station service switchgear replacement. Continued spillway gate modifications. Began installation of main unit transformers.
- FY 2020. Continue spillway gate modifications and installation of main unit transformers. Begin fire suppression upgrades.
- FY 2021. Continue spillway gate modifications, installation of main unit transformers and fire suppression upgrades.

Libby Dam:
- FY 2019. Completed hydropower critical spares warehouse. Continued intake gantry crane replacement and system control console replacement.
- FY 2020. Complete intake gantry crane replacement. Continue system control console replacement. Begin powerhouse gantry crane rehabilitation, DC boards and breakers system replacement, and security system upgrades.
- FY 2021. Complete security system upgrades. Continue system control console replacement, powerhouse gantry crane rehabilitation, and DC boards and breakers system replacement. Begin left abutment rock slide stabilization.

Chief Joseph Dam:
- FY 2019. Completed generator cooling system upgrades and DC and preferred AC upgrades. Began upgrades for station service units.
- FY 2020. Continue upgrades for station service units and intake gantry crane rehabilitation. Begin powerbus replacement, exciter replacements, fire suppression upgrades, and intake gantry crane rehabilitation.
- FY 2021. Complete intake gantry crane rehabilitation. Continue upgrades for station service units, powerbus replacement, exciter replacements, and fire suppression upgrades. Begin generator rewinds and cooling.

Dworshak Dam
- FY 2019. Continued exciter replacement, RO valve upgrades and tailrace crane rehabilitation. Began exciter replacements.
- FY 2020. Complete tailrace crane rehabilitation and RO valve upgrade. Continue exciter replacements.
- FY 2021. Complete exciter replacements.

McNary Dam
- FY 2019. Continued 4160-480V station service rehabilitation, drainage system oil water separator, spillway gate rehabilitation and turbine design and replacement. Purchased 230kV transformer. Began exciters upgrade, governor systems upgrade, levee drainage pump station upgrades, powerhouse control system upgrade, and station service units rehabilitation.
- FY 2020. Complete 4160-480V station service rehabilitation and drainage system oil water separator. Continue exciters upgrade, governor systems upgrade, levee drainage pump station upgrades, turbine design and replacement, spillway gate rehabilitation, powerhouse control system upgrade, and station service units rehabilitation. Begin intake gantry crane replacement and rehabilitation of spillway gates.
- FY 2021. Complete intake gantry crane replacement. Continue exciters upgrade, governor systems upgrade, levee drainage pump station upgrades, turbine design and replacement, spillway gate rehabilitation, powerhouse control system upgrade, and station service units rehabilitation. Begin headgate system rehabilitation.

Ice Harbor Dam
- FY 2019. Completed 115kV disconnect upgrades. Continued station service transformer replacements, drainage system oil water separator installation, Units 1-3 turbine runner replacements and stator winding replacements.

- FY 2020. Complete drainage system oil water separator installation, and station service transformer replacements. Continue units 1-3 turbine runner replacements and stator winding replacements. Begin intake gantry crane controls upgrade.
- FY 2021. Continue units 1-3 turbine runner replacements, stator winding replacements and intake gantry crane controls upgrade. Begin intake gate hydraulic system upgrades and HVAC system upgrade.

Little Goose Dam

- FY 2019. Complete station service transformers replacement. Continue drainage and unwatering pump replacement and drainage system oil water separator installation. Begin headgate repair pit upgrade.
- FY 2020. Complete drainage and unwatering pump replacement and drainage system oil water separator installation. Continue headgate repair pit upgrade. Begin DC system and LV switchgear upgrade and powerhouse roof replacement.
- FY 2021. Complete headgate repair pit upgrade and powerhouse roof replacement. Continue DC system and LV switchgear upgrade. Begin intake gate rehabilitation.

Lower Granite Dam

- FY 2019. Completed digital governor upgrades and drainage system oil water separator. Continued DC system and LV switchgear upgrade. Began isophase bus and housing upgrade and intake gate rehabilitation.
- FY 2020. Continue DC system and LV switchgear upgrade, isophase bus and housing upgrade, and intake gate rehabilitation.
- FY 2021. Complete isophase bus and housing upgrade. Continue DC system and LV switchgear upgrade. Begin trashrake crane and rake replacement.

Lower Monumental Dam

- FY 2019. Completed digital governor replacements, drainage system oil water separator installation and drainage and unwatering pump replacements. Continued DC system and LV switchgear upgrades. Began intake gate rehabilitation.
- FY 2020. Continue DC and LV switchgear upgrades and intake gate rehabilitation. Begin headgate repair pit upgrades and isophase bus upgrades.
- FY 2021. Complete isophase bus upgrades. Continue DC system and LV switchgear upgrades, intake gate rehabilitation and headgate repair pit upgrades.

Bureau of Reclamation Projects
($K)

FY 2019 Actual	FY 2020 Estimate	FY 2021 Estimate
38,871	114,929	138,037

Grand Coulee Dam

- FY 2019. Completed compressed air system upgrades and powerplant battery replacements. Continued Block 31 elevator replacement, Supervisory Control and Data Acquisition (SCADA) replacement, G22-24 wear ring replacements, left and right powerhouse bridge crane replacements, G1-G18 penstock stoplogs, crane control upgrades, roof replacement in the Third Powerplant, and firehouse construction.
- FY 2020. Complete SCADA replacement, Block 31 elevator replacement, Third Powerplant roof replacement, G22-G24 wear ring replacements, firehouse construction and G1-G18 penstock stoplogs. Continue, left and right powerhouse bridge crane replacements, and crane control upgrades. Begin fire alarm system upgrades and units G21-G24 transformer replacements.
- FY 2021. Complete crane control upgrades. Continue left and right powerhouse bridge crane replacements, units G21-G24 transformer replacements, and fire alarm system upgrades. Begin 230kV switchyard modernization.

Keys Pump Generating Plant

- FY 2019. Continued P5 and P6 impeller and core replacement and rewinds. Continued P1-P6 exciters, relays and unit controls and PG7-12 governors, exciters, relays and unit controls. Continued phase reversal switch replacement.
- FY 2020. Complete P5 and P6 impeller and core replacement and rewinds. Continue P1-P6 exciters, relays and unit controls, PG7-12 governors, exciters, relays and unit controls and phase reversal switch replacement.
- FY 2021. Continue P1-P6 exciters, relays and unit controls, PG7-12 governors, exciters, relays and unit controls and phase reversal switch replacement.

Hungry Horse Dam

- FY 2019. Continued SCADA replacement, control room panel revisions, powerplant crane controls, and main unit transformer fire protection system replacement.
- FY 2020. Complete SCADA replacement and control room panel revisions. Continue powerplant crane controls, and main unit transformer fire protection system replacement. Begin static exciters replacement.
- FY 2021. Continue powerplant crane controls, main unit transformer fire protection system replacement and static exciters replacement.

Chandler Dam

- FY 2019. No planned capital projects.
- FY 2020. No planned capital projects.
- FY 2021. No planned capital projects.

Palisades Dam

- FY 2019. Completed arc flash mitigation. Continued microwave system backbone modernization.
- FY 2020. Complete microwave system backbone modernization. Begin switchyard modernization.
- FY 2021. Complete switchyard modernization.

Green Springs Dam

- FY 2019. Completed transformer replacement. Continued excitation system replacement.
- FY 2020. Complete excitation system replacement.
- FY 2021. No planned capital projects.

Black Canyon Dam

- FY 2019. No ongoing capital projects.
- FY 2020. Begin 69kV switchyard installation and station service arc flash mitigation.
- FY 2021. Continue 69kV switchyard installation and station service arc flash mitigation. Begin units 1 and 2 life safety modernization.

Anderson Ranch Dam

- FY 2019. No planned capital projects.
- FY 2020. No planned capital projects.
- FY 2021. No planned capital projects.

Roza Dam

- FY 2019. Continued switchyard rehabilitation and breaker upgrade.
- FY 2020. Continue switchyard rehabilitation and breaker upgrade.
- FY 2021. Continue switchyard rehabilitation and breaker upgrade.

Minidoka Dam

- FY 2019. Completed arc flash mitigation project. Continued microwave system backbone modernization and switchyard modernization.
- FY 2020. Complete microwave system backbone modernization and switchyard modernization.
- FY 2021. No planned capital projects.

Fish & Wildlife
($K)

FY 2019 Actual	FY 2020 Estimate	FY 2021 Estimate
22,313	47,266	47,266

Overview

Bonneville continues to develop budgets for the suite of fish and wildlife mitigation projects originally adopted in FY 2007 based on recommendations from the Council. Bonneville reaffirmed and expanded many project-specific commitments in subsequent agreements and processes, including BiOps and 2018 Fish Accord extensions, and since then, virtually all these projects received independent science review through the Council and its project review processes. Bonneville's funding decisions embrace many of the management objectives and priorities in the Program and continue to integrate ESA compliance as described in the NOAA Fisheries' and USFWS's FCRPS BiOps. Coordination continues among Bonneville, Council, federal resource management agencies, states, tribes, and others to support the projects that satisfy Bonneville's mitigation responsibilities.

Bonneville intends to continue implementing the kinds of capital projects listed below. These projects are based upon the best available science and are regionally important in that they provide high priority mitigation and protection actions for fish and wildlife populations affected by the construction and operation of the FCRPS dams. Projects and facilities listed below deliver direct on-the-ground benefits to both ESA listed and non-listed fish and wildlife throughout the Columbia River Basin and have been evaluated and coordinated with the Council, state, federal and tribal fish and wildlife resource managers, local governments, watershed and environmental groups, and other interested parties. Specifically, as capital construction projects, hatchery facilities typically go through the Council's three-step process, which includes development of a Master Plan, environmental compliance, ESA consultation, value engineering analysis, and review by the Independent Science Review Panel.

The three types of fish and wildlife projects that Bonneville capitalizes are as follows:

1) Fish passage structures – Structures funded with capital that enhance fish access to habitat in the Columbia River Basin include but not limited to wells, ladders, screens, pumping, culverts, diversion (irrigation) consolidation, piping to reduce water loss, irrigation efficiencies (drip irrigation), lining of ditches (seepage reduction), removal of objects impeding fish passage or pushup dams, and construction-related habitat restoration.
2) Hatchery facility construction – Projects and activities relating to the construction, improvement, and replacement of fish hatcheries, including related satellite facilities (acclimation ponds and collection weirs). This may also include construction-related habitat restoration.
3) Land acquisition and stewardship – Land acquisition projects protect, enhance, and maintain fish and wildlife habitat and provide credit to Bonneville, such as acres for wildlife or instream miles for resident fish, to fulfill the legal obligation of Bonneville to mitigate the impacts from construction and operation of the FCRPS.

New construction-related habitat restoration projects that may require capital funds in FY 2021 include the following:

- Svensen Island: The Svensen Island Restoration Project will reconnect the 320 acre island, east of Astoria, Oregon, directly to the mainstream Columbia River to increase ecological function and provide refuge and rearing capacity for out-migrating juvenile salmon and steelhead. Specifically, the project will remove and lower approximately 1.5 miles of existing levee; remove approximately 100 pile dikes on the northern side of the island, to provide unobstructed access to 40 acres of re-connected and newly excavated floodplain and tributary habitats for salmonids and lamprey. The Columbia Restoration Group is leading the project, in partnership with the Columbia Land Trust. This estuary project ranks high on the list of priorities in the estuary and will help to meet the responsibilities of the new NMFS Biological Opinion that will release concurrently with the Columbia River System EIS. Capital construction is scheduled to begin in FY 2021 and will last one year.

-Catherine Creek/Hall Ranch: Project is intended to improve off channel rearing habitat complexity for Chinook, steelhead, and bull trout by restoring dynamic channel geomorphology and habitat forming processes in Catherine Creek and Milk

Creek. It will improve floodplain connectivity through removal and relocation of one mile of State Highway 203 and re-connecting 50 acres of historic Catherine Creek floodplain and channel network. The request is for a project-funding match of $3,294,616 from Bonneville against additional project investment from other Federal and State partners for a total projected project cost of $5,994,616. This project has multiple coordination points, requires an environmental impact statement and the environmental compliance process may impact implementation timeframes where the project is currently expected to start construction in FY 2021.

The Further Consolidated Appropriations Act, 2019 (Public Law 116-94) provided Expenditure Authority for the following project:

- Steigerwald Project: The Steigerwald Floodplain Restoration Project is a collaborative project that will reconfigure the Port of Camas-Washougal's (Port) existing Columbia River levee system to reduce flood risk, reconnect 960 acres of Columbia River floodplain, and increase ecological function at the Steigerwald Lake National Wildlife Refuge. Specifically, the project will construct 1.6 miles of setback levee; completely remove 2.2 miles of existing levee; provide unobstructed access to floodplain and tributary habitats for salmonids and lamprey; and greatly reduce flood risk to the Port's Industrial Park and City of Washougal's wastewater treatment plant, which serves 15,000 residents. Bonneville is working with the lower Columbia Estuary Partnership, which is leading the project. The project will provide seven survival benefit units (approximately 15% of the Action Agencies' total goal in the estuary). Other partners include the Port, USFWS, Washington State Department of Transportation, City of Washougal, and several private landowners. Capital construction is scheduled to begin in FY 2020 and will last three years. This project requires the approval of Bonneville expenditure authority.

The Consolidated Appropriations Act, 2016 (Public Law 114-113) provided Expenditure Authority for the following projects:

- Shoshone Paiute Trout Hatchery: The Shoshone Paiute Tribes of the Duck Valley Reservation, Idaho, have proposed that Bonneville fund the purchase or construction of a trout hatchery. The Tribes would own and operate the hatchery to produce trout to stock the Duck Valley Reservation reservoirs. The hatchery would meet contemporary aquaculture standards and achieve fish production goals. The Tribes believe they can reduce federal reservoir stocking costs, some of which Bonneville currently pays on an annual basis.

- Spokane Tribal Hatchery: Bonneville funded construction of the Spokane Tribal Hatchery in 1989 as partial mitigation for the impacts of the FCRPS. The facility is near Wellpinit, Washington and owned and operated by the Spokane Tribe of Indians. The facility serves as a spawning, rearing, and incubation site for Kokanee salmon and rainbow trout. In June 2015, the Tribe and Bonneville signed a 20-year agreement renewing commitments to operate and maintain the facility. The renewed agreement also plans to upgrade aging infrastructure, including groundwater pumps and rearing containers. Contracting for this work began in FY 2017 and all capital work is complete.

- Snake River Sockeye Weirs: Bonneville funds efforts implemented by the Idaho Department of Fish and Game and the Shoshone Bannock Tribes to repopulate Snake River sockeye throughout the species' historic range. The combination of increased numbers of returning adults and the increased production at the Springfield Sockeye Hatchery, has created the need for the construction, operation, and maintenance of weirs to further sockeye management objectives.

The FY 2014 Omnibus Appropriations Act (Public Law No. 113-76) provided Expenditure Authority for the following projects:

- John Day Reprogramming and Construction: The Columbia River Inter-Tribal Fish Commission (CRITFC) has proposed this project in order to balance the upriver and downriver salmon hatchery production that mitigates for the effects of John Day and The Dalles Dams. The Tribes, the Corps, and Bonneville are still analyzing the final reprogramming facilities and locations. The project area encompasses the mainstream Columbia River from the base of McNary Dam downstream to The Dalles Dam. Capital dollars for this project will integrate with the Corps funds for the construction of new or existing FCRPS hatchery facilities to accommodate the reprogramming of hatchery fish.

- Columbia River Basin White Sturgeon Hatchery: This project, proposed by the CRITFC, will mitigate for the decline of the white sturgeon population caused by consistently poor recruitment upstream of Bonneville Dam. Bonneville would fund

the construction of a new facility, or the acquisition of an existing facility, to produce 15,000 - 30,000 yearling white sturgeons per year. The final project may include the collection, holding and spawning of broodstock, the rearing of wild-spawned juveniles, and the acclimation of juveniles prior to release. The site of the Yakama Nation's existing Marion Drain Sturgeon Hatchery near Toppenish, Washington has been proposed as a location. The project team is working on additional analyses to respond to Council comments and to begin the environmental review process.

- Kelt Reconditioning and Reproductive Success Evaluation Research: CRITFC is proposing a facility to recondition female steelhead (kelts) after they have spawned. The fish will be held and fed until they have re-matured and then be released into the Snake River where they will contribute to the spawning run. The capital portion of the project is expected to be constructed in the Snake River Basin, potentially at the Nez Perce Tribal Hatchery in Idaho. Pursuant to the 2008 FCRPS BiOp and Supplemental FCRPS BiOps issued in 2010 and 2014, Bonneville will implement the kelt reconditioning plan to improve the productivity of Snake River basin B-run steelhead populations that are listed for protection under the ESA. NOAA's analysis of Prospective Actions indicates that a combination of transportation, kelt reconditioning, and in-stream passage improvements (e.g., spill-flow modifications) could increase kelt returns enough to achieve a targeted six-percent increase in the number of returning Snake River B-run steelhead spawners to Lower Granite Dam. The Master Plan for the facility is currently in the second of the Council's amended, shortened, Artificial Production Three-Step Review Process.

Ongoing Projects (Expenditure Authority previously received):

- Crystal Springs Hatchery Facilities: This proposed project is for a rearing and out-planting facility to benefit resident fish in southern Idaho. The facility would be located near the American Falls Reservoir in Idaho where it would produce Yellowstone cutthroat trout, a resident fish. The facility is expected to produce up to 10,000 Yellowstone cutthroat annually for a put and take Tribal fishery. The facility is sponsored by the Shoshone-Bannock Tribes, who are expected to operate and manage the facility once it is complete.

- Redfish Lake Sockeye Salmon program: Snake River sockeye salmon, an Evolutionarily Significant Unit (ESU), is a listed species under the Endangered Species Act. The Snake River Sockeye Salmon Captive Broodstock Program supports the survival of endangered Snake River sockeye salmon. The program has helped to successfully conserve the genetic resources of the founding population, and is producing fish for rebuilding the naturally spawning population in Redfish Lake. The program uses state-of-the-art hatchery facilities, fish husbandry protocols, genetic support, and monitoring and evaluation to continue rebuilding the sockeye population. Currently, the program retains replicate, captive broodstock within multiple facilities, including the Eagle Fish Hatchery in Idaho, and the Burley Creek Fish Hatchery and Manchester Research Station, both in Washington State). Eggs produced from these locations are transferred to other facilities for release programs. The project continues to expand by increasing the capacity of existing facilities and acquiring a new facility under the Idaho Fish Accord extension. The newly constructed Springfield Fish Hatchery in Idaho produces additional smolts as recommended in the NOAA Fisheries FCRPS BiOp. The expanded smolt releases have already resulted in an increase in the abundance and productivity of the naturally spawning population. This strategy will greatly increase the likelihood of higher adult returns. Additional expansions include improvements at the Redfish Lake Creek trap and Sawtooth Fish Hatchery weir to hold/trap an increased number of adults to support increased smolt production from Springfield Fish Hatchery. The biological goals are to increase the number of adults spawning naturally in the Sawtooth Valley and transition the captive broodstock to a conventional hatchery production program that uses anadromous adults as broodstock.

