DOE/CF-0184
Volume 4

Department of Energy
FY 2023 Congressional Budget Request

Energy Efficiency and Renewable Energy
Electricity
Nuclear Energy
Fossil Energy and Carbon Management

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DEPARTMENT OF ENERGY
Appropriation Summary
(dollars in thousands)

Department of Energy	FY 2021 Enacted	FY 2022 Annualized CR	FY2023 Request	FY 2023 vs. FY 21 Enacted	
				$	%
Department of Energy					
Energy Efficiency and Renewable Energy	2,861,760	2,861,760	4,018,885	1,157,125	40.4%
Electricity	211,720	211,720	297,386	85,666	40.5%
Cybersecurity, Energy Security, and Emergency Response	156,000	156,000	202,143	46,143	29.6%
Petroleum Reserves					
Strategic Petroleum Reserves	188,000	188,000	214,175	26,175	13.9%
Naval Petroleum & Oil Shale Reserves	13,006	13,006	13,004	-2	0.0%
SPR - Petroleum Account	1,000	1,000	8,000	7,000	700.0%
Northeast Home Heating Oil Reserves	6,500	6,500	7,000	500	7.7%
Subtotal, Petroleum Reserves	**208,506**	**208,506**	**242,179**	**33,673**	16.1%
Grid Deployment Office	-	-	90,221	90,221	N/A
Federal Energy Management Program (FEMP)	-	-	169,661	169,661	N/A
Office of Manufacturing & Energy Supply Chains (MESC)	-	-	27,424	27,424	N/A
Office of State and Community Energy Programs (SCEP)	-	-	726,897	726,897	N/A
Nuclear Energy	1,357,800	1,357,800	1,518,460	160,660	11.8%
Nuclear Waste Disposal	27,500	27,500	10,205	-17,295	-62.9%
Fossil Energy and Carbon Management	750,000	750,000	893,160	143,160	19.1%
Uranium Enrichment Decontamination and Decommissioning Fund (UED&D)	841,000	841,000	822,421	-18,579	-2.2%
Energy Information Administration	126,800	126,800	144,480	17,680	13.9%
Non-Defense Environmental Cleanup	319,200	319,200	323,249	4,049	1.3%
Science	7,026,000	7,026,000	7,799,211	773,211	11.0%
Office of Technology Transitions	-	-	21,558	21,558	N/A
Office of Clean Energy Demonstrations	-	-	214,052	214,052	N/A
Advanced Research Project Agency-Energy	427,000	427,000	700,150	273,150	64.0%
Departmental Administration	166,000	166,000	397,203	231,203	139.3%
Indian Energy Policy and Programs	22,000	22,000	150,039	128,039	582.0%
Office of Inspector General	57,739	57,739	106,808	49,069	85.0%
Loan Programs					
Title 17 - Innovative Technology Loan Guarantee Program (1)	29,000	29,000	168,206	139,206	480.0%
Advanced Technology Vehicles Manufacturing Loan Program	5,000	5,000	9,800	4,800	96.0%
Tribal Energy Loan Guarantee Program	2,000	2,000	1,860	-140	-7.0%
Subtotal, Loan Programs	**36,000**	**36,000**	**179,866**	**143,866**	**399.6%**
Subtotal, Energy Programs	**14,595,025**	**14,595,025**	**19,055,658**	**4,460,633**	**30.6%**
National Nuclear Security Administration					
Federal Salaries and Expenses	443,200	443,200	496,400	53,200	12.0%
Weapons Activities	15,345,000	15,345,000	16,486,298	1,141,298	7.4%
Defense Nuclear Nonproliferation	2,260,000	2,260,000	2,346,257	86,257	3.8%
Naval Reactors	1,684,000	1,684,000	2,081,445	397,445	23.6%
National Nuclear Security Administration	**19,732,200**	**19,732,200**	**21,410,400**	**1,678,200**	**8.5%**
Environmental and Other Defense Activities					
Defense Environmental Cleanup	6,426,000	6,426,000	6,914,532	488,532	7.6%
Defense UED&D Fund (2)	-	-	-	-	N/A
Other Defense Activities	920,000	920,000	978,351	58,351	6.3%
Subtotal, Environmental and Other Defense Activities	**7,346,000**	**7,346,000**	**7,892,883**	**546,883**	**7.4%**
Nuclear Energy (050)	149,800	149,800	156,600	6,800	4.5%
Subtotal, Atomic Energy Defense Activities	**27,228,000**	**27,228,000**	**29,459,883**	**2,231,883**	**8.2%**
Power Marketing Administrations					
Southeastern Power Administration (SEPA)	-	-	-	-	N/A
Southwestern Power Administration (SWPA)	10,400	10,400	10,608	208	2.0%
Western Area Power Administration	89,372	89,372	98,732	9,360	10.5%
Falcon and Amistad Operating and Maintenance Fund	228	228	228	0	0.0%
Colorado River Basins Marketing Fund	-21,400	-21,400	-8,568	12,832	-60.0%
Subtotal, Power Marketing Administrations	**78,600**	**78,600**	**101,000**	**22,400**	**28.5%**
Subtotal, Department of Energy	**41,901,625**		**48,616,541**	**6,714,916**	**16.0%**
Federal Energy Regulatory Commission	-	-	-	-	N/A
Receipts and Offsets					
Excess Fees and Recoveries, FERC	-9,000	-9,000	-9,000	-	0.0%
Title XVII Loan Guar. Prog Section 1703 Negative Credit Subsidy Receipts	-	-	-7,000	-7,000	N/A
UED&D Fund Discretionary Payments	-		-417,000	-417,000	N/A
Receipts and offsets	**-9,000**	**-9,000**	**-433,000**	**-424,000**	**4711.1%**
Department of Energy	**41,892,625**	**41,892,625**	**48,183,541**	**6,290,916**	**15.0%**

DEPARTMENT OF ENERGY
Appropriation Summary
(dollars in thousands)

Department of Energy	FY 2021 Enacted	FY 2022 Annualized CR	FY2023 Request	FY 2023 vs. FY 21 Enacted	
				$	%
DOE Budget Function					
NNSA Defense (050) Total	19,732,200	19,732,200	21,410,400	1,678,200	8.5%
Non-NNSA Defense Total	7,495,800	7,495,800	8,049,483	553,683	7.4%
Defense (050)	**27,228,000**	**27,228,000**	**29,459,883**	**2,231,883**	**8.2%**
Science (250)	7,026,000	7,026,000	7,799,211	773,211	11.0%
Energy (270)	7,638,625	7,638,625	10,924,447	3,285,822	43.0%
Non-Defense (Non-050)	**14,664,625**	**14,664,625**	**18,723,658**	**4,059,033**	**27.7%**

(1) The FY 2021 and FY 2022 Continuing Resolution entries for Title 17 and ATVM do not reflect rescissions of prior year emergency balances enacted in Public Law 116-260. Including the rescissions, the final amounts for Title 17 and ATVM would be -$363 million and -$1,903 million, respectively.

(2) In the FY 2023 Request, Defense Uranium Decontaination and Decommissioning is requested within the Defense Environmental Cleanup Appropriation.

Energy Efficiency and Renewable Energy

Energy Efficiency and Renewable Energy

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, [$2,864,000,293] $4,018,885,000, to remain available until expended: Provided, that of such amount, [$165,000,000] $224,474,000 shall be available until September 30, [2022] 2024, for program direction [: Provided further, that of the unobligated balances available from amounts appropriated in Public Law 111–8 under this heading, $806,831 is hereby rescinded: Provided further, That of the unobligated balances available from amounts appropriated in Public Law 111–85 under this heading, $1,433,462 is hereby rescinded: Provided further, that no amounts may be rescinded under the previous two provisos 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].

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)
PL 95-617, "Public Utility Regulatory Policies Act Of 1978" (1978)
P.L. 95-618, "Energy Tax Act" (1978)
P.L. 95-619, "National Energy Conservation Policy Act" (NECPA) (1978)
P.L. 95-620, "Power Plant and Industrial Fuel Use Act" (1978)
P.L. 95-238, Title III –"Automotive Propulsion Research and Development Act" (1978)
P.L. 96-512, "Methane Transportation Research, Development and Demonstration Act" (1980)
P.L. 96-294, "Energy Security Act" (1980)
P.L. 100-12, "National Appliance Energy Conservation Act" (1987)
P.L. 100-357, "National Appliance Energy Conservation Amendments" (1988)
P.L. 100-494, "Alternative Motor Fuels Act" (1988)
P.L. 100-615, "Federal Energy Management Improvement Act" (1988)
P.L. 101-218, "Renewable Energy and Energy Efficiency Technology Competitiveness Act" (1989)
P.L. 101-566, "Spark M. Matsunaga Hydrogen Research, Development, and Demonstration Act of 1990"
P.L. 101-575, "Solar, Wind, Waste, and Geothermal Power Production Incentives Act" (1990)
P.L. 102-486, "Energy Policy Act of 1992" (WIND)
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. 110-69, "America Competes Act of 2005"
P.L. 110-140, "Energy Independence and Security Act of 2007"
P.L. 110-140, title VI, Sec. 641, "US Energy Storage and Competitiveness 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. 112-210, "American Energy Manufacturing Technical Corrections Act (2012)
P.L. 115-244, "Energy and Water, Legislative Branch, and Military Construction and Veterans Affairs Appropriations Act, 2019"
P.L. 115-246, "Department of Energy Research and Innovation Act" (2018)
P.L. 116-92, "National Defense Authorization Act for Fiscal Year 2020"
P.L. 116-260, "Consolidated Appropriations Act of 2020" (Section Z: Energy Act of 2020)

Energy Efficiency and Renewable Energy
($K)

FY 2021 Enacted[1]	FY 2022 Annualized CR	FY 2023 Request	FY 2023 Request vs FY 2022 Request
2,861,760	2,861,760	4,018,885	+1,154,885

Overview
The Office of Energy Efficiency and Renewable Energy (EERE) is the largest investor in clean energy technology development in the Federal Government. EERE's mission is to accelerate the research, development, demonstration, and deployment of technologies and solutions to equitably transition America to a carbon pollution-free electricity sector by 2035 and a net-zero emission economy by no later than 2050, creating good-paying jobs with the opportunity to join a union and bargain collectively, and ensuring the clean energy economy benefits all Americans, especially workers and communities impacted by the energy transition, and those historically underserved by the energy system and overburdened by pollution.

To achieve this mission, EERE invests in the integration of clean energy technologies that are ready to be demonstrated and deployed, as well as research and development (R&D) activities that advance early-stage technologies with a clear path to deployment.

EERE's FY 2023 investment strategy continues its focus on making investments in five programmatic priority areas[2] that are central pillars in lowering the U.S. greenhouse gas (GHG) profile:

- Decarbonizing the electricity sector: To transition to a carbon pollution-free electricity sector by 2035, EERE's focus is to support technologies that will allow the U.S. to generate all U.S. electricity from clean, renewable sources. EERE invests in activities critical to reduce the cost of renewables, as well as to make major strides in renewables integration to ensure reliability, security, and resiliency as the grid evolves.
- Decarbonizing transportation across all modes: air, sea, rail, and road: The transportation sector has historically relied heavily on petroleum, which supports over 90 percent of the sector's energy needs today.; as a result, the sector has surpassed electricity generation to become the largest source of CO_2 emissions in the country[3]. The goal of this investment is to develop, demonstrate, and deploy technologies that can cost-effectively decarbonize all modes of transportation, including electrification of on-road vehicles, sustainable aviation fuel, and hydrogen fuel cells for long-haul heavy-duty trucks. EERE aims to do this while ensuring affordable mobility solutions for people and goods across all economic and social groups, reducing the impact on local air quality and using sustainable water and land practices.
- Decarbonizing energy-intensive industries: Industrial processes significantly contribute to the Nation's carbon emissions.[4] To phase out emissions, EERE supports approaches that substantially improve material and energy efficiency, electrify processes to take advantage of a decarbonizing electricity grid, switch to clean fuels and feedstocks, and capture and use carbon emissions. EERE's Industrial Decarbonization Roadmap will guide research, development, demonstration, and deployment (RDD&D) activities across the Department to reduce GHG emissions across the industrial sector, with an emphasis on the highest emitting sectors (e.g., iron/steel, cement/concrete, chemicals, food production, et al.).
- Reducing the carbon footprint of buildings: Residential and commercial buildings are the single largest energy-consuming sector in the U.S. economy, representing approximately 40 percent of its total energy consumption, 75 percent of the Nation's electricity use, an even greater share of peak power demand, and are responsible for 35percent of energy-related carbon dioxide emissions.[5] As a result, Americans spend over $400 billion annually to power and otherwise energize the Nation's 130 million homes, offices, schools, hospitals, and other commercial and residential buildings.[6] However, these energy bills are not equally felt by all. The energy burden for low-income households is on

[1] Reflects rescission of prior year balances of $2.24 million.
[2] Please note because investments can support multiple priority areas, there is overlap among the totals.
[3] U.S. Energy Information Administration. Monthly Energy Review, 2022, https://www.eia.gov/totalenergy/data/monthly/index.php.
[4] U.S. Energy Information Administration. Monthly Energy Review, 2022, https://www.eia.gov/totalenergy/data/monthly/index.php.
[5] U.S. Energy Information Administration. Monthly Energy Review, 2022, https://www.eia.gov/totalenergy/data/monthly/index.php.
[6] Spending derived from the U.S. Energy Information Administration Monthly Energy Review. https://www.eia.gov/totalenergy/data/monthly/.

average three times that of others and low-income households typically receive a lower quality of energy services.[1] EERE supports critical deployment activities needed to transform the energy economy at the state and local levels as well as investments in high priority research, development, and demonstration (RD&D) needed for new affordable housing and advanced energy efficient retrofits for buildings. EERE supports efforts to reduce the carbon footprint of the U.S. building stock by 50 percent by 2035 while maintaining or improving affordability, comfort, and performance. EERE will accomplish this priority through three routes. First, by decarbonizing the power grid, which in turn decarbonizes the electricity that serves buildings. Second, by electrifying a significant share of building end uses that currently use fossil fuels, such as space and water heating. Finally, by significantly improving the efficiency of buildings and equipment, including heating and lighting systems, as well as the building envelope.

- Decarbonizing the agriculture sector, specifically focused on the nexus between energy and water: Agriculture represents nearly 10 percent of the Nation's GHG emissions[2], and EERE prioritizes RDD&D investments to help drive a cleaner agriculture sector while achieving our decarbonization goals. This focus includes expanding EERE's work related to reducing GHG emissions in the agricultural sector through development of biofuels, greater efficiency of off-road agricultural vehicles, on-site production of animal waste to clean energy, and better understanding and prediction of water flow to design more water and energy efficient irrigation systems. The work will be additive and complementary to the Department of Agriculture's work.

To accomplish these five programmatic priorities, EERE has identified four key emphasis areas that are inherent to all its work:

- Energy Justice: It is essential that EERE's work ensures clean energy economy benefits for all Americans. EERE recognizes that marginalized and low-income communities have long endured disproportionate pollution to the air, water, and soil within these communities. EERE is fully committed to aligning programs and policies with the Administration's Justice40 Initiative, focused on delivering 40 percent of the benefits of Federal clean energy and climate investments to historically disadvantaged communities. The Request includes increased support for program elements with proven success working in collaboration with disadvantaged and energy transition communities and plans to target equitable distribution of benefits in the near and longer term. EERE's FY 2023 investments take a strategic approach to partnering with a broader array of stakeholders across the RDD&D portfolio while expanding American clean energy innovation leadership.
- Workforce: EERE is committed to an office-wide approach to workforce development, which includes, for example, funding research to understand the career opportunities created by the Administration's American Made Challenge program, decarbonization, jobs and infrastructure initiatives, identifying opportunities across technologies and industry sectors, and working with labor unions, trade associations, and educational institutions to enable the training programs and career pathways needed to prepare the American workforce for these good-paying jobs that provide a fair and free choice to join a union.
- Diversity in STEM**:** The Request increases outreach and raises awareness of clean energy research and job opportunities at minority-serving institutions and minority professional organizations, ensuring that organizations that receive EERE funding are prioritizing diversity and equity in their own work. EERE recognizes that one of the main ways to achieve its goals is to be highly inclusive in development of new technical talent, as well as in the research that is supported by EERE's offices and the National Laboratories. This includes efforts to expand STEM pipeline development programs and new research partnerships among underutilized Minority Serving Institutions across the country, including Historically Black Colleges and Universities (HBCU), Hispanic Serving Institutions, Tribal Colleges and Universities, and many others.
- State and Local Partnership: EERE recognizes the essential role that state and local governments play in the transition to a clean energy economy; EERE works in a unified and coordinated way with its state and local partners to accelerate an equitable transition to a clean energy economy and ensure that EERE's investments benefit everyone. In FY 2023, EERE will fund initiatives that empower state and local leaders to develop locally driven, practical, and evidenced-based solutions to create clean energy jobs and the local ecosystem that sustains them. EERE also will collaborate with state and local policymakers, business leaders, community advocates, academics, utilities, transit agencies, and other partners to leverage their regions' unique strengths to tackle the climate crisis and to create healthy, safe, and thriving

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[1] U.S. Department of Energy. Low-Income Community Energy Solutions. https://www.energy.gov/eere/slsc/low-income-community-energy-solutions.

[2] U.S. EPA. 2022. Draft Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2020. U.S. Environmental Protection Agency, EPA 430-P-22-001. https://www.epa.gov/ghgemissions/draft-inventory-us-greenhouse-gas-emissions-and sinks-1990-2020.

communities with clean energy jobs that cater to different education and experience levels. EERE's place-based initiatives are designed to accelerate deployment of clean energy in every pocket of the country, with an emphasis on communities that have been hardest hit by economic, racial, and environmental injustices.

In addition to individual program efforts associated with the key emphasis areas, the Request includes several jointly developed, managed, and funded investments designed to ensure that the clean energy economy benefits all Americans, especially workers and communities impacted by the energy transition and those historically underserved by the energy system and overburdened by pollution.

In FY 2023, EERE renews its international coordination capabilities within the Office of the Principal Deputy Assistant Secretary to function as a central point of contact between EERE's Technology Offices and DOE's Office of International Affairs. The U.S. accounts for only 15 percent of GHG emissions[1], and therefore cannot solve the climate crisis alone. Strategic engagement with select countries, and through multilateral collaborations, can accelerate technological development for climate mitigation, as well as prime major global markets for American technologies and services. The funding request allows EERE to make targeted investments in international collaboration efforts that have the greatest value for potential emissions reductions and creating American jobs.

The FY 2023 Request additionally reflects the realignment within DOE. The following programs functionally transfer from the Office of the Energy Efficiency and Renewable Energy (EERE) appropriation account to the Office of the Under Secretary for Infrastructure:

- The Advanced Manufacturing Office's Industrial Assessment Centers functionally transfer to the new Office of Manufacturing and Energy Supply Chains;
- The Federal Energy Management Program functionally transfers to the new Office of Federal Energy Management Programs, and
- The Weatherization and Intergovernmental Programs functionally transfer to the Office of State and Community Energy Programs.

Future Years Energy Program (FYEP)
($K)

	FY 2023 Request	FY 2024	FY 2025	FY 2026	FY 2027
Energy Efficiency and Renewable Energy	4,018,885	4,111,000	4,206,000	4,303,000	4,402,000

Outyear Priorities and Assumptions
In the FY 2012 Consolidated Appropriations Act (P.L. 112-74), Congress directed the Department to include a future-years energy program (FYEP) in subsequent requests that reflects the proposed appropriations for five years. This FYEP shows outyear funding for each account for FY 2024 - FY 2027. The outyear funding levels use the growth rates from and match the outyear account totals published in the FY 2023 President's Budget for both the 050 and non-050 accounts. Actual future budget request levels will be determined as part of the annual budget process.

Highlights and Major Changes in the FY 2023 Budget Request
In FY 2023, EERE will invest $4,018,885,000 to help achieve a carbon pollution-free electricity sector by 2035 and net-zero emissions, economy-wide, by no later than 2050 through investments in the five programmatic priority areas described above, and through the lens of its four key emphasis areas. The Request prioritizes increased investments to reduce emissions drastically in the near term, while investing in research to ensure American leadership and competitiveness in advanced clean energy technology. In FY 2023, EERE will also continue to streamline and enhance its operations, conduct rigorous analysis and evaluations of its portfolio, and achieve the greatest possible impact in each of its technical pillars designed to advance cross-technology solutions, and a Corporate Program pillar that serves as the central organization for all EERE products, services, processes, and systems.

Sustainable Transportation ($1,128,731,000) supports RDD&D efforts to decarbonize transportation across all modes, including vehicle electrification, commercially viable hydrogen fuel cell trucks, sustainable aviation fuel from biomass and waste carbon resources and low-GHG options for off-road vehicles, rail, and maritime.

Many newly proposed investments in this pillar are focused on the deployment or demonstration of technology to show viable commercial paths, including several programmatic performance milestones by 2030 related to decarbonizing transportation across all modes. The Request in this pillar also supports hydrogen use for industrial decarbonization and energy storage as well as sustainable biomass to achieve reduced GHG from the agricultural sector and to decarbonize chemicals in the industrial sector.

- Vehicle Technologies ($602,731,000) supports RD&D of new, efficient, and clean mobility options that are affordable for all Americans. The office's investments leverage the unique capabilities and world-class expertise of the National Laboratory system to develop new innovations in vehicle technologies, including: advanced battery technologies; advanced materials for lighter-weight vehicle structures and better powertrains; 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); renewable-fuel powered combustion engines to reduce GHG emissions; and technology deployment and integration at the local and state level. In coordination with the other offices across EERE and DOE, the Vehicle Technologies Office advances technologies that assure affordable, reliable mobility solutions for people and goods across all economic and social groups; enable and support competitiveness for industry and the economy/workforce; and address local air quality and use of water, land, and domestic resources.

  Batteries are a key technology supporting many significant objectives associated with decarbonization, both in transportation directly, and in energy storage more broadly to support decarbonization of the electricity sector. The Request initiates support for projects aimed at achieving the following new objectives: reducing electric vehicle (EV) battery cell cost by 50 percent to $60/kWh by 2030 to achieve EV cost parity with internal combustion engine vehicles; eliminating dependence on critical materials such as cobalt, nickel, and graphite, reducing battery supply chain vulnerabilities by 2030; and establishing a lithium battery recycling ecosystem to recover 90 percent of spent lithium batteries and re-introducing 90 percent of key materials into the battery supply chain by 2030. The Request also expands the SuperTruck 3 activity with a focus on electrifying medium and heavy-duty trucks (plug-in hybrid EV, battery EV, and fuel cell EV) and improving the energy efficiency of the entire freight system.[1]

  The Request initiates the process of ensuring Federal funding no longer directly subsidizes fossil fuels, as required by Section 209 of Executive Order 14008, Tackling the Climate Crisis at Home and Abroad. In partnership with state and local partners, this program will leverage results from prior year activities to (1) deploy systems-level tools for mobility design/planning, (2) advance cooperative driving automation to reduce traffic congestion and energy consumption, and (3) improve the efficiency of public transportation. This Request prioritizes maintaining programmatic alignment to the Communities to Clean Energy (C2C) initiative for Transportation and the Integrated Heavy Duty Zero Emissions Vehicle (ZEV) Fueling and Connected Grid initiative. This Request also prioritizes expanding demonstration and deployment projects to accelerate the nationwide adoption and deployment of EVs and charging infrastructure, especially to benefit underserved communities. These activities support the Administration's goal to deploy 500,000 PEV charging stations throughout the Nation.

- Bioenergy Technologies ($340,000,000) advances technologies that convert domestic biomass and other waste resources into affordable, low-carbon biofuels and bioproducts. These technologies hold the promise of enabling a transition to a clean energy economy, creating high-quality jobs, supporting rural economies, and spurring innovation in renewable energy and chemicals production as part of the bioeconomy. The funding increase reflects the critical need to integrate and scale-up advanced bioenergy technologies to decarbonize all modes of transportation. The Request supports RD&D to produce "drop-in" biofuels that are compatible with existing fueling infrastructure and vehicles across a range of transportation modes, including diesel, jet, and marine fuels. This Request increases support for a Sustainable Aviation Fuel (SAF) Initiative that will support RDD&D to enable the U.S. production of the airline industry's demand for SAF. The major focus of the effort is to construct and operate integrated biorefineries at demonstration scale that can produce SAF.

[1] Fuel cell electric vehicle work is in coordination with and funded by HFTO.

Efforts include an initiative to reduce CO_2 at "traditional" biofuel facilities, and a program to establish public-private partnerships to target environmental issues from operations that produce manure and other wet wastes. Technologies and practices include low-carbon agricultural practices, fuel switching to renewable process heat and power (i.e., renewable natural gas, or biomass), and new productivity or conversion efficiency measures to assess the costs and verify the lifecycle GHG benefits. If these technologies and practices were deployed across U.S. industry, it would preserve current biofuels jobs and could reduce GHG emissions by over 42.7 MMT (CO_2-eq) per year – or approximately 2 percent of total U.S. transportation emissions.

In support of EERE's priority to deploy technologies to help decarbonize the agricultural sector while achieving the above goals, the Request initiates an R&D program to study sustainable agriculture practices and help farmers maximize profits on marginal lands while providing valuable feedstocks for bioenergy production. This will include RD&D to develop sensors and tools for soil carbon monitoring and soil carbon enhancement via biochar while enabling carbon credit banking markets and other activities requiring verifiable carbon emission data.

- Hydrogen and Fuel Cell Technologies ($186,000,000) supports efforts to enable widespread adoption of hydrogen and fuel cell technologies. This can be achieved by reducing cost, improving performance and durability, demonstrating and deploying technologies, and addressing safety, codes, standards, and workforce development. Producing affordable clean hydrogen is a key priority in conjunction with enabling diverse end uses including grid integration and stationary energy storage; transportation (e.g., trucks, marine, rail, aviation); chemicals (e.g., ammonia, synthetic fuels); industry (e.g., iron and steel making); backup power (e.g., emergency power, data centers); and others.

The Request represents continued focus on accelerating RD&D to enable more affordable and durable fuel cell system costs, which are nearly $200/kW today. This R&D is also applicable to fuel cells for stationary markets, enabling resilience and potential future deployment in disadvantaged communities and in poor air quality regions to address environmental justice priorities. The Request also includes an increased focus on systems design and integration to accelerate progress towards deployable systems. This includes increased support for the Million Mile Fuel Cell Truck consortium (M2FCT), in which National Laboratories partner with universities and industry to accelerate RD&D that will enable a fuel cell durability of a million miles—a market requirement for long haul trucks. The Request also represents a focus on accelerated target-driven RD&D in Hydrogen Technologies with an emphasis on significantly reducing the cost of hydrogen generated by electrolysis over a greatly accelerated timeline compared to prior years. To support the Hydrogen Energy Earthshot (to produce near-zero GHG hydrogen at $1/kg H2 by 2031) and the H2@Scale initiative, the Request supports RD&D activities on clean hydrogen production, delivery, and storage, including materials development, and integration with diverse net-zero emissions generation sources. This includes increased funding to demonstrate the use of low GHG hydrogen as a feedstock or direct reducing agent to decarbonize ammonia and steel production, in support of H2@Scale.

Additionally, the Request reflects the prioritization of enabling fuels for heavy duty applications, particularly long-haul, heavy-duty trucks. In FY 2023, Fuel Cell Technology efforts will primarily include scale-up and demonstration activities focused on durability protocols and real-world validation of performance. For Hydrogen Technology, the main shift in FY 2023 will be emphasizing R&D and accelerating the timeline for electrolyzer cost reductions to meet the Hydrogen Shot goal. This Request reflects the program's increased focus on applied materials and systems for RD&D for hydrogen production, storage, and infrastructure.

Renewable Power ($1,330,195,000) supports RD&D efforts to reduce the costs and accelerate the integration and utilization of renewable energy technologies as part of a reliable, secure, and resilient fully decarbonized power system by 2035 and a net zero energy system by 2050. This Request drives critical cost reductions and technical improvements in wind, solar, geothermal, and water power technologies to increase the options for cost-competitive, non-emitting energy generation resources across the country, provides new research and technologies to facilitate the siting and integration of the high levels of renewable power generation needed to fully decarbonize the power system, and supports the development of diversified, resilient supply chains for all renewable energy technologies to help ensure the long-lasting security of the U.S. energy supply and provides thousands of good-paying jobs to American workers.

- Renewable Energy Grid Integration (REGI) ($57,730,000) The FY 2023 Request maintains Renewable Energy Grid Integration as a critical program for EERE. This Congressional control point, established in the FY 2022 Appropriations Act, will address system-level challenges to the reliable integration of renewable energy into the power system. Investments in FY 2023 will focus on work that directly supports decision-makers responsible for the planning, operation, regulation, and policies of the grid as a whole. This work builds on technology-specific RD&D in offices across EERE to support system wide planning and operation for grids with high levels of variable renewable energy, and includes improved technologies, tools, data, and operational practices, as well as system-level simulations and demonstrations to validate the safety, reliability, and affordability of up to 100% decarbonized power systems. In partnership with other EERE Offices, this Request funds new initiatives that aim to develop, validate, and deploy technologies addressing charging of Heavy Duty EVs and the associated grid requirements. Efforts will address the unique fueling needs of heavy-duty trucks operating in large scale depots, ports and the corridors that connect them. REGI support will focus particularly on integrating renewable electricity as a primary source of power for charging.

- Solar Energy Technologies (SETO) ($534,575,000) accelerates the development and deployment of solar technologies – creating many thousands of good-paying jobs in the process – while supporting the reliability, resilience, and security of the U.S. electric grid. SETO's priority is developing the domestic solar manufacturing value chain, in large part through the new Solar Manufacturing Accelerator. The Request includes efforts targeting innovative approaches in emerging market segments, including building-integrated photovoltaics in coordination with the Building Technologies Office. The Request also supports new rounds of the American-Made Solar Prize to incentivize and transition new solar technologies into prototypes ready for real world validation, and other prize competitions to spur U.S. business innovation in solar and create good paying jobs with the free and fair chance to join a union and bargain collectively.

  The Request provides $150 million for a Solar Manufacturing Accelerator, a new initiative in partnership with EERE's Advanced Manufacturing Office. It will work to enhance the domestic capability to produce technologically advanced solar energy components that avoid supply chains that may be reliant in part on unethically sourced materials or vulnerable foreign supply chains.

  The Request includes funding to advance confidence in the ability of PV and PV plus storage to contribute to the reliability, resilience, and security of the grid and avoid barriers to accelerated deployment. The Request includes new tools for grid planning and grid operation to understand and control a power system with increasing amounts of variable renewables, EVs, and smart loads, as well as continued RDD&D of new cybersecurity technologies to keep up with a rapidly evolving threat landscape. Furthermore, the Request will establish an assistance program to address barriers to interconnecting variable renewable energy to the electric grid, in collaboration with the Wind Energy Technologies Office.

  The Request supports a new, cross-cutting initiative to grow a skilled and diverse solar and clean energy workforce and connect trainees with the industry. To drive large-scale deployment, the Request increases funding for RD&D activities needed to accelerate cost reductions in PV energy toward the 2030 goal of $0.02/kWh electricity without subsidies with systems lasting 50 years or more. This includes funding for work needed to ensure photovoltaics can operate over a long lifetime in the face of extreme weather conditions including heat, cold, hail, and wind.
  Additionally, the Request supports EERE's priority to decarbonize industry through increased funding for RD&D to use concentrated solar thermal energy to replace fossil fuels in industrial processes, with a particular focus on high-temperature processes like steel manufacturing, cement production, and chemical/fuels production.

- Wind Energy Technologies ($345,390,000) supports an updated and expanded portfolio of research and innovation to accelerate the advancement and deployment of offshore, land-based, and distributed wind energy technologies and their integration with the electric grid. Progress in technology, grid systems integration, and unique solutions to deployment challenges, will drive an increase in American-made wind energy and create good paying jobs with the free and fair chance to join a union and bargain collectively.

  Critical near-term efforts to accelerate deployment include significantly increased support for R&D of technologies to reduce environmental and siting barriers to land-based and offshore wind, as well as efforts to partner with industry, communities, utilities, and other stakeholders to remove barriers to distributed wind deployment. To realize wind energy's full potential to the U.S. power system, Wind Energy Technologies will aggressively pursue continued innovation and cost-reduction by capturing economies of scale. Additionally, WETO will expand efforts to develop larger, light-weight turbines that allow operation at greater heights, platforms, and turbine designs to enable ultra-large floating wind turbines to access the 58 percent of U.S. offshore wind resources that are in deep water. The Request also supports research to maximize production and efficiency from individual turbine siting and operation within a wind facility. The Request also supports critical R&D to expand U.S. manufacturing capacity and domestic job creation, including manufacturing innovations to enable highly flexible, rail-transportable blades, and support to domestic offshore wind advanced manufacturing, supply chain development, and recycling. The Request also substantially increases funding to support the integration of wind into a cost-effective, reliable, secure, and resilient power grid.

In addition, the Request increases support for cross-technology investments that leverage wind energy technologies, including a new effort to integrate and demonstrate a multi-megawatt water electrolyzer coupled with wind power generation to produce low-cost, emissions-free hydrogen, and to demonstrate the robustness of grid services, such as frequency regulation, load following, and contingency reserves.

- Water Power Technologies ($190,500,000) supports a broad portfolio of research activities to strengthen the body of scientific and engineering knowledge, and support industry efforts to develop, maintain, and deploy hydropower and marine energy technologies at all scales.

  The Request builds on WPTO's efforts through optimization of the existing hydropower fleet by increasing funding of its HydroWIRES (Water Innovation for a Resilient Electricity System) initiative to demonstrate hybrid systems of hydropower with other resources, improve valuation tools to fully capture power and non-power value provided by pumped storage hydropower (PSH), and quantify emission benefits associated with new PSH and expanded hydropower flexibility. With respect to climate change effects on watersheds and hydropower, the Request builds on current efforts to develop a suite of climate and hydrologic models, advanced hydrologic sensors, and decision-making tools to provide accurate state-of-the-art climate information and diagnostic capabilities for predicting and managing water and power systems. The Request also expands WPTO's current scope of work in new, low-impact hydropower by investing in demonstration of technologies to power nonpowered dams or infrastructure, including demonstrating and deploying irrigation modernization to serve agricultural end-users.

  The Request sustains support for the design, fabrication, and testing of marine energy conversion devices at a range of sizes (including grid-scale and PBE technologies); continued investigation into marine powered Carbon Dioxide Removal (CDR) and aquaculture opportunities; demonstrations of marine energy powered ocean observing systems; and demonstrations of novel concept (including flexible material) marine energy device designs. To address the key challenge of testing for validation of all scales of marine energy, the Request also continues support of the Testing Expertise and Access for Marine Energy Research (TEAMER) initiative, a rolling test campaign developed in collaboration with U.S. universities and National Laboratories to provide technology developers with quick and economical access to marine energy testing facilities and capabilities across the U.S.

  The Request expands the Powering the Blue Economy initiative, which focuses on applications beyond grid-scale serving devices. This includes robust funding for desalination technologies and other systems for multiple applications and scales ranging from disaster relief to small communities to at-sea applications – like aquaculture, carbon dioxide removal monitoring – and building systems tested through the Ocean Observing Prize. Funding continues to support the Energy Transition Initiative Partnership Project (ETIPP), supporting device design and fabrication to serve remote coastal and islanded communities based on outcomes of the ETIPP cohorts.

  To support a more diverse and robust workforce in the marine and hydropower industries, the Request expands on work conducted to date in developing effective strategies to support STEM and workforce gaps in water power. This includes relevant water power educational materials and programs, holding collegiate competitions in both marine energy and hydropower, and supporting teacher-training workshops.

- Geothermal Technologies ($202,000,000) supports the deployment of geothermal energy in both the electric and non-electric sectors to help reach a carbon pollution-free electricity sector by 2035 and a net-zero economy by 2050.

The Request prioritizes support for R&D at the Frontier Observatory in Research in Geothermal Energy (FORGE). This flagship initiative, started in FY 2014, has drilled several major wells on the Utah site, including the first-ever highly deviated geothermal well, drilled at 8,000+ foot depth at a rate twice the industry standard. In FY 2023, GTO will drill a third, long-reach horizontal well, providing an opportunity to further advance drilling improvements and enable additional simulation and zonal isolation testing. In addition, the Request will provide increased support for the next FORGE R&D solicitation, enabling technological progress toward ensuring the commercial viability of enhanced geothermal systems and contributing to Administration goals for a carbon pollution-free electric sector.

The Request continues support for the Geothermal Energy from Oil and gas Demonstrated Engineering (GEODE) consortium designed to leverage oil and gas subsurface assets, technologies, and expertise to help solve geothermal energy's toughest challenges. The Request also continues activities to assist Federal agencies to deploy geothermal energy, with a focus on powering installations with large electricity demands in partnership with the Federal Energy Management Program (FEMP). In addition, the Request will build on successes of the FY 2022 Community Geothermal Heating & Cooling initiative with a new focus on the use of direct use heating and cooling for both community and agriculture to address local energy scarcity and/or food security needs in underserved areas of the U.S. With respect to energy storage, the Request will facilitate pilot demonstrations of promising Reservoir Thermal Energy Storage (RTES), that have the potential to unlock terawatt-scale thermal energy storage using the Earth as our battery.

Energy Efficiency ($974,500,000) supports RDD&D to decarbonize America's homes, buildings, and industrial facilities while also strengthening U.S. manufacturing competitiveness and producing thousands of good-paying jobs. The Request increases demonstration and deployment support as well as high impact R&D of technologies to increase energy efficiency, improve demand flexibility, and reduce on-site emissions from our nation's 125 million homes and commercial buildings to reduce total emissions by 50% by 2030 and net-zero by 2050. It also increases investment in RDD&D across the multiple decarbonization technologies and approaches necessary to achieve net-zero emissions by 2050, including industry-specific decarbonization investments focused on the chemicals, iron and steel, cement, and food products industries. In addition, the Request includes significant funding increases for public investment in federal, state and community programs to accelerate investments in decarbonizing all sectors of the U.S. economy.

- Advanced Manufacturing ($582,500,000) invests in energy-related advanced manufacturing technologies and practices to drive U.S. economic competitiveness and an equitable transition to a net zero carbon economy by 2050. As industrial processes contribute significantly to the nation's carbon emissions, the FY 2023 Request substantially increases industrial decarbonization efforts, including RD&D of emerging zero-carbon technologies for steel, cement, and chemical manufacturing. It also advances technologies for clean energy manufacturing, including through the new Solar Manufacturing Accelerator, works to realize secure and sustainable material supply chains and provides technical assistance and workforce development for the U.S. manufacturing sector.

  The FY 2023 Request supports industry-specific decarbonization RD&D, with initiatives focusing on the chemicals, iron and steel, concrete and cement, and food products industries. It includes advancing crosscutting, platform technologies to reduce carbon emissions within existing manufacturing processes and promoting the development and growth of manufacturing in multiple emerging energy fields. The Request provides $50 million for the Solar Manufacturing Accelerator, a new initiative in partnership with the Solar Energy Technologies Office that will focus collective efforts on strengthening domestic manufacturing capabilities of solar products and inputs. The Request also prioritizes the development of manufacturing innovations to achieve lower manufacturing cost, higher performance, and accelerated demonstration and deployment of clean energy technologies, such as energy storage systems, hydrogen, and wide bandgap semiconductors. The Request will also Expand the DOE's Better Plants and Better Climate Challenge programs to include new initiatives related to energy-intensive manufacturers, carbon reduction, technology validation, and training opportunities. In addition, the Request also supports resources and trainings to increase the impact of existing workforce related programs, including within energy communities, underserved communities, and tribal communities.

  Additional highlights include: (1) Pursuit of priority cross-cutting technologies for decarbonization based on a soon-to-be published industrial decarbonization roadmap, including electrification of process heat, electrochemical processes, innovative separations, circular economy approaches, and CO_2 reuse; (2) support of an integrated and coordinated RD&D program for high priority critical materials; and (3) lower cost, lower energy intensive water treatment technologies to create a more modern, equitable, climate-adaptive, and sustainable water infrastructure from both freshwater and non-traditional water sources

- Building Technologies (BTO) ($392,000,000) reduces the energy intensity and related carbon emissions resulting from homes and commercial buildings through the application of cost-effective technologies and practices. Throughout the building lifecycle there are multiple opportunities to work towards emission reductions, increasing energy efficiency, and encouraging demand flexibility, including: new building design and construction; ongoing management, maintenance, and appliance replacements; and building shell renovation and improvements. The Request focuses on maximizing impact in each of these stages through strategic investment in RDD&D, adoption, acceleration, and regulatory mechanisms. Acceleration of building sector technology innovation and deployment of these high impact technologies play an essential role towards a U.S. net-zero emission economy by 2050. Energy reductions across building electric end uses (e.g., cooling, commercial ventilation, lighting, and refrigeration) are an important part of the transition to a net-zero emission economy.

  The Request increases support for climate and clean energy goals by focusing broadly on three crosscutting initiatives that allow for strategic implementation of these priorities, including the E3 Heat Pump Initiative for Better Energy, Emissions, and Equity, the Advanced Building Construction Initiative, and the Better Buildings Initiative and Better Climate Challenge. The Better Climate Initiative is a broad DOE platform that engages with commercial, industrial, and multifamily partners to set ambitious goals and work in partnership to develop and share replicable solutions for the market. The Request supports workforce development activities to 1) expand interest in careers that will enable a low-carbon, modernized U.S. building stock among underrepresented groups; and 2) improve the skills of existing trades and professionals, as well as streamline pathways from education and training to viable careers. This Request increases support to develop new and amended test procedures and energy conservation standards to decrease energy and water use and help support emissions reductions in appliances, lighting, and equipment used in buildings. In addition, the Request shows a renewed emphasis on supporting activities that will maximize the impact of building energy codes at the Federal, State, and local level, including supporting energy code updates, localized technical assistance, and innovative building energy code approaches such as building performance standards and stretch codes.