- Klickitat Production Expansion: In 2008, the Klickitat River Master Plan was submitted by the Yakama Nation, reviewed by the Independent Science Review Panel, recommended with comments by the Council, and conditionally approved by Bonneville. The plan's original goals were to protect and increase naturally producing populations of spring Chinook and steelhead, localize brood collection of harvest stocks (fall chinook and coho), while protecting the biological integrity and the genetic diversity of indigenous fish stocks in the sub-basin. A component of the Master Plan was implemented in 2009, including the completion of upgrades to Lyle Falls Fishway and Castile Falls Fishway, and the construction of a new bridge at the Klickitat Hatchery. In July 2009, a new Klickitat Hatchery Complex EIS was initiated to examine options for the development and operation of new production and supplementation facilities, acclimation alternatives, and additional upgrades to the existing hatchery facility. The Yakama Nation issued a revised Master Plan in July, 2012 that provided updates to their fish management plans. Bonneville suspended the NEPA process while the Yakama Nation refined its

proposal in response to site and budgetary limitations and comments on the draft EIS. Since that time, the National Marine Fisheries Service (NMFS) has completed its Mitchell Act EIS and BiOp, helping inform its funding responsibilities in the sub-basin. Bonneville negotiated a new scope of work with the Yakama Nation, and a revised Master Plan was submitted to the Council in 2017 and approved in 2018. The new scope of work targets design and construction activities for the expansion of the current spring Chinook program only, from 600,000 to 800,000 smolt, and converting to a wild broodstock collection program, as well as general water supply and water abatement upgrades. Bonneville has initiated a new EIS process and construction will occur after Bonneville issues a NEPA ROD and alongside a three-way operations and maintenance agreement which affirms that NMFS will remain responsible for providing funding post-construction.

- Hood River Production Facility: This project has been ongoing since the early 1990s. It currently produces 150,000 spring Chinook salmon smolts and 50,000 winter steelhead smolts annually. The Powerdale Dam Fish Trap formerly provided the foundation for many of the activities associated with implementation of the Hood River Production Program. These include monitoring escapement, collecting life history characteristics, and broodstock acquisition. PacifiCorps' 2010 demolition of its Powerdale Dam and the associated fish trapping facility necessitated the development of alternative adult broodstock trapping sites. One permanent fish trap on the West Fork of the Hood River was completed in 2013, and a temporary trapping site is operational on the East Fork of the Hood River. A permanent trap site on the East Fork is currently being evaluated. The Hood River Production Program has four primary goals: 1) re-establish naturally sustaining runs of spring chinook in the Hood River; 2) re-build naturally sustaining runs of winter steelhead in the Hood River; 3) maintain genetic characteristics of Hood River fish populations; and 4) provide fish for sustainable harvest by both sport and tribal fishers.

- Mid-Columbia Coho Restoration: This Yakama Accord project is intended to re-establish naturally reproducing coho salmon populations in the Wenatchee River and Methow River sub-basins at biologically sustainable levels that also provide significant harvests. This program will construct a facility on the Wenatchee River for holding and spawning broodstock, incubating eggs, and rearing juveniles. Additional semi-natural ponds will also be constructed in the Wenatchee and Methow sub-basins for acclimating smolts prior to their release. The phased approach, including associated facilities, incorporates development of a mid-Columbia hatchery broodstock, local adaptation to tributaries in the Wenatchee and Methow Basins, and habitat restoration that will benefit coho as well as ESA-listed spring chinook, steelhead, and bull trout. Major facility construction is expected to continue through FY 2020.

- Walla Walla Hatchery: The Confederated Tribes of the Umatilla Indian Reservation (CTUIR) proposed the construction of the Walla Walla Hatchery. The Tribes will own and operate the hatchery, which will produce up to 500,000 spring Chinook smolts annually for release into the Walla Walla River. A 30 percent design was completed in June 2015, and a draft EIS was completed in September 2016. However, due to budget overruns, the project was reconfigured. Design and construction was successfully rebid, and construction has been on hold awaiting issuance of a NPDES permit by the state water authority. Construction started in fall 2019. The facility will hold, spawn, incubate, and rear spring Chinook on the South Fork Walla Walla River near Milton-Freewater, Oregon.

- Yakima Melvin R. Sampson Coho Facility: This hatchery was proposed by the Confederated Tribes and Bands of the Yakama Nation, and is presented in the Yakima River Subbasin Summer and Fall Run Chinook and Coho Salmon Hatchery Master Plan. The Yakama Nation will own and operate the hatchery which will produce up to 700,000 coho smolts using broodstock collected at Roza and Sunnyside dams. Bonneville holds the design and construction contract on behalf of the Yakama Nation. Bonneville published a final EIS on November 6, 2017, and a Record of Decision April 9, 2018, with construction beginning August 2018. The facility is still under construction and is expected to be completed in FY20.

Potential non-construction capital Wildlife and Resident Fish Habitat Acquisitions (including Conservation Easements) eligible for capitalization are:

- Albeni Falls Wildlife Mitigation
- Willamette Wildlife Habitat Acquisitions
- Libby and Hungry Horse Reservoirs Resident Fish Acquisitions
- Southern Idaho Habitat Acquisitions

Activities and Explanation of Changes ($K)

FY 2020 Estimate	FY 2021 Estimate	Explanation of Changes FY 2021 vs FY 2020 Estimate
Power Services – Capital $285,266	**$303,266**	**$18,000/6.3%**
Associated Projects $238,000 Milestones [1]: • Complete GSU transformer instrumentation at Bonneville Dam. • Complete emergency gantry crane replacement at John Day Dam. • Complete GDACS installation across the Willamette Valley, Detroit spillway gate rehabilitation, and Big Cliff intake gantry crane replacement at Willamette Plants. • Complete intake gantry crane replacement at Libby Dam. • Complete upgrades for station service units and powerhouse HVAC upgrade at Chief Joseph Dam. • Complete tailrace crane rehabilitation at Dworshak Dam. • Complete station service transformer replacements at Ice Harbor Dam. • Complete DC system and LV switchgear upgrade at Lower Granite Dam. • Complete SCADA replacement, Third Powerplant roof replacement and G1-G18 penstock stoplogs at Grand Coulee Dam. • Complete P5 and P6 impeller and core replacement and rewinds, and phase reversal switch replacement at Keys Pump Generating Plant.	**$256,000** Milestones: • Complete control room fire protection upgrades and oil water separator improvements at Bonneville Dam. • Complete trash rack crane replacement at John Day Dam. • Complete transformer replacements at The Dalles Dam. • Complete security system upgrades at Libby Dam. • Complete intake gantry crane rehabilitation Chief Joseph Dam. • Complete intake gantry crane replacement at McNarry Dam. • Complete headgate repair pit upgrade and powerhouse roof replacement at Little Goose Dam. • Complete isophase bus and housing upgrade at Lower Granite Dam. • Complete isophase bus upgrades at Lower Monumental Dam. • Complete crane control upgrades at Grand Coulee Dam. • Complete switchyard modernization at Palisades Dam.	**$18,000/7.6%** • The increase reflects a reshaping of funding needs for investment in the hydroelectric system assets.

[1] FY 2020 milestones have been updated from the FY 2020 Congressional submission due to updated forecasts.

FY 2020 Estimate	FY 2021 Estimate	Explanation of Changes FY 2021 vs FY 2020 Estimate
Fish & Wildlife $47,266 Milestones: • Continue implementation of the Program, BiOps and 2018 Fish Accord extension.	**$47,266** Milestones: • Continue implementation of the Program, BiOps and 2018 Fish Accord extension.	**$0/0.0%** • Fish & Wildlife will continue long-term, planned effort to reshape funding necessary to implement the BiOps, 2018 Fish Accord extension, Columbia River Basin Fish and Wildlife activities.

Transmission Services – Capital
Funding Schedule by Activity
Funding ($K)

	FY 2019 Actual	FY 2020 Estimate	FY 2021 Estimate	FY 2021 vs FY 2020 $	FY 2021 vs FY 2020 %
Transmission Services – Capital					
Main Grid	3,575	2,714	27,087	$24,373	898.0%
Area & Customer Services	38,395	80,453	90,935	10,481	13.0%
Upgrades & Additions	29,173	55,683	49,464	-6,219	-11.2%
System Replacements	120,933	329,914	306,819	-23,095	-7.0%
Projects Funded in Advance	239,228	85,896	66,179	-19,717	-23.0%
Total, Transmission Services - Capital	**431,305**	**554,661**	**540,484**	**-14,177**	**-2.6%**

Outyears ($K)

	FY 2021 Estimate	FY 2022 Estimate	FY 2023 Estimate	FY 2024 Estimate	FY 2025 Estimate
Transmission Services - Capital					
Main Grid	27,087	25,054	33,487	45,520	39,405
Area & Customer Services	90,935	74,145	69,070	55,922	66,319
Upgrades & Additions	49,464	68,536	103,993	120,543	75,036
System Replacements	306,819	300,217	300,528	303,454	311,204
Projects Funded in Advance	66,179	60,463	39,848	39,823	40,947
Total, Transmission Services - Capital	**540,484**	**528,415**	**546,925**	**565,262**	**532,911**

Transmission Services – Capital

Overview

Transmission Services (TS) is responsible for about 75 percent of the Pacific Northwest's high-voltage transmission. TS provides funding for all additions and upgrades (Expansion Investments), and replacements (Sustain Investments) to the Bonneville transmission system, resulting in reliable service to Northwest generators and transmission customers. The Bonneville transmission system also facilitates the delivery of power under sales and exchange agreements to and from the Pacific Northwest Region. The TS Capital Program is structured with a balanced focus on Expansion and Sustain investments.

In addition to replacing aging and obsolete equipment, TS continues to make significant infrastructure improvements and additions to the system to assure reliable transmission in the Northwest. These improvements and additions will help the Bonneville transmission system continue to comply with national reliability standards and remove constraints that limit economic trade or the ability to maintain the system. Some of the proposed TS projects may be funded through Bonneville lease-purchase agreements. The lease-purchases obligate Bonneville to make expenditures to acquire the use of the related facilities and are identified on an as needed basis. Bonneville may also make related expenditures to facilitate lease-purchase opportunities. Consistent with the FY 2018, FY 2019, and FY 2020 Budget Requests, the FY 2021 Budget Request maintains the proposal that the Federal government be authorized to sell the transmission assets of Bonneville.

Expansion Investments

Expansion investments continue to make significant infrastructure improvements and additions to the Bonneville transmission system to assure reliable transmission operations in the Northwest and fall into two categories:

- Internally driven Expansion requests, which are derived from system engineering studies, technology innovation research, system operations and maintenance functions, and system event analysis.
- Externally driven Expansion Investment requests, which are derived from governmental initiatives and regulations, consumer demand, and the integration of customer load service and generation needs.

These investments are categorized into:

1. Main Grid – System investments affecting the major interties or internal paths and flowgates that transfer bulk power across the system.
2. Area & Customer Service – System investments related to geographical load service areas.
3. Upgrades & Additions – Upgrades are system investments that replace existing assets to increase capacity, reliability, or functionality and Additions are net new assets added to the system.
4. Projects Funded in Advance – System investments that are requested, and funded in advance, by customers.

Congressionally-approved Production Tax Credits (PTC) for renewable energy enacted in 2005 was extended through 2021. The PTC begins to phase out after 2021. The incentives created by these credits, along with Renewable Portfolio Standards (RPS) mandates implemented by the states of Oregon, Washington, and California, have spurred a large number of renewable projects interconnection requests to the Bonneville transmission system grid. As of July 2019, Bonneville has interconnected a total of 5,285 MW of renewable qualified generation projects. Bonneville has more than 10,000 MW in additional renewable (wind, solar, biomass, geothermal, etc.) interconnection requests still remaining in the study queue. Solar project interconnection requests are currently making up the majority of the new requests in Bonneville's queue. The current projections are possibly 9,000 MW of renewable generation projects interconnected by 2025. Much of the remaining generation project transmission demand is the result of the Renewable Portfolio Standards and other legislations enacted by Oregon and Washington that require retail utilities to acquire more than 8,000 MW of renewable energy in the Northwest by 2025. Exports of power from the Northwest to California are limited by California laws and are expected to remain at 2,000 MW to 2,500 MW during the same period. Also in the BPA transmission interconnection request queue is approximately 1,500 MW of natural gas fired generation. Efficiency improvements to the FCRPS hydro units that qualify as renewable are also proposed between 2018 and 2024.

In June 2008, Bonneville's first Network Open Season (NOS) received 153 requests from 28 customers for 6,410 MW of new service, about three-fourths for wind energy integration. Bonneville subsequently offered 1,782 MW of new transmission service on its existing system. Bonneville identified four new Main Grid capital projects from the 2008 NOS: (1) McNary-John Day 500 kV transmission line (part of West of McNary Reinforcements Group 1); (2) Big Eddy-Knight 500 kV transmission line and substation (part of West of McNary Reinforcements Group 2); (3) Central Ferry- Lower Monumental

500 kV Reinforcement (formerly Little Goose Area Reinforcement); and (4) I-5 Corridor 500 kV Reinforcement. Construction of the McNary-John Day 500 kV transmission line is complete and Bonneville has completed construction of the Big Eddy-Knight project and the Central Ferry-Lower Monumental 500 kV Reinforcement project. On May 18, 2017, Bonneville announced its decision to not build the I-5 Corridor Reinforcement Project. Bonneville continues to work with constituents and stakeholders to study more cost effective options to mitigate the current limitations along this path. Public meetings began in July 2017 to address alternatives to building. An update to Bonneville's Available Transfer Capability (ATC) methodology increased the available transmission service on the Westside paths by a few hundred MW. Other alternatives, such as energy storage devices, are still being evaluated. Bonneville released its 2019 Cluster Study results in June of 2019 and 1475 MW of new transmission service have been offered and are being reviewed by customers.

Bonneville's 2009, 2010, 2013, 2016, and 2019 study processes for new Transmission Service Requests (TSR) total 14,992 MW, including 5,840 MW of wind project interconnection and 1,555 MW of solar project interconnection. The 2010 study process identified the Montana to Washington project, for which environmental review was begun, however, the requests to support this project have been subsequently withdrawn and so all work on the project was terminated. The 2016 and 2019 study processes re-identified the Montana to Washington and Garrison to Ashe projects to move new wind generation in Montana to the Northwest. The 2013 study process identified upgrades to the Monroe-Novelty Hill 230-kV transmission line which were re-identified for additional new requests in the 2016 study process. The 2016 study process identified network upgrades in Central Oregon, Walla Walla, Washington and across the Raver-Paul flowgate. The 2019 study process identified additional reinforcements across the Raver-Paul flowgate, the same Central Oregon and Walla Walla projects, and some significant impacts to third parties, specifically PGE and PSE. Efforts are currently underway to evaluate the financial impacts and move forward with required agreements and processes within the TSR Study and Expansion Process (TSEP).

Sustain Investments

Sustain investments are made to maintain the health of the existing infrastructure to assure reliable transmission in the Pacific Northwest. These replacements enable continued compliance with national reliability standards, replace aging and obsolete equipment, and remove constraints that limit economic trade or the ability to maintain the transmission system.

In 2009, TS began implementing best practice frameworks that provide a standardized structure and approach to Asset Management. As a result, TS's Asset Management Strategies, derived from the Agency's Strategic Plan, drive Bonneville's Asset Plans, which determine its capital and expense investment priorities. Sustain investments are forecasted, prioritized within asset programs, and optimized across the asset base for asset planning and approval. BPA now bundles both sustain and expand capital projects in an effort to improve execution and to lower risks and costs. TS's capital program does remain somewhat fluid and subject to changes as the complexity of the transmission system produces unexpected needs resulting from equipment failure, climate/weather incidents, changes in performance and/or operation of connected systems, outage schedules and conflicts, updated regulations, customer interconnection requests, etc. For these and other reasons, specificity with Sustain investments in the transmission system is somewhat limited.

The TS Sustain Program Asset Programs include:

1. Steel Lines – Transmission lines with steel structures including footings, insulators assemblies, vibration dampers, grounding systems, conductor, ground wire.
2. Wood Lines – Transmission lines with wood structures including cross arm systems, insulator assemblies, vibration dampers, grounding systems, conductor, ground wire.
3. Rights-of-Way – Real property including land parcels, easements, use right, access roads.
4. AC Substations – Substations managing AC current including transformers, reactors, shunt capacitors, power circuit breakers, circuit switchers, series capacitors, disconnect switches.
5. Power System Controls and System Telecommunications – Control and communication equipment including SCADA, transfer trips, fiber, communications, SONET, Telephone, RAS.
6. System Protection and Control – Control equipment including relays, Control Houses, meters.
7. DC Substations – Celilo DC converter station, Static VAR Compensators, DC control systems.
8. Control Centers – Various control equipment and software.
9. Tools and Equipment Acquisition Program (TEAP) –Tools, equipment, fleet.
10. Facilities – Non-electric facilities including warehouses, operational structures, hangar, and maintenance centers.

Notwithstanding that the capital program for TS is subject to change, Bonneville has identified several general areas where capital investments will occur.

Bonneville will continue to fund fiber optic communications facilities needed to meet Bonneville's projected operational needs. To the extent that these investments create temporary periods of excess fiber optic capacity, such dark fiber capacity can be made available to telecommunications providers and to non-profits to meet public benefit internet access needs for rural areas and other needs in Bonneville's service area. Bonneville's investments in fiber optics, including the role of the private sector in building fiber optic networks, is consistent with the "Fiber Optic Cable Plan" submitted to Congress on May 24, 2000, accompanying the FY 2000 Energy and Water Development Appropriations Act. In accordance with this plan, when possible, Bonneville will establish partnerships with fiber optic facility and service providers to meet its needs.

In December 2004, Congress passed and the President signed the Commercial Spectrum Enhancement Act (CSEA, Title II of P.L. 108-494), creating the Spectrum Relocation Fund (SRF) to streamline the relocation of federal systems from certain spectrum bands to accommodate commercial use by facilitating reimbursement to affected agencies of relocation costs. The Federal Communications Commission has auctioned licenses for reallocated federal spectrum, which will facilitate the provision of Advanced Wireless Services to consumers. Funds were made available to agencies in FY 2007 for relocation of communications systems operating on the affected spectrum. These funds are mandatory and will remain available until expended, and agencies will return to the SRF any amounts received in excess of actual relocation costs. The estimated Bonneville cost of this relocation was $48.7 million. The project was completed in November 2013 with a cost of approximately $40 million and the operational system performance was being observed during FY 2014 and early FY 2015 to determine that it has achieved comparable capability as defined under the CSEA. Bonneville determined in December 2014 that comparable capability had been achieved.

Bonneville began participating in a new spectrum relocation effort in FY 2015. The NTIA has approved and, in July 2014, web-posted federal agency relocation plans, including the Bonneville relocation plan. The FCC held an auction of this spectrum on November 13, 2014. Bonneville received an additional $5.2 million from the Spectrum Relocation Fund on July 29, 2015, to fully pay for this new relocation effort, including, as in the prior relocation, the purchase and installation of new digital radio equipment.

As part of the Homeland Security Presidential Directives, Bonneville has completed a physical security assessment of all critical facilities and is implementing security enhancements at these facilities. These security enhancements increase controlled access to Bonneville's facilities and provide video surveillance and monitoring capabilities.

Accomplishments

- The BP-20 - Rate Case final record of decision was released July 25, 2019. FERC granted interim approval to proposed rates on September 30, 2019.
- Integrated 5,285 MW of renewable energy through July 2019 on Bonneville's transmission system.
- Completed construction of the Bakeoven and Slatt Substations Series Capacitor Upgrade Projects.