Corporate Support Programs ($585,459,000) support a range of activities to make EERE more efficient and effective. This effort includes support to strengthen EERE's overall performance, organization, budget, laboratory management, operations, human capital, and project management. This investment includes support for program direction and facilities and infrastructure as part of EERE's stewardship of the National Renewable Energy Laboratory (NREL) in Golden, Colorado.

- Facilities and Infrastructure ($301,600,000) ensures EERE fulfills its role as NREL's steward and maintains and upgrades existing research and support infrastructure in key areas to attract world-class research scientists and to develop innovative solutions to the most challenging technology issues. NREL serves as the Nation's preeminent institution for delivering impactful scientific knowledge and technology innovations that transform renewable energy technologies, systems, and markets.

  The Request prioritizes increased investments in the Advanced Research in Integrated Energy Systems (ARIES) initiative. The ARIES goal for these investments is to address the challenges of designing and constructing future energy systems using the basic principles of operating large-scale hybrid energy systems that interconnect multiple generation and storage technologies. FY 2023 investments will focus on solving the complex problem of controlling the interactions between millions of distributed assets.

  The Request also supports the Energy Materials and Processing at Scale (EMAPS) line-item construction project, a planned design and construction of a multi-disciplinary research capability in process integration that draws on bench-scale innovations from multiple institutions and transforms them into integrated and scalable hybrid technology processes needed to ready DOE innovations for commercial development.

  Additionally, this Request provides funding for the design and first segment of construction of the Carbon-Free District Heating and Cooling System on the South Table Mountain (STM) campus. Completion of the CD-0, Mission Need Statement, is expected in FY 2023.

- Program Direction ($224,474,000) enables EERE to maintain and support a world-class Federal workforce. The Request provides additional 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. This includes increased staffing and contract support for areas such as appliance standards development and building codes development. In addition, the Request includes increased funding for information technology systems development to ensure EERE can collect and analyze data on its investments to make sure every dollar is contributing to its mission.

- Office of Strategic Programs ($59,385,000) supports high-impact, crosscutting, integrative activities most efficiently executed by a single crosscutting organization in coordination with EERE technology programs and other DOE offices. This includes support for a core portfolio of energy and environmental justice-focused activities to provide resources to capacity-constrained communities, support to inform key EERE audiences and stakeholders about the work that EERE is doing to transition the Nation to a clean energy economy and fight the global climate crisis, and funding to address high energy costs, reliability, and inadequate infrastructure challenges faced by islands and remote communities as part of the Energy Transitions Initiative.

Energy Efficiency and Renewable Energy
($K)

	FY 2021 Enacted	FY 2022 Annualized CR[1]	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted	
				$	%
Sustainable Transportation					
Vehicle Technologies	400,000	400,000	602,731	+202,731	+50.7%
Bioenergy Technologies	255,000	255,000	340,000	+85,000	+33.3%
Hydrogen and Fuel Cell Technologies	150,000	150,000	186,000	+36,000	+24.0%
Renewable Power					
Renewable Energy Integration	0	0	57,730	+57,730	NA
Solar Energy Technologies	280,000	280,000	534,575	+254,575	+90.9%
Wind Energy Technologies	110,000	110,000	345,390	+235,390	+214.0%
Water Power Technologies	150,000	150,000	190,500	+40,500	+27.0%
Geothermal Technologies	106,000	106,000	202,000	+96,000	+90.6%
Energy Efficiency					
Advanced Manufacturing	396,000	396,000	582,500	+186,500	+47.1%
Federal Energy Management Program	40,000	40,000	0	-40,000	-100.0%
Building Technologies	290,000	290,000	392,000	+102,000	+35.2%
Weatherization and Intergovernmental Programs					
Weatherization Assistance Program	310,000	310,000	0	-310,000	-100.0%
Training and Technical Assistance	5,000	5,000	0	-5,000	-100.0%
State Energy Program	62,500	62,500	0	-62,500	-100.0%
Total, Weatherization and Intergovernmental Programs	**377,500**	**377,500**	**0**	**-377,500**	**-100.0%**
Corporate Support Programs					
Facilities and Infrastructure (NREL)	130,000	130,000	210,100	+80,100	+61.6%
21-EE-001-Energy Materials and Processing at Scale (EMAPS)	0	0	60,000	+60,000	NA
23-EE-TBD, STM Carbon Free District Heating/Cooling	0	0	31,500	+31,500	NA
Total, Facilities and Infrastructure	**130,000**	**130,000**	**301,600**	**+171,600**	**+132.0%**
Program Direction	165,000	165,000	224,474	+59,474	+36.0%
Strategic Programs	14,500	14,500	59,385	+44,885	+309.6%
Subtotal, EERE	**2,864,000**	**2,864,000**	**4,018,885**	**+1,154,885**	**+40.3%**
P.L. 116-260: Unobligated Balance Rescission	-2,240	-2,240	0	0	-100%
Total, EERE	**2,861,760**	**2,861,760**	**4,018,885**	**+1,157,125**	**+40.4%**

SBIR/STTR:

- FY 2021 Transferred: SBIR: $70,331,509; STTR $10,140,474
- FY 2022 Annualized CR: SBIR: $59,706,000; STTR $8,396,000
- FY 2023 Request: SBIR: $89,582,000; STTR: $12,598,000

[1] The FY 2022 Annualized CR amounts reflect the P.L. 117-95 continuing resolution level annualized to a full year.

Bipartisan Infrastructure Law (BIL) Investments

EERE was appropriated funds through the Bipartisan Infrastructure Law (BIL) (P.L. 117-58). Not all BIL activities will be managed by the organization to which funds were appropriated. In February 2022, the Department announced an organizational realignment, establishing new Office of the Under Secretary for Infrastructure (S3). This realignment was intended to establish a structure to effectively implement the clean energy investments provided through BIL. In the FY 2023 Request, funding from EERE was functionally realigned to stand up three new offices: State and Community Energy Programs (SCEP), Manufacturing and Energy Supply Chains (MESC), Federal Emergency Management Program (FEMP), and Grid Deployment Office (GDO).

($K)

	FY 2022 BIL Appropriation	FY 2023 BIL Appropriation	Managing Organization
Energy Efficiency and Renewable Energy			
Vehicles			
Battery Manufacturing and Recycling Grants	600,000	600,000	MESC
Battery Material Processing Grants	600,000	600,000	MESC
Electric Drive Vehicle Battery Recycling & Second-Life Applications Program	40,000	40,000	EERE
Lithium-Ion Battery Recycling Prize Competition	10,000	0	EERE
Weatherization Assistance Program	3,500,000	0	SCEP
Buildings			
Building Grants	45,000	45,000	EERE
Building, Training, and Assessment Centers	10,000	0	SCEP
Career Skills Training	10,000	0	SCEP
EERE Revolving Loan Fund	250,000	0	SCEP
Energy Auditor Training Program	40,000	0	SCEP
Energy Efficiency & Renewable Energy Improvements at Public School Facilities	100,000	100,000	SCEP
Implementation Grants for Industrial Research & Assessment Centers	80,000	80,000	MESC
Industrial Research and Assessment Centers	30,000	30,000	MESC
Advanced Manufacturing			
Battery processing & manufacturing / battery & critical mineral recycling	125,000	0	MESC
Advanced Energy Manufacturing and Recycling Grant Program	150,000	150,000	MESC
Clean Hydrogen Manufacturing Recycling RD&D Program	100,000	100,000	
Energy Efficiency Materials Pilot Program Grants	50,000	0	SCEP
Manufacturing Leadership	50,000	0	MESC
Clean Hydrogen Electrolysis Program	200,000	200,000	EERE
Water			
Hydroelectric Production Incentives	125,000	0	GDO
Hydroelectric Efficiency Improvement	75,000	0	GDO
Hydroelectric Initiatives	276,800	276,800	GDO
National Marine Energy Centers	40,000	0	EERE
Pumped Storage Hydropower Wind & Solar Integrated and System Reliability Initiative	10,000	0	EERE
National Marine Renewable Energy RD&D Centers	36,000	0	EERE
Energy Efficiency			
Energy Efficiency and Conservation Block Grant Program	550,000	0	SCEP
Energy Efficient Transformer Rebates	10,000	0	MESC
Extended Product System Rebates	10,000	0	MESC

($K)

	FY 2022 BIL Appropriation	FY 2023 BIL Appropriation	Managing Organization
Section 635 Energy Independence and Security Act Activities	70,400	0	EERE
State Energy Program	500,000	0	SCEP
FEMP - Assisting Federal Facilities with Energy Conservation Grant Program	250,000	0	FEMP
Wind			
Wind Energy Tech. Manufacturing Recycling RD&D Program	40,000	0	EERE
Wind Energy Technology Program	60,000	0	EERE
Geothermal - Enhanced geothermal systems R&D	84,000	0	EERE
Solar			
Solar Energy Technology Program Activities	40,000	0	EERE
Advanced Solar Energy Manufacturing Initiative	20,000	0	EERE
Solar Energy Tech. Recycling RD&D Program	20,000	0	EERE
Total, Energy Efficiency and Renewable Energy	**8,207,200**	**2,221,800**	

Additional Activities Managed by EERE

EERE will be responsible for overseeing $300 million of BIL funds to facilitate a collaborative Joint Office between DOE and the U.S. Department of Transportation to support the deployment of zero-emission, convenient, accessible, equitable transportation infrastructure. The Joint Office will align resources and expertise across the two departments toward leveraged outcomes. The office will be a critical component in the implementation of the BIL, providing support and expertise to a multitude of programs that seek to deploy a network of electric vehicle chargers, zero-emission fueling infrastructure, and zero-emission transit and school buses.

Vehicle Technologies

Overview

Vehicles move our national economy. Each year in the U.S., vehicles transport 18 billion tons of freight – about $55 billion worth of goods each day[1] – and move people more than 3 trillion vehicle-miles.[2] The transportation sector accounts for approximately 27 percent of total U.S. energy needs[3] and over 17 percent of average U.S. household expenditures[4], making it, as a percentage of spending, the most costly personal expenditure after housing. Transportation is critical to the overall economy, from the movement of goods to providing access to jobs, education, and healthcare.

The transportation sector has historically relied heavily on petroleum, which supports over 90 percent of the sector's energy needs today[5] and, as a result, has surpassed electricity generation to become the largest source of CO_2 emissions in the country[6]. Transportation sector decarbonization is therefore critical to achieving the overall goal of economy-wide decarbonization by 2050. The Vehicle Technologies Office (VTO) will play a leading role in decarbonizing the transportation sector and address the climate crisis by driving innovation and deploying clean transportation technologies, all while maintaining transportation service quality and safety. VTO will also support the Biden Administration's goal to achieve carbon pollution-free electricity by 2035 (e.g., through electric vehicles (EVs) and managed charging) and deliver an equitable, clean energy future, and put the U.S. on a path to achieve net-zero emissions, economy-wide, by no later than 2050, leading to improved air quality for all Americans. VTO will also support Administration goals for equity and justice by delivering 40 percent of the overall benefits of investments to disadvantaged communities.

Achieving deep decarbonization in transportation will require vehicle efficiency improvements, low lifecycle carbon-intensity fuels, and overall system-wide improvements in the transportation system. VTO funds research, development, demonstration, and deployment (RDD&D) of new, efficient, and clean mobility options that are affordable for all Americans. VTO leverages the unique capabilities and world-class expertise of the National Laboratory system to develop new innovations in vehicle technologies, including: advanced battery technologies; advanced materials for lighter-weight vehicle structures and better powertrains; energy-efficient mobility technologies (including automated and connected vehicles as well as innovations in efficiency-enhancing connected infrastructure); innovative powertrains to reduce greenhouse gas (GHG) and criteria emissions from hard to decarbonize off-road, maritime, rail, and aviation sectors; and technology integration that helps demonstrate and deploy new technology at the community level. Across these technology areas and in partnership with industry, VTO has established aggressive technology targets to focus RDD&D efforts and ensure there are pathways for technology transfer of Federally supported innovations into commercial application.

Working closely and in collaboration with EERE's Bioenergy Technologies and Hydrogen and Fuel Cell Technologies Offices, VTO advances technologies that assure affordable, reliable mobility solutions for people and goods across all economic and social groups; enable and support competitiveness for industry and the economy/workforce; and address local air quality and use of water, land, and domestic resources.

DOE is committed to pushing the frontiers of science and engineering, creating good-paying clean energy jobs through RDD&D, and ensuring environmental justice and inclusion of disadvantaged communities. VTO supports the federal government in pursuing a comprehensive approach to advancing equity for all, including people of color and others who have been historically underserved, marginalized, and adversely affected by persistent poverty and inequality, including those in energy communities. Affirmatively advancing equity, civil rights, racial justice, and equal opportunities are the responsibility of the whole of our government. By advancing equity across the Federal Government, we can create opportunities for the improvement of communities that have been historically underserved, which benefits everyone.

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[1] Bureau of Transportation Statistics, DOT, Transportation Statistics Annual Report 2020, Table 4-1. https://www.bts.gov/tsar.

[2] Transportation Energy Data Book 39th Edition, ORNL, 2021. Table 3.8 Shares of Highway Vehicle-Miles Traveled by Vehicle Type, 1970-2018.

[3] U.S. Energy Information Administration. Monthly Energy Review, 2022, https://www.eia.gov/totalenergy/data/monthly/index.php

[4] Davis, Stacy C., and Robert G. Boundy. Transportation Energy Data Book: Edition 39. Oak Ridge National Laboratory, 2020, https://doi.org/10.2172/1767864

[5] Transportation Energy Data Book 39th Edition, ORNL, 2021. Table 2.3 Distribution of Energy Consumption by Source and Sector, 1973 and 2019.

VTO also supports the key emphasis areas of energy justice, workforce, diversity in STEM, and state and local partnerships. Investments associated with Workforce Development will support training and develop good paying clean energy jobs for the American people – especially workers and communities impacted by the energy transition and those historically underserved by the energy system and overburdened by pollution. Investments associated with Diversity in STEM support outreach and will raise awareness of clean energy research and job opportunities at minority-serving institutions and minority professional organizations and ensure that organizations receiving EERE funding are thinking through diversity and equity in their own work. Investments in State and Local partnerships will enable state and local governments to be more effective in facilitating the nation's (and their own) affordable and resilient clean energy and efficiency goals. As an example, at the national level, VTO's Technology Integration Program offers technical assistance, information resources, online training, and an array of data and analysis tools. At the local level, more than 75 Clean Cities Coalitions leverage these resources to create networks of community stakeholders and provide hands-on technical assistance to fleets. Investments associated with Energy and Environmental Justice will support approaches and processes to reach new groups of Americans historically underserved by the energy system.

Highlights of the FY 2023 Request

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

- Advanced Battery R&D: Identify new battery chemistry and cell technologies with the potential to reduce the cost of electric vehicle battery cells, in support of EVs and batteries across clean energy applications, including the Energy Storage Grand Challenge. Activities will focus on scaling up recycling technologies and promising near-term approaches; the scale-up of lithium battery technologies such as no-cobalt/no-nickel cathodes, lithium anodes, and solid-state systems to reduce constraints from scarce materials; technologies that can enhance environmental sustainability; and the development of a U.S.-based circular lithium battery supply chain.
- Electric Drive Systems and Electrification: Address the challenge of transportation electrification through powertrain and vehicle charging technologies and the interaction of electrified vehicles with the overall electric grid. Emphasize work with stakeholder groups and partnerships to guide RD&D decisions and efforts that can demonstrate benefits to all communities.
- Decarbonization of Off-Road, Rail, Marine, and Aviation Technologies: Focus on these difficult to decarbonize sectors by developing technologies to efficiently utilize electrification, including hybridization and renewable fuels, such as advanced biofuels, renewable hydrogen, and e-fuels, to significantly reduce GHG emissions while achieving near-zero criteria emissions. Technologies developed for off-road, rail, and marine will also be applicable to HD trucks along with the integration of hybrid and plug-in hybrid powertrains. Work will include research to cost-effectively reduce emissions from non-road engines, while reducing/replacing critical minerals, i.e., platinum group metals.
- Materials Technology: 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 and develop lightweight alloys with improved strength and fatigue performance for cast and additive manufacturing methods for weight reduction and efficiency improvements in electric powertrain and suspension components.
- Energy Efficient Mobility Systems: Create and deploy breakthrough modeling, simulation, 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 and support the equitable transition to a net-zero economy by 2050.
- Technology Integration & Deployment: Accelerate the nationwide adoption and deployment of EVs and charging infrastructure through a major, new Integrated Heavy-Duty Zero Emission Vehicle (ZEV) Fueling and Connected Grid demonstration project, in partnership with the Hydrogen and Fuel Cell Technology Office and other DOE offices for grid connectivity. Pursue new community focused transportation initiatives to provide technical assistance at the community level to achieve clean energy goals. Continue to fulfill statutory requirements for providing alternative fuel information, publishing the Fuel Economy Guide, and implementing the state and alternative fuel provider fleet program. Expand demonstration and deployment projects for advanced transportation technologies and charging infrastructure, especially to benefit underserved communities. Other projects seek 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 (STEM) education objectives through an advanced vehicle technology competition to provide hands-on training to university students and prepare them for the future workforce.
- SuperTruck: As a VTO crosscut, develop energy efficient powertrain technologies that will improve commercial vehicles.

Projects will pioneer electrified medium- and heavy-duty trucks and freight system concepts to achieve higher efficiency and zero emissions.
- Data, Modeling, and Analysis: Conduct technical-, economic-, and interdisciplinary analyses using advanced vehicle and transportation data that result in insights critical to informing Vehicle Technologies' targets and program planning.

Contributions to DOE-wide Crosscutting Investments
VTO is involved in several crosscutting initiatives, including the following:
- Advanced Manufacturing ($50,000,000) – Focus on new joining technologies for multi-material structures in vehicles including composites and other new lightweight materials and develop high temperature metal alloys for additive manufacturing. Address innovations in advanced battery material, electrode, cell, and recycling processing technologies;
- Critical Minerals and Materials ($73,600,000) – Addresses lithium, cobalt, nickel, and graphite use and recycling for batteries; reducing heavy rare-earth materials (RE) in EV drive systems; reduce/replace platinum group metals in engine emissions control systems;
- Energy Storage ($181,700, 000) – R&D focused on high-energy and high-power battery materials, cells, and systems; and
- Grid Modernization ($20,000,000) – Projects for managing grid charging of EVs, charging infrastructure cybersecurity, and MD/HD high power EV charging.

The 2023 Budget begins the process of ensuring that Federal funding no longer directly subsidizes fossil fuels, as required in Section 209 of Executive Order 14008, Tackling the Climate Crisis at Home and Abroad. The Department will ensure that, to the extent consistent with applicable law, VTO will instead focus on developing efficient combustion and fuels technology for hard to electrify segments of the transportation sector, such as off-road vehicles, including construction, agriculture and forestry, and rail, marine and aviation that can utilize renewable fuels, such as advanced biofuels, hydrogen, and e-fuels, or hybrid electric powertrains where full electrification is not yet feasible, so as to reduce GHG and criteria emissions to near-zero levels.

EERE Program Priorities
In FY 2023, VTO continues to support an investment strategy aligned to the following programmatic priority area that is a central pillar to the U.S. GHG profile:

Vehicle Technologies
Funding ($K)

	FY 2021 Enacted	FY 2022 Annualized CR[1]	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted
Decarbonizing transportation across all modes: air, sea, rail, and road	400,000	400,000	602,731	+202,731

[1] The FY 2022 Annualized CR amounts reflect the P.L. 117-95 continuing resolution level annualized to a full year.

Vehicle Technologies
Funding ($K)

	FY 2021 Enacted	FY 2022 Annualized CR[1]	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted
Vehicle Technologies				
Battery and Electrification Technologies	178,700	-	260,000	+81,300
Decarbonization of Off-Road, Rail, Marine, and Aviation Technologies	70,000	-	25,000	-45,000
Materials Technology	40,000	-	50,000	+10,000
Energy Efficient Mobility Systems	45,000	-	60,000	+15,000
Technology Integration & Deployment	60,300	-	199,731	+139,431
Data, Modeling, and Analysis	6,000	-	8,000	+2,000
Total, Vehicle Technologies	**400,000**	**400,000**	**602,731**	**+202,731**

SBIR/STTR:

- FY 2021 Transferred: SBIR: $10,768,000; STTR: $1,514,000
- FY 2022 Annualized CR: SBIR: $11,734,000; STTR: $1,650,000
- FY 2023 Request: SBIR: $16,142,000; STTR: $2,270,000

[1] The FY 2022 Annualized CR amounts reflect the P.L. xxx-yyy continuing resolution level annualized to a full year. These amounts are shown only at the congressional control level and above, below that level, a dash (-) is shown.

Vehicle Technologies
Explanation of Major Changes
($K)

	FY 2023 Request vs FY 2021 Enacted
Vehicle Technologies	
Battery and Electrification Technologies: The Request will increase support for R&D to reduce EV battery cell cost to achieve EV cost parity with internal combustion engine (ICE) vehicles through enhanced R&D focused on lithium metal, solid state, and next generation lithium-ion battery technologies; and reduce or eliminate dependence on critical materials such as cobalt, nickel, and graphite, thereby mitigating battery supply chain risks. VTO will research next generation lithium-ion batteries such as no-cobalt/no-nickel cathodes, and silicon-based anodes; and establish a lithium battery recycling ecosystem to recover 90 percent of spent lithium batteries and re-introduce 90 percent of key materials into the battery supply chain by 2030. Battery recycling R&D includes the development of new recycling processing technologies and scale-up of lithium battery recycling in addition to expanded joint work between industry and researchers through the existing Recycling Center. In addition, the funding increase will support technical assistance to stakeholders to enable vehicle grid integration capabilities. The increase in funding level for this subprogram reflects the emphasis on prioritization of key crosscutting R&D areas across EERE and the Department, including the Energy Storage Grand Challenge, Critical Materials, Advanced Manufacturing, and the Grid Modernization Initiative.	**+81,300**
Decarbonization of Off-Road, Rail, Marine, and Aviation Technologies: The Request shifts focus to research and demonstration on large vehicles that are difficult to decarbonize by utilizing electrification, including hybridization, renewable fuels, such as advanced biofuels, renewable hydrogen, and e-fuels, to reduce GHG emissions and achieve near-zero criteria emissions. A multi-lab initiative for heavy-duty commercial off/on-road vehicles will work with industry and focus on research to improve engine efficiency, utilizing renewable fuels and hybrid powertrains. Shift focus of catalysis research to cost-effectively reduce emissions to meet future standards and durability requirements from medium- and heavy-duty non-road engines, while reducing/replacing critical minerals, i.e., platinum group metals.	**-45,000**
Materials Technology: The Request continues to support key advances in materials development and manufacturing to decrease lifecycle GHG emissions and manufacturing cost of electrified vehicles supporting the transition to electric light duty vehicles. The increase in funding reflects the need to advance the state of the art for the development and processing of lightweight metals including novel architectures and manufacturing methods to meet the challenging cost reduction goals by 2030. In addition, increase industry engagement by building on advances made in the Composites Core Program. The Materials Technology subprogram will coordinate closely with the Battery and Electrification Technologies subprogram to support materials research and development to address key challenges in electrical conductivity, thermal conductivity, magnetic materials, and high temperature operation currently limiting advances in electric powertrain and wireless charging.	**+10,000**

	FY 2023 Request vs FY 2021 Enacted
Energy Efficient Mobility Systems (EEMS): The Request will continue to support efforts to research, develop, demonstrate, and deploy advanced transportation solutions that leverage results of prior year activities in Computational Modeling and Simulation and Connectivity and Automation Technology, with increased funding to support engagement with state and local partners to deploy systems-level tools for mobility design and planning, advancing cooperative driving automation to reduce traffic congestion and energy consumption, and technologies to improve the efficiency of public transportation. EEMS will continue to support key activities in Computational Modeling and Simulation, including deployment of an integrated transportation modeling platform developed through the Systems and Modeling for Accelerated Research in Transportation (SMART) Mobility National Laboratory Consortium – a multi-disciplinary approach to assess the system-level energy productivity impacts from future mobility technologies and transportation systems, identify pathways to improve mobility energy productivity, and accelerate the transition to a net-zero carbon emission transportation system.	**+15,000**
Technology Integration & Deployment: The Request includes support for a major new Integrated Heavy-Duty ZEV Fueling Corridor Initiative, in partnership with the Hydrogen and Fuel Cell Technology Office and other DOE offices related to grid connectivity. This demonstration will address the unique fueling needs of heavy-duty trucks operating in large scale depots, ports and the corridors that connect them. These trucks are a backbone to the economy and industry has indicated the need to move to battery and hydrogen fuel cell electrification. This project will demonstrate the real-world issues with fueling these vehicles and associated demands on the electric grid. The increase in funding will also be used to support transportation, which will address cross-cutting, clean energy challenges with a community-centered focus. The subprogram will continue to address the barriers to light-, medium-, and heavy-duty plug-in electric vehicle (PEV) deployment, especially in energy communities and other underserved communities (e.g., low-income, rural, and demographics that currently have minimal access to PEVs). Lack of charging infrastructure, PEV cost parity with conventional vehicles, education, and workforce training impede widespread PEV adoption. Improving equitable access to the benefits of electrified transportation must take into consideration PEVs and charging infrastructure availability for mobility choices such as personal vehicle ownership, car sharing, ride sharing, school transport, and transit. This also includes projects demonstrating Smart Charging technologies, and other business models, that improve cost and efficiency for the acquisition and operation of new EV models for local governments, utilities, transit, schools, ports, and goods movement. These projects will demonstrate that new electric transportation solutions, combined with wide-spread technical assistance, can support efforts at the State level to advance the Administration's goal of deploying 500,000 EV chargers.	**+139,431**
Data, Modeling, and Analysis (formerly Analysis): The Request includes funding to solicit external perspectives, methods, and projects for increasing access to low-carbon mobility for underserved communities. Work will continue to provide 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. In FY 2023, projects will continue to support analytical capabilities and tools unique to DOE's National Laboratories.	**+2,000**
Total, Vehicle Technologies	**+202,731**

Vehicle Technologies
Battery and Electrification Technologies

Description

The Battery and Electrification Technologies subprogram supports the decarbonization of transportation across all modes, serves to increase American advancement/manufacturing of battery technology, and creates good paying jobs with the free and fair chance to join a union and bargain collectively. The subprogram supports research with partners in academia, National Laboratories, and industry covered under the Energy Storage Grand Challenge key priority and four distinct crosscuts including: Critical Materials, Grid Modernization, Advanced Manufacturing, and Energy Sector Cybersecurity. The Energy Storage Grand Challenge encompasses R&D across energy storage and electrification including the discovery of lithium-alternative battery materials, processing for raw materials, development of advanced battery cells, discovery of innovative cell manufacturing techniques, battery recycling, and electric vehicle charging infrastructure. The Critical Minerals crosscut aims to reduce or eliminate cobalt and nickel in lithium battery cathode materials, develop substitutes for graphite such as silicon composite anodes and lithium metal anodes, develop advanced recycling and processing through scale up of bench-scale recycling processes and innovative separation processes seedlings, and realize electric drive motor innovations through high energy product magnet R&D to reduce or eliminate heavy rare earth magnet materials. Grid Modernization will continue developing Smart Charge Management technologies for fleets, including medium and heavy-duty vehicles, enabling DC-as-a-service based EV charging facilities, integrating the control and management of EV fleet vehicles to provide more advanced grid services such as resiliency of the charging network and continuity of grid and emergency services operations during disruptive events. The Advanced Manufacturing crosscut is focused on coordination with the Advanced Manufacturing Office for joint projects scaling up solid state battery materials and lithium metal electrode processing technologies addressing critical materials for batteries. Energy Sector Cybersecurity research is conducted at National Laboratories for electric vehicle grid connection critical technologies, methodologies, and tools to address the highest priority cyber security risks.

Battery R&D: The Battery R&D activity supports early-stage R&D of high-energy and high-power battery materials, cells, and battery development that can enable industry to significantly reduce the cost, weight, volume, and charge time of PEV batteries. This activity is organized into three sub-activities: advanced battery materials research, advanced battery cell R&D, and battery recycling 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) 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 reduction of over 80%2008 baseline., 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. Battery recycling R&D includes the development of innovative battery materials recycling and reuse technologies, and the Lithium-Ion Battery Recycling Prize, both of which aim to assure sustainability and domestic supplies of key battery materials and minerals.

Electric Drive R&D: The Electric Drive R&D activity supports R&D for extreme high-power density electric drive systems that have the potential to enable radical new vehicle architectures by dramatic volume/space reductions and increased durability and reliability. The cost of electric traction drive systems, including power electronics and electric motors, will be reduced through high-density integration technologies, novel circuit topologies, new materials for high-density electric motors, and leveraging high performance computing for modeling and optimization. VTO will use electric traction drive system design, integration, and testing to verify performance and progress towards meeting R&D targets.

Electrification R&D: The Electrification R&D activity supports R&D to understand the potential impacts on, and benefits of, EV 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 EV charging, charge management, Distributed Energy Resources (DER) integration, grid services, and cyber-physical security technologies for reliable and cost-effective charging of light-, medium-, and heavy-duty electric vehicles. This includes technical support and research for technologies related to cybersecurity for electric vehicle charging/supply equipment, and integration with the electric grid.

Battery and Electrification Technologies

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Battery and Electrification Technologies $178,700,000	**$260,000,000**	**+$81,300,000**
Battery R&D $115,000,000	$192,500,000	+$77,500,000
• 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 liquid electrolyte formulations, low and/or no cobalt cathode materials, lithium metal anodes, sulfur-based cathodes, solid-state electrolyte materials, and other promising battery technologies. Research into these different material systems is based on their potential to significantly reduce battery weight, volume, and cost.	• Continue researching next generation battery materials such as lithium-ion, Lithium metal and Lithium Sulfur based chemistries, including solid-state material systems. Expand research for material processing and characterization, including high voltage, high energy cathodes. This early-stage materials research complements Bipartisan Infrastructure Law (BIL) manufacturing investments by maintaining a pipeline of future technologies that will be competitive and contain less critical materials for the next generation of electric drive vehicle batteries.	• Increase funding to improve the performance and energy storage potential of lithium-metal and solid-state materials systems. This class of materials is one of the most promising pathways to achieve cost and critical material reduction targets.
• Fund National Laboratory advanced battery cell projects focused on novel anode and cathode pairing, new electrode structures, fast charging capabilities, and cell manufacturing improvements.	• Accelerate early-stage research for a new class of battery cell materials that contain no cobalt and no nickel. Work with Industry to begin cell evaluations supporting the scale-up of these new materials. This early-stage cell research complements BIL manufacturing investments by validating battery material and materials system research at a stage that potentially could be adopted and manufactured by the same facilities.	• Shift focus toward critical materials use and recyclability since fundamental research has demonstrated that these materials may be a viable alternative to current lithium battery cathode materials, significantly reducing critical material needs.
• Support R&D to enable affordable lithium-ion battery recycling technologies and the Lithium-Ion Battery Recycling Prize. Fund battery development work addressing barriers such as pack and module fast charging, thermal management, and design for recycling or second	• Continue growing joint industry and lab work through the existing Recycling Center. Expand on the most promising reuse and recycling business model innovations from the Lithium-Ion Battery Recycling Prize. Maintain support for behind the meter storage technologies.	• Increase funding to support the most promising reuse and recycling business model innovations from the Lithium-Ion Battery Recycling Prize to encourage technology commercialization.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
use. Continue support for the Behind the Meter Storage (BTMS) in collaboration with the Solar Energy and Buildings Technologies Offices.		
Electric Drive R&D $44,000,000	$30,000,000	-$14,000,000
• 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.	• Complete early-stage research targeting the development of technologies that will enable low-cost, high-power density electric drive systems. Projects will advance electric drive systems and meet development targets for lower cost and higher performance. Key research areas include wide bandgap power semiconductors, semiconductor packaging, passive devices, motor materials including improved copper conductors, and electromagnetic and thermal analysis.	• Early-stage research will prioritize technologies that can most effectively enable low-cost, high-power density electric drive systems.
• Continue competitively awarded research and development projects, working with industry and university partners to address technology gaps in electric drive system performance.	• Integrate disparate technical advancements into a system context. This validates vehicle-level improvements and provides critical feedback to subcomponent researchers.	• Prioritize funding by down-selecting to the technologies with highest impact on system performance and most promising system architectures.
• SuperTruck III: Through five competitively awarded projects, develop energy efficient powertrain technologies that will improve commercial vehicles.	• SuperTruck III: Provide the second year of planned funding for projects selected in FY 2021 and support additional awards. The aim of the projects is to develop energy efficient powertrain technologies that will improve commercial vehicles. Projects will pioneer electrified medium- and heavy-duty trucks and freight system concepts to achieve higher efficiency and zero emissions.	• No significant change.
Electrification R&D $19,700,000	$37,500,000	+$17,800,000
• Support competitively awarded industry led R&D projects to research, develop, and demonstrate affordable and secure plug-in electric vehicle smart charging systems.	• Continue a laboratory research consortium to address the challenges of electric vehicle grid integration across light, medium, and heavy-duty vehicle applications. Technical focus areas include smart charge management, high power	• Increased focus on charging load management including approaches such as stationary storage and distributed energy resources (DERs) to meet vehicle charging loads.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
	charging, wireless charging, cybersecurity, and testing standards.	
• Support National Laboratory research projects focused on enabling extreme fast charging of electric vehicles, advancing wireless charging technology, promoting vehicle-grid integration, controlling smart charging, and designing for cyber-physical security.	• In support of the Cybersecurity crosscut, continue projects to develop secure vehicle-grid connection and communication technologies. Additional projects will also address cybersecurity needs for vehicle charging and charging infrastructure resilience.	• Expand the focus of these projects to incorporate providing resilient communications appropriate for providing grid services for supporting distribution and transmission operations.
• No funding requested	• Working with utility and local partners, these projects will address the unique challenges and opportunities presented by the concentration of vehicle charging loads.	• Initiate projects to further advance the integration of high power and concentrated charging loads presented by large charging sites and medium and heavy-duty vehicles.
• SuperTruck III: Through five competitively awarded projects, develop energy efficient powertrain technologies that will improve commercial vehicles.	• SuperTruck III: Develop energy efficient powertrain technologies that will improve commercial vehicles. Projects will pioneer electrified medium- and heavy-duty trucks and freight system concepts to achieve higher efficiency and zero emissions.	• No significant change.

Vehicle Technologies
Decarbonization of Off-Road, Rail, Marine, and Aviation Technologies

Description

The Decarbonization of Off-Road, Rail, Marine, and Aviation Technologies subprogram supports RD&D to develop and deploy new propulsion and vehicle technologies in applications that reduce GHG emissions and achieve a net-zero economy by 2050, all while creating good paying jobs with the free and fair chance to join a union and bargain collectively. These technologies include electrified and hybrid systems as well as powertrains that can utilize renewable fuels, such as advanced biofuels, hydrogen, and e-fuels. The subprogram also works on optimization of high efficiency engines and emission control systems that can utilize low GHG, renewable fuels and the integration of electrified and hybrid powertrains into these vehicles in furtherance of emissions reductions.

The subprogram supports cutting-edge research at the National Laboratories, in close collaboration with industry to achieve goals for decarbonization of the sector. The 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 improve combustion engines using renewable fuels that will provide efficiency improvements and GHG and criteria emission reductions.

The subprogram will also work closely with the DOE Office of Science to build on research results at the National Laboratories. It will use a multi-laboratory initiative, including high performance computing (HPC) and hardware in-the-loop resources, for research to optimize the efficiency of off-road medium- and heavy-duty vehicles. Research in this area also will be applicable to hard to electrify on-road heavy-duty vehicles.

This subprogram will support industry-led RD&D for off-road medium and heavy-duty vehicles, including engines used for marine, rail, and aviation, focused on electrified and hybrid systems as well as powertrains that can utilize renewable fuels, such as advanced biofuels, hydrogen, and e-fuels. The goal of this portfolio is to conduct coordinated research with industry, universities, and the National Laboratories through Cooperative R&D Agreements (CRADAs). The subprogram will coordinate with and utilize expertise from other Program Offices and VTO subprograms as needed.

The subprogram will support industry needs to develop predictive, high-fidelity sub-models and simulation tools that are scalable and can leverage future exascale computing capabilities. The activity will fund research of renewable 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 for use by industry.

Decarbonization of Off-Road, Rail, Marine, and Aviation Technologies

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Decarbonization of Off-Road, Rail, Marine, and Aviation Technologies $70,000,000	**$25,000,000**	**-$45,000,000**
Applied Efficiency, Fuels and Emissions Research $70,000,000	$25,000,000	-$45,000,000
• Predictive Modeling of Engine Combustion and Fuels: Develop computer simulations and high-fidelity 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: No funding requested.	• FY 2022 represents the final year of funding for this activity.
• 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 using single- and 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.	• Commercial Off-Road Powertrains, Fuels and Emission Control R&D: Support use of advanced experimental research tools at the National Laboratories (e.g., laser, X-ray light sources), single and multi-cylinder research engines, and modeling and simulation capabilities to improve the understanding of advanced combustion processes and emissions formation inside engines using renewable biofuels. Integrate hybridized/electrified powertrains to further improve efficiency and reduce GHG and criteria emissions with advanced emission control technologies. Conduct research to improve conversion efficiency and reduce need for	• Shift efforts toward improving the efficiency of off-road engine/powertrains, which show the most potential toward meeting GHG emission targets. Increase efforts using single- and multi-cylinder engines for experimental validation of simulation models. Focus on reducing emissions from off-road engines and the impact of renewable fuels on catalysts.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
	critical minerals (i.e., platinum group metals) to reduce the cost of emission control systems.	
• Co-Optimization of Engines and Fuels (Co-Optima): Support 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.	• Heavy-duty Consortium: Support a multi-lab effort focusing on improving rail, marine and aviation engine efficiency, compatibility with renewable fuels, and fuel effects on emission control systems, using experimental data and high- performance computing algorithms. Work collaboratively with BETO and HFTO to efficiently use renewable fuels such as advanced biofuels and renewable hydrogen while reducing their impact on emission control systems. Continue development of computer models to simulate the performance of multi-functional emission control systems and integration of hybrid/electric powertrains.	• Shift focus to HD non-road powertrains, and renewable fuels with hybrid powertrains and their impact on emission control systems.
• Continue 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 propane engine and vehicle availability through competitively awarded projects with industry and universities.	• No funding requested.	• Projects will continue using prior year funds until completed.
• Continue two cost-shared research projects, competitively selected in FY 2019, that will design and demonstrate lightweight high-efficiency engines 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 using prior year funds until completed.
• Continue research, through competitively awarded projects selected in FY 2019, FY 2020 and FY 2021 that support improving the vehicle-level energy efficiency of commercial off-road	• No funding requested.	• Current projects will continue using prior year funds until completed.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
vehicles using fluid power systems that are directly applicable to the agricultural, construction, mining, and forestry sectors.		
• Continue research on opposed-piston two-stroke engines to increase efficiency and reduce emissions through competitively awarded projects to industry-led teams in FY 2020 and FY 2021.	• No funding requested.	• Projects will continue using prior year funds until completed.
• SuperTruck II: Through five competitively awarded projects selected in FY 2016, 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 2021, compared to a 2009 baseline vehicle, and demonstrate applicability and cost-effectiveness of these technologies to heavy-duty Class 8 regional-haul vehicles.	• SuperTruck II: No funding requested for competitive awards.	• SuperTruck II activities will continue using prior year funds until completed.
• SuperTruck III: Competitively select and award industry-led 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, powertrain hybridization, materials, vehicle-level technologies, and mobility systems that can reduce fuel consumption through more efficient operation.	• SuperTruck III: No funding requested.	• SuperTruck III activities will continue using prior year funds until completed.
• No funding requested	• Rail, Maritime and Aviation Engine R&D: Initiate efforts with industry and universities to utilizes electrification and hybridization and to improve	• Prioritize focus on these modes since they will continue to use engines for several decades and will produce an increasing portion of GHG and

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
	the efficiency of large engines and their ability to utilize renewable fuels such as advanced biofuels and hydrogen to reduce GHG and criteria emissions.	criteria emissions as other sectors become electrified.
• 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: No funding requested.	• Projects concluded due to shift toward off-road vehicle application.
• Conduct research at the National Laboratories on single-atom catalysis to improve conversion efficiency and reduce precious metal content.	• No funding requested.	• Projects concluded due to shift toward off-road vehicle application.
• Continue development of 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 for multi-mode combustion systems and hybrid powertrains.	• No funding requested.	• Projects concluded due to shift toward off-road vehicle application.

Vehicle Technologies
Materials Technology

Description

The Materials Technology subprogram supports VTO's goals of achieving 100 percent decarbonization of the transportation sector by 2050. This ambitious goal will be realized through the increased deployment of electric and hydrogen fuel cell vehicles. Materials play an important role in increasing the efficiency of electric vehicles through weight reduction as well as enabling additional functionality such as faster charging and new sensing technologies. Lighter weight vehicle structures and electric drivetrains will require fewer batteries to achieve the same range, which in turn reduces battery cost, material needs, and reduces the GHG emissions from battery production. Multi-functional materials with improved properties such as electrical conductivity, thermal conductivity, and unique sensing capabilities will enable innovations in charging and autonomous vehicles. The materials and manufacturing methods used to make vehicles also contribute to GHGs, and the Materials Technology subprogram supports research, development, and deployment to increase recyclability and reduce the overall embodied energy of vehicles. The Materials Technology subprogram accomplishes its technical objectives through research programs with academia, National Laboratories, and industry.