Explanation of Changes

Bonneville's budget includes $540.5 million in FY 2021 for TS Capital which is a 2.6 percent decrease from the FY 2020 forecasted level. The FY 2021 budget increases the levels for Main Grid (+$24.4 million) and Area & Customer Services (+$10.5 million). The budget decreases levels for Upgrade & Addition (-$6.2 million), System Replacements (-$23.1 million), and PFIA (-$19.8 million).

Strategic Asset Management

Transmission Services provides transmission and energy services while integrating renewable resources across the Pacific Northwest. This effort is coordinated throughout Bonneville in conjunction with the newly developed Strategic Asset Management Plan (SAMP). TS continues to implement integrated detailed Asset Plans to serve the region:

1. To improve system adequacy, reliability, and availability, Bonneville has embarked on major transmission infrastructure projects. The identified projects reinforce the transmission system and help meet the region's future power needs. These projects address multiple challenges, such as integration of renewable energy, the need to relieve a number of

congested transmission paths, the challenge to keep up with growing energy demands, and the need to meet changing regulatory and customer requirements.

2. Open access policy in support of competitive markets for load and generation.

3. The replacement of aging assets is vital to the reliability of the existing transmission system. To that end, TS has developed specific long-term strategies for the following asset categories:
    a. Substations AC
    b. Power System Control/System Telecommunications
    c. Wood Lines
    d. Steel Lines
    e. Rights of Way (ROW), (Land Rights, Access Roads, and Vegetation Management)
    f. System Protection and Control
    g. Control Centers
    h. Non-Electric Facilities

The following external factors present the strongest impact to overall achievement of the program's strategic goal:

- Continually changing economic and institutional conditions
- Competitive dynamics
- Ongoing changes in the electric industry
- Siting issues

Main Grid
($K)

FY 2019 Actual	FY 2020 Estimate	FY 2021 Estimate
3,575	2,714	27,087

Overview

Bonneville's strategic objectives for Main Grid projects are to assure compliance with the NERC and Western Electricity Coordinating Council (WECC) reliability criteria, provide voltage support, provide a reliable transmission system for open access, and provide for relief of transmission system congestion. During this budgeting period, projects are planned that will provide transmission reinforcement and voltage support to major load areas that are primarily west of the Cascade Mountains.

Continued investments in Main Grid assets include:

Monroe Line Re-termination

- FY 2019. Continue construction.
- FY 2020. Complete construction.
- FY 2021. No planned capital projects.

Schultz-Wautoma 500KV Series Capacitors

- FY 2019. Begin construction.
- FY 2020. Continue construction.
- FY 2021. Continue construction.

Continue Planning Studies to: (all years)

- Identify infrastructure additions.
- Identify projects driven by NERC and WECC reliability criteria.
- Identify system reactive needs to mitigate unacceptable low or high voltage problems and other system additions.
- Relieve transmission system congestion and integrate new generation facilities.

Area & Customer Service
($K)

FY 2019 Actual	FY 2020 Estimate	FY 2021 Estimate
38,395	80,453	90,935

Overview
Bonneville's strategic objective for Area and Customer Service projects is to assure that Bonneville meets reliability standards and contractual obligations to its load service areas.

Continued investments in Area & Customer Service assets include:

Hooper Springs Substation
- This project will now be constructed and owned by Lower Valley Energy and completed in FY 2020.

Midway-Grandview 115 kV Line upgrade
- FY 2019. Completed construction.
- FY 2020. No planned capital projects.
- FY 2021. No planned capital projects.

Puget Sound Area Northern Intertie (PSANI)
- FY 2019. Continue construction.
- FY 2020. Complete construction.
- FY 2021. No planned capital projects.

McNary Substation 500/230 kV Bank Addition
- FY 2019. Completed construction.
- FY 2020. No planned capital projects.
- FY 2021. No planned capital projects.

Paul Substation 500 kV Shunt Reactor Addition
- FY 2019. Completed construction.
- FY 2020. No planned capital projects.
- FY 2021. No planned capital projects.

Big Eddy Breaker Additions
- FY 2019. No planned capital projects.
- FY 2020. Begin design.
- FY 2021. Begin construction.

Drummond 115kV Breaker Additions
- FY 2019. Completed construction.
- FY 2020. No planned capital projects.
- FY 2021. No planned capital projects.

Midway –Ashe Double Circuit 230kV Line
- FY 2019. No planned capital projects.
- FY 2020. Begin design.
- FY 2021. Begin construction

Carlton Substation Upgrade
- FY 2019. No planned capital projects.

- FY 2020. Begin design.
- FY 2021. Begin construction.

Conkelley Substation Retirement
- FY 2019. No planned capital projects.
- FY 2020. Complete design.
- FY 2021. Begin construction.

Continuous Activities (all years)
Continue preliminary engineering and design for miscellaneous facilities required to meet contractual obligations and maintain reliable service for Bonneville's service area.

Upgrades & Additions
($K)

FY 2019 Actual	FY 2020 Estimate	FY 2021 Estimate
29,173	55,683	49,464

Overview

Bonneville's strategic objectives for Upgrades and Additions are to replace older 60 Hz (Hertz) communications and controls with newer technology including fiber optics in order to maintain or enhance the capabilities of the transmission system; to implement special remedial action control schemes to accommodate new generation and mitigate immediate operational and market constrained paths; and to support communications and remedial action schemes, among other proposals.

During this budget period, Bonneville will complete design, material acquisition, construction, and activation of several fiber optics facilities to provide bandwidth capacity and high-speed data transfers to eventually replace microwave analog radios, which are technologically obsolete and nearing the end of their useful life. Temporarily, in some areas, excess dark fiber capacity is being offered for a term to telecommunications providers or to public entities such as public utilities, schools, libraries, and hospitals, providing them access to high-speed telecommunication services as a public benefit.

Continued investments in Upgrades & Additions assets include:

VHF Radio System Upgrade

- FY 2019. Continue construction.
- FY 2020. Continue construction.
- FY 2021. No planned capital projects.

VCC (Vancouver Control Center)

- FY 2019. No planned capital projects.
- FY 2020. Begin Scoping and design as well as some demolition.
- FY 2021. Complete design and begin construction.

Bell-Boundary #DC SONET Ring Upgrade

- FY 2019. Complete construction.
- FY 2020. No planned capital projects.
- FY 2021. No planned capital projects.

Operational Megabit Ethernet (OMET) System

- FY 2019. Continue construction.
- FY 2020. Continue construction.
- FY 2021. Continue construction.

500 kV Spares at Wind Integration Substations

- FY 2019. Continue construction.
- FY 2020. Complete construction.
- FY 2021. No planned capital projects.

Continuous Activities (all years)

- Upgrading two miles of fiber between Bonneville Power House and Bonneville Control House.
- Planning, design, material acquisition, and construction of special remedial action control schemes required for interconnecting new generation projects and mitigating immediate constrained paths.
- Planning, design, material acquisition, and construction of various system additions and upgrades necessary to maintain a reliable system for Bonneville's service area.
- Construction of secondary fiber related projects and digital radio system upgrades to improve the operational telecommunication system.

- Material procurement and construction to upgrade the main fiber optic backbone system (#KC and #NC systems).

System Replacements
($K)

FY 2019 Actual	FY 2020 Estimate	FY 2021 Estimate
120,933	329,914	306,819

Overview

Bonneville's strategic objectives for the Sustain Program are to replace high-risk, obsolete, and maintenance-intensive facilities and equipment and to reduce the chance of equipment failure by: (1) replacing high voltage transformers and power circuit breakers which are at or near the end of their useful life; (2) replacing risky, outdated and obsolete control and communications equipment and systems, including mandated replacements due to legislation; and (3) replacing all other existing high-risk equipment and facilities affecting the safety and reliability of the transmission system. Transmission Services uses a total economic cost model to determine priorities for replacement.

Continued investments in System Replacements assets include:
Continuous Activity (all years)

Non-Electric Replacements

- Continue non-electric replacements as necessary.
- Continue the design, material acquisition, and construction for the Access Road program capital component and the Land Rights program capital component in support of the Lines and ROW Programs.
- Continue design and construction of capital improvements for identified existing facilities.
- Continue replacement of tools, equipment, and vehicle fleet.
- Replace BPA fixed-wing aircraft with a helicopter in FY 2020 utilizing General Services Administration exchange sale authority.

Electric Replacements

- Continue replacement of system protection and control equipment and other substation and line facilities as needed to maintain reliability using Reliability Centered Maintenance criteria. Such replacements include relays, annunciators, oscillographs, metering, and various types of communication related equipment replacing and migrating analog to digital technology and SCADA equipment.
- Begin design and replacement of the Keeler and Maple Valley SVC units. Completion scheduled for FY2020.
- Continue replacement of under-rated and high maintenance substation equipment.
- Continue replacing insulators and refurbishing foundations on 500 kV Lines.
- Continue replacement of older generations of digital equipment that is obsolete.
- Continue replacing critical, operational tools and business systems at the Dittmer and Munro Control Centers.
- Continue replacing deteriorating wood pole transmission line structures, spacer dampers, and insulators.

Projects Funded in Advance
($K)

FY 2019 Actual	FY 2020 Estimate	FY 2021 Estimate
239,228	85,896	66,179

Overview

This category includes those facilities and/or equipment where Bonneville retains control or ownership but which are funded or financed by a third party or with reserves, either in total or in part.

Continued investments in PFIA assets include:

Umatilla Electrical Cooperative - Phase 2

- FY 2019. Continue construction.
- FY 2020. Complete construction.
- FY 2021. No planned capital projects.

Summit Ridge Wind Project

- FY 2019 Project cancelled.
- FY 2020. No planned capital projects.
- FY 2021. No planned capital projects.

Bakeoven Wind Project

- FY 2019. No planned capital projects.
- FY 2020. Begin design
- FY 2021. Begin construction.

Quenett Creek Load Service Project

- FY 2019. Continue construction.
- FY 2020. Continue construction.
- FY 2021. Complete construction.

PacifiCorps' Ponderosa Project Vitesse

- FY 2019. Complete construction.
- FY 2020. No planned capital projects.
- FY 2021. No planned capital projects.

Midway-Ashe Line Project

- FY 2019. No planned capital projects.
- FY 2020. Begin design.
- FY 2021. Begin construction.

Avangrid Montague 1 Wind Project

- FY 2019. Continue construction.
- FY 2020. Complete construction.
- FY 2021. No planned capital projects.

Invenergy's Heppner Wind Project

- FY 2019. No planned capital projects.
- FY 2020. No planned capital projects.
- FY 2021. Begin design.

Morrow Solar Project

- FY 2019. No planned capital projects.
- FY 2020. No planned capital projects.
- FY 2021. Begin design

2 Morrow Energy LLC's Ella 3 Wind Project
- FY 2019. Begin design.
- FY 2020. Begin construction.
- FY 2021. Continue construction.

Whistling Ridge 230 kV Ring Bus Project
- FY 2019. No planned capital projects.
- FY 2020. No planned capital projects.
- FY 2021. Begin design.

Continuous Activity (all years)
- Continue to integrate various new generation and line/load projects into Bonneville transmission grid based on requests placed and processed in accordance with transmission tariff.
- Continue planning studies to identify system impacts and needs regarding proposed new generation projects.
- Engineer and begin construction of several large wind generation interconnection substations.

Activities, Milestones, and Explanation of Changes ($K)

FY 2020 Estimate	FY 2021 Estimate	Explanation of Changes FY 2021 vs FY 2020 Estimate
Transmission Services – Capital $554,661	**$540,484**	**$-14,177/-2.6%**
Main Grid $2,714 Milestones: • Complete construction of Monroe 500 kV Line Re-termination #2. • Begin construction of Schultz-Wautoma 500Kv Series Capacitors.	**$27,087** Milestones: • Continue construction of Schultz-Wautoma 500KV Series Capacitors.	**$24,373/898.0%** • The increase is due to increased construction planned for FY 2021.
Area & Customer Service $80,453 Milestones: • Begin construction of Carlton Substation Upgrade. • Begin construction of Midway- Ashe Double Circuit 230kV line. • Complete construction of the PSANI project. • Begin construction of Conkelley Upgrade.	**$90,935** Milestones: • Begin construction of Big Eddy Breaker Additions. • Continue construction of Midway-Ashe Double Circuit 230kV. • Continue construction of Carlton Substation Upgrade. • Begin construction of Conkelley Substation Retirement.	**$10,481/13.0%** • The increase reflects increased construction planned for FY 2021.

FY 2020 Estimate	FY 2021 Estimate	Explanation of Changes FY 2021 vs FY 2020 Estimate
Upgrades & Additions $55,683 Milestones: • Continue construction of VHF Radio System Upgrade.	**$49,464** Milestones: • Continue construction of Operational Megabit Ethernet (OMET) System.	**$-6,219/-11.2%** • The decrease reflects decreased planned capital projects for FY 2021.
Systems Replacements $329,914 Milestones: • Continue design and construction of capital improvements for identified existing facilities. • Continue non-electric replacements as necessary. • Continue replacement of system protection and control equipment and other substation and line facilities as needed to maintain reliability using Reliability Centered Maintenance criteria. • Complete construction of Keeler-Maple Valley Upgrade.	**$306,819** Milestones: • Continue design and construction of capital improvements for identified existing facilities. • Continue non-electric replacements as necessary. • Continue replacement of system protection and control equipment and other substation and line facilities as needed to maintain reliability using Reliability Centered Maintenance criteria.	**$-23,095/-7.0%** • The decrease reflects decreased planned capital projects for FY 2021.
Projects Funded in Advanced $85,896	**$66,179**	**$-19,717/-23.0%**

FY 2020 Estimate	FY 2021 Estimate	Explanation of Changes FY 2021 vs FY 2020 Estimate
Milestone: • Continue to integrate new generation as requested. • Continue planning studies on needs and impacts of proposed new generation. • Complete construction of Bakeoven Series Capacitors. • Continue construction of PacifiCorps' Project Vitesse. • Complete construction of Avangrid Montague 1 project. • Begin construction of 2 Morrow Energy LLC's Ella 3 Wind Project. • Complete construction of Morrow Solar Project.	Milestones: • Continue to integrate new generation as requested. • Continue planning studies on needs and impacts of proposed new generation. • Begin construction of Bakeoven Wind Project. • Complete construction of Quenett Creek Load Service Project. • Begin construction of Midway-Ashe Line Project. • Begin design of Invenergy's Heppner Wind Project. • Begin design of Morrow Solar Project. • Continue construction of 2 Morrow Energy LLC's Ella 3 Wind Project. • Begin design of Whistling Ridge 230kV Ring Bus Project.	• The decrease reflects decreased planned PFIA capital projects for FY 2021.

Capital Information Technology & Equipment/Capitalized Bond Premium
Funding Schedule by Activity
Funding ($K)

	FY 2019 Actual	FY 2020 Estimate	FY 2021 Estimate	FY 2021 vs FY 2020 $	FY 2021 vs FY 2020 %
Capital Information Technology (IT) & Equipment/Capitalized Bond Premium					
Capital IT & Equipment	10,029	22,100	22,131	32	0.1%
Capitalized Bond Premium	0	0	0	0	0.0%
Total, Capital IT & Equipment/Capitalized Bond Premium	**10,029**	**22,100**	**22,131**	**32**	**0.1%**

Outyears ($K)

	FY 2021 Estimate	FY 2022 Estimate	FY 2023 Estimate	FY 2024 Estimate	FY 2025 Estimate
Capital Information Technology (IT) & Equipment/Capitalized Bond Premium					
Capital IT & Equipment	22,131	22,296	22,268	21,146	20,271
Capitalized Bond Premium	0	0	0	0	0
Total, Capital IT & Equipment/Capitalized Bond Premium	**22,131**	**22,296**	**22,268**	**21,146**	**20,271**

Capital Information Technology & Equipment/Capitalized Bond Premium

Overview

Capital Information Technology (IT) provides for the acquisition of general and some dedicated special purpose capital information technologies, and acquisition of special-use capital and IT equipment in support of Bonneville's strategic objectives. This category also includes Bonneville's on-going efforts to facilitate delivery of a highly resilient organization able to anticipate, withstand, and effectively respond to disruptive events affecting it and its partners in the Northwest region. The four main areas of resiliency focus continue to include asset management, emergency management, crisis management, and continuity of operations.

Bonneville continues to move its IT infrastructure to a more efficient architecture. This FY 2021 Budget supports this effort. IT continues to eliminate redundancies in tools and applications, establish an agency-wide IT architecture with standardized IT purchasing criteria, standardize software licensing processes and minimize agency liabilities through stronger contracts, apply continuous improvement practices to IT project management, and implement an agency IT portfolio cost management strategy. The IT estimates in this FY 2021 Budget under Capital IT and Equipment include all IT functions within the agency except TS grid operations. See the Capital Program – TS section of this budget for additional discussion of grid operations-related IT requirements acquisitions.

Capital equipment provides for the acquisition of general and some dedicated special purchases of capital office furniture and equipment.

Bonneville can incur a bond premium when it repays a U.S. Treasury bond before the due date. When bonds are refinanced and premiums are incurred, the bond premiums can be capitalized. Historically, Bonneville generally has chosen to finance capitalized bond premiums with bonds issued to the U.S. Treasury, as envisioned by the Transmission Act.

Capital Information Technology & Equipment
($K)

FY 2019 Actual	FY 2020 Estimate	FY 2021 Estimate
10,029	22,100	22,131

Overview
This category includes enhancements to Bonneville's information technology processes to provide cost effective efficiencies for secure, timely, and accurate information. Investments will enable continued enhancements to Bonneville's enterprise systems that are designed to link key information systems throughout Bonneville and improve business processes. Current efforts include continued functional process improvements in areas not included in the initial development phase. Other investments include acquisition of capital office furniture and equipment, capital automated data processing (ADP) based administrative telecommunications equipment, ADP equipment (hardware), and support of capital software development for certain Bonneville programs.

Continued investments in Capital IT & Equipment assets include:
Continuous Activity (all years)
Capital system developments in support of:

- Corporate IT Projects
- IT Infrastructure Projects
- Power IT Projects
- Transmission Services IT Projects (excluding grid operations)

Capitalized Bond Premium
($K)

FY 2019 Actual	FY 2020 Estimate	FY 2021 Estimate
0	0	0

Overview
Continue to assess financial market and when cost-effective, refinance available bonds as prudent.