Lightweight Materials: This activity supports National Laboratory, academia, and industry-led 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 focus areas for the activity include reducing the cost of polymer matrix composite components, novel manufacturing processes to improve the properties of light metals, maturing new joining technologies for multi-material structures in vehicles towards industry readiness, and developing multifunctional materials to incorporate smart sensing, thermal management, and wiring into structural components to reduce weight and enable innovative vehicle designs as well as increase battery management system efficiency and electric motors efficiency of EVs. 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 fiber, matrix, and filler materials, efficient intermediate processes, and manufacturing methods suitable for high volume production. To provide the maximum amount of lightweighting, the automotive industry today takes the approach of implementing the right material in the right place. For lightweight metals, this has resulted in the proliferation of new aluminum and steel alloys with specialized properties. Unfortunately, this creates challenges for automakers by increasing the complexity of supply chains, storage of materials, and recycling of scrap metal. Development of scalable processing methods to locally enhance the properties of aluminum and magnesium will eliminate the conflict between optimal lightweighting solutions and manageable production environments. New joining methods are required to incorporate these lightweight composites and tailored property metals into the vehicle assembly. Vehicle weight reduction and efficiency improvement will be enabled by broadening the applicability of individual joining methods, moving lab-scale joining methods towards industry readiness, addressing challenges with adhesion and corrosion, and providing the automotive industry confidence in the quality of dissimilar material joints. VTO 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. Lightweight Materials activities focus on the following cost and performance targets, which contribute to VTO program level goals:

- Enable a 25 percent weight reduction for light-duty vehicles including body, chassis, and interior as compared to a 2020 baseline by 2030, without significantly increasing costs; and
- Develop lightweight alloys with improved strength and fatigue performance for cast and additive manufacturing methods resulting in a 25 percent weight reduction in powertrain and suspension components by 2030.

Powertrain Materials: This activity supports research at National Laboratories, academia, and industry to develop higher performance materials to address the future properties needs of electric and hydrogen fuel cell vehicles to increase efficiency and decrease manufacturing cost, supporting the transition to all electric light duty vehicles by 2035. Research funded through this activity applies advanced characterization and multi-scale computational materials methods, including

HPC, to accelerate discovery and early-stage development of cutting-edge structural and high temperature materials for lighter and more efficient powertrains. In FY 2023, a multi-lab research effort for powertrain materials research will support weight reduction and electric powertrain system efficiency improvements for heavy-, medium-, and light-duty vehicles by expanding to address the materials property requirements of challenging components such as inverters, motors, and gear-train using an integrational materials engineering approach to alloy development and innovative production techniques like additive manufacturing. This early-stage research will support the development of new alloys with improved electrical/mechanical properties and enhanced resistance to corrosion/oxidation of components operating in harsh environments such as electrical bus bars, lightweight gears, underbody suspension, and brakes. Current priority focus areas for the subprogram include: (1) lightweight alloys with high fatigue strength for suspension components, (2) high temperature materials for lighter brakes, (3) predictive models for powertrain materials, and (4) Integrated Computational Materials Engineering (ICME) tools that use HPC capabilities, multi-length scale (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.

Materials Technology

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Materials Technology $40,000,000	**$50,000,000**	**+$10,000,000**
Lightweight Materials $33,500,000	$43,000,000	+$9,500,000
• Initiate Joining Core Program Phase 2 research efforts awarded through FY 2020 lab call to broaden the applicability of individual joining methods, move lab-scale joining methods towards industry readiness, and develop Artificial Intelligence and Machine Learning (AI/ML) techniques to ensure quality of dissimilar material joints.	• Complete research to broaden the applicability of individual joining methods, move lab-scale joining methods towards industry readiness, and develop AI/ML techniques to ensure quality of dissimilar material joints.	• No significant change.
• Support polymer composite materials research at the National Laboratories, including the operation of the Carbon Fiber Technology Facility (CFTF) at Oak Ridge National Laboratory (ORNL) and the Composites Core Program targeting core innovation science R&D, and two cost-shared industry led projects competitively selected in FY 2020.	• Support polymer composite materials research including the operation of the Carbon Fiber Technology Facility (CFTF) and the Composites Core Program targeting core innovation science R&D, high- volume manufacturing.	• No significant change.
• Establish new Light Metals Core Program at the National Laboratories awarded through FY 2020 lab call to research advanced processing techniques to tailor localized microstructure and properties of metal alloys to increase penetration of lightweight metals and address challenges for recyclability.	• Research advanced processing techniques to tailor localized microstructure and properties of metal alloys to increase penetration of lightweight metals and address challenges for recyclability.	• No significant change.
• Competitively select and award 1-3 projects to demonstrate multi-material joining at an industrially relevant scale on a prototype sub-assembly that represents a weight savings of 160 lbs.	• No funding requested.	• Projects selected in FY 2021 will continue using prior-year funds until completed.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
• No funding requested.	• Competitively select and award 3-5 projects to advance the state of the art for the development and processing of lightweight metals including novel architectures and manufacturing methods to decrease weight at low cost.	• Focus on supporting efforts that target weight reduction at low cost to achieve the 2030 goal of 25% light-weighting at less than $5/kg-saved.
Powertrain Materials $6,500,000	$7,000,000	+$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.	• Research materials development relevant to increased efficiency and decreased manufacturing cost of electric powertrain applications. Advanced characterization tools and computational methods through the National Laboratories will be maintained.	• Expand development and characterization of materials supporting electrification such as lightweight conductors, ferrites, and high Si-steels for electrified powertrains. No new funding for research specific to ICE applications. This shift away from combustion toward electrification shows more potential toward meeting GHG targets.
• No funding requested.	• Research affordable, recyclable, high conductivity materials for lightweight electric powertrain components. Address the materials property requirements of challenging electric vehicle powertrain components such as inverters, motors, and gear-train.	• Initiate new research effort to address key materials challenges currently limiting advances in electric powertrain and wireless charging.
• Continue two cost-shared research projects, competitively selected in FY 2019 that will design and demonstrate lightweight high-efficiency engines that will enable a 25 percent fuel economy improvement and 15 percent powertrain weight reduction relative to a medium duty 2015 baseline truck engine.	• No funding requested.	• Activities will continue using prior year funds until planned completion.
• SuperTruck III: Competitively select and award industry-led projects focused on improving the energy and operational efficiency of moving freight with medium and heavy-duty trucks. This effort will support work in the areas of electrified driveline systems, powertrain hybridization, and lightweight materials to	• R&D to improve freight efficiency and reduce emissions from MD/HD vehicles and incorporate advanced materials for light-weighting, hybridization and electrification. This effort will support work on lightweight powertrain materials to reduce fuel consumption through more efficient operation.	• No significant change.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
reduce fuel consumption through more efficient operation.		

Vehicle Technologies
Energy Efficient Mobility Systems

Description

The Energy Efficient Mobility Systems (EEMS) subprogram supports RDD&D of innovative mobility solutions that improve the affordability, accessibility, and energy productivity[1] of the overall transportation system. EEMS leverages emerging disruptive technologies such as connected and automated vehicles, information-based mobility-as-a-service platforms, and artificial intelligence-based transportation control systems to accelerate the transition to a zero carbon-emission transportation future. The EEMS subprogram also develops and utilizes large-scale transportation modeling and simulation capabilities to evaluate the impacts of new mobility solutions across multiple geographies and populations, ensuring that all Americans, especially underserved populations and energy communities, benefit from the development and deployment of clean transportation technologies.

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 feasible system-level pathways and develop innovative technologies and systems that can dramatically improve mobility energy productivity for individuals and businesses when adopted at scale. The EEMS subprogram has developed 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, is used by the subprogram to evaluate success and by the transportation community to inform planning decisions. The EEMS subprogram's target is a 20 percent improvement in mobility energy productivity[1] by 2040 relative to a 2020 baseline.

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 refinement and deployment of city/regional-scale multi-fidelity transportation system-level models to identify feasible pathways to improve mobility energy productivity, determine the most promising approaches to decarbonize the transportation sector, and assist local decision-makers in planning transportation investments that benefit all segments of their communities.

As part of the Computational Modeling and Simulation activity, EEMS will initiate a focused effort to engage with state and local organizations to deploy systems-level tools for mobility design and planning. This activity will accelerate the transition of tools and capabilities developed through SMART Mobility and other initiatives to be used by local governments, policy makers, and transportation planners. EEMS will work with local stakeholders to evaluate technology and policy options and deploy transportation solutions that increase mobility, reduce congestion, improve air quality, and provide affordable mobility options to Americans in multiple locations.

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' research, development, modeling, simulation, and demonstration of advanced vehicles and transportation systems. 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, and accessibility, and to accelerate the transition to zero-carbon mobility through connected and automated transportation system-level solutions. The Connectivity and Automation Technology activity will develop technology solutions that

[1] Mobility Energy Productivity is the ability of an area's transportation system to connect individuals to goods, services, employment opportunities, and other activities while accounting for time, cost, and energy; www.nrel.gov/transportation/mobility-energy-productivity-metric.html

improve the mobility energy productivity of both passenger and freight movement through the development of connectivity, communication, automation, and other transportation solutions that are enabled by artificial intelligence and advanced computing technologies. EEMS will support national lab and industry research and development and engage with local stakeholders to conduct demonstration and deployment of advanced cooperative driving automation systems. These projects will remove technical barriers and accelerate the efficiency and mobility benefits of cooperative driving automation.

As part of the Connectivity and Automation Technology activity area, EEMS will coordinate with other VTO subprograms and the Hydrogen Fuel Cell Technologies Office to continue to support industry projects under the SuperTruck III initiative, improving the energy and operational efficiency of moving freight with medium and heavy-duty trucks. EEMS will also coordinate with other agencies to research and develop solutions to improve the efficiency and convenience of public transit systems, leveraging the benefits of this shared mode to accelerate the path to transportation decarbonization and provide mobility access.

Energy Efficient Mobility Systems

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Energy Efficient Mobility Systems $45,000,000	**$60,000,000**	**+$15,000,000**
Computational Modeling and Simulation $26,000,000	$31,000,000	+$5,000,000
• Support the validation, refinement, application, and deployment of transportation system models to specific cities and regions, to simulate mobility and energy outcomes across various future transportation scenarios, through projects initiated through the FY 2020 lab call for SMART Mobility 2.0.	• Conduct SMART Mobility research to develop a suite of transportation system-level modeling, simulation, design, and planning capabilities ready to be deployed to local stakeholders.	• VTO will complete the SMART Mobility integrated modeling platform in FY 2023, and emphasize engagement with local departments of transportation and transportation planners to deploy software to multiple geographies and populations.
• Building upon transportation data science and strategic computing capabilities validated in the previous year, initiate three new transportation system optimization projects through the "AI for Mobility" (AIM) lab call, using artificial intelligence and deep-learning techniques to accelerate the pace of solution discovery in mobility planning and operations.	• A new deployment emphasis on System-Level Tools for Design and Planning will focus on Transition tools developed from SMART Mobility, AI for Mobility, and other previous initiatives to local city/state transportation planners and decision-makers.	• Shift focus toward deployment of System-Level Tools for Design and Planning and stakeholder engagement.
• Develop, maintain, and apply core vehicle energy consumption simulation and data management tools and lab testing and evaluation capabilities critical to support early-stage mobility research.	• Initiate new national lab core capabilities and tools in mobility simulation, evaluation, and data selected through competitive lab call in the previous year.	• Maintain support for core laboratory evaluation and data management activities as these investments enable mobility research across the subprogram portfolio.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Connectivity and Automation Technologies $19,000,000	$22,000,000	+$3,000,000
• Initiate up to three new competitively selected advanced R&D projects to develop low-cost infrastructure-based enablers for cooperative driving automation, and in collaboration with the Technology Integration subprogram, initiate up to 5 new competitively selected awards to implement energy efficient mobility systems technologies in real-world applications.	• Conduct demonstration and deployment of advanced Cooperative Driving Automation (CDA) systems that use vehicle-to-vehicle and vehicle-to-infrastructure communications to reduce transportation energy consumption by over 20 percent.	• Shift Lab-scale research on cooperative driving automation to increased emphasis on local demonstration and deployment.
• No activity in FY 2021 (new activity for FY 2023).	• Conduct R&D to improve the efficiency and convenience of public transit, integrating this shared mode into the broader zero-carbon transportation system though electric-drive transit vehicles, transit system optimization, and more efficient intermodal transitions.	• Support of R&D to improve the efficiency and convenience of public transit and ensure research is coordinated with DOT/FTA will further advance the state of the art in public transit technologies.
• 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.	• Existing project to validate initial SMART Mobility connected and automated vehicle modeling results will conclude with no new projects initiated in FY 2023.
• 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.	• Continue funding selected projects previously awarded under the cross-cutting VTO and HFTO SuperTruck III solicitation.	• Previously selected projects will continue, with a focus on system-level freight efficiency.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes

		FY 2023 Request vs FY 2021 Enacted
Workforce Development and Clean Energy Mobility Solutions for Underserved Communities $0	$7,000,000	+$7,000,000
No activity in FY 2021.	• Initiate support for Clean Energy Workforce and other support services to help people build careers in the clean energy industry, with a focus on underserved and underrepresented communities. This will assist the transition of individuals into the clean energy workforce, creating pathways to union membership and supporting energy and environmental justice goals	• FY 2023 is the first year of funding for this activity.

Description

The Technology Integration & Deployment subprogram supports the decarbonization of the transportation sector through various initiatives that accelerate the adoption of EVs and charging infrastructure. The program covers a broad technology portfolio that includes alternative fuels (e.g., advanced biofuels, electricity, hydrogen, renewable natural gas) and energy efficient mobility systems. The successful deployment of these technologies can support the decarbonization of the transportation sector, strengthen national security through fuel diversity and the use of domestic fuel sources, reduce transportation energy costs for businesses and consumers, address the needs of underrepresented communities, and support energy resiliency with affordable alternatives to conventional fuels that may face unusually high demand in emergency situations.

At the national level, the Technology Integration & Deployment subprogram offers technical assistance, information resources, online training, and an array of data and analysis tools. At the local level, the subprogram manages and supports the Clean Cites coalitions that leverage these national resources to create networks of community stakeholders and provide hands-on technical assistance to communities and fleets. Clean Cities serves as a backbone for partnering with cities, towns, and rural areas across the country on clean transportation technology.

Heavy-duty Truck Fueling Corridor: This activity will fund an Integrated Heavy-Duty Zero Emission Vehicle (ZEV) Fueling and Connected Grid project to demonstrate integrated clean corridor solutions, connecting truck depots, ports, highways, and end users, providing electric vehicle charging infrastructure and freight solutions needed to move good and materials from first mile to last. Demonstrating an effective, integrated, grid-connected solution to refueling at freight depots and along highways corridors is critical to prove out capability, test new megawatt level charging in real-world operating conditions and build confidence that will spur market growth.

Communities to Clean Energy: As cities and communities set clean energy, equitable transportation, and climate resilience goals they require unbiased expertise, tools, and resources to achieve these goals. The Technology Integration & Deployment subprogram will engage with stakeholders to identify and provide the needed technical assistance to achieve these clean energy goals.

Technical Assistance and Demonstration: This activity supports projects that provide information, insight, online tools, and technology assistance to cities, states, and regions working to implement clean transportation solutions 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 2023, the activity will provide funding to support technical assistance activities that support the C2C initiative and the Integrated Heavy-Duty ZEV Fueling and Connected Grid Demonstration project. The activity will continue to provide technical support to the State and Alternative Fuel Provider regulatory program.

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 provide fleets and local decision makers with a suite of resources to identify and address technology barriers. This includes projects to disseminate data, information, and insights. For FY 2023, the activity will provide 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 2023, student teams will complete and implement their vehicle design through hardware development and engineering and planning will commence for the next iteration of EcoCar with an emphasis on diversity, equity, and inclusion. The activity will continue to support and expand Workforce Development activities that address the needs of first responders, codes and safety officials, and automotive technicians

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Technology Integration & Deployment $60,300,000	**$199,731,000**	**+$139,431,000**
Technical Assistance $49,900,000	$ 187,831,000	+$137,931,000
• 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.
• Support the Clean Cities Coalition's cooperative agreements to work in communities across the country to help local decision makers and fleets understand and implement advanced technology vehicles and infrastructure, new mobility choices, and emerging transportation technologies.	• Expand the Clean Cities Coalition's work in communities across the country to help local decision makers and fleets understand and implement advanced technology vehicles and infrastructure, new mobility choices, and emerging transportation technologies.	• Expand work to strengthen the existing Clean Cities network and improve their ability to serve local stakeholders.
• Initiate two to five competitively awarded, small-scale alternative fuel 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.	• No funding requested.	• Projects will continue using prior year funds.
• No Funding requested.	• Initiate funding support and technical assistance to communities in analyzing clean energy transportation needs	• Focus on projects that will address cross cutting clean energy challenges with a community-centered focus. TI efforts will focus on stakeholder engagement to address mobility/transportation needs.
• **No Funding requested.**	• Initiate funding to support the Integrated Heavy-Duty ZEV Fueling Corridor Demonstration project.	• New project that aims to validate technologies that address charging of Heavy Duty EVs and the associated grid requirements and impacts.
• Initiate three to five competitively awarded large-scale Electric Vehicle Charging Community Partner projects to encourage strong local and/or regional partnerships to create an	• Initiate Electric Vehicle Charging Community Partner projects to encourage strong local and/or regional partnerships to create an enduring local ecosystem to support increased	• Increased funding will expand and encourage strong local/regional/national partnerships to accelerate EV acquisitions with an emphasis on

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
enduring local ecosystem to support increased consumer and business PEV use. Projects are encouraged to demonstrate various PEV applications by concentrating multiple sub-projects in a region or geographic area. Projects for consumers in underserved communities are a high priority.	consumer and business PEV use. Projects are encouraged to demonstrate various PEV applications by concentrating multiple sub-projects in a region or geographic area. Projects for consumers in underserved communities are a high priority.	underserved and underrepresented communities.
• In collaboration with the Energy Efficient Mobility Systems subprogram, initiate three to five competitively awarded projects that focus on the implementation of energy efficient mobility systems technologies into real-world system applications.	• No funding requested.	• Projects will continue using prior year funding.
• No activity in FY 2021	• New competitively awarded projects will focus on EV Charger Deployment with States to support the Administration's 500K EV Charging initiative.	• Increased funding will provide technical assistance to states that will support National Electric Vehicle Infrastructure and the Joint Office of Energy and Transportation.
• No activity in FY 2021	• Initiate a Smart Charging Vehicle-Grid Integration Project to demonstrate smart charging and business models that improve costs and efficiency for the acquisition and operation of new EV models for local governments, utilities, transit, schools, ports, and goods movement.	• Projects will demonstrate smart charging and business models that improve costs and efficiency for the acquisition and operation of new EV models for local governments, utilities, transit, schools, ports, and goods movement.
• No activity in FY 2021	• Fund competitively selected projects to engage with regional and local partners, especially underserved and energy communities, on planning, and to develop and demonstrate innovative technologies to enhance community resilience to physical hazards using distributed solar, energy storage, EVs, and other DERs (joint EERE-OE effort).	• New projects will address environmental justice and equity for underrepresented communities

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
• No activity in FY 2021	• Funding for Super Truck III demonstration projects.	• New projects will provide real-world validation of new technologies being developed by the Super Truck III teams.
Data Collection and Dissemination $7,900,000	$7,900,000	$0
• 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, cost calculator tool, incentives database, and fuel savings strategy information in the Alternative Fuels Data Center. • 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.	• 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, cost calculator tool, incentives database, and fuel savings strategy information in the Alternative Fuels Data Center. • 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.	• No change. • No change.
STEM and Workforce Development $2,500,000	$4,000,000	+$1,500,000
• Complete the final phase of the EcoCAR Mobility Challenge, during which student teams will implement designs developed in FY 2022 into hardware.	• Implement the next EcoCar student competition. The EcoCar EV Challenge will challenge teams to apply innovative solutions to address equity and electrification challenges in the future of mobility, advanced powertrain, charging, and thermal systems to use grid electricity intelligently.	• Additional funds will support the addition of multiple Minority Serving Institutions into the Mobility Challenge.

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. In FY 2023, projects will continue to support analytical capabilities and tools unique to DOE's National Laboratories. For data activities, trusted and public data are critical to VTO's efforts and are an integral part of transportation and vehicle modeling and simulation. For modeling activities, the subprogram supports the creation, maintenance, and utilization of vehicle and system models to explore energy impacts of new technologies relevant to the VTO portfolio. Finally, for analysis activities, integrated and applied analyses will 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

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Request
Data, Modeling, and Analysis $6,000,000	**$8,000,000**	**+$2,000,000**
• 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 to support analytical capabilities and tools unique to National Laboratories, including expanding analysis to identify cost-efficient and equitable transportation decarbonization scenarios to inform and prioritize technology investments and research portfolio planning.	• No significant change.
• No funding requested.	• Solicit external (non-DOE/ Lab) perspectives, methods, and projects for increasing access to low-carbon mobility for underserved communities, through a combination of data collection, modeling, and related analysis on vehicle consumer markets with an emphasis on underserved communities and used vehicle markets, as well as EV infrastructure awareness and expected charging behavior.	• Initiate efforts to identify cost-efficient and equitable transportation decarbonization scenarios to inform and prioritize technology investments, with emphasis on underserved communities.

Bioenergy Technologies

Overview

The Bioenergy Technologies Office (BETO) conducts research, development and demonstration (RD&D) to advance technologies that convert domestic biomass and waste resources into cost effective, low-carbon biofuels and bioproducts bioeconomy. DOE's investments in cutting-edge technologies designed to produce biofuels and bioproducts are expanding the viability of the Nation's abundant biomass and waste resources including forest and agriculture residues, municipal solid waste (MSW), herbaceous and woody energy crops, and algae. As part of a comprehensive strategy to decarbonize all modes of transportation, BETO is primarily focused on RD&D to produce "drop-in" biofuels that are compatible with existing fueling infrastructure and vehicles across a range of transportation modes, including diesel, jet, and marine fuels. The program also supports RD&D on converting biomass into high-value chemicals, products, and power where they can enhance the economics of biofuel production, help grow critical infrastructure to support the bioeconomy and further reduce carbon emissions of the U.S. economy. The program also supports RD&D on converting biomass into high-value chemicals and products in support of decarbonizing the chemical industry, sustainable development of bioenergy crops, the use of residues and low carbon agriculture practices to support decarbonization of agriculture and help grow critical infrastructure to support the bioeconomy and further reduce carbon emissions of the U.S. economy. This multi-faceted approach is part of the Administration's strategy to spur the development of homegrown biofuels, which is critical to expanding Americans' options for affordable fuel in the short-term and to building real energy independence in the long-term by reducing our reliance on fossil fuels.

Today, the U.S. transportation sector relies almost completely on petroleum, which supplies over 90 percent of its energy needs. In 2017, the transportation sector surpassed electricity generation to become the largest source of CO_2 emissions in the country[1]. Aviation, marine, and heavy-duty vehicles account for 37 percent of transportation energy use.[2] Aviation, maritime and heavy-duty vehicle use (on and off-road) are projected to grow considerably faster than other modes and are more difficult to electrify, making drop-in biofuels a near-term option to reduce petroleum use and CO_2 emissions. As part of a series of actions announced by government and industry partners, the Departments of Energy, Transportation, and Agriculture launched a government-wide Sustainable Aviation Fuel (SAF) Grand Challenge in September 2021.[3] The Grand Challenge aims to reduce cost, enhance sustainability, and expand domestic production and use of SAF to meet 10% of domestic aviation fuel demand by 2030, and 100% of domestic aviation fuel demand by 2050, the latter of which is projected to be around 35 billion gallons per year.

Based on the DOE's *Billion Ton Study*[4], BETO estimates that over 1 billion dry tons/year of biomass can be grown sustainably to produce 50-60 billion gallons of advanced biofuels and 40-50 billion pounds of renewable chemicals without impacting agriculture, trade, and current uses of biomass. If fully utilized, this is sufficient to achieve the SAF Grand Challenge goal of 35 billion gallons per year while also supplying fuel for some maritime and diesel applications and providing renewable alternatives to displace petroleum-based chemicals[5].

DOE investments can help realize this potential by focusing on 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. Cost sharing development and demonstration reduce the risks of market entry and encourage investment from across the industry. BETO continues to conduct research and development (R&D) to develop new technologies that will maximize biofuels and bioproduct production through enabling a diverse supply of biomass and cost-effective conversion technologies nationwide while emphasizing later stage demonstration of technology to accelerate deployment.

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[1] https://www.eia.gov/energyexplained/use-of-energy/transportation.php.

[2] Davis, Stacy C., and Robert G. Boundy. Transportation Energy Data Book: Edition 39. Oak Ridge National Laboratory, 2020, https://doi.org/10.2172/1767864.

[3] https://www.whitehouse.gov/briefing-room/statements-releases/2021/09/09/fact-sheet-biden-administration-advances-the-future-of-sustainable-fuels-in-american-aviation.

[4] https://www.energy.gov/eere/bioenergy/2016-billion-ton-report

[5] https://www.energy.gov/sites/default/files/2016/12/f34/2016_billion_ton_report_12.2.16_0.pdf.

BETO also supports the key emphasis areas of energy justice, workforce, diversity in STEM, and state and local partnerships. Investments associated with Workforce Development will support training and develop good paying clean energy jobs for the American people, especially workers, communities impacted by the energy transition, and those historically underserved by the energy system and overburdened by pollution. Investments associated with Diversity in STEM support outreach and will raise awareness of clean energy research and job opportunities at minority-serving institutions and minority-focused professional organizations, and ensure that organizations receiving EERE funding are thinking through diversity and equity in their own work. Investments in State and Local partnerships will support state and local governments with the necessary resources to be more effective in facilitating affordable and resilient clean energy and efficiency goals. Investments associated with Energy and Environmental Justice will support approaches and processes to reach new groups of Americans historically underserved by the energy system.

Highlights of the FY 2023 Request

Bioenergy Technologies funding in FY 2023 will support RD&D across several key areas, including:

- A substantial increase in the scale-up of promising technical pathways that produce cost effective biofuels with a priority on the production of sustainable aviation fuel (SAF), in support of the SAF Grand Challenge. The major focus of the effort is to construct and operate integrated biorefineries at demonstration scale that are capable of producing SAF. These projects would increase the domestic production of SAF and put the transportation sector on the trajectory for net-zero emissions by 2050 as part of a strategy to decarbonize Transportation. BETO will conduct a down-select from previously funded cost-shared projects, advancing the strongest to construction, and add new projects to the portfolio to support de-risking and demonstration of production processes for fuels from a variety of domestic biomass and waste feedstocks. The successful scale-up and commercial deployment of these integrated biorefineries will contribute to decreasing CO_2 emissions by 450 million metric tons (MMT) per year by 2050.
- Continued efforts to demonstrate strategies that will reduce CO_2 emissions at "traditional" biofuels facilities from currently 40 percent[1] to over 70 percent compared with petroleum. Technologies and practices include low-carbon agricultural practices, fuel switching to renewable process heat and power (i.e., renewable natural gas, or biomass), and new productivity or conversion efficiency measures in order to assess the costs and verify the lifecycle greenhouse gas (GHG) benefits. If these technologies and practices were deployed across the existing U.S. industry, it would preserve current biofuels jobs and could reduce GHG emissions by over 42.7 MMT (CO_2-eq) per year – or approximately 2 percent of total U.S. transportation emissions.
- Continued support for community-scale, public-private partnerships to reduce harmful emissions and other environmental issues from operations that produce manure and other wet wastes. The program pursues engineering, construction, and operation of up to 2 pilot-scale projects that employ advanced technologies suitable for various community circumstances to demonstrate overall potential.
- Continued R&D to study sustainable agriculture practices and help farmers maximize profits on marginal lands while providing valuable feedstocks for bioenergy production. The Request supports RD&D to develop sensors and tools for soil carbon monitoring and soil carbon enhancement via biochar while enabling carbon credit banking markets and other activities requiring verifiable carbon emission data.

BETO 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 R&D is fostering partnerships that will support American industry and rural economies, including start-up enterprises, to create new jobs in emerging energy and manufacturing fields ultimately benefiting the U.S. economy and all Americans.

Contributions to DOE-wide Crosscutting Investments

BETO is involved in several crosscuts, including the following:

- Advanced Manufacturing ($16,000,000): supports the development of valuable chemicals and materials that can replace petrochemicals with renewable alternatives. This work includes R&D on bioderived polymers and plastics that provide performance advantages to traditional materials;
- Biotechnology ($57,250,000): supports RD&D of technologies for biochemical conversion of biomass and waste feedstocks, including the development of bioengineering techniques and their application in microbes to optimize

[1] Argonne study.

production of chemicals and materials. This also includes development of biological methods for plastic deconstruction and upcycling;

- Carbon Dioxide Removal ($13,000,000): supports RD&D efforts to enable net-negative renewable carbon feedstocks and support the modernization, security, and resilience of our interconnected food, water, and energy systems. BETO investments focus on technologies, systems and practices to increase carbon removal from biomass, including sustainable agriculture, forest management, and the use of biomass CO_2 from point sources and DAC technologies to improve the productivity of algal biomass;
- Energy Water ($15,000,000): supports RD&D on strategies to manage wet wastes, including municipal wastewater, food waste, and manures. These efforts focus on manure management strategies to decarbonize the agricultural sector through reduction in fugitive methane emissions and addressing energy and environmental justice through efforts on wastewater treatment; and
- Industrial Decarbonization ($109,000,000): supports the development of the development of alternative feedstocks, and energy efficient conversion processes to produce fuels, chemicals, and materials. BETO's alternative feedstocks R&D focuses on technologies to produce sustainable, cost-effective, conversion-ready feedstocks, including biomass and wastes, such as CO_2. BETO also supports RD&D conversion technologies can utilize these alternative feedstocks to produce valuable chemicals and materials that can replace petrochemicals with renewable alternatives. This work includes R&D on bioderived polymers and plastics that provide performance advantages to traditional materials and development of novel biological approaches to break down traditional plastics and polymers to improve recycling.

EERE Program Priorities:
In FY 2023, BETO continues to support an investment strategy aligned to the following programmatic priority areas that are central pillars to the U.S. greenhouse gas (GHG) profile:

Bioenergy Technologies
Funding ($K)

	FY 2021 Enacted	FY 2022 Annualized CR	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted
Decarbonizing transportation across all modes: air, sea, rail, and road	255,000	255,000	296,500	+41,000
Decarbonizing energy-intensive industries	15,500	15,500	24,000	+8,500
Decarbonizing the agriculture sector, specifically focused on the nexus between energy and water	9,000	9,000	32,320	+23,320

Bioenergy Technologies
Funding ($K)
(Comparable)

	FY 2021 Enacted	FY 2022 Annualized CR[1]	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted
Bioenergy Technologies				
System Development and Integration	55,500	-	152,500	**+97,000**
Feedstock and Algal System Technologies	80,000	-	68,000	**-12,000**
Conversion Technologies	110,000	-	110,000	**0**
Data, Modeling, and Analysis	9,500	-	9,500	**0**
Total, Bioenergy Technologies	**255,000**	**255,000**	**340,000**	**+85,000**

Funding ($K)
(Non-Comparable)

	FY 2021 Enacted	FY 2022 Annualized CR	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted
Bioenergy Technologies				
System Development and Integration	55,500	-	152,500	+97,000
Feedstock Technologies	40,000	-	0	-40,000
Advanced Algal Systems	40,000	-	0	-40,000
Feedstock and Algal System Technologies	0	-	68,000	+68,000
Conversion Technologies	110,000	-	110,000	0
Data, Modeling, and Analysis	9,500	-	9,500	0
Total, Bioenergy Technologies	**255,000**	**255,000**	**340,000**	**+85,000**

SBIR/STTR:

- FY 2021 Projected: SBIR $7,128,000; STTR $1,514,000
- FY 2022 Annualized CR: SBIR $8,131,000; STTR $1,143,000
- FY 2023 Request: SBIR $10,630,000; STTR $1,495,000

[1] The FY 2022 Annualized CR amounts reflect the P.L. 117-95 continuing resolution level annualized to a full year. These amounts are shown only at the congressional control level and above, below that level, a dash (-) is shown.

Proposed FY 2023 Budget Structure

FY 2021 Budget Structure	System Development and Integration	Conversion Technologies	Feedstock and Algal System Technologies	Data, Modeling, and Analysis	Total
System Development and Integration	152,500	0		0	**152,500**
Feedstock Technologies	0	0	48,000	0	**48,000**
Advanced Algal Systems	0	0	20,000	0	**20,000**
Conversion Technologies	0	110,000		0	**110,000**
Data, Modeling, and Analysis	0	0		9,500	**9,500**
Total, Bioenergy Technologies	**152,500**	**110,000**	**68,000**	**9,500**	**340,000**

Bioenergy Technologies
Explanation of Major Changes ($K)

	FY 2023 Request vs FY 2021 Enacted
Bioenergy Technologies	
Systems Development and Integration: The increase in funding for this subprogram reflects the critical need to integrate and scale-up advanced bioenergy technologies to decarbonize all modes of transportation, providing necessary operational data at engineering-scale for commercial deployment. New competitive awards will focus on supporting scale-up of biofuel production technologies with an emphasis on SAF in support of the Administration's goals to put the U.S. economy on a path to net-zero carbon emissions no later than 2050, and the SAF Grand Challenge goal to expand domestic production to 35 billion gallons by 2050. The increased funding will be used to support three high-priority areas: competitive awards for pilot- and demonstration-scale biorefineries with a focus on producing sustainable aviation fuel (SAF) increasing the number of new biomass feedstocks, like algae, that can be processed to final fuels; competitive awards to demonstrate deep decarbonization of existing biofuels facilities; and new competitive awards for persistent challenges in preprocessing and handling high-impact, cellulosic biomass feedstocks.	**+97,000**
Feedstock and Algal System Technologies: The new Feedstock and Algal System Technologies subprogram will focus on developing technologies to produce sustainable, cost-effective, conversion-ready feedstocks for producing sustainable aviation fuels (SAF). This work will enable additional sustainable feedstock production to reach the Administration's SAF Grand Challenge goal of 35 billion gallons of SAF by 2050. This subprogram continues R&D efforts previously funded under both the Feedstock Technologies and the Advanced Algal Systems subprograms, but the decrease in funding reflects a move of the algae pilot and demonstration work to the Systems Development and Integration subprogram. The Feedstock and Algal System Technologies subprogram will pursue negative emissions feedstocks by developing tools and remote sensors for soil carbon monitoring, researching the long-term carbon-drawdown potential of biochar, pursuing landscape design analysis, and investigating the feasibility and carbon sequestration potential of sustainable bioenergy carbon capture and sequestration (BECCS) practices. These efforts will support enabling a net-zero emissions agricultural sector that supports the modernization, security, and resilience of our interconnected food, water, and energy systems.	**-12,000**
Conversion Technologies: The funding in this subprogram will prioritize support for technologies to decarbonize transportation by producing SAF, diesel, and marine fuels, and decarbonizing industry by developing bio-derived chemicals and products, including those with improved performance properties. This includes continued support for the deconstruction of biomass into useful intermediates needed for the production of low carbon fuels and chemicals via biological and chemical or thermal means. Intermediates will then be upgraded to targeted products using biological organisms, chemical catalysis, or a combination of the two. Co-products R&D will focus laboratory work on predictive model development for performance-advantaged bioproducts and partnering with industry to accelerate adoption of biobased chemicals and materials that can reduce GHG emissions from the industrial sector while growing the supply chain of biomass	**0**

	FY 2023 Request vs FY 2021 Enacted
feedstocks necessary for fuels production. Research on up-cycling of plastics and design of polymers for recyclability in collaboration with the Advanced Manufacturing Office will also continue leveraging unique BETO-funded expertise and core capabilities in the areas of complex organic polymers derived from years of work with diverse biomass feedstocks. The subprogram will continue support for CO_2 conversion and utilization research to further draw down carbon from the atmosphere to create useful end products. No funds are requested for competitive awards to produce renewable natural gas, in favor of strategies to produce sustainable aviation fuels and higher-value products.	
Data, Modeling, and Analysis: This subprogram's investments will prioritize techno-economic and lifecycle analyses and strategies to achieve price reductions for biofuel and bioproduct production, including analyses of additional pathways to produce sustainable aviation fuels. Activities will also include analysis to determine the best use of biomass resources to achieve GHG reduction goals in the transportation, industry, and agricultural sectors as part of a transition to a 100 percent clean energy economy no later than 2050.	**0**
Total, Bioenergy Technologies	**+85,000**

Bioenergy Technologies
Systems Development and Integration

Description

The Systems Development and Integration subprogram supports RD&D 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, with an emphasis on SAF. 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. Specifically, this subprogram will work to support the EERE program priority to decarbonize transportation across all modes, including to meet 100% of the Nation's sustainable aviation fuel needs by 2050. Development work will also support advanced biofuels for marine and heavy-duty vehicle applications.

Production Process R&D: This activity develops, tests, and verifies engineering-scale R&D for integrated biorefinery process performance to reduce technology uncertainty. This work also supports cost-shared pre-pilot, pilot- and demonstration-scale biorefinery projects with industry, as well as investments in the DOE National Laboratories to support these 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.

This activity represents an increasing emphasis on enabling scale-up of low-carbon fuels through demonstration of cost-effective production pathways with an emphasis on SAF. FY 2023 will be the third year of a continuing, multi-year strategy to fill the pipeline as technologies are ready to scale, ultimately demonstrating enough feedstock-conversion variations to support commercialization and meet the SAF Grand Challenge goal of 35 B gal/year SAF production by 2050.

This will be the second year of an initiative to demonstrate solutions that can reduce CO_2 emissions from "traditional" biofuels facilities from 40 percent to over 70 percent compared with petroleum through sustainable agriculture, fuel switching, productivity enhancements, and/or conversion-efficiency measures. This effort will reduce CO_2 emissions in the near term through use in light duty vehicles and support SAF production in the mid to long term.

Further, there will be a new initiative to focus on challenges in processing high impact feedstocks from the bale yard inside the plant gate into various types of conversion reactors. Feedstock handling has been a significant challenge for many commercial next generation biofuels facilities over the last decade.

Fuels and Co-Products R&D: This activity area will identify fuel properties that can enhance engine efficiency and reduce emissions for multiple end uses, including sustainable aviation fuels, marine shipping, and medium- and heavy-duty vehicles and non-road applications. This activity will support analysis, in coordination with the Department of Agriculture, the Department of Transportation, and other Biomass R&D Board agencies to accelerate the commercialization of sustainable aviation fuels. The program will also launch a new effort under this activity to perform analytical evaluation and community stakeholder engagement to design place-based initiatives supporting the energy transition.

Systems Development and Integration

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Systems Development and Integration $55,500,000	**$152,500,000**	**+$97,000,000**
Production Process R&D $53,000,000	$147,500,000	+$94,500,000
• Competitive awards to support scale-up of biofuel production technologies with a focus on sustainable aviation fuels to directly support the Biden Administration priorities through decarbonization of the transportation sector, supporting a 100 percent clean energy economy no later than 2050.	• The Request supports DOE strategies to decarbonize all modes of transportation with expanded competitive awards to support scale-up of biofuel production technologies with a focus on sustainable aviation fuel. These large, industry-partnered projects are important to de-risk essential new technologies that can produce drop-in biofuels from a variety of domestic biomass and waste resources.	• Significant increase in funding for scale-up of integrated biorefineries, expanding feedstock conversion options, including algae, in support of the SAF Grand Challenge and decarbonizing the aviation sector.
• National Lab research and development to lower risk and enable scale-up of integrated systems to produce biofuels, bioproducts, and biopower.	• Continue work to focus primarily on process development units to verify R&D to produce drop-in biofuels from biomass feedstocks. Additional work will focus on technologies related to improving performance of lab capabilities to support technology scale-up, as well as the development of aviation and marine biofuels.	• No change.
• No funding.	• Demonstrate technologies and strategies to reduce greenhouse emissions from existing biofuel production, including implementation of sustainable agricultural practices and measures to improve efficiency or reduce emissions from fuel production.	• Increased focus on understanding of the costs and benefits of incorporating advanced sustainable bioenergy measures into existing biorefineries to deliver near-term greenhouse gas emission benefits.
• No funding.	• A new initiative to focus on challenges in processing high impact feedstocks, from the bale yard inside the plant into various types of conversion reactors. This initial effort will support projects to using feedstocks and	• Increased focus will address persistent feedstock handling challenges at industry-relevant scales that will enable U.S. bioenergy industry to use widely available, but challenging feedstocks, such as agricultural wastes and woody biomass.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
	conversion technologies that are expected to begin deployment post-2030.	
• No funding	• Support for competitive awards with industry to demonstrate waste-to-energy technologies, targeting manure and other organic wastes suitable for community circumstances. These technologies will be replicable, reduce waste as well as nitrogen, phosphorus and potassium often found in these waste streams.	• Pilot projects will provide community-based solutions to waste management challenges.
• Competitive awards to support the development and testing of low-emission, high efficiency, and cost competitive residential wood heaters.	• No funds are requested.	• This activity will conclude in FY 2022 as part of the program's continued emphasis on scaling up biofuel production technologies with a focus on sustainable aviation fuel (SAF) in support of the SAF Grand Challenge.
Fuels and Co-Products R&D $2,500,000	$5,000,000	$2,500,000
• No funding.	• Support R&D and analysis, in coordination with the Department of Agriculture, the Department of Transportation, and other Biomass R&D Board agencies to accelerate the commercialization of Sustainable Aviation Fuels.	• Increase support for interagency efforts under the SAF Grand Challenge to advance the domestic production and use of drop-in biofuels to decarbonize aviation.
• No funding requested.	• BETO will expand place-based initiatives to provide analytical evaluation and conduct community stakeholder engagement to design and support clean energy transitions.	• Increased emphasis on place-based efforts to support the Biden Administration's focus on decarbonization and energy and environmental justice.
• Complete research by the National Laboratories under the Co-Optima initiative on R&D and related analysis on biofuel candidates to support fuel economy and efficiency targets for advanced compression ignition (ACI) engines used in medium- and heavy-duty vehicles, including competitive selections to transition R&D to industry and academia.	• No funds are requested.	• The National Laboratory Consortium research under Co-Optima is completed; the program will pursue biofuel candidates through separate investments in the RD&D portfolio.