Activities, Milestones, and Explanation of Changes ($K)

FY 2020 Estimate	FY 2021 Estimate	Explanation of Changes FY 2020 vs FY 2019 Estimate
Capital Information Technology & Equipment/Capitalized Bond Premium $22,100	**$22,131**	**$32/0.1%**
Capital Information Technology & Equipment $22,100 Milestones: Capital system developments in support of: • Corporate IT Projects • IT Infrastructure Projects • Power IT Projects • Transmission Services IT Projects	**$22,131** Milestones: Capital system developments in support of: • Corporate IT Projects • IT Infrastructure Projects • Power IT Projects • Transmission Services IT Projects	**$32/0.1%** • Virtually no change for investment in the IT system assets.
Capitalized Bond Premium $0	**$0**	**$0/0.0%**

Power Services – Operating Expense
Funding Schedule by Activity
Funding ($K)

	FY 2019 Actual	FY 2020 Estimate	FY 2021 Estimate	FY 2021 vs FY 2020 $	FY 2021 vs FY 2020 %
Power Services - Operating Expenses					
Production	1,067,952	1,089,284	1,126,600	37,317	3.4%
Associated Projects Costs	460,582	459,646	457,660	-1,986	-0.4%
Fish & Wildlife	227,881	248,988	249,416	428	0.2%
Residential Exchange Program	241,276	257,122	255,399	-1,723	-0.7%
NW Power & Conservation Council	11,275	11,725	11,956	231	2.0%
Energy Efficiency & Renewable Resources	141,582	158,053	156,513	-1,540	-1.0%
Total, Power Services - Operating Expenses	**2,150,547**	**2,224,818**	**2,257,544**	**32,727**	**1.5%**

Outyears ($K)

	FY 2021 Estimate	FY 2022 Estimate	FY 2023 Estimate	FY 2024 Estimate	FY 2025 Estimate
Power Services - Operating Expenses					
Production	1,126,600	1,128,304	1,131,808	1,138,106	1,146,045
Associated Projects Costs	457,660	467,820	478,253	488,870	499,625
Fish & Wildlife	249,416	254,814	260,355	265,993	271,705
Residential Exchange Program	255,399	261,069	266,891	272,816	278,818
NW Power & Conservation Council	11,956	12,221	12,494	12,771	13,052
Energy Efficiency & Renewable Resources	156,513	159,987	163,555	167,186	170,864
Total, Power Services - Operating Expenses	**2,257,544**	**2,284,216**	**2,313,355**	**2,345,743**	**2,380,108**

Power Services – Operating Expense

Overview

Production includes certain Bonneville non-federal debt service (including Energy Northwest debt service), O&M costs for federal base system power system generation resources (including a large nuclear plant (CGS), business operations, and short- and long-term power purchases[3]), electric utility marketing of power, and oversight of the FCRPS hydroelectric projects and CGS. Bonneville develops power products and services to meet the needs of Bonneville's wholesale customers and acquires power as needed.

In FY 2018, Bonneville completed a long-term Resource Program, whose purpose is to assess BPA's future need for power and reserves and to develop an acquisition strategy to meet those projected needs. In the event that Bonneville does acquire output from a generating resource on a long-term basis, Bonneville will comply with section 6 of the Northwest Power Act and will modify its budget to reflect the acquisition.

Associated Projects Costs represents funding for operation and maintenance costs for the FCRPS hydroelectric projects, minor additions, improvements and replacements, and costs of the Corps and the Reclamation hydroelectric projects in the Pacific Northwest, which serve many purposes. All agencies emphasize efficient power production from existing facilities and improvement of the performance and availability of power generating units. Bonneville pays additional financing costs of the FCRPS facilities through its Interest Expense and Capital Transfer budget programs. Bonneville provides funding for the operations and maintenance costs that are part of the USFWS's Lower Snake River Compensation Plan (LSRCP) hatcheries. Bonneville is responsible for annual payments to the Confederated Tribes of the Colville Reservation for their contribution to the production of hydropower by the Grand Coulee Dam in accordance with the Settlement Agreement between the United States and the Colville Tribes (April 1994). Additionally, the Spokane Tribe of Indians of the Spokane Reservation Equitable Compensation Act (Public Law 116-100), enacted on December 20, 2019, provides for equitable compensation to the Spokane Tribe of Indians of the Spokane Reservation for the use of tribal land for the production of hydropower by the Grand Coulee Dam, and for other purposes. Bonneville is pleased that this longstanding issue has been resolved equitably for the Spokane Tribe. The Act provides Bonneville and Northwest electric ratepayers cost certainty on this issue as we move toward discussions of long-term power sales contracts with our utility customers. Bonneville expenditures under the settlement that would begin in FY 2021 are estimated at $6 million annually.

Bonneville's Fish and Wildlife Program provides for extensive protection, mitigation, and enhancement of Columbia River Basin fish and wildlife adversely affected by the development and operation of the FCRPS. Bonneville satisfies its fish and wildlife responsibilities by funding projects and activities designed to be consistent with the Program under the Northwest Power Act. Through the Program, Bonneville also implements measures to aid in the protection of fish and wildlife in the Columbia River and its tributaries, both listed as threatened or endangered as well as unlisted, under the ESA (see ESA discussion in the Power Services – Capital Overview section).

Bonneville's mitigation expenditures will focus on activities that benefit Columbia River Basin fish and wildlife resources, following priorities established through ESA consultations, agreements with resource managers, and the Program, including actions that:

- increase survival of ESA-listed and non-listed fish at FCRPS dams and reservoirs;
- increase survival of ESA-listed and non-listed fish throughout their life cycle by protecting and enhancing important habitat areas;
- protect and enhance important wildlife habitat;
- use hatcheries to contribute to conservation and recovery of ESA-listed and non-listed fish;
- provide offsite mitigation projects and habitat, passage, and other improvements that address factors limiting improvements of target species; and
- support a focused and well-coordinated research, monitoring, and evaluation program.

[3] Including expenses associated with the use of power financial instruments to hedge Bonneville's exposure to market price risk and certain index sales contract provisions as permitted by Bonneville's internal power transacting risk management guidance.

The Energy and Water Development Appropriations Act of 1996 added section 4(h)(10)(D) to the Northwest Power Act, directing the Council to appoint an ISRP "to review a sufficient number of projects" proposed to be funded through Bonneville's annual fish and wildlife budget "to adequately ensure that the list of prioritized projects recommended is consistent with the Program." The Northwest Power Act further states that "in making its recommendations to Bonneville, the Council shall consider the impact of ocean conditions on fish and wildlife populations and shall determine whether the projects employ cost effective measures to achieve program objectives." Today, most mitigation projects funded by Bonneville receive ISRP review as part of the Council recommendation process. The Council has shifted to a multi-year project review cycle during which the ISRP reviews categories of projects grouped together.

The Council's major activities include the periodic preparation of a Northwest Conservation and Electric Power Plan (a 20-year electric energy demand and resources forecast and conservation program – known as the Power Plan) and the Fish and Wildlife Program. The Northwest Power Act directs that expenses of the Council, subject to certain limits based on forecasted Bonneville power sales, shall be included in Bonneville's annual budget to Congress. The cost of funding the Council is recovered through Bonneville's power rates.

Bonneville's Energy Efficiency program promotes the efficient use of energy in the Pacific Northwest and acquires conservation measures as resources. Such actions will: 1) meet energy efficiency targets; 2) achieve a least cost resource mix; 3) lessen the cost impacts of power purchases; 4) avoid the costs of ramping programs and infrastructure up and down; 5) extend the value of the FCRPS to customers; and 6) build the region's resource portfolio with energy efficiency. Bonneville is also exploring how best to integrate demand-side management, distributed generation, and other leading edge technologies into its generation and transmission planning processes.

Bonneville's Energy Efficiency program offers several ways for customer utilities to participate in energy efficiency. Program components include: (1) standard offer efficiency measures and custom projects, which result in customer proposals to conserve energy through such programs as residential weatherization; commercial lighting; heating, ventilation, and air conditioning (HVAC); industrial processes and lighting; and irrigated agriculture; (2) third-party delivery programs, such as Simple Steps Smart Savings, Energy Smart Industrial, and the Green Motors programs; and (3) programs to help regional federal installations reduce energy use, including federal hatcheries and irrigation districts, and to support the Corps of Engineers and Bureau of Reclamation in their efforts to reduce energy use; (4) efficiency achieved independently through the market or through codes and standards, i.e. Momentum Savings; and (5) market transformation through the Northwest Energy Efficiency Alliance (NEEA).

Bonneville's Energy Efficiency budgets reflect BPA's commitment to provide energy efficiency supportive of the Northwest Power and Conservation Planning Council's 7th Power Plan which forecasts regional electricity demand and resource strategies for the next 20 years. The 7th Power Plan's preferred resource strategy calls for the region to acquire 1,400 aMW of energy efficiency between 2016 and 2021. Bonneville is pursuing a plan to achieve a portion of that goal (560-600 aMW). BPA recently updated its Resource Program to complement the Council's plan, identifying BPA's specific electricity demand obligations and potential resource strategies.

In meeting its energy efficiency goals, Bonneville may employ resource acquisition agreements, as authorized by Northwest Power Act section 6, and customer self-funded conservation as well as research, evaluation, contract support, NEEA support, and emerging technology development.

The Residential Exchange Program (REP) was created by section 5(c) of the Northwest Power Act to extend the benefits of low-cost federal power to the residential and small farm loads of Pacific Northwest retail electric utilities that have high average system costs. These benefits are passed directly to the consumers. Currently, the region's six investor-owned utilities (IOUs) and two of the region's consumer-owned utilities are actively participating in the REP. Payments under the REP are made to individual IOUs based on the difference between Bonneville's utility-specific Priority Firm (PF) Exchange rates and each utility's average system cost (ASC), times a utility's residential and small farm loads. ASCs are determined in accordance with BPA's 2008 Average System Cost Methodology (ASCM). Participating retail utility ASCs are established in a public process that occurs prior to and during Bonneville's power rate cases. Bonneville's utility-specific PF Exchange rates are determined each rate period. As described below, Bonneville and regional parties reached a settlement of the REP in

2011 under which the total amount of REP benefits available to the IOUs was established through 2028. Payments to the IOUs are made monthly based on historical invoiced exchange loads and the terms of the settlement.

Over the past decade, and prior to the settlement, regional parties filed multiple lawsuits challenging Bonneville's implementation of the REP. These lawsuits were consolidated into four cases that were stayed before the U.S. Court of Appeals for the Ninth Circuit. On July 26, 2011, Bonneville adopted a regionally supported settlement, referred to as the 2012 REP Settlement. Under the settlement, the region's six IOUs will receive about $4.1 billion in REP payments over the 17-year term of the settlement, beginning at $182.1 million in FY 2012, and increasing to $286.1 million in FY 2028. In addition to this settlement, Bonneville has reached related REP settlements with two consumer-owned utilities. A single challenge to the 2012 REP Settlement was dismissed by the U.S. Court of Appeals for the Ninth Circuit in October of 2013.

Explanation of Changes

Bonneville's budget includes $2,257.5 million in FY 2021 for Power Services operating expenses, which is an increase of 1.5 percent over the FY 2020 forecasted level.

The FY 2021 budget increases the level for Production (+$37.3 million), Fish & Wildlife (+$0.4 million), and Planning Council (+$0.2 million) and decreases the Associated Projects Costs (-$2 million), Residential Exchange (-$1.7 million), and Conservation and Energy Services (-$1.5 million).

Production
($K)

FY 2019 Actual	FY 2020 Estimate	FY 2021 Estimate
1,067,952	1,089,284	1,126,600

Overview

Power Purchases: Includes power purchased to cover power sales obligations as well as balancing loads with generation from the hydro system. These power purchases can be made in the form of long-term purchases to meet BPA's contract obligations to its utility and other customers based on long-term planning requirements or they can be made within the year due to the monthly shape of the customers' loads and the monthly shape of the hydroelectric generation. Also, power purchases can be made within the month and within the day to fill temporary shortages due to fluctuations in the hydro system capability and in BPA's load.

Power Scheduling/Marketing: Scheduling and marketing (buy/sell) of electric energy with Bonneville's customers and the Pacific Northwest's interconnected utilities. Scheduling includes Power Services' implementation of physical and memo power schedules and associated transmission schedules, implementation of Electronic Tagging (ETag) in accordance with NERC and in accordance with FERC, and implementation of electronic scheduling.

Columbia Generating Station (CGS): Bonneville has acquired full lifetime project capability of CGS. CGS is on a 24-month fuel and outage cycle. Maintenance and refueling outage occurred in the spring of 2017 and 2019.

Continued investments in Production include:
Continuous Activity (all years)

- Provide oversight of all power supply contracts and related projects from which Bonneville purchases generation capability to ensure that all Bonneville approval rights are protected; coordinate, communicate, and administer agreements, issues, and programs between Bonneville and the project owners.
- Provide wind resource integration services for wind generation.
- Power Purchases.
- Power Scheduling/Marketing.
- Provide oversight of all contracts signed to date. Pursue cost-effective means to mitigate capacity demands associated with interconnecting large amounts of wind into the Bonneville system.
- Pursue acquisition of additional cost-effective generation to meet load growth.
- Provide oversight on the wind resource integration services currently purchased by public power customers and offer additional renewable resource shaping services to such customers using wind generation to serve their load.

Associated Projects
($K)

FY 2019 Actual	FY 2020 Estimate	FY 2021 Estimate
460,582	459,646	457,660

Overview

Support FCRPS project costs and work to strengthen interagency and regional relationships to improve project performance, supporting functions, and to better understand project resource requirements and costs. This helps to maintain FCRPS reliability and system performance, as well as to attain Bonneville's strategic business objectives.

Continued investments in Associated Projects include:

Continuous Activity (all years)

Bureau of Reclamation:

- Continue direct funding Reclamation O&M power activities.

Corps of Engineers:

- Continue direct funding Corps O&M power activities.

Fish & Wildlife
($K)

FY 2019 Actual	FY 2020 Estimate	FY 2021 Estimate
227,881	248,988	249,416

Overview

Bonneville implements a mature fish and wildlife mitigation program based on recommendations made by the region's fish and wildlife management agencies and tribes to the Council. Several recent Council reviews have made additional fish and wildlife project recommendations to Bonneville. Bonneville, in coordination with the Council, reviews new and on-going projects for consistency with the Program and purposes of the Northwest Power Act. Bonneville reviews and resets project-specific funding commitments annually, including projects under the FCRPS BiOps and other agreements. Bonneville informs its funding decisions with the management objectives and priorities in the Program (including ISRP reviews) and the Accord extensions as it integrates their implementation with actions necessary to fulfill ESA responsibilities. Regular coordination on implementation priorities continues among Bonneville, the Council, federal resource management agencies, states, Tribes, and others.

Continued investments in Fish &Wildlife include:
Continuous Activity (all years)

- Anadromous Fish: Continue implementing both ongoing and new projects that support ESA-listed species and other measures called for under the 2019 FCRPS BiOp, the Washington Estuary Agreement, the Kalispel Agreement, and the Willamette and Southern Idaho agreements and 2018 Fish Accord extensions. Prioritize projects that address the factors that contribute most to mitigation success and that fulfill Bonneville's responsibility for mitigating the impacts from the FCRPS. Implement and develop activities that protect and enhance tributary and estuary habitat, improve mainstream habitat, reduce potentially harmful hatchery practices on ESA-listed populations, and contribute to sustainable fisheries.
- Resident Fish: Implement activities to mitigate the impacts of the FCRPS on lamprey, sturgeon, and bull trout and promote the reproduction and recruitment of Kootenai River white sturgeon. These activities have been selected in response to the USFWS's 2000 bull trout and 2006 Libby BiOp, the Program, and the 2018 Fish Accord extensions.
- Mitigation using resident fish to offset anadromous fish losses (substitution): mitigate for reservoir power operation impacts to resident fish and wildlife by seeking projects that benefit both simultaneously. Those resident fish habitat acquisition projects that meet Bonneville's Capitalization Policy will be funded under the capital portion of Bonneville's Fish and Wildlife budget and credited for both fish and wildlife where appropriate.
- Wildlife: Use existing Bonneville policies to continue the current effort to mitigate wildlife in a manner consistent with the Program and fulfill commitments in wildlife agreements such as the Kalispel Agreement, Willamette Wildlife Agreement, and Southern Idaho Wildlife Agreement. Those wildlife projects that meet Bonneville's Capitalization Policy will be funded under the capital portion of Bonneville's Fish and Wildlife budget and credited against both wildlife and fish obligations according to Bonneville's crediting policy and applicable mitigation contracts.

Residential Exchange, Northwest Power and Conservation Council, and Energy Efficiency & Renewable Resources

($K)

FY 2019 Actual	FY 2020 Estimate	FY 2021 Estimate
394,133	426,900	423,868

Overview

Residential Exchange Program (REP)

- Includes forecasted REP benefits based on the 2012 REP Settlement.

Northwest Power and Conservation Council

- Continue support of the Council activities, as directed under the Northwest Power Act, including regional power plan development and maintenance and fish and wildlife program activities.

Energy Efficiency Resources

- Conservation Purchases: Provide programmatic savings reimbursements and energy efficiency incentives to Bonneville customers to purchase conservation savings. This includes performance payments and Energy Smart Reserved Power payments for federal installations and fish hatcheries and irrigation districts.

- Conservation Infrastructure: All support for programs and operations, including third-party program implementation, contract support, market research (Momentum Savings research), evaluation, and emerging technology research.

- Market Transformation: Support for NEEA's market transformation initiatives. NEEA identifies barriers and opportunities to increase the market adoption of efficiency by leveraging its regional partnerships.

Activities, Milestones, and Explanation of Changes ($K)

FY 2020 Estimate	FY 2021 Estimate	Explanation of Changes FY 2021 vs FY 2020 Estimate
Power Services - Operating Expense $2,224,818	**$2,257,544**	**$32,727/1.5%**
Production $1,089,284 Milestones: • Continue to provide oversight of all signed contracts. • Continue to provide wind resource integration services for customer wind generation.	**$1,126,600** Milestones: • Continue to provide oversight of all signed contracts. • Continue to provide wind resource integration services for customer wind generation.	**$37,317/3.4%** • The increase is primarily due to higher CGS and support costs.
Associated Project Costs $459,646 Milestones: • Continue direct funding of Corps and Reclamation O&M power activities.	**$457,660** Milestones: • Continue direct funding of Corps and Reclamation O&M power activities.	**$-1,986/-0.4%** • The small decrease reflects changes to security, biological opinion requirements, non-routine extraordinary maintenance, WECC/NERC compliance activities, and improvements, replacements, and minor additions at the projects.
Fish & Wildlife Costs $248,988 Milestones: • Continue implementing both ongoing and new projects that support ESA-listed species and other measures called for under the 2008, 2010, and 2014 FCRPS BiOps, the 2018 Fish Accord extensions, the Washington Estuary Agreement, the Kalispel Agreement, the Southern Idaho Agreement, and the Willamette Agreement.	**$249,416** Milestones: • Continue implementing both ongoing and new projects that support ESA-listed species and other measures called for under the 2008, 2010, and 2014 FCRPS BiOps, the 2018 Fish Accord extensions, the Washington Estuary Agreement, the Kalispel Agreement, the Willamette Agreement, and the Southern Idaho Agreement.	**$428/0.2%** • No material change in funding. The costs reflect funding associated with the Biological Opinions, 2018 Fish Accord extension commitments, and Northwest Power Act activities.

FY 2020 Estimate	FY 2021 Estimate	Explanation of Changes FY 2021 vs FY 2020 Estimate
Residential Exchange Program $257,122 Milestones: • Continue to provide REP benefits.	**$255,399** Milestones: • Continue to provide REP benefits.	**$-1,723/-0.7%** • The decrease reflects the lower scheduled in the amount of REP payments payable to the IOUs prescribed by the Residential Exchange Settlement.
NW Power & Conservation Council $11,725 Milestones: • Continue support of the Council activities, as directed under the Northwest Power Act, including regional power plan development and maintenance, and fish and wildlife program activities.	**$11,956** Milestones: • Continue support of the Council activities, as directed under the Northwest Power Act, including regional power plan development and maintenance, and fish and wildlife program activities.	**$231/2.0%** • No material change in funding. The increase reflects continuing emphasis on the NW Power and Conservation Council.
Energy Efficiency & Renewable Resources $158,053 Milestones: • Continue close-out of the legacy conservation resource acquisition contracts, which support Bonneville's contractual obligation to serve customer loads. • Continue to support utility incentive programs. • Continue to support regional energy efficiency programs. • Continue supporting energy efficiency at direct serve federal agencies.	**$156,513** Milestones: • Continue close-out of the legacy conservation resource acquisition contracts, which support Bonneville's contractual obligation to serve customer loads. • Continue to support utility incentive programs. • Continue to support regional energy efficiency programs. • Continue supporting energy efficiency at direct serve federal agencies.	**$-1,540/-1.0%** • The decrease reflects our cost cutting effort while continuing emphasis on the energy efficiency program consistent with the Power Plan.