Bioenergy Technologies
Feedstock and Algal System Technologies

Description

To achieve sustainable aviation fuel targets, the U.S. will need to produce sufficient quantities of a wide variety of sustainable, conversion-ready feedstocks including terrestrial-, aquatic-, and waste- feedstocks. The primary goal of the Feedstock and Algal System Technologies subprogram is to conduct R&D to enable the deployment of sustainable, cost-effective, conversion-ready feedstocks for bioenergy applications. No single bioenergy feedstock can be sustainably produced at the volumes necessary to displace petroleum-derived fuels and chemicals. This subprogram addresses the unique technical challenges posed by each class feedstock.

To best meet the needs of a decarbonized fuel and agriculture sector, the Feedstock and Algal System Technologies subprogram supports R&D in the following two activities:

Terrestrial and Waste Feedstocks R&D: This activity includes feedstock production, feedstock preprocessing, supply chain analysis, and the development of methods to identify, quantify, and mitigate supply chain risk. This activity aims to increase the type and availability of new cost-advantaged feedstocks, including energy crops, into the subprogram portfolio and to lower the cost of producing biofuels and bioproducts. This activity includes work on sustainable agriculture practices, including soil organic carbon sequestration, landscape design, and other climate-friendly soil, agriculture, and forest management work.

This activity includes feedstock preprocessing R&D to 1) improve understanding of the fundamental physical properties that govern feedstock behavior, energy density, and conversion performance; and 2) develop new technologies to convert terrestrial and waste biomass into more reliably convertible resources. This work addresses the flowability and abrasiveness challenges that have caused problematic feed handling events at integrated biorefineries. This activity supports the Feedstock Conversion Interface Consortium (FCIC), a consortium involving eight National Laboratories focused on addressing feed handling issues encountered by integrated biorefineries. Funds also support 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.

Aquatic Feedstocks R&D: This activity includes R&D, cross-cutting analysis and resource assessments, and workforce development activities to lower the production costs, improve yields, and increase reliability of aquatic feedstock production systems, including algal systems. This area includes: developing stable algal cultivars that produce high yields, resist predators, and are suitable for cultivation in farming operations; developing processes and technologies for microalgae crop protection; understanding the interface between harvested algae biomass and conversion processes, including the potential for water and nutrient recycle; improving carbon dioxide delivery and utilization; and integrating systems to optimize productivity and yield.

This activity also supports techno-economic and life-cycle analyses, resource use analysis, and operational integration of systems components. Efforts include the characterization and verification of cultivation performance 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. The interface between algae biomass production and the conversion of algae feedstocks to fuels and co-products is a particularly critical area to support the Program's goals of decarbonizing the transportation sector through SAF production.

Feedstock and Algal System Technologies
(Formerly Feedstock Technologies and Advanced Algal Systems)

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Feedstock and Algal System Technologies $80,000,000	**$68,000,000**	**-$12,000,000**
Terrestrial and Waste Feedstocks R&D$40,000,000	$48,000,000	+$8,000,000
• 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.	• Continue research on supply chain analysis and developing methods to identify, quantify, and mitigate supply chain risk.	• No change.
• No funding.	• R&D will produce a series of analyses that build upon the *Billion Ton Study* and addresses carbon sequestration, environmental justice, climate change, and end uses such as sustainable aviation fuels.	• Increased funding for analyses initiated in FY 2022. These analyses will quantify the regional availability of a variety of biomass resources to aid in the development of a regional approach to producing SAF and other biobased products.
• No funding.	• R&D will focus on the interface of carbon management and how sustainable agriculture, biogenic carbon drawdown and forestry can advance decarbonization priorities.	• Expand investment in this area to help identify decarbonization potential of this promising research space.
• No funding.	• Sustainable Energy Crop R&D for use in the production of sustainable aviation fuel (SAF).	• Expand R&D on energy crops that are critical to reaching the Program's outyear SAF volumetric targets.
• No funding .	• Support energy and environmental justice R&D which may include multi-year studies on a) phytoremediation on reclaimed mine lands and b) field testing of bioenergy crops for ecosystem services immediately upstream or upwind of pollution burdened communities.	• New initiative for ecosystem improvements.
• Support National Laboratory research under the Feedstock-Conversion Interface Consortium (FCIC) to improve operational reliability of biomass	• Continue research under the FCIC to improve the operational reliability of integrated biorefineries through increased understanding of biomass materials and the fundamental properties that	• No change.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
feedstock handling, preprocessing and conversion.	govern feedstock behavior, energy density, and conversion performance.	
• National Laboratory R&D will focus on harvest logistics and biomass analytics tools.	• Continue research on harvest logistics and biomass analytics.	• No change.
• Support competitive awards for industry-led R&D on Characterization of Municipal Solid Waste (MSW).	• No funding is requested.	• Decrease in funding for MSW R&D reflects the conclusion of a three-year funding campaign to address challenges in MSW utilization for conversion into fuels and products.
• Infrastructure and equipment upgrades at the Biomass Feedstock National User Facility at the Idaho National Laboratory.	• No funding is requested.	• Continue planning and implementation of infrastructure upgrades at the Biomass Feedstock National User Facility using prior year funds. No additional funds required - activity will continue with prior year funds.
Aquatic Feedstocks $40,000,000	$20,000,000	-$20,000,000
• Support the National Laboratory DISCOVR Consortium to integrate bench-to-field research and stress-testing of novel algae technologies.	• The Request includes Support for the DISCOVR Consortium, which focuses on improving areal productivity and reducing biomass production costs, including developing crop protection strategies to prevent pond crashes.	• No change.
• National Laboratory research on applications of foundational genomics for algae strains to harness algal diversity towards meeting subprogram targets for productivity and quality.	• Continue research on applications of foundational genomics for algae strains to harness algal diversity to improve productivity and quality.	• No significant change.
• State of technology cultivation trials to verify progress towards productivity improvements using indoor simulations.	• State of technology cultivation trials will continue to verify R&D progress	• No change.
• National Laboratory research on resource use and sustainable designs in algae cultivation (including addressing harmful algal blooms) with bioenergy systems to align these systems with cost and quality goals for algae biomass.	• Continue research in sustainable algae cultivation while addressing ecosystem services like wastewater treatment.	• No significant change.
• Competitive awards on Algae productivity to increase productivity by 20 percent by 2025 while meeting composition requirements.	• No funding is requested.	• Technologies funded through this program that support pre-pilot, pilot, and demonstration scale projects necessary to make cost-effective algal

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
		biofuels will shift to the Systems Development and Integration program

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 bio-based chemicals and products. 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 (SAF, marine fuels, and legacy fuels such as diesel), fuel components, and chemical intermediates.

In recent years, there has been a growing urgency to address the carbon emissions from hard to electrify modes of transportation, which include aviation fuels. Given the diversity of biomass and waste resources - including forest and agriculture residues, municipal solid waste (MSW), herbaceous and woody energy crops, and algae - there is no single, superior conversion process or pathway to use to convert all these streams across America. Therefore, the program conducts applied research on a portfolio addressing technical challenges that support promising feedstock-flexible conversion technologies that can produce cost effective low-carbon drop-in fuels to meet market demand. 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 and co-products and/or add value to a thermal conversion process by converting a current waste stream to a fuel and 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. The ABF consortium consists of several DOE National Laboratories and industrial partners guided by an Industrial Advisory Board.

Catalysts R&D: The goal of 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, as well as research to understand 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, BETO will develop advanced numerical modeling techniques for computational chemistry and fluid dynamics to address numerous challenges in the bioenergy space related to the design and operation of processes and equipment in an integrated biorefinery. This activity also undertakes research into electrocatalytic conversion of carbon-dioxide (CO_2) to intermediates and use of chemical catalysis to convert those intermediates to fuels, chemicals, and bioproducts.

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, supporting lower carbon alternatives for the chemical industry. The lignin valorization subactivity 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 or fuels. 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 subactivity 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, models as well as artificial intelligence and machine learning 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 fuels and products via well-defined conversion technology pathways. The 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 represent a widely available and relatively affordable feedstock for the production of fuels and products. 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 and bioproducts while also improving the quality of discharged water and reducing environmental impacts from these materials, which are often located in disadvantaged urban and rural communities.

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.

Conversion Technologies

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Conversion Technologies $110,000,000	**$110,000,000**	**+$0**
Bio-Processing R&D $28,500,000	$36,500,000	+$8,000,000
• Agile BioFoundry consortium to accelerate the R&D of new biologically-derived molecules through the completion of ≥ five 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.	• In FY 2023 the Agile BioFoundry will continue accelerating DBTL cycles and increasing metabolic flux toward industry-relevant beachhead molecules with a broad exemplar molecule product range, and with reduced GHG impacts compared to the incumbent. Continued work will expand artificial intelligence and machine learning and software capacity to improve the predictive design of organisms and pathways. Production will be demonstrated at industrially relevant titers, rates, and yields and will contribute tools to advance cost and performance of biofuel and bioproduct pathways. This will include pathways to identified "beach-head" molecules that can subsequently be synthesized into a variety of valuable end-products.	• Additional funding will support Administration priorities for biotechnology and biomanufacturing by continuing to expand efforts from FY 2022 in Artificial Intelligence/Machine Learning and establish collaboration with the Department of Defense BioMADE Institute. ABF will continue to work with select industrial partners, applying tools and techniques developed by ABF to rapidly tailor organism metabolic pathways to desired end products. ABF will solicit partners via the Minority Serving Institutions R&D Consortium (MSRDC) to collaborate on synthetic biology R&D and increase diversity in consortium participation and inclusion of minority serving institutions.
• Continued improvements to processes for producing cellulosic sugars and organisms for the biological upgrading of sugars and other intermediates via acid and diol pathways.	• Biochemical conversion R&D will investigate carbon negative (or low carbon intensive) products/chemicals through the deconstruction of diverse types of biomass feedstocks.	• R&D will increase emphasis on leveraging synthetic biology tools developed at the Agile BioFoundry and will continue enzyme engineering and robust organism development with a focus on intermediates most suitable for conversion to sustainable aviation fuels. Investments will also support work to examine other process configurations to potentially reduce the number and scale of R&D barriers to be overcome. The program will prioritize efforts to integrate a broader scope of organism engineering. Work on new fuels for light duty vehicles will be defunded.
Catalyst R&D $16,500,000	$34,500,000	+$18,000,000

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
• The Chemical Catalysis for Bioenergy (CCB) National Laboratory consortium research on catalytic upgrading of intermediates from indirect liquefaction and biochemical processing, CO_2, catalytic fast pyrolysis, catalyst synthesis and characterization, and computational physics and chemistry for faster, less-expensive development of catalytic processes, including partnerships with industry to address challenges in developing new catalyst technologies.	• CCB will continue to accelerate catalyst and process development for bioenergy applications with a focus on SAF, marine/heavy duty fuels, and bioproducts. Enabling technologies and core catalyst optimization such as ethanol and C1/C2 conversion to SAF are instrumental in the decarbonization of transportation and industry. Catalyst performance and cost improvements should enable fuel pathways that reduce GHG emissions up to 70 percent compared to petroleum fuels/products, at market competitive costs.	The increase will allow CCB to solicit partners via the Minority Serving Institutions R&D Consortium (MSRDC) to collaborate on projects to improve catalyst stability and durability, and to develop predictive tools and methods for accelerated catalyst development, while increasing diversity in consortium participation and inclusion of minority serving institutions.
• Seed funding for partnerships between National Laboratories and industry to evaluate and develop technologies for conversion of CO_2 to useful end-products including fuels and chemicals.	The CO_2 initiative will continue to focus primarily on converting carbon dioxide to intermediates and also work on subsequent intermediate upgrading to fuels and chemicals. This would continue the CO_2-to-Fuels work initiated in FY 2021. The end goal is to enable fuel pathways that could supply SAF (or other products that are difficult to decarbonize) to the market by 2050.	• Significant expansion of R&D on carbon dioxide utilization.
Co-Products R&D $15,500,000	$16,000,000	+$500,000
• Initiate the fully realized National Laboratory consortium and competitive funding for innovative technologies for plastics recycling and up-cycling (Bio-Optimized Technologies to Keep Thermoplastics out of Landfills and the Environment, BOTTLE), and launch partnerships with industry and academia, with a focus on the most abundant synthetic polymers, as well as novel biological plastic degradation technologies. Support competitive awards on plastics recycling and new biobased plastics for multilayer films.	• The BOTTLE consortium, jointly funded with the Advanced Manufacturing Office, will continue to develop biobased plastics designed with superior recyclability and biodegradability as well as new methods to recycle and upcycle existing plastic waste. [Plastics Innovation Challenge].	• The program will continue to increase emphasis on technoeconomic and lifecycle analyses to focus efforts on plastic reduction and substitution strategies with the greatest impact on greenhouse gas emissions and targeting plastics with low recycling rates.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
• National Laboratory R&D will synthesize and verify the predicted performance for at least one performance-advanced bioproduct.	• Projects in the Performance-advantaged Bioproducts (PAB) area will focus on scaling up the identification and production of products that can be produced from biomass with some performance advantage over incumbent petroleum-based products. Performance advantage targets will include decreasing carbon intensity compared to the incumbent petroleum product by at least 20 percent while also being produced at a reduced cost.	• In FY 2023, the program will focus on producing products at a scale necessary for product testing to support off-take agreements and end-user/market acceptance by 2025. Increased emphasis on industry partnerships to increase adoption and scale-up of advanced, high-value bioproducts to reduce greenhouse gas emissions from chemicals production and grow the supply chain of biomass feedstocks.
• 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 to support cost effective biofuel production will continue through catalytic, solvent-assisted, and biological processes.	• Prioritize Research on lignin conversion to biofuels based on anticipated research findings and analysis during FY 2022, while reducing funding to converting lignin to co-products .
Deconstruction and Synthesis R&D $49,500,000	$23,000,000	-$26,500,000
• National Laboratory-based research on pretreatment, process hydrolysis and integration of these unit operations into functional bench scale systems	• Continue biochemical conversion R&D with focus on conversion of lignocellulosic biomass to upgradable intermediates primarily in the areas of improvements to pretreatment and hydrolysis.	• No change.
• National Laboratory research on conversion of wet wastes to energy and modeling and analysis of these systems.	• Continue research, modeling and analysis on strategies to convert wet wastes to fuels, bio-based chemicals and products.	• No change.
• 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.	• Continue research under the Bioprocessing Separations Consortium to enable comprehensive and scalable bioprocess development with a focus on technologies and barriers identified as most central to value-added chemicals and fuels including separation of organic acids for conversion to aviation fuels.	• No change.
• Competitive awards for industrial partnerships to produce and demonstrate suitability of clean cellulosic sugars.	• No funds requested.	• Multi-year awards will continue using prior year funds.
• Competitive funding for industrial partnership to develop and demonstrate advanced separation	• Increased emphasis will be placed on developing energy-efficient separations approaches that	• Funding is reduced for separations targeted specifically at upgrading of digester products

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
technologies for the production of fuels and other useful intermediates including from anaerobic digestion processes.	meet critical needs identified by industry.	following a robust effort to address these issues in FY 2021 and FY 2022.
• Competitive funding for development and piloting of technologies to produce renewable natural gas as well as community assistance in assessing local waste resources and their potential for energy production.	• Technical assistance program with local governments/municipalities to address challenges related to management of organic wastes will continue. These efforts will focus on wastewater treatment in urban areas in coordination with the Advanced Manufacturing Office and Weatherization and Intergovernmental Program to deliver a variety of benefits. BETO's focus in this area will be in managing the residuals and technology development that can handle multiple sources of organic waste simultaneously.	• Increased focus on technical assistance on managing urban organic waste. Funding is reduced for biogas upgrading work and renewable natural gas R&D. Support for waste-to-energy demonstrations targeting manures and other community-scale organic wastes is supported under the Systems Development and Integration subprogram.
• Complete research by the National Laboratories under the Co-Optima initiative on R&D and related analysis on biofuel candidates to support fuel economy and efficiency targets for advanced compression ignition (ACI) engines used in medium- and heavy-duty vehicles.	• No funds are requested.	• No funding requested. Work has concluded under this six-year effort. EERE has defunded the development of new combustion engine and fuel regimes and instead has prioritized investments in electrification and drop-in biofuels for hard-to-electrify modes of transportation, such as aviation, marine, heavy-duty and off-road applications.

Bioenergy Technologies
Data, Modeling, and Analysis

Description

The Data, Modeling, and Analysis subprogram activities provide quantitative analysis to inform BETO's decisions regarding the future direction and scope of its RD&D portfolio. Activities include techno-economic, life-cycle, 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 plays a key role in determining the most efficient ways to use bioenergy technologies to achieve the largest GHG emissions reductions for the least cost.

The subprogram's sustainability activities focus 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 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Data, Modeling, and Analysis $9,500,000	**$9,500,000**	**+$0**
• Begin development of analysis for additional GHG reduction potential in each current BETO State of Technology pathway, as well as widely used industrial pathways, to accelerate progress toward a 100 percent clean energy economy no later than 2050.	• Continue strategic analyses on current State of Technology and industrial pathways to optimize for GHG reduction and other key environmental factors, identifying strategies to accelerate progress toward decarbonization of transportation, industry, and agriculture.	• No change.
• No funding.	• Continue analysis initiated in FY 2022 to identify ways to address administration priorities in equity and environmental justice.	• Continue analysis to provide insights on BETO's R&D portfolio to meet the objectives of equity and environmental justice.
• No funding.	• Biomass can meet needs in reducing GHG This new analysis will examine the most impactful use of biomass to meet the administration goal of a 100 percent clean energy economy by 2050.	• Continue analysis to determine the best use of biomass resources to decarbonize transportation, industry and agriculture including determining which processes can reduce emissions the most for the lowest cost and use results from this work to guide BETO Strategic Planning.
• Updated models and tools (including Greenhouse gases, Regulated Emissions, and Energy use in Transportation, GREET, Water Analysis Tool for Energy Resources, WATER and Feedstock Production Emissions to Air Model, FPEAM) and apply them to conduct high-priority National Laboratory sustainability research and analyses to identify and fill knowledge gaps related to land and water resources.	• Update models and tools (including GREET and WATER) to continue high-priority sustainability research and analyses.	• No change.
• Bioenergy sustainability research by the National Laboratories to identify and fill	• Continue bioenergy sustainability research to quantify environmental and social sustainability benefits and identify and fill	• Increased emphasis on social sustainability benefits.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
knowledge gaps related to land and water resources.	knowledge gaps related to land and water resources.	
• Conducted supporting analysis for the Co-Optima Program on biofuel candidates to support fuel economy and efficiency targets for advanced compression ignition (ACI) engines used in medium- and heavy-duty vehicles.	• No funds are requested for this effort.	• Analysis work to support the Co-Optima program has been completed. EERE has de-emphasized the development of new combustion engine and fuel regimes and instead has prioritized investments in electrification and drop-in biofuels for hard-to-electrify modes of transportation, such as aviation, marine, heavy-duty and off-road applications.

Hydrogen and Fuel Cell Technologies

Overview

Hydrogen and fuel cell technologies are part of a comprehensive portfolio of solutions needed to address the climate crisis and position America as a global leader in clean energy technology and clean energy jobs, as well as provide benefits to all Americans. The versatility of affordable, clean hydrogen as an energy carrier across applications offers opportunities to accelerate economy-wide decarbonization, including in hard-to-decarbonize sectors. In transportation, the use of hydrogen-powered fuel cells in heavy-duty fleets offers one opportunity to reduce emissions, while meeting long driving-range and short refueling-time requirements. Heavy and medium duty vehicles, including trucks and buses, can utilize hydrogen fuel cells to reduce local pollution, addressing environmental justice and equity in regions that may typically have poor air quality. In the industrial and chemical sectors, steel manufacturers, fertilizer producers, and producers of liquid fuels – such as sustainable aviation fuels – are increasingly turning to clean hydrogen as one of the few means to achieve their decarbonization goals. The use of clean hydrogen technologies in such industries can also address environmental justice in certain regions of the country and support good paying jobs in new clean energy industries. In the power sector, clean hydrogen can play a role in achieving the Administration's goal of zero carbon pollution by 2035. Integrated hybrid energy systems can incorporate clean hydrogen and fuel cell technologies for energy storage and grid services, such as voltage and frequency stabilization. Finally, clean hydrogen can offer the potential for long-duration energy storage, a key enabler to renewables and achieving the Administration's goal for a carbon-free grid by 2035.