Transmission Services – Operating Expense
Funding Schedule by Activity
Funding ($K)

	FY 2019 Actual	FY 2020 Estimate	FY 2021 Estimate	FY 2021 vs FY 2020 $	FY 2021 vs FY 2020 %
Transmission Services - Operating Expense					
Engineering	77,418	76,289	82,689	6,399	8.4%
Operations	193,500	199,231	193,883	-5,348	-2.7%
Maintenance	207,553	204,652	205,039	387	0.2%
Total, Transmission Services - Operating Expense	**478,471**	**480,172**	**481,610**	**1,438**	**0.3%**

Outyears ($K)

	FY 2021 Estimate	FY 2022 Estimate	FY 2023 Estimate	FY 2024 Estimate	FY 2025 Estimate
Transmission Services - Operating Expense					
Engineering	82,689	84,362	86,076	87,820	89,585
Operations	193,883	196,679	199,531	202,424	205,351
Maintenance	205,039	208,412	211,858	215,358	218,901
Total, Transmission Services - Operating Expense	**481,610**	**489,453**	**497,466**	**505,602**	**513,837**

Transmission Services – Operating Expense

Overview

This activity provides for the transmission system services of engineering, operations, and maintenance for Bonneville's electric transmission system, and the associated power system control and communication facilities. Primary goals of this program are: 1) maintain the safety and reliability of the transmission system; 2) increase the focus on meeting customers' needs; 3) optimize the transmission system; 4) provide open and non-discriminatory transmission access; and 5) improve Bonneville's cost effectiveness. Consistent with the FY 2018, FY 2019, and FY 2020 Budget Requests, the FY 2021 Budget Request maintains the proposal that the Federal government be authorized to sell the transmission assets of Bonneville.

Explanation of Changes

Bonneville's budget includes $481.6 million in FY 2021 for TS operating expense which is a 0.3 percent increase over the FY 2020 forecasted level. The increase still continues the operation and maintenance of Bonneville's transmission assets.

The FY 2021 budget increases the levels for Engineering (+$6.4 million) and Maintenance (+$0.4 million) and decreases the level for Operations (-$5.3 million).

Engineering
($K)

FY 2019 Actual	FY 2020 Estimate	FY 2021 Estimate
77,418	76,289	82,689

Overview
Continue efforts to identify best methods for improving system reliability and maintenance practices, and continue cost reduction efforts by identifying opportunities for low-cost reinforcement and voltage support of the existing transmission system.

Continued investments in Engineering include:
Continuous Activity (all years)

- Research and Development (R&D): Conduct research focused on technologies related to business challenges Bonneville faces including reliability, energy efficiency, and integration of renewable energy resources. Technologies of interest are identified in Bonneville's Technology Roadmaps. A portfolio of research is selected every year through Bonneville's Portfolio Decision Framework.

- System Development Planning and Analysis: Continue providing technical support and asset planning to deploy the Asset Management approach to sustain existing assets and expand the system to meet Agency objectives.

- Technical Support: Provide technical support activities, such as transmission system planning and studies to optimize portions of the system. Provide support for non-wires solutions studies and pilot projects.

- Capital-to-Expense Adjustments: Conduct annual analysis of Bonneville's outstanding capital work orders to assess whether they should be expensed. As obsolete inventory is identified and disposed of, it is expensed.

- Regulatory Fees: WECC dues and loop flow payments, Department of Commerce/National Telecommunications and Information Administration licensing costs for radio frequencies, DOE Radio Spectrum staff and contractor support, and NERC Critical Infrastructure Protection (CIP) compliance program costs. Includes membership in ColumbiaGrid, a transmission planning organization in the region.

- Reimbursable Transactions: Enter into written agreements with federal and non-federal entities that have work or services to be performed by Bonneville staff at the expense of the benefiting entities. The projects must be beneficial, under agreed upon criteria, to Bonneville operations and to the federal or non-federal entity involved or otherwise be aligned with or supportive of Bonneville's strategic objectives. Additionally, these activities generally contribute to more efficient or reliable construction of the federal transmission system or otherwise enhance electric service to the region.

- Leased and Other Costs: Includes leases, lease purchases, and other costs of financing transmission, delivery, and voltage support facilities when such arrangements are operationally feasible and cost effective to deliver power. Leases and lease purchases enable Bonneville to continue to invest in infrastructure to support a safe and reliable system for the transmission of power. Other costs included are the accrued interest costs associated with Large Generator Interconnection Agreements (LGIA).

Operations ($K)		
FY 2019 Actual	FY 2020 Estimate	FY 2021 Estimate
193,500	199,231	193,883

Overview

Substation Operations: Perform operations functions necessary to provide electric service to customers and to protect the federal investment in electric equipment and other facilities. Includes equipment adjustments, switching lines and equipment during emergencies or maintenance, isolating damaged equipment, restoring service to customers, inspecting equipment, and reading meters.

Power System Dispatching and Supporting Functions: Perform central dispatching, control, and monitoring of the electric operation of the federal transmission system. Also includes load, frequency, and voltage control of federal generating plants, and coordinating long- and short-term outages of system equipment. In addition, provides technical engineering support of dispatching function and provides all technical and systems support for Dittmer Control Center (DCC) and Munro Control Center (MCC).

Marketing and Sales: Provide management and direction of transmission rates, and provide business strategy in marketing of transmission and ancillary products and services of Transmission Services. Involve customers and constituents in the process of product and rate development. Maintain accurate and complete historical records of current and past legacy transmission agreements. Provide guidance for current and future transmission contract negotiations. Provide financial analysis of market strategies. Monitor and report on the financial health of Transmission Services. Support cost management by effective reporting and analysis of current expenditures. Ensure official budget submittals reflect current management financial strategies and adequately fund transmission programs.

Transmission Scheduling: Provide non-discriminatory, open access to the Bonneville transmission system consistent with Bonneville's Open Access Transmission Tariff (OATT). Schedule transmission capacity to eligible Bonneville customers, which include customers acquiring services under Use of Facilities (UFT), Formula Power Transmission (FPT), Integration of Resources (IR), and Part II or Part III of the OATT. Manage the reservations and scheduling of all transmission services associated with the OATT. Update practices, policies, and commercial systems to accommodate a large diversity of resources, including wind.

Continuous Activity (all years):

- Continue to operate within parameters of NERC and WECC.
- Continue support of increased compliance activities related to the reliability of the transmission system, including cyber security.
- Continue developing facilities, policies, procedures, and implementing systems to support integrating the diversity of resources into the transmission grid.
- Continue preparation for increased complexity of transmission scheduling, power system operations, and dispatching, including congestion management and outage scheduling.
- Continue developing the Dittmer Scheduling Center and Munro Scheduling Center facilities to support continuous real time scheduling operations from both facilities.
- Continue developing a long-term approach to optimize transmission availability through streamlined, cost-effective, and sustainable processes.
- Continue to address succession planning issues across key functions.
- Continue development and implementation of business systems and tools.

Maintenance ($K)		
FY 2019 Actual	FY 2020 Estimate	FY 2021 Estimate
207,553	204,652	205,039

Overview

In all aspects of maintenance, Bonneville is continuing the use of Reliability Centered Maintenance (RCM) practices. The use of RCM practices is focused on improving system reliability, increasing availability, and meeting new and existing compliance regulations at lowest lifecycle costs. In addition Bonneville is deploying Asset Management to optimize maintain/replace decision making. Maintenance costs are expected to increase as Bonneville addresses the aging transmission system, meeting reliability standards, including vegetation management, and environmental constraints associated with construction, enhancement, and maintenance of the system. The Bonneville transmission system encompasses 15,238 circuit miles on over 11,860 right-of-way miles (many of these miles are through rugged, inaccessible terrain).

Continued investments in Maintenance include:

Continuous Activity (all years)

- Continue to improve performance to meet System Average Interruption Frequency Index (SAIFI) and System Average Interruption Duration Index (SAIDI) targets.
- Continue refining processes and procedures for monitoring and tracking compliance activities related to the reliability of the transmission system.
- Continue to improve system availability performance through new maintenance procedures and work practices.
- Continue to develop and implement work practices and procedures for implementation of a new specialty crew using bare-hand live line practices for maintenance of high-voltage transmission lines.
- Continue increased emphasis on replacement of line hardware (life extension programs for insulators, connectors, dampers, and fiber optic cable hardware).
- Continue to prepare for the impact of an expected high attrition rate among Bonneville's aging workforce by recruiting apprentices and replacements for critical minimum crew size workload positions.
- Increase outage-scheduling planning and coordination to increase customer satisfaction and system availability.
- Maintain vegetation management levels to ensure system reliability.
- Continue access road work to provide reliable access to facilities and ensure environmental compliance.
- Continue improving environmental stewardship.

Transmission Line Maintenance: Maintain and repair 15,238 circuit miles of high voltage transmission lines, of which over 4,734 circuit miles are 500 kV transmission extra-high voltage (EHV). Maintenance of EHV lines is two and one-half times more labor-intensive than maintenance of lower transmission voltages, although more efficient in transmission of power. This responsibility includes maintaining transmission rights-of-way to ensure system reliability, safety, and environmental compliance. Adopt work practices that improve system availability, reliability, and compliance.

Right-of-Way Maintenance: Maintain over 11,860 of Bonneville's right-of-way miles. This responsibility includes vegetation management, danger tree management, and access road maintenance to ensure system reliability, safety, and environmental compliance. Adopt procedures and processes that improve system availability, reliability, environmental compliance, and reliability compliance. Continue to deploy new technologies such as LiDAR (Light Detection and Ranging) to reliably and cost-effectively manage vegetation.

Substation Maintenance: Maintain and repair the transmission system power equipment located in Bonneville's 260 substations. Work includes inspections, diagnostic testing, and predictive and condition-based maintenance.

System Protection Maintenance: Maintain relaying metering and remedial action scheme equipment used to control and protect the electrical transmission system and to meter energy transfers for the purpose of revenue billing. Additionally,

field-engineering services provide technical advice and assure the correct operation of power system relaying and special control systems used to support interregional energy transmission capabilities.

Power System Control Maintenance: Test, repair, and provide field engineering support of Bonneville's highly complex equipment, communications, and control systems, including seven major microwave systems, fiber optic systems, and other critical communications and control equipment that support the power system.

Non-Electric Plant Maintenance: Maintain and manage Bonneville's non-electric facilities. Includes site, building, and building utility maintenance; custodial services; station utility; and other maintenance service activities, as well as facilities asset management on Bonneville-owned or Bonneville-leased non-electric facilities.

Maintenance Standards and Engineering: Establish, monitor, and update system maintenance standards, policies, and procedures, and review and update long-range plans for maintenance of the electric power transmission system.

Activities, Milestones, and Explanation of Changes ($K)

FY 2020 Estimate	FY 2021 Estimate	Explanation of Changes FY 2021 vs FY 2020 Estimate
Transmission Services - Operating Expense $480,172	**$481,610**	**$1,438/0.3%**
Engineering $76,289 Milestones: • Continue efforts to identify best methods for improving system reliability and maintenance practices. • Continue cost reduction efforts by identifying opportunities for low-cost reinforcement and voltage support of the existing transmission system.	**$82,689** Milestones: • Continue efforts to identify best methods for improving system reliability and maintenance practices. • Continue cost reduction efforts by identifying opportunities for low-cost reinforcement and voltage support of the existing transmission system.	**$6,399/8.4%** • The increase reflects continued emphasis on system reliability standards compliance and research and development.
Operations $199,231 Milestones: • Continue to operate within parameters of NERC and WECC. • Continue support of increased compliance activities related to the reliability of the transmission system including cyber security.	**$193,883** Milestones: • Continue to operate within parameters of NERC and WECC. • Continue support of increased compliance activities related to the reliability of the transmission system including cyber security.	**$-5,348/-2.7%** • The decrease reflects our tightening costs effort and emphasis on reliability compliance activities, resource integration activities, key strategic initiative, security, and control center systems support.
Maintenance $204,652 Milestones: • Continue to improve performance to meet System Average Interruption Frequency Index (SAIFI) and System Average Interruption Duration Index (SAIDI) targets.	**$205,039** Milestones: • Continue to improve performance to meet System Average Interruption Frequency Index (SAIFI) and System Average Interruption Duration Index (SAIDI) targets.	**$387/0.2%** • The increase reflects implementation of facilities asset management plans, continued implementation of live-line crew, NERC/WECC compliance activities related to land rights and vegetation management, continuing maintenance program activities, including system protection, right-of-way, line maintenance, and performance improvements.

Interest, Pension, and Post-retirement Benefits
Operating Expense
Funding Schedule by Activity
Funding ($K)

	FY 2019 Actual	FY 2020 Estimate	FY 2021 Estimate	FY 2021 vs FY 2020 $	FY 2021 vs FY 2020 %
Interest, Pension, and Post-retirement Benefits					
BPA Bond Interest (Net)	179,453	119,928	138,612	18,684	15.6%
BPA Appropriation Interest	30	0	0	0	0.0%
Corps of Engineers Appropriation Interest	51,130	54,930	57,490	2,560	4.7%
Lower Snake River Comp Plan Interest	183	139	139	0	0.0%
Bureau of Reclamation Appropriation Interest	1,153	1,150	1,150	0	0.0%
Bond Premiums Paid/Discounts (not capitalized)	(288)	559	559	0	0.0%
Subtotal, Interest – Operating Expense	**231,662**	**176,705**	**197,950**	**21,245**	**12.0%**
Additional Pension, and Post-retirement Benefits	41,298	38,015	40,124	2,109	5.5%
Total, Interest, Pension, and Post-retirement Benefits	**272,960**	**214,720**	**238,074**	**23,354**	**10.9%**

Outyears ($K)

	FY 2021 Estimate	FY 2022 Estimate	FY 2023 Estimate	FY 2024 Estimate	FY 2025 Estimate
Interest, Pension, and Post-retirement Benefits					
BPA Bond Interest (Net)	138,612	203,498	232,442	261,073	295,652
BPA Appropriation Interest	0	0	0	0	0
Corps of Engineers Appropriation Interest	57,490	58,180	59,077	60,631	63,530
Lower Snake River Comp Plan Interest	139	139	139	139	139
Bureau of Reclamation Appropriation Interest	1,150	1,150	1,150	1,150	1,150
Bond Premiums Paid/Discounts (not capitalized)	559	9,411	12,470	1,951	559
Subtotal, Interest – Operating Expense	**197,950**	**272,379**	**305,278**	**324,944**	**361,029**
Additional Pension, and Post-retirement Benefits	40,124	41,015	41,929	42,860	43,803
Total, Interest, Pension, and Post-retirement Benefits	**238,074**	**313,394**	**347,207**	**367,804**	**404,833**

Interest, Pension and Post-retirement Benefits
Operating Expense

Overview

Interest expense provides for interest due on bonds issued to the U.S. Treasury and appropriations repayment responsibilities. The appropriation repayments relate to capital investment in FCRPS hydroelectric generating and transmission facilities of Bonneville, and the Corps and Reclamation. Investments were financed by Congressional appropriations and Bonneville borrowings from the U.S. Treasury. Bonneville repays these amounts through revenue raised in its power sales and transmission services revenues.

Since initially receiving U.S. Treasury borrowing authority in 1974 under the Transmission Act, all of Bonneville's U.S. Treasury borrowing has been at market rates. As of October 1, 1996, all of Bonneville's repayment obligations on FCRPS appropriated investment (Corps and Reclamation FCRPS investment and Bonneville investment financed with appropriations prior to the Transmission Act that were unpaid as of September 30, 1996) were restructured and assigned new current-market interest rates. The Bonneville Appropriations Refinancing Act of 1996 (Refinancing Act) called for re-setting (reducing) the unpaid principal of FCRPS appropriations and reassigning (increasing) interest rates. New principal amounts were established as of the beginning of FY 1997 at the present value of the principal and annual interest payments Bonneville would make to the U.S. Treasury for these obligations in the absence of the legislation, plus $100.0 million. The new principal amounts were assigned prevailing market interest rates as of October 1, 1996. Bonneville's outstanding appropriations repayment obligations at the end of FY 1996 were $6.7 billion with a weighted average interest rate of 3.4 percent. The refinancing reduced the principal amount to $4.1 billion with a weighted average interest rate of 7.1 percent. Implementation of the refinancing took place in 1997 after audited actual financial data were available. Pursuant to the legislation, Bonneville submitted its calculations and interest rate assignments implementing the Refinancing Act to the U.S. Treasury for its review and approval. The U.S. Treasury approved the implementation calculations in July 1997. The Refinancing Act also calls for all future FCRPS appropriations to be assigned prevailing U.S. Treasury yield curve interest rates. Bonneville's outstanding appropriations may be prepaid prior to their stated maturities.

Interest estimates are a function of costs of U.S. Treasury borrowing to Bonneville, repayment status of outstanding FCRPS investments, and projected additions to FCRPS plant in service. These estimates may change over time depending on forecasted market conditions. The interest cost estimates include the impact of Bonneville's appropriation refinancing legislation.

Federal employees associated with the operation of the FCRPS participate in either the Civil Service Retirement System or the Federal Employees Retirement System. Employees may also participate in the Federal Employees Health and Benefit Program and the Federal Employee Group Life Insurance Program. As a Federal agency, all post-retirement activity is managed by the Office of Personnel Management; therefore, neither the assets of the plans or the accumulated plan benefits are recorded by Bonneville. Since 1997, Bonneville has made additional annual contributions to the General Fund of the U.S. Treasury (receipt account 892889) related to the Federal post-retirement benefit programs provided to employees associated with the operation of the FCRPS.

Capital Transfers
Funding Schedule by Activity
Funding ($K)

	FY 2019 Actual	FY 2020 Estimate	FY 2021 Estimate	FY 2021 vs FY 2020 $	FY 2021 vs FY 2020 %
Capital Transfers					
BPA Bond Amortization[1]	506,000	350,933	401,721	50,788	14.5%
Reclamation Appropriation Amortization	2,976	0	0	0	0.0%
BPA Appropriation Amortization	421	0	0	0	0.0%
Corps Appropriation Amortization	224,033	0	0	0	0.0%
Lower Snake River Comp Plan Amortization	74	0	0	0	0.0%
Total, Capital Transfers	733,505	350,933	401,721	50,788	14.5%

Outyears ($K)

	FY 2021 Estimate	FY 2022 Estimate	FY 2023 Estimate	FY 2024 Estimate	FY 2025 Estimate
Capital Transfers					
BPA Bond Amortization[1]	401,721	370,837	329,598	313,705	300,902
Reclamation Appropriation Amortization	0	0	0	0	0
BPA Appropriation Amortization	0	0	0	0	0
Corps Appropriation Amortization	0	0	0	0	0
Lower Snake River Comp Plan Amortization	0	0	0	0	0
Total, Capital Transfers	401,721	370,837	329,598	313,705	300,902

Overview

This activity conveys funds to the U.S. Treasury for repayment of certain FCRPS costs not included in the Associated Project Costs budget. Since capital transfers are cash transactions, they are not considered budget obligations.

[1] Bonneville "Bond(s)" in this FY 2021 Budget refers to all bonds issued by Bonneville to and advances received from the U.S. Treasury. This reference is consistent with section 13(a) of the Transmission Act (P.L. 93-454), which defines Bonneville bonds as all bonds, notes, and other evidences of indebtedness issued and sold by Bonneville to the U.S. Treasury.

Additional Tables

BONNEVILLE POWER ADMINISTRATION
TOTAL OBLIGATIONS/OUTLAYS
Current Services
(in millions of dollars)

BP-1 SUMMARY[1/3/]	FISCAL YEAR									
	2019		2020		2021		2022	2023	2024	2025
	Oblig.	Outlays	Oblig.	Outlays	Oblig.	Outlays	Oblig.	Oblig.	Oblig.	Oblig.
1 Residential Exchange Program	241	241	257	257	255	255	261	267	273	279
2 Power Services[2/]	1,595	1,595	1,550	1,550	1,585	1,585	1,596	1,610	1,627	1,646
3 Transmission Services	671	671	949	949	956	956	957	1,005	1,031	1,001
4 Conservation & Energy Efficiency	142	142	158	158	157	157	160	164	167	171
5 Fish & Wildlife	250	250	296	296	297	297	298	303	306	312
6 Interest/ Pension[4/]	273	273	215	215	238	238	313	347	368	405
7 Associated Project Cost - Capital	200	200	238	238	256	256	281	300	306	313
8 Capital Equipment	10	10	22	22	22	22	22	22	21	20
9 Planning Council	11	11	12	12	12	12	12	12	13	13
10 Projects Funded in Advance	239	239	86	86	66	66	60	40	40	41
11 Capitalized Bond Premiums	0	0	0	0	0	0	0	0	0	0
12 **TOTAL OBLIGATIONS/ OUTLAYS**[3/]	**3,631**	**3,631**	**3,783**	**3,783**	**3,844**	**3,844**	**3,962**	**4,070**	**4,152**	**4,200**

REVENUES AND REIMBURSEMENTS

Current Services

(in millions of dollars)

	BP-1 SUMMARY	FISCAL YEAR									
		2019		2020		2021		2022	2023	2024	2025
		Oblig.	Outlays	Oblig.	Outlays	Oblig.	Outlays	Oblig.	Oblig.	Oblig.	Oblig.
13	Revenues [5/]	3,684	3,684	3,860	3,860	3,888	3,888	3,934	3,977	3,992	4,016
14	Project Funded in Advance	239	239	86	86	66	66	60	40	40	41
15	**TOTAL**	**3,923**	**3,923**	**3,946**	**3,946**	**3,954**	**3,954**	**3,994**	**4,017**	**4,032**	**4,057**
16	**BUDGET AUTHORITY (NET) [6/]**	**(4)**		**425**		**398**		**443**	**543**	**579**	**559**
17	**OUTLAYS (NET) [6/7/8]**		**67**		**(163)**		**(110)**	**(33)**	**53**	**120**	**143**

These notes are an integral part of this table.

[1/] This FY 2021 budget includes capital and expense estimates based on final spending proposals from Bonneville's 2018 IPR process.

Capital funding levels reflect external factors such as the significant changes affecting West Coast power and transmission markets, along with planned infrastructure investments designed to address the long-term needs of the region.

Budget estimates included in this budget are subject to change due to rapidly changing economic and institutional conditions in the evolving electric utility industry.

[2/] Power Services doesn't include Fish & Wildlife, Residential Exchange Program, Planning Council, Conservation & Energy Efficiency and Associated Project Costs which have been shown separately for display purposes.

[3/] This budget has been prepared in accordance with PAYGO. Under PAYGO all Bonneville budget estimates are treated as mandatory and are not subject to the discretionary caps included in the Budget Control Act of 2011. These estimates support activities that are separate from discretionary activities and accounts. Thus, any changes to Bonneville estimates cannot be used to affect any other budget categories which have their own dollar caps. Because Bonneville's obligations are and will be incurred under pre-existing legislative authority, Bonneville is not subject to a "pay-as-you-go" test regarding its revision of current-law funding estimates.

[4/] See Interest Expense, Pension and Post-retirement Benefits and Capital Transfers section of this budget for a complete discussion of these cost estimates.

[5/] Revenues, included in the Net Outlay formulation, are calculated consistent with cash management goals and assume a combination of adjustments. Assumed adjustments include the use of a combination of tools, including upcoming rate adjustment mechanisms, a net revenue risk adjustment, debt service refinancing strategies and/or short-term financial tools to manage net revenues and cash. Some of these potential tools will reduce costs rather than generate revenue, causing the same Net Outlay result. Adjustments for depreciation and 4(h)(10)(C) credits of the Northwest Power Act are also assumed.

[6/] Bonneville received $48.7 million of additional budget authority in FY 2007 to accommodate the work necessary to relocate the radio spectrum consistent with the Commercial Spectrum Enhancement Act (P.L. 108-494). In accordance with Federal law, Bonneville plans to return the forecasted unused balance of approximately $8.2 million to the U.S. Treasury as soon as the National Telecommunications Information Administration notifies the Federal Communications Commission that the DOE relocation effort is complete.

[7/] Net Outlay estimates are based on current cost savings to date and anticipated cash management goals. They are expected to follow anticipated management decisions throughout the rate period that, along with actual market conditions, will impact revenues and expenses. Actual Net Outlays are volatile and are reported in Report on Budget Execution and Budgetary Resources (SF-133). Actual Net Outlays could differ from estimates due to changing market conditions, streamflow variability, continued restructuring of the electric industry, and other reasons.

[8/] FY 2019 Net Outlays are calculated using Bonneville's audited actual revenue. FYs 2020 to 2025 Net Outlays are based on 2018 final IPR assumptions and an escalation factor from using the FY 2018 White Book Loads and Resources Report

EXPENSED OBLIGATIONS/OUTLAYS [1,4/]
Current Services
(in millions of dollars)
FISCAL YEAR

BP-2	2019		2020		2021		2022	2023	2024	2025
	Oblig.	Outlays	Oblig.	Outlays	Oblig.	Outlays	Oblig.	Oblig.	Oblig.	Oblig.
1 Residential Exchange Program	241	241	257	257	255	255	261	267	273	279
2 Power Services [2/]	1,595	1,595	1,550	1,550	1,585	1,585	1,596	1,610	1,627	1,646
3 Transmission Services	478	478	480	480	482	482	489	497	506	514
4 Conservation & Energy Efficiency	142	142	158	158	157	157	160	164	167	171
5 Fish & Wildlife	228	228	249	249	249	249	255	260	266	272
6 Interest/ Pension [3/]	273	273	215	215	238	238	313	347	368	405
7 Planning Council	11	11	12	12	12	12	12	12	13	13
8 TOTAL EXPENSE	2,968	2,968	2,921	2,921	2,978	2,978	3,087	3,158	3,219	3,299
9 Projects Funded in Advance	239	239	86	86	66	66	60	40	40	41

CAPITAL OBLIGATIONS/OUTLAYS [1/]

Current Services

(in millions of dollars)

FISCAL YEAR

BP-2 continued	2019		2020		2021		2022	2023	2024	2025
	Oblig.	Outlays	Oblig.	Outlays	Oblig.	Outlays	Oblig.	Oblig.	Oblig.	Oblig.
10 Transmission Services	192	192	469	469	474	474	468	507	525	487
11 Associated Project Cost	200	200	238	238	256	256	281	300	306	313
12 Fish & Wildlife	22	22	47	47	47	47	43	43	40	40
13 Capital Equipment	10	10	22	22	22	22	22	22	21	20
14 Capitalized Bond Premiums	0	0	0	0	0	0	0	0	0	0
15 **TOTAL CAPITAL INVESTMENTS**	**424**	**424**	**776**	**776**	**800**	**800**	**814**	**872**	**893**	**860**
16 **TREASURY BORROWING AUTHORITY TO**										
17 **FINANCE CAPITAL OBLIGATIONS [4/]**	**424**		**776**		**800**		**814**	**872**	**893**	**860**

These notes are an integral part of this table.

[1/] This FY 2021 budget includes capital and expense estimates based on final spending proposals from Bonneville's 2018 IPR process.

Capital funding levels reflect external factors such as the significant changes affecting West Coast power and transmission markets, along with planned infrastructure investments designed to address the long-term needs of the region.

Budget estimates included in this budget are subject to change due to rapidly changing economic and institutional conditions in the evolving electric utility industry.

[2/] Power Services doesn't include Fish & Wildlife, Residential Exchange Program, Planning Council, Conservation & Energy Efficiency and Associated Project Costs which have been shown separately for display purposes.

[3/] See Interest Expense, Pension and Post-retirement Benefits and Capital Transfers section of this budget for a complete discussion of these cost estimates.

[4/] This budget has been prepared in accordance with PAYGO. Under PAYGO all Bonneville budget estimates are treated as mandatory and are not subject to the discretionary caps included in the Budget Control Act of 2011. These estimates support activities that are separate from discretionary activities and accounts. Thus, any changes to Bonneville estimates cannot be used to affect any other budget categories which have their own dollar caps. Because Bonneville's obligations are and will be incurred under pre-existing legislative authority, Bonneville is not subject to a "pay-as-you-go" test regarding its revision of current-law funding estimates.

BP-3

CURRENT SERVICES

(in millions of dollars)

CAPITAL TRANSFERS — **FISCAL YEAR**

	Amortization:	2019 Payment	2020 Payment	2021 Payment	2022 Payment	2023 Payment	2024 Payment	2025 Payment
18	BPA Bonds	506	351	402	371	330	314	301
19	Reclamation Appropriations	3	0	0	0	0	0	0
20	BPA Appropriations	0	0	0	0	0	0	0
21	Corps Appropriations	224	0	0	0	0	0	0
22	Lower Snake River Comp Plan Amortization	0	0	0	0	0	0	0
23	**TOTAL CAPITAL TRANSFERS**	**734**	**351**	**402**	**371**	**330**	**314**	**301**
24	**FULL-TIME EQUIVALENT (FTE)**	**2,727**	**3,000**	**3,000**	**3,000**	**3,000**	**3,000**	**3,000**

PROGRAM & FINANCING SUMMARY

Current Services

(in millions of dollars)

Identification Code: 89-4045-0-3-271

		2019	2020	est. 2021	2022	2023	2024	2025
Program by activities:								
	Operating expenses:							
0.01	Power Services	1,134	1,089	1,127	1,128	1,132	1,138	1,146
0.02	Residential Exchange Program	241	257	255	261	267	273	279
	Associated Project Costs:							
0.05	Bureau of Reclamation	161	154	152	155	158	162	166
0.06	Corps of Engineers	253	253	253	258	264	270	276
0.07	Colville Settlement	20	23	23	24	24	25	25
0.19	U.S. Fish & Wildlife Service	27	30	30	31	32	33	33
0.20	Planning Council	11	12	12	12	12	13	13
0.21	Fish & Wildlife	228	249	249	255	260	266	272
0.23	Transmission Services	478	480	482	489	497	506	514
0.24	Conservation & Energy Efficiency	142	158	157	160	164	167	171
0.25	Interest	232	177	198	272	305	325	361
0.26	Pension and Health Benefits [1/]	41	38	40	41	42	43	44
0.91	**Total operating expenses [2/]**	**2,968**	**2,920**	**2,977**	**3,087**	**3,158**	**3,219**	**3,299**
	Capital investment:							
1.01	Power Services	200	238	256	281	300	306	313
1.02	Transmission Services	192	469	474	468	507	525	487
1.04	Fish & Wildlife	22	47	47	43	43	40	40
1.05	Capital Equipment	10	22	22	22	22	21	20
1.06	Capitalized Bond Premiums	0	0	0	0	0	0	0
1.07	**Total Capital Investment [3/]**	**424**	**776**	**800**	**814**	**872**	**893**	**860**
2.01	Projects Funded in Advance	239	86	66	60	40	40	41
10.00	**Total obligations [4/]**	**3,631**	**3,782**	**3,843**	**3,962**	**4,070**	**4,152**	**4,200**

These notes are an integral part of this table.

[1/] See Interest Expense, Pension and Post-retirement Benefits and Capital Transfers section of this budget for a complete discussion of these cost estimates.

[2/] Assumes expense obligations, not accrued expenses.

Power Services doesn't include Fish & Wildlife, Residential Exchange Program, Planning Council, Conservation & Energy Efficiency and Associated Project Costs which have been shown separately for display purposes.

Bonneville makes an accounting adjustment to the production services component of FY 2019 Bonneville's audited actual obligations. This past year adjustment relates primarily to long- term obligation requirements consistent with Bonneville's FY 2019 Combined Schedules of Budgetary Resources and the GTAS FY 2019 Treasury reports for Bonneville.

[3/] Assumes capital obligations, not capital expenditures.

[4/] This FY 2021 budget includes capital and expense estimates based on final spending proposals from Bonneville's 2018 IPR process.

For purposes of this table, this FY 2021 budget reflects, for FY 2019, actual third party financing expense only for PFIA.

Capital funding levels reflect external factors such as the significant changes affecting West Coast power and transmission markets, along with planned infrastructure investments designed to address the long-term needs of the region.

Budget estimates included in this budget are subject to change due to rapidly changing economic and institutional conditions in the evolving electric utility industry.

Refer to 16 USC Chapters 12B, 12G, 12H, and Bonneville's other organic laws, including P.L. 100-371, Title III, Sec. 300, 102 Stat. 869, July 19, 1988, regarding Bonneville's ability to obligate funds.

Program and Financing (continued)

Current Services

(in millions of dollars)

		2019 est.	2020	2021	2022	2023	2024	2025
Financing:								
1000	Unobligated balance available, start of year. [5/]	13	12	10	0	0	0	0
1050	Unobligated balance available, end of year.[5/]	12	10	8	0	0	0	0
1900	**Budget authority (gross)**	**3,620**	**4,371**	**4,352**	**4,438**	**4,560**	**4,611**	**4,616**
Budget Authority:								
1400	Permanent Authority: Authority to borrow from Treasury (indefinite) [6/]	255	776	800	814	872	893	860
1600	Contract Authority	2,850						
1800	Spending authority from off-setting collections	3,657	3,946	3,954	3,994	4,017	4,032	4,057
1825	Portion applied to debt reduction	(506)	(351)	(402)	(371)	(330)	(314)	(301)
1850	**Spending authority from offsetting collections (adjusted)**	**515**	**3,595**	**3,552**	**3,624**	**3,687**	**3,718**	**3,756**
900	Total obligations	3,631	3,783	3,844	3,962	4,070	4,152	4,200
4110	Outlays (gross)	3,724	3,783	3,844	3,962	4,070	4,152	4,200
Adjustments to budget authority and outlays:								
	Deductions for offsetting collections:							
4120	Federal funds	(54)	(90)	(90)	(90)	(90)	(90)	(90)
4121	Interest on Federal Securities	(9)						
4123	Non-Federal sources	(3,594)	(3,856)	(3,864)	(3,904)	(3,927)	(3,942)	(3,967)
4130	Total, offsetting collections	(3,657)	(3,946)	(3,954)	(3,994)	(4,017)	(4,032)	(4,057)
4160	**Budget authority (net)**	**(4)**	**425**	**398**	**443**	**543**	**579**	**559**
4170	**Outlays (net) [7/8/]**	**67**	**(163)**	**(110)**	**(33)**	**53**	**120**	**143**

These notes are an integral part of this table.

[5/] Reflects estimated cost for radio spectrum fund.

[6/] The Permanent Authority: Authority to borrow (indefinite) from the U.S. Treasury amounts reflect both Bonneville's capital program financing needs and either the use of, or creation of, deferred borrowing. Deferred borrowing is created when, as a cash and debt management decision, Bonneville uses cash from revenues to liquidate capital obligations in lieu of borrowing at that time from the U.S. Treasury. This temporary use of cash on hand instead of borrowed funds creates the ability in future years to borrow money, when fiscally prudent. The FY 1989 Energy and Water Development Appropriations Act (P.L. 100-371 0f 7/19/88) confirmed that Bonneville has authority to incur obligations in excess of U.S. Treasury borrowing authority and cash in the BPA fund. Total includes BPA's self-financing activities and funds for Radio Spectrum Relocation. In addition, BPA has negotiated with the U.S. Treasury access to a $750 million short term note as part of the $7.7 billion borrowing authority.

[7/] Net Outlay estimates are based on current cost savings to date and anticipated cash management goals. They are expected to follow anticipated management decisions throughout the rate period that, along with actual market conditions, will impact revenues and expenses. Actual Net Outlays are volatile and are reported in Report on Budget Execution and Budgetary Resources (SF-133). Actual Net Outlays could differ from estimates due to changing market conditions, streamflow variability, continued restructuring of the electric industry, and other reasons.

Revenues, included in the Net Outlay formulation, are calculated consistent with cash management goals and assume a combination of adjustments. Assumed adjustments include the use of a combination of tools, including upcoming rate adjustment mechanisms, a net revenue risk adjustment, debt service refinancing strategies and/or short-term financial tools to manage net revenues and cash. Some of these potential tools will reduce costs rather than generate revenue, causing the same Net Outlay result. Adjustments for depreciation and 4(h)(10)(C) credits of the Northwest Power Act are also assumed.

This budget has been prepared in accordance with PAYGO. Under PAYGO all Bonneville budget estimates are treated as mandatory and are not subject to the discretionary caps included in the Budget Control Act of 2011. These estimates support activities that are separate from discretionary activities and accounts. Thus, any changes to Bonneville estimates cannot be used to affect any other budget categories which have their own dollar caps. Because Bonneville's obligations are and will be incurred under pre-existing legislative authority, Bonneville is not subject to a "pay-as-you-go" test regarding its revision of current-law funding estimates.

[8/] FY 2019 Net Outlays are calculated using Bonneville's audited actual revenue. FYs 2020 to 2025 Net Outlays are based on 2018 final IPR assumptions and an escalation factor from using the FY 2018 White Book Loads and Resources Report

BONNEVILLE POWER ADMINISTRATION
BPA STATUS of U.S. TREASURY BORROWING
CURRENT SERVICES

BP-4A

Fiscal Year

	2019				2020			
	Net Capital Obs	Net Capital Obs Subject to BA	Net Capital Expend.	Bonds Out-Standing	Net Capital Obs	Net Capital Obs Subject to BA	Net Capital Expend.	Bonds Out-Standing
Start-of-Year: Total	4,305	3,763	5,204	5,531	4,223	3,681	5,122	5,280
Plus: Annual Increase								
Cum.-Annual Treasury Borrowing	424	424	424	255	776	776	776	776
Treasury Borrowing (Cash)								
Less:								
BPA Bond Amortization	506	506	506	506	351	351	351	351
Net Increase/(Decrease):	(82)	(82)	(82)	(251)	425	425	425	425
Cum.-End-of-Year: Total	4,223	3,681	5,122	5,280	4,648	4,106	5,547	5,705
Total Remaining Treasury Borrowing Amount				2,420				1,995
Total Legislated Treasury Borrowing Amount				7,700				7,700

These notes are an integral part of this table.

In any given year, Bonneville may issue lower principal amount of bonds to the U.S. Treasury than forecast depending on net revenues, borrowing costs, and other cash management factors. In such cases, Bonneville accumulates a deferred borrowing balance that it accesses as necessary in the future.

Capital funding levels reflect external factors such as the significant changes affecting West Coast power and transmission markets, along with planned infrastructure investments designed to address the long-term needs of the region.

In this FY 2021 budget, Bonneville "bond(s)" refers to all bonds issued by Bonneville to and advances received from the U.S. Treasury. This reference is consistent with section 13 (a) of the Transmission Act, which defines Bonneville bonds as all bonds, notes, and other evidences of indebtednesses issued and sold by Bonneville to the U.S. Treasury.

As in the past, Bonneville may pursue future restructuring of total debt as opportunities arise.

Budget estimates included in this budget are subject to change due to rapidly changing economic and institutional conditions in the evolving electric utility industry.

Bonneville reserve financing of $15 million annually was part of TS capital-PFIA for FYs 2018-2019.

Cumulative advance amortization payments as of the end of FY 2019 are $5,791 million.

Total includes BPA's self-financing activities and funds for Radio Spectrum Relocation. In addition, BPA has negotiated with the U.S. Treasury access to a $750 million short term note as part of the $7.7 billion borrowing authority.

BONNEVILLE POWER ADMINISTRATION
BPA STATUS of U.S. TREASURY BORROWING
CURRENT SERVICES
(in millions of dollars)

BP-4B

	2021				2022			
	Net Capital Obs	Net Capital Obs Subject to BA	Net Capital Expend.	Bonds Out-Standing	Net Capital Obs	Net Capital Obs Subject to BA	Net Capital Expend.	Bonds Out-Standing
Start-of-Year: Total	4,648	4,106	5,547	5,705	5,046	4,504	5,945	6,103
Plus: Annual Increase								
Cum.-Annual Treasury Borrowing	800	800	800	800	814	814	814	814
Treasury Borrowing (Cash)								
Less:								
Total BPA Bond Amortization	402	402	402	402	371	371	371	371
Net Increase/(Decrease):								
Total	398	398	398	398	443	443	443	443
Cum.-End-of-Year: Total	5,046	4,504	5,945	6,103	5,490	4,948	6,389	6,547
Total Remaining Treasury Borrowing Amount				1,597				1,153
Total Legislated Treasury Borrowing Amount				7,700				7,700

These notes are an integral part of this table.

In any given year, Bonneville may issue lower principal amount of bonds to the U.S. Treasury than forecast depending on net revenues, borrowing costs, and other cash management factors. In such cases, Bonneville accumulates a deferred borrowing balance that it accesses as necessary in the future.

Capital funding levels reflect external factors such as the significant changes affecting West Coast power and transmission markets, along with planned infrastructure investments designed to address the long-term needs of the region.

In this FY 2021 budget, Bonneville "bond(s)" refers to all bonds issued by Bonneville to and advances received from the U.S. Treasury. This reference is consistent with section 13 (a) of the Transmission Act, which defines Bonneville bonds as all bonds, notes, and other evidences of indebtednesses issued and sold by Bonneville to the U.S. Treasury.

As in the past, Bonneville may pursue future restructuring of total debt as opportunities arise.

Budget estimates included in this budget are subject to change due to rapidly changing economic and institutional conditions in the evolving electric utility industry.

Bonneville reserve financing of $15 million annually was part of TS capital-PFIA for FYs 2018-2019.

Cumulative advance amortization payments as of the end of FY 2019 are $5,791 million.

Total includes BPA's self-financing activities and funds for Radio Spectrum Relocation. In addition, BPA has negotiated with the U.S. Treasury access to a $750 million short term note as part of the $7.7 billion borrowing authority.

BONNEVILLE POWER ADMINISTRATION
BPA STATUS of U.S. TREASURY BORROWING
CURRENT SERVICES
(in millions of dollars)

BP-4C Fiscal Year

	2023				2024			
	Net Capital Obs	Net Capital Obs Subject to BA	Net Capital Expend.	Bonds Out-Standing	Net Capital Obs	Net Capital Obs Subject to BA	Net Capital Expend.	Bonds Out-Standing
Start-of-Year: Total	5,490	4,948	6,389	6,547	6,032	5,490	6,931	7,089
Plus: Annual Increase								
Cum.-Annual Treasury Borrowing Treasury Borrowing (Cash)	872	872	872	872	893	893	893	893
Less:								
Total BPA Bond Amortization	330	330	330	330	314	314	314	314
Net Increase/(Decrease):								
Total	543	543	543	543	579	579	579	579
Cum.-End-of-Year: Total	6,032	5,490	6,931	7,089	6,611	6,069	7,510	7,668
Total Remaining Treasury Borrowing Amount				611				32
Total Legislated Treasury Borrowing Amount				7,700				7,700

These notes are an integral part of this table.

In any given year, Bonneville may issue lower principal amount of bonds to the U.S. Treasury than forecast depending on net revenues, borrowing costs, and other cash management factors. In such cases, Bonneville accumulates a deferred borrowing balance that it accesses as necessary in the future.

Capital funding levels reflect external factors such as the significant changes affecting West Coast power and transmission markets, along with planned infrastructure investments designed to address the long-term needs of the region.

In this FY 2021 budget, Bonneville "bond(s)" refers to all bonds issued by Bonneville to and advances received from the U.S. Treasury. This reference is consistent with section 13 (a) of the Transmission Act, which defines Bonneville bonds as all bonds, notes, and other evidences of indebtednesses issued and sold by Bonneville to the U.S. Treasury.

As in the past, Bonneville may pursue future restructuring of total debt as opportunities arise.

Budget estimates included in this budget are subject to change due to rapidly changing economic and institutional conditions in the evolving electric utility industry.

Bonneville reserve financing of $15 million annually was part of TS capital-PFIA for FYs 2018-2019.

Cumulative advance amortization payments as of the end of FY 2019 are $5,791 million.

Total includes BPA's self-financing activities and funds for Radio Spectrum Relocation. In addition, BPA has negotiated with the U.S. Treasury access to a $750 million short term note as part of the $7.7 billion borrowing authority.

BONNEVILLE POWER ADMINISTRATION
BPA STATUS of U.S. TREASURY BORROWING
CURRENT SERVICES
(in millions of dollars)

BP-4D

	Fiscal Year 2025			
	Net Capital Obs	Net Capital Obs Subject to BA	Net Capital Expend.	Bonds Out-Standing
Start-of-Year: Total	6,611	6,069	7,510	7,668
Plus: Annual Increase				
Cum.-Annual Treasury Borrowing	860	860	860	860
Treasury Borrowing (Cash)				
Less:				
Total BPA Bond Amortization	301	301	301	301
Net Increase/(Decrease):				
Total	559	559	559	559
Cum.-End-of-Year: Total	7,171	6,629	8,070	8,228
Total Remaining Treasury Borrowing Amount				(528)
Total Legislated Treasury Borrowing Amount				7,700

These notes are an integral part of this table.

In any given year, Bonneville may issue lower principal amount of bonds to the U.S. Treasury than forecast depending on net revenues, borrowing costs, and other cash management factors. In such cases, Bonneville accumulates a deferred borrowing balance that it accesses as necessary in the future.

Capital funding levels reflect external factors such as the significant changes affecting West Coast power and transmission markets, along with planned infrastructure investments designed to address the long-term needs of the region.

In this FY 2021 budget, Bonneville "bond(s)" refers to all bonds issued by Bonneville to and advances received from the U.S. Treasury. This reference is consistent with section 13 (a) of the Transmission Act, which defines Bonneville bonds as all bonds, notes, and other evidences of indebtednesses issued and sold by Bonneville to the U.S. Treasury.

As in the past, Bonneville may pursue future restructuring of total debt as opportunities arise.

Budget estimates included in this budget are subject to change due to rapidly changing economic and institutional conditions in the evolving electric utility industry.

Bonneville reserve financing of $15 million annually was part of TS capital-PFIA for FYs 2018-2019.

Cumulative advance amortization payments as of the end of FY 2019 are $5,791 million.

Total includes BPA's self-financing activities and funds for Radio Spectrum Relocation. In addition, BPA has negotiated with the U.S. Treasury access to a $750 million short term note as part of the $7.7 billion borrowing authority.

BONNEVILLE POWER ADMINISTRATION
POTENTIAL THIRD PARTY FINANCING TRANSPARENCY
(in millions of dollars)

BP-5

		Fiscal Year						
Transmission Services - Capital		**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**
Main Grid	Requirements	4	3	27	25	33	46	39
Area & Customer Services		38	80	91	74	69	56	66
Upgrades & Additions		29	56	49	69	104	121	74
System Replacements		121	330	307	300	301	303	308
Projects Funded in Advance		239	86	66	60	40	40	41
Total, Transmission Services - Capital		431	555	540	528	547	565	528
Associated Project Costs - Capital								
Associated Project Costs	Requirements	200	238	256	281	300	306	313
Projects Funded in Advance[1/]		0	0	0	0	0	0	0
Total, Associated Project Costs - Capital		200	238	256	281	300	306	313
Federal and Non-Federal Funding								
Projects Funded in Advance	Source	239	86	66	60	40	40	41
U.S. Treasury Borrowing Authority		392	707	730	749	807	831	800
Scenario								
Projects Funded in Advance[1/]	Scenario	0	0	0	0	0	0	0
Third Party Financing		48	117	119	117	127	131	122
Alternate Treasury Borrowing Authority		NA	590	612	632	680	700	678

These notes are an integral part of this table.

1/ In this instance, Projects Funded in Advance represents prepayment of Power customers' bills reimbursed by future credits and third party non-federal financing for Conservation initiatives.

The table above shows both the potential use of U.S. Treasury borrowing authority for transmission capital projects based on this FY 2021 budget and the use adjusted for potential third-party financing to fund appropriate capital expenditures when feasible in lieu of U.S. Treasury borrowing. Estimates included in this FY 2021 budget are uncertain and may change due to revised capital investment plans, changing economic conditions, and an evolving financial market environment. The estimates of third-party financing included in the table show a reduction in the use of U.S. Treasury borrowing and do not reflect the actual notional third party financing commitment Bonneville may enter into in that particular year. The difference of reduction in use of U.S. Treasury borrowing and the actual notional third party financing commitment is primarily due to the difference in the timing of financing transactions between U.S. Treasury and third-party financing for capital projects with multi-year construction schedules.

Bonneville's Third Party Financing for Transmission Services consists primarily of lease-purchase agreements, which are capitalized obligations that enable Bonneville to acquire the use of transmission facilities over time. Bonneville also undertakes the construction and installation of facilities from funds that customers advance to Bonneville for construction of BPA-owned facilities that assist the customers in obtaining necessary transmission service from Bonneville. These customers receive monetary payment credits in bills for transmission services from Bonneville up to the amount of funds advanced to Bonneville, plus interest.

Bonneville's historical Third Party Financing amounts may vary over time due to re-assignment of certain lease-purchase agreements to Treasury Financing.

Bonneville Status of U.S. Treasury Borrowing with Potential Third Party Financing & PFIA Scenario

With the potential use of third party financing assumed in the scenario above, Bonneville's total remaining U.S. Treasury Borrowing Amount would be extended to the following amounts. See BP-4 BPA Status of Treasury Borrowing- Current Services.

	Fiscal Year						
	2019	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**
Start-of-Year: Total Bonds Outstanding	5,531	5,280	5,588	5,867	6,194	6,610	7,057
Plus:							
U.S. Treasury Borrowing (Cash)	255	776	800	814	872	893	860
Less:							
Potential Third Party Financing & PFIA	48	117	119	117	127	131	122
BPA Bond Amortization	506	351	402	371	330	314	301
Net Increase/(Decrease) Bonds Outstanding:	(251)	308	279	326	416	448	438
Cum.-End-of-Year: Total	5,280	5,588	5,867	6,194	6,610	7,057	7,495
Total Remaining U.S. Treasury Borrowing Amount	2,420	2,112	1,833	1,506	1,090	643	205
Total Legislated U.S.Treasury Borrowing Amount	7,700	7,700	7,700	7,700	7,700	7,700	7,700

U.S. TREASURY PAYMENTS

(in millions of dollars)

		FISCAL YEAR						
		2019	2020	2021	2022	2023	2024	2025
A.	**INTEREST ON BONDS & APPROPRIATIONS**							
	Bonneville Bond Interest							
1	Bonneville Bond Interest (net)	147	120	139	203	232	261	296
2	AFUDC [1/]	32	34	34	34	33	32	32
	Appropriations Interest							
3	Bonneville	0	0	0	0	0	0	0
4	Corps of Engineers [2/]	51	55	57	58	59	61	64
5	Lower Snake River Comp. Plan	0	0	0	0	0	0	0
6	Bureau of Reclamation [3/]	1	1	1	1	1	1	1
7	Bond Premiums paid/Discounts (not capitalized)	0	1	1	9	12	2	1
8	**Total Bond and Approp. Interest**	**232**	**210**	**232**	**307**	**338**	**357**	**393**
B.	**ASSOCIATED PROJECT COST**							
9	Bureau of Reclamation Irrigation Assistance	56	24	15	16	13	15	14
10	Bureau of Rec. O & M [4/]	0	0	0	0	0	0	0
11	Corps of Eng. O & M [4/]	1	0	0	0	0	0	0
12	L. Snake River Comp. Plan O & M [4/]	0	0	0	0	0	0	0
13	**Total Assoc. Project Costs**	**57**	**24**	**15**	**16**	**13**	**15**	**14**
C.	**CAPITAL TRANSFERS**							
	Amortization							
14	Bonneville Bonds [6/]	506	351	402	371	330	314	301
15	Bureau of Reclamation Appropriations	3	0	0	0	0	0	0
16	Corps of Engineers Appropriations	224	0	0	0	0	0	0
17	Lower Snake River Comp. Plan	0	0	0	0	0	0	0
18	Bonneville Appropriations	0	0	0	0	0	0	0
19	**Total Capital Transfers [/8]**	**734**	**351**	**402**	**371**	**330**	**314**	**301**
D.	**OTHER PAYMENTS**							
20	Unfunded Post-Retirement Liability [5/]	41	38	40	41	42	43	44
21	**TOTAL TREASURY PAYMENTS**	**1,064**	**624**	**689**	**735**	**723**	**728**	**751**

These notes are an integral part of this table.

1/ This interest cost is capitalized and included in BPA's Transmission System Development, System Replacements, and Associated Projects Capital programs. AFUDC is financed through the sale of bonds.

2/ Includes interest on construction funding for Corp of Engineers (Corps) fish bypass facilities at Corps dams in the Columbia River Basin, including Lower Monumental, Ice Harbor, and The Dalles.

3/ Includes payments paid by Reclamation to the U.S. Treasury on behalf of Bonneville.

4/ Costs for power O&M is funded directly by Bonneville as follows (in millions):

FISCAL YEAR	2019	2020	2021	2022	2023	2024	2025
Bureau of Reclamation	161	154	152	155	158	162	166
Corps of Engineers	253	253	253	258	264	270	276
Subtotal Bureau and Corps	414	406	404	413	422	432	441
Lower Snake River Comp. Plan	27	30	30	31	32	33	33
Total	441	437	435	444	454	464	475

5/ See Interest Expense, Pension and Post-retirement Benefits and Capital Transfers section of this budget for a complete discussion of these cost estimates.

6/ In this FY 2021 budget, Bonneville "bond(s)" refers to all bonds issued by Bonneville to and advances received from the U.S. Treasury. This reference is consistent with section 13 (a) of the Transmission Act, which defines Bonneville bonds as all bonds, notes, and other evidences of indebtednesses issued and sold by Bonneville to the U.S. Treasury.

Does not include Treasury bond premiums on refinanced Treasury bonds.

8/ FY 2019 data reflects actual capital transfer.

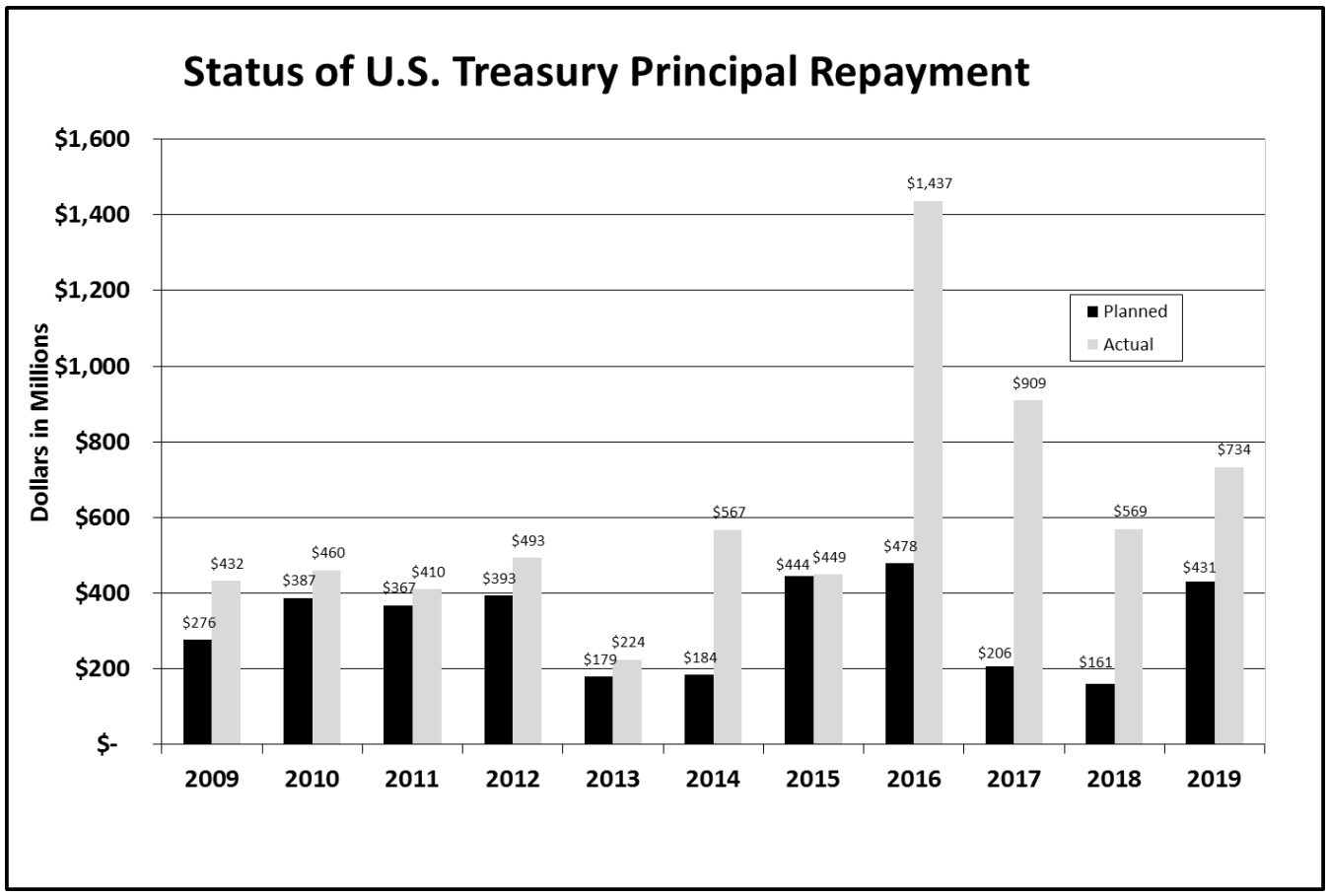


Chart Notes

[1/] This chart displays principal repayment only.

[2/] U.S. Treasury payment outyear estimates for planned amortization of principal are based on rate case estimates when available and are planned amortization for future rate case periods. These estimates may change due to revised capital investment plans, actual U.S. Treasury borrowing, and advanced amortization payments. Bonneville's aggregate FY 2019 U.S. Treasury payment was $1,064 million, composed of $734 million in principal repayment (including $228 million in early retirement of higher interest rate U.S. Treasury debt), $232 million in interest, $56 million in irrigation assistance payments, and $41 million in pension and post-retirement benefits.

[3/] FYs 2002-2012 payments include portions of advance amortization amounts consistent with Bonneville's capital strategy plan and the Bonneville /Energy Northwest debt optimization program.

[4/] Advance amortization due to sale of transmission facilities includes $12.7 million in FY 2003, $5.3 million in FY 2006, $2.0 million in FY 2011, $0.4 million in FY 2013 and $0.4 million in FY 2014, and $0.6 million in FY 2017.

[5/] The cumulative amount of actual advance amortization payments as of the end of FY 2019 is $5,791 million.

[6/] FYs 2014-2019 include advance amortization under the Regional Cooperation Debt initiative with Energy Northwest (EN) under which EN extended maturities on Bonneville-backed debt which enabled the early amortization of higher cost appropriations.

OBJECT CLASSIFICATION STATEMENT

(in millions of dollars)

		ESTIMATES				
		2019		**2020**		**2021**
11.1	Full-time permanent	261		272		276
11.3	Other than full-time permanent	1		1		1
11.5	Other personnel compensation	80		83		85
11.9	**Total personnel compensation**	**342**		**356**		**362**
12.1	Civilian personnel benefits	159		166		168
13.0	Benefits for former personnel	-		-		-
21.0	Travel and transportation of persons	5		5		5
22.0	Transportation of things	1		1		1
23.1	Rental payments to GSA	0		0		0
23.2	Rents, other	37		39		39
23.3	Communication, utilities & misc. charges	11		11		12
25.1	Consulting Services	98		102		104
25.2	Other Services	2,297		2,392		2,431
25.5	R & D Contracts	4		5		5
26.0	Supplies and materials	35		36		37
31.0	Equipment	176		183		186
32.0	Lands and structures	117		122		124
41.0	Grants, subsidies, contributions	48		50		51
43.0	Interest and dividends	301		313		318
99.0	**Total obligations**	**3,631**		**3,782**		**3,843**

Estimate of Receipts
(in millions of dollars)

	Fiscal Year						
	2019	2020	2021	2022	2023	2024	2025
Reclamation Interest	1	1	1	1	1	1	1
Reclamation Amortization	3	0	0	0	0	0	0
Reclamation O&M	0	0	0	0	0	0	0
Reclamation Irrig. Assist.	56	24	15	16	13	15	14
Revenues Collected by Reclamation	-15	-7	-7	-7	-7	-7	-7
Distributed in Treasury Account (credit)							
Colville Settlement (credit)	-5	-5	-5	-5	-5	-5	-5
Total 1/ Reclamation Fund	**40**	**13**	**4**	**5**	**2**	**4**	**3**
Corps O&M							
CSRS	41	38	40	41	42	43	44
Total 2/ Repayments on miscellaneous costs	**41**	**38**	**40**	**41**	**42**	**43**	**44**

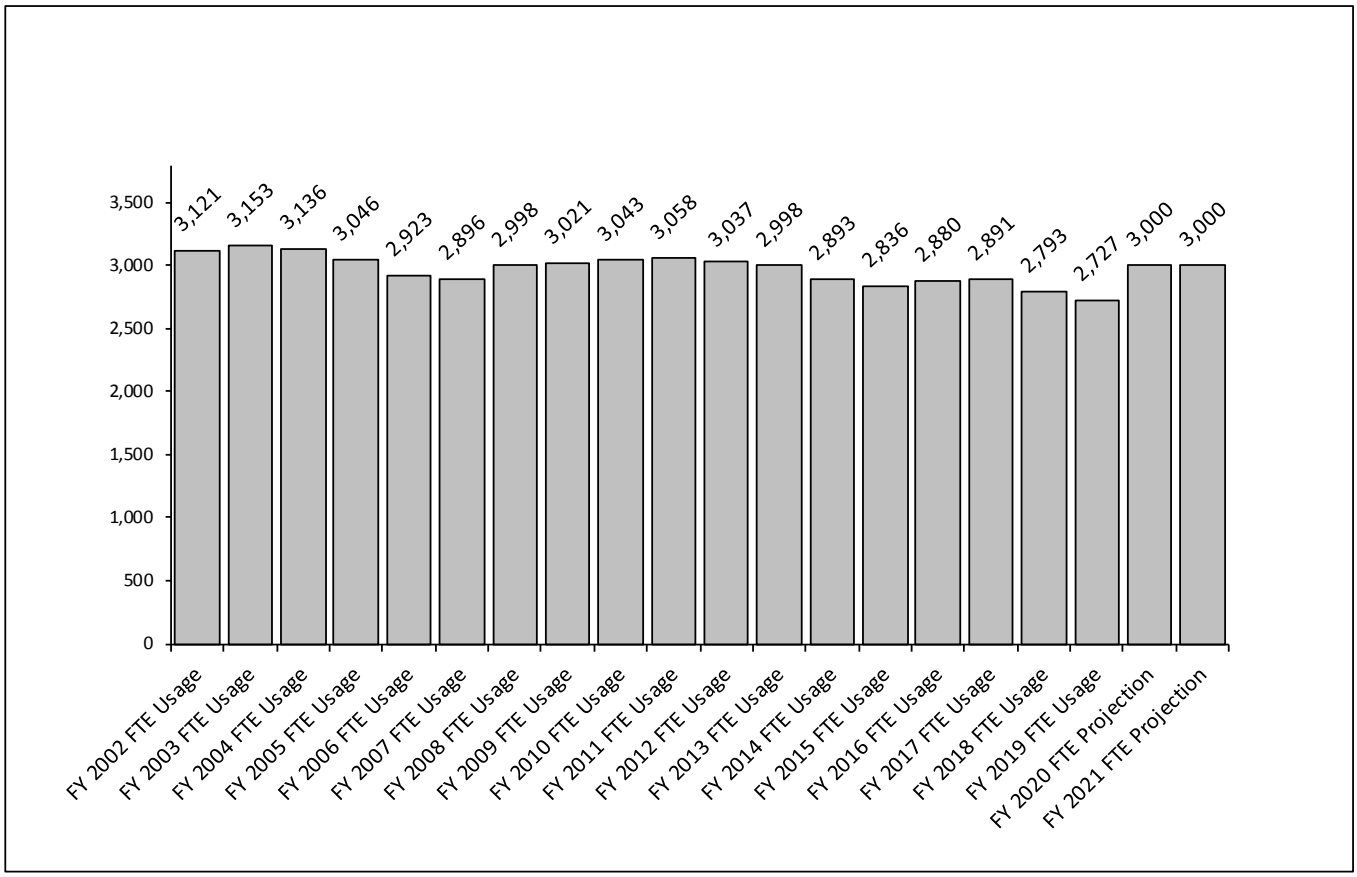
1/ Includes amortization of appropriations and irrigation assistance, and interest costs for Reclamation. The cost of power O&M for Reclamation is no longer included in Proprietary Receipts due to Direct Funding by Bonneville. Represents transfer to Account #895000.26

2/ The costs of power O&M for the Corps and Lower Snake River Comp. Plan are no longer included in Proprietary Receipts due to Direct Funding by Bonneville. Represents transfers to Account #892889, Repayments on misc. recoverable costs, not otherwise classified. Costs for power O&M is funded directly by Bonneville as follows (in millions)

	2019	2020	2021	2022	2023	2024	2025
Bureau of Reclamation	161	154	152	155	158	162	166
Corps of Engineers	253	253	253	258	264	270	276
Lower Snake River Comp. Plan	27	30	30	31	32	33	33
Total	**441**	**437**	**435**	**444**	**454**	**464**	**475**

See Interest Expense, Pension and Post-retirement Benefits and Capital Transfers section of this budget for a complete discussion of these cost estimates.

BONNEVILLE FTE



These notes are an integral part of this chart.

1. Actual FTE data is consistent with DOE personnel reports.

2. FTE outyear data are estimates and may change. Bonneville is facing a dynamic and changing transmission marketplace and operations while, at the same time, many of its employees are eligible to retire in the near future. It is important that Bonneville continue to attract and retain skilled individuals to meet the growing demands of a competitive and rapidly changing industry. Accordingly, FTE estimates may need to be adjusted in the future.

3. As of October 25, 2019 DOE HR staff has reported FY 2019 BPA's FTE usage at 2,727.

Total Cost of BPA Fish & Wildlife Actions ($ in millions)

COST ELEMENT	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
CAPITAL INVESTMENTS [1/]											
BPA FISH AND WILDLIFE	27.4	40.0	90.2	57.5	52.1	37.4	21.4	16.0	5.4	30.7	22.3
BPA SOFTWARE DEVELOPMENT COSTS	0.6	1.2	0.8	0.4	0.0	0.1	1.4	1.2	1.4	0.8	0.0
ASSOCIATED PROJECTS (FEDERAL HYDRO)	135.7	56.4	103.0	114.5	103.6	101.7	81.4	34.1	58.9	51.8	55.5
TOTAL CAPITAL INVESTMENTS	**163.7**	**97.6**	**193.9**	**172.3**	**155.7**	**139.2**	**104.1**	**51.4**	**65.7**	**83.2**	**77.9**
PROGRAM EXPENSES											
BPA DIRECT FISH AND WILDLIFE PROGRAM	177.9	199.6	221.1	248.9	239.0	231.8	258.2	258.1	254.7	258.7	240.4
FISH & WILDLIFE SOFTWARE EXPENSE COSTS	0.0	0.0	0.0	0.0	0.2	0.3	0.1	0.0	0.0	0.1	0.0
SUPPLEMENTAL MITIGATION PROGRAM EXPENSES [2/]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
REIMBURSABLE/DIRECT-FUNDED PROJECTS [3/]											
O & M LOWER SNAKE RIVER HATCHERIES	20.8	23.3	24.5	22.0	28.7	31.0	30.9	28.6	26.0	31.4	26.7
O & M CORPS OF ENGINEERS	34.3	36.5	40.3	41.1	39.2	47.8	46.4	48.2	46.8	47.1	48.9
O & M BUREAU OF RECLAMATION	4.5	5.2	5.0	5.3	5.6	6.6	2.6	6.0	7.0	5.2	8.7
NW POWER AND CONSERVATION COUNCIL ALLOCATED @ 50%	4.7	4.7	4.5	4.6	5.0	4.9	4.9	5.4	5.4	5.5	5.6
SUBTOTAL (REIMBURSABLE/DIRECT-FUNDED)	64.3	69.7	74.3	73.0	78.5	90.3	84.9	88.2	85.2	89.2	89.9
TOTAL OPERATING EXPENSES	**242.1**	**269.3**	**295.3**	**321.9**	**317.70**	**322.40**	**343.17**	**346.34**	**339.90**	**347.97**	**330.30**
PROGRAM RELATED FIXED EXPENSES [4/]											
INTEREST EXPENSE	78.7	80.5	79.2	80.6	89.1	83.4	89.2	85.6	58.6	41.0	39.7
AMORTIZATION EXPENSE	24.6	25.0	28.3	30.2	35.7	38.7	41.3	42.5	42.5	43.4	45.1
DEPRECIATION EXPENSE	16.7	18.0	19.6	20.7	18.6	19.2	20.1	20.1	20.3	20.8	21.0
TOTAL FIXED EXPENSES	**120.0**	**123.5**	**127.2**	**131.5**	**143.4**	**141.3**	**150.6**	**148.2**	**121.4**	**105.1**	**105.8**
GRAND TOTAL PROGRAM EXPENSES	**362.1**	**392.8**	**422.5**	**453.4**	**461.1**	**463.7**	**493.7**	**494.6**	**461.3**	**453.0**	**436.1**
FORGONE REVENUES AND POWER PURCHASES											
FOREGONE REVENUES	142.8	99.4	156.7	152.2	135.5	122.7	195.8	76.6	9.6	2.9	174.4
BPA POWER PURCH. FOR FISH ENHANCEMENT	240.3	310.1	70.7	38.5	85.8	196.2	67.5	50.3	(20.5)	24.3	177.6
TOTAL FOREGONE REVENUES AND POWER PURCHASES	**383.1**	**409.5**	**227.4**	**190.7**	**221.3**	**318.9**	**263.3**	**126.9**	**(10.9)**	**27.2**	**352.0**
TOTAL PROGRAM EXPENSES, FOREGONE REVENUES, & POWER PURCHASES	**745.3**	**802.3**	**649.9**	**644.1**	**682.4**	**782.6**	**757.0**	**621.5**	**450.4**	**480.2**	**788.1**
CREDITS											
4(h)(10)(C)	(99.5)	(122.8)	(85.3)	(77.0)	(84.1)	(103.9)	(77.7)	(72.6)	(53.7)	(70.2)	(98.2)
TOTAL CREDITS	**(99.5)**	**(122.8)**	**(85.3)**	**(77.0)**	**(84.1)**	**(103.9)**	**(77.7)**	**(72.6)**	**(53.7)**	**(70.2)**	**(98.2)**

This information has been made publicly available by BPA. The figures shown are consistent with audited actuals that contain Agency approved financial information, except for forgone revenues and power purchases which are estimates and do not contain Agency approved financial information

1/ Capital Investments include both BPA's direct Fish and Wildlife Program capital investments, funded by BPA's Treasury borrowing, and "Associated Projects", which include capital investments at Corps of Engineers' and Bureau of Reclamation projects, funded by appropriations and repaid by BPA. The annual expenses associated with these investments are included in "Program-Related Fixed Expenses", below.

2/ Includes High Priority and Action Plan Expenses and other supplemental programs.

3/ "Reimbursable/Direct-Funded Projects" includes the portion of costs BPA pays to or on behalf of other entities that is determined to be for fish and wildlife purposes.

4/ "Fixed Expenses" include depreciation, amortization, and interest on investments on the Corps and Bureau's projects, and amortization and interest on the investments associated with BPA's direct Fish and Wildlife Program.

GENERAL PROVISIONS—DEPARTMENT OF ENERGY
(INCLUDING TRANSFER AND CANCELLATION 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)*, and (h)*, the amounts made available by this title shall be expended as authorized by law for the programs, projects, and activities specified in the "Final Bill" column in the "Department of Energy" table included under the heading "Title III-Department of Energy" in the explanatory statement described in section 4 (in the matter preceding division A of this consolidated 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) *EXCLUSIONS.—Subsections (d), (e), and (f) shall not apply to applied energy program funds transferred or reprogrammed under —*

(1) *the small business innovation research program under section 9 of the Small Business Act (15 U.S.C 638); or*

(2) *the small business technology transfer program under that section.*

(**[**h**]***i*) 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 2020 until the enactment of the Intelligence Authorization Act for fiscal year 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. (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. 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. Of the offsetting collections, including unobligated balances of such collections, in the "Department of Energy-Power Marketing Administration-Colorado River Basins Power Marketing Fund, Western Area Power Administration", $21,400,000 shall be transferred to the "Department of Interior-Bureau of Reclamation-Upper Colorado River Basin Fund" for the Bureau of Reclamation to carry out environmental stewardship and endangered species recovery efforts.**]**

[SEC. 308. (a) Of the unobligated balances available from amounts appropriated in prior Acts under the heading "Title III-Department of Energy-Energy Programs", $12,723,000 is hereby rescinded.

(b) No amounts may be rescinded under (a) from amounts that were designated by the Congress as an emergency requirement pursuant to a concurrent resolution on the budget or the Balanced Budget and Emergency Deficit Control Act of 1985.**]**

[SEC. 309. Beginning in fiscal year 2021 and for each fiscal year thereafter, fees collected pursuant to subsection (b)(1) of section 6939f of title 42, United States Code, shall be deposited in "Department of Energy-Energy Programs-Non-Defense Environmental Cleanup" as discretionary offsetting collections.**]**

[SEC. 310. During fiscal year 2020 and each fiscal year thereafter, notwithstanding any provision of title 5, United States Code, relating to classification or rates of pay, the Southeastern Power Administration shall pay any power system dispatcher employed by the Administration a rate of basic pay and premium pay based on those prevailing for similar occupations in the electric power industry. Basic pay and premium pay may not be paid under this section to any individual during a calendar year so as to result in a total rate in excess of the rate of basic pay for level V of the Executive Schedule (section 5316 of such title).**]**

SEC. 307. 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) in the matter preceding paragraph (1), 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 2021, 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 remediation functions and activities described in subsections (a)(1) through (a)(6).".

SEC. 308. Section 2307 of the Energy Policy Act of 1992 (42 U.S.C 13526) is repealed.

SEC. 309. Notwithstanding section 161 of the Energy Policy and Conservation Act (42 U.S.C. 6241), the Secretary of Energy shall draw down and sell 15 million barrels of refined petroleum product from the Strategic Petroleum Reserve during fiscal year 2021. Proceeds from sales under this section shall be deposited into the general fund of the Treasury during fiscal year 2021, with the exception of $242,000,000 from such proceeds to be deposited in the "Naval Petroleum and Oil Shale Reserves" account for comprehensive remediation of the Naval Petroleum Reserve–1 site near Elk Hills, California, to remain available until expended.

SEC. 310. Treatment of Lobbying and Political Activity Costs as Allowable Costs under Department of Energy Contracts.—

(a) *Allowable Costs.—*

(1) *Section 4801(b) of the Atomic Energy Defense Act (50 U.S.C. 2781(b)) is amended—*

(A) *by striking "(1)" and all that follows through "the Secretary" and inserting "The Secretary"; and*

(B) *by striking paragraph (2).*

(2) *Section 305 of the Energy and Water Development Appropriation Act, 1988, as contained in section*

101(d) of Public Law 100–202 (101 Stat. 1329–125), is repealed.

(b) *Regulations Revised.—The Secretary of Energy shall revise existing regulations consistent with the repeal of 50 U.S.C. 2781(b)(2) and section 305 of Public Law 100–202 and shall issue regulations to implement 50 U.S.C. 2781(b), as amended by subsection (a) of this section, 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. 311. Pursuant to a request by the Secretary of Defense, and upon determination by the Director of the Office of Management and Budget in consultation with the Secretary of Energy that such action is necessary, the Secretary of Energy may, with the approval of the Office of Management and Budget, transfer not to exceed $2,500,000,000 of funds made available in this Act to the Department of Energy for National Nuclear Security Administration functions to the Department of Defense, to be merged with and to be available for the same purposes, and for the same time period, as the appropriation or fund to which transferred: Provided, That the Secretary of Energy shall notify the Congress promptly of all transfers made pursuant to this authority or any other authority in this Act: Provided further, That this transfer authority is in addition to any other transfer authority provided in this Act.

TITLE V—GENERAL PROVISIONS
(INCLUDING TRANSFER OF FUNDS)

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 explanatory statement described in section 4 (in the matter preceding division A of this consolidated 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 explanatory statement described in section 4 (in the matter preceding division A of this consolidated 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.