The role of the Hydrogen and Fuel Cell Technologies Office (HFTO) is to drive the research, development, demonstration, and deployment (RDD&D) of innovative technologies to facilitate widespread adoption of clean hydrogen and fuel cell technologies across sectors. This can be achieved by reducing the cost, improving performance and durability, demonstrating, and deploying technologies, incentivizing domestic manufacturing, and addressing safety, codes, standards, and workforce development. Producing affordable clean hydrogen is a key priority in conjunction with enabling diverse end uses, including grid integration and energy storage; transportation (e.g., trucks, marine, rail, aviation); chemicals (e.g., ammonia, synthetic fuels); industry (e.g., iron and steel making); backup power (e.g., emergency power, data centers); and others. HFTO has established application-specific targets relevant to the affordability of these options, considering expectations regarding cost and performance for different markets. These efforts will help pave the way for low-greenhouse gas (GHG) emissions and hydrogen-powered fleets that are affordable and attractive to the consumer.

The HFTO portfolio comprises core materials-, components-, and systems-level research, development, and demonstration (RD&D) in fuel cells and hydrogen production, storage, and distribution technologies; as well as deployment projects targeting scale-up and affordability of integrated energy systems essential to H2@Scale[1]. A key priority is the recently launched Hydrogen Energy Earthshot (Hydrogen Shot) to achieve the bold, ambitious target of $1 for 1 kilogram of clean hydrogen in 1 decade (i.e., by 2031) – "1 1 1". Additional supporting activities include efforts to reduce vulnerabilities and build supply chain resilience (e.g., in rare earth and critical minerals used as catalysts in fuel cells and electrolyzers); accelerate RD&D through machine learning and -high-performance computing; build and strengthen the STEM (Science, Technology, Engineering and Mathematics) workforce in the hydrogen and fuel cell communities; and prioritize investments that facilitate and strengthen multisector partnerships consistent with H2@Scale. In addition to its collaborative partnerships with the National Laboratories, HFTO also drives strategic coordination with other DOE offices (such as Fossil Energy and Carbon Management (FECM), Nuclear Energy (NE), the Office of Science (SC), and the Office of Clean Energy Demonstrations (OCED)), Federal agencies, state and local governments, industry, and non-governmental partners. Environmental justice remains a key focus of these partnerships to ensure that the economic and environmental benefits of HFTO investments are available to disadvantaged communities (underserved or pollution over-burdened communities). HFTO investments also focus on building a well-trained workforce, creating energy-focused jobs, and advancing diversity in STEM within hydrogen and fuel cell industries.

HFTO also includes support in the key emphasis areas of energy justice, workforce, diversity in STEM and state and local partnerships. Investments associated with Workforce Development will support training and develop good paying clean energy jobs for the American people – especially workers and communities impacted by the energy transition and those

[1] H2@Scale is a concept that explores the potential for wide-scale hydrogen production and utilization in the United States to enable resiliency of the power generation and transmission sectors, while also aligning diverse multibillion dollar domestic industries, domestic competitiveness, and job creation.

historically underserved by the energy system and overburdened by pollution. Investments associated with Diversity in STEM support outreach and will raise awareness of clean energy research and job opportunities at minority-serving institutions and minority professional organizations and ensure that organizations receiving EERE funding are thinking through diversity and equity in their own work. Investments in State and Local partnerships will enable state and local governments to be more effective in facilitating the nation's (and their own) affordable and resilient clean energy and efficiency goals. Investments associated with Energy and Environmental Justice will support approaches and processes to reach new groups of Americans historically underserved by the energy system.

Highlights of the FY 2023 Request

- Fuel Cell Technologies will focus on applied fuel cell component and systems RD&D with potential for both transportation and crosscutting applications, such as reversible fuel cells, which contribute to the priorities of net zero emissions by 2050 and a clean grid by 2035. In FY 2023, the Million Mile Fuel Cell Truck consortium (M2FCT) will be a key focus area, which includes National Laboratories in partnership with universities and industry to accelerate RD&D that would enable a fuel cell durability of a million miles – a market requirement for long haul trucks. The main shift in FY 2023 is from early-stage research to accelerating RD&D to enable an affordable fuel cell system cost. The cost and durability R&D are also applicable to fuel cells for stationary markets enabling resiliency and potential future deployment in disadvantaged communities and in poor air quality regions to address environmental justice priorities. In addition to materials and components R&D, there will be continued focus on systems design and integration to accelerate progress towards deployable systems. Such systems and systems integration work includes stacks and innovative balance of plant (BOP) components and systems. Efforts on fuel cell stack components (e.g., membranes, catalysts, membrane electrode assemblies, gas diffusion layers) and component integration will enable meeting targets for fuel cell performance and durability across applications. Activities will strengthen the domestic supply chain, enabling economies of scale across applications (e.g., trucks, maritime, rail, mining/construction, datacenters, reversible fuel cells, and energy storage).
- Hydrogen Technologies will emphasize applied RD&D related to materials, components, systems, and process development to enable meeting the Hydrogen Shot goal of $1/kg of clean hydrogen through deployment of commercially viable, low, or zero-carbon hydrogen production, storage, and infrastructure technologies. The main focus in FY 2023 is on target-driven RD&D to enable affordable clean hydrogen. To support the H2@Scale initiative, activities include RD&D on clean hydrogen production, delivery, and storage, including materials development, and integration with diverse generation sources. Hydrogen production efforts will focus on RD&D to enable high-performing, durable, cost-competitive technologies, including photo-electrochemical, solar-thermal hydrogen production, and microbial hydrogen production pathways. Hydrogen storage efforts will focus on applied RD&D on advanced storage technologies for stationary and mobile applications offering high-energy density at lower pressures and higher round-trip efficiencies compared to today's systems, as well as reducing costs of carbon fiber tanks. HFTO will continue to support RD&D on chemical carriers, materials-based and advanced innovative hydrogen storage technologies, hydrogen liquefaction, compression, and dispensing, as well as materials compatibility, particularly with hydrogen blends. Activities will be coordinated with other offices within DOE involved in hydrogen.
- Electrolysis. In FY 2023, the efforts on reducing the cost of clean hydrogen through electrolysis will be moved under the Bipartisan Infrastructure Law Clean Hydrogen Electrolysis Provision. This includes the H2NEW consortium established in 2021, which is comprised of National Labs, industry, and academia partners in a cohesive, concerted effort to meet electrolyzer cost, efficiency, and durability targets.
- Systems Development & Integration RD&D will focus on medium- and heavy-duty transportation, industrial and chemical applications, grid energy storage and power generation, and safety, codes and standards. Within transportation, RD&D will accelerate medium- and heavy-duty fuel cell electric trucks operating on clean hydrogen to reduce emissions and improve the energy and operational efficiency of moving freight. Efforts will also include the Integrated Heavy-Duty ZEV Fueling Corridor Demonstration project offering high-flow hydrogen fueling stations need to support the build-out of fuel cell electric heavy-duty trucks. In addition, new market opportunities for hydrogen and fuel cells across applications such as marine, rail, aviation, and agricultural/mining equipment will continue to be evaluated. Within industrial and chemical processes, RD&D will be focused on demonstrating use of clean hydrogen as a feedstock or direct reducing agent to decarbonize steel and ammonia production. The grid energy storage and power generation work will involve integration of megawatt-scale electrolyzers coupled with other baseload power or intermittent renewables (e.g., wind/offshore wind, solar, etc.) to produce and store clean hydrogen that can be utilized in various applications, such as providing microgrids for underserved communities or backup power to data centers.

This subprogram also includes RD&D to demonstrate novel technologies related to the production, delivery, storage, and end use of hydrogen and provide feedback to the R&D subprograms in support the Hydrogen Shot goals. Finally, the subprogram will enable the development of codes and standards with an emphasis on large-scale hydrogen applications as well as developing and sharing best practices on hydrogen safety and preventing hydrogen leakage (for both safety and climate considerations). State and regional engagement to support environmental justice, as well as diversity, equity, and inclusion, particularly related to training and workforce development, will be a priority in these activities.

- Data, Modeling and Analysis will focus 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 a Federal advisory committee. State and regional engagement, particularly on analyses of co-locating high volume production and end use of hydrogen, will be a key priority. Analyses on life cycle emissions reduction will also be coordinated with other relevant DOE offices such as FECM.

Through the above activities, the program supports the following strategic priorities: decarbonizing transportation; enabling a carbon pollution-free electricity sector no later than 2035 and a 100 percent clean energy economy with net-zero emissions no later than 2050.

Contributions to DOE-wide Crosscutting Investments

HFTO is involved in several crosscuts, including the following:

- Advanced Manufacturing ($25,000,000): Includes fuel cells under M2FCT and carbon fiber for composite tanks. Outcome supports $9/kWh for hydrogen storage and $80/kW for fuel cell targets;
- Critical Minerals ($30,000,000): in support of the DOE's Critical Minerals initiative, efforts include R&D to reduce Platinum Group Metals (PGM) catalysts for fuel cells and electrolyzer technologies, as well as additional supporting activities to reduce vulnerabilities and build supply chain resilience;
- Energy Storage Grand Challenge ($123,000,000): Activities include wind/offshore wind, energy storage, grid integration (ARIES) and reversible fuel cells, and a key priority is systems development and integration;
- Grid Modernization, formerly Grid Modernization Initiative ($17,000,000): Includes energy storage and grid integration (ARIES); reversible fuel cells; and systems development and integration, including hybrid energy systems such as wind/offshore-wind to hydrogen, and microgrids for underserved communities; along with supporting analysis;
- Industrial Decarbonization ($176,150,000): Includes all H2 technologies and use of hydrogen as an alternative fuel/feedstock for ammonia and steel; and other hard to decarbonize sectors.
- Hydrogen ($186,000): All HFTO's activities are included in this newly created crosscut, and HFTO will coordinate with all relevant offices, particularly FECM, NE, the Office of Electricity (OE), SC, OCED and the Advanced Research Project Agency-Energy (ARPA-E). Activities include hydrogen production, delivery/infrastructure, storage, fuel cells, and end uses, including systems development and integration, as well as safety, codes, standards, and workforce development.

EERE Program Priorities

In FY 2023, HFTO continues to support an investment strategy aligned to the following programmatic priority areas that are central pillars to the U.S. GHG profile:

Hydrogen and Fuel Cell Technologies
Funding ($K)

	FY 2021 Enacted	FY 2022 Annualized CR[1]	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted
Decarbonizing the electricity sector	125,000	125,000	117,000	-8,000
Decarbonizing transportation across all modes: air, sea, rail, and road	132,000	132,000	110,000	-20,00
Decarbonizing energy-intensive industries	114,000	114,000	82,000	-32,000
Reduce the carbon footprint of the U.S. building stock	63,000	63,000	91,000	+28,000
Decarbonizing the agriculture sector, specifically focused on the nexus between energy and water	34,000	34,000	15,000	-19,000

[1] The FY 2022 Annualized CR amounts reflect the P.L. xxx-yyy continuing resolution level annualized to a full year.

Hydrogen and Fuel Cell Technologies
Funding ($K)

	FY 2021 Enacted	FY 2022 Annualized CR[1]	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted
Hydrogen and Fuel Cell Technologies				
Fuel Cell Technologies	25,000	-	25,000	0
Hydrogen Technologies	71,000	-	71,000	0
Systems Development & Integration	51,000	-	87,000	+36,000
Data, Modeling & Analysis	3,000	-	3,000	0
Total, Hydrogen and Fuel Cell Technologies	**150,000**	**150,000**	**186,000**	**+36,000**

SBIR/STTR:

- FY 2021 Transferred: SBIR: $4,936,000; STTR: $536,000
- FY 2022 Annualized CR: SBIR:4,776,000 $; STTR: $ 672,000
- FY 2023 Request: SBIR: $5,374,188; STTR: $755,745

[1] The FY 2022 Annualized CR amounts reflect the P.L. xxx-yyy continuing resolution level annualized to a full year. These amounts are shown only at the congressional control level and above, below that level, a dash (-) is shown.

	FY 2023 Request vs FY 2022 Request
Hydrogen and Fuel Cell Technologies	
Fuel Cell Technologies: The Request reflects prioritization of enabling fuel cells for heavy duty applications, particularly long-haul, heavy-duty trucks. FY 2023 efforts will include systems, scale-up and demonstration related activities in support of the M2FCT. This subprogram will focus on not only improving catalyst performance but on integration at the electrode, stack, and system level, and on development of other components (e.g., gas diffusion layers, and balance-of-plant components), to enable meeting cost and performance requirements. In addition, demonstration activities will help determine the durability protocols that must be developed to emulate typical drive cycles. Real world validation of performance will be critical in guiding RD&D to meet the fuel cell system cost targets. This effort will be complemented by the Bipartisan Infrastructure Law's (BIL) Clean Hydrogen Manufacturing Program focused on enhancing domestic manufacturing of clean hydrogen use, storage, and related equipment and the BIL's Clean Hydrogen Technology Recycling RD&D Program that covers recycling of equipment for clean hydrogen processing, delivery, storage, and use, including fuel cells.	**0**
Hydrogen Technologies: The Request prioritizes applied materials and systems RD&D for hydrogen production, storage, and infrastructure to enable meeting the Hydrogen Shot goal. The subprogram will continue efforts within HydroGEN consortia on early-stage R&D for longer term clean hydrogen production pathways. Infrastructure RD&D will continue to focus on efficient, safe, and low-cost options, including RD&D on carriers, materials-compatibility, and innovative hydrogen liquefaction technologies. Hydrogen Storage RD&D will focus on development and demonstration of higher density materials compared to gaseous hydrogen, increase efforts on cryogenic liquid hydrogen and will continue support for carbon fiber tanks. Activities will include materials RD&D related to harsh environments such as cryogenic temperatures and high pressures, as well as blending with natural gas. Materials related research will apply artificial intelligence techniques, machine learning, and other computational tools. The FY 2023 Request shifts the RD&D focused on reducing the cost of electrolyzers under the BIL's Clean Hydrogen Electrolysis Program.	**0**
Systems Development & Integration: In FY 2023, the subprogram will be reorganized by hydrogen end use: Transportation; Industrial and Chemical Applications; Grid Energy Storage and Power Generation; and Safety, Codes and Standards (including Workforce Development). Within Transportation, additional funds will be focused on accelerating medium- and heavy-duty vehicle demonstrations including the demonstration of low-cost, high-flow hydrogen fueling stations. Deployment of Heavy Duty (HD) fuel cell vehicles will require hydrogen fueling stations that can affordably and reliably provide fast fueling times comparable to incumbent technologies (i.e., diesel trucks). This will require hydrogen flow rates approximately five times greater than those in current light-duty hydrogen fueling stations. While the fill rate required will vary depending upon a truck's class and vocation, DOE's fueling rate target for Class 8 long-haul trucks is 10 kg H_2/min (average fill rate), to enable full fills within timeframes comparable to those for today's diesel trucks (e.g., less than 10 minutes). This sub-program will also work towards enabling Class 8 long-haul hydrogen fuel cell trucks to achieve a 750-mile driving range between refueling, which will require onboard storage of approximately 60-100 kg of H_2.	**+36,000**
Data, Modeling & Analysis: The Request focuses support on analysis to identify key areas in which to strategically prioritize R&D efforts. The primary change will be on including analyses related to decarbonization goals as well as hydrogen and fuel cell related jobs.	**0**
Total, Hydrogen and Fuel Cell Technologies	**+36,000**

Description
The Fuel Cell Technologies subprogram supports applied RD&D and innovative concepts to simultaneously reduce costs, improve durability and efficiency, and enhance performance of fuel cells (including, power density, start-up time, transient response, robust operation, etc.). Key goals include developing and validating concepts to meet several metrics to enable fuel cells to be competitive with incumbent and other advanced technologies. Targets are application specific, such as durability for heavy-duty trucks, or durability for automotive applications. Despite the differences, the fundamental knowledge gained from the RD&D this subprogram supports will focus on key materials and components and can thus have impact on a range of applications, including transportation and crosscutting applications such as stationary power (primary and backup), off-road applications, and energy storage. Because today's fuel cells rely on expensive Platinum Group Metals (PGM) as catalysts within the electrodes, a key objective of this subprogram, in support of the DOE's Critical Minerals initiative, 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 BOP components such as air systems. The applied RD&D this subprogram supports 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. This in turn will create high-quality domestic manufacturing jobs across the U.S. (including areas impacted by deindustrialization) for both the supply chain and system integrators and operators. The subprogram will also encourage diversity, equity and inclusion through fostering STEM outreach and fellowships/internships, including collaboration at National Laboratories. Selected activities will also support international collaborations, particularly to leverage global resources, such as developing uniform protocols for accelerated testing of fuel cells and gathering data from global deployments to guide the sub-program's RD&D.

<u>Materials and Component R&D</u>: The Materials and Component R&D activity area encompasses all R&D 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, bipolar plates, and gas diffusion layers, as well as advances in modeling. Advances in low-cost materials and components are critical to reaching the Fuel Cell Technologies subprogram's application-specific targets. Improving fuel cell durability, efficiency and performance will also address priorities beyond transportation including grid resiliency, energy storage and national space mission priorities. 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 M2FCT and ElectroCat National Laboratory consortia will provide critical contributions by providing unique capabilities in synthesis, characterization, and computation to competitively selected projects at universities, industry, and National Laboratories. More specifically, activity under M2FCT directly relates to heavy-duty applications.

<u>Systems Integration R&D</u>: Includes the integration of MEAs and other stack components (e.g., bipolar plates) developed in the Materials and Component R&D key activity, into systems. Efforts include the development and demonstration of fuel cell stacks and BOP components (e.g., innovative low-cost air handling and power electronics for fuel cell systems to reduce cost and improve durability) with manufacturability and sustainability in mind. 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, Efforts will be supported by modeling and will incorporate stack and BOP standardization approaches, and energy storage (e.g., unitized reversible fuel cells). Advances in these areas will enable the U.S. to retain and establish global leadership, strengthen the supplier base, and expand domestic manufacturing capability.

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Fuel Cell Technologies $25,000,000	**$25,000,000**	**$0**
Materials and Component R&D $18,000,000	$18,000,000	$0
• Focus R&D on low-PGM MEAs with enhanced durability through M2FCT and lab/industry/university projects to enable meeting ultimate fuel cell cost and durability targets with a focus on heavy-duty applications.	• Continue to accelerate R&D on low-PGM MEAs with enhanced durability through M2FCT and lab/industry/university projects to enable meeting ultimate fuel cell cost and durability targets across heavy-duty applications.	• Increased emphasis on materials integration to meet 2030 targets for heavy-duty applications.
• Fund R&D on PGM-free catalysts and electrodes through lab consortium (ElectroCat) and funding opportunities to enable meeting ultimate fuel cell cost and durability targets across applications and mitigate U.S. dependence on foreign precious metal imports.	• Continue R&D on PGM-free catalysts and electrodes through lab consortium (ElectroCat) to enable meeting ultimate fuel cell cost and durability targets across applications and mitigate U.S. dependence on foreign precious metal imports.	• Maintain critical mass of activities in support of ElectroCat with an increased focus on durability in line with heavy-duty/heavy load application needs.
• Initiate the development of innovative materials, concepts, and manufacturing processes through industry/university projects in coordination with the M2FCT for bipolar plates suited for heavy-duty applications.	• Continue R&D beyond early-stage concepts, in coordination with M2FCT (e.g., gas diffusion layers) to strengthen the domestic supply base.	• Shifting support for manufacturing activities to programs funded by the BIL.
• Emphasize R&D on MEA components, including high-temperature membranes, through the M2FCT consortium and industry/university projects to improve the durability and efficiency of MEAs for heavy-duty applications.	• Continue R&D on MEA components and MEAs through the M2FCT consortium and industry/university projects to improve the durability and efficiency of MEAs for heavy-duty applications meeting ultimate targets.	• No change.
Systems Integration R&D $7,000,000	$7,0000,000	$0
• R&D on BOP components, including low-cost air handling, that would be relevant to both reversible fuel cells and fuel cells for a range of power generation and energy storage applications.	• Continue RD&D and systems integration, including on BOP components, particularly power electronics, as well as stack and BOP manufacturing and standardization approaches to strengthen the domestic supply chain, that would be relevant to both reversible fuel cells and fuel cells and enable economies of scale across applications.	• No change.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
• Initiate projects for heavy/medium duty trucks as part of the SuperTruck funding opportunity in collaboration with the Vehicle Technologies Office.	• Demonstrate hydrogen fuel cells for stationary power generation applications and reversible fuel cells for resiliency to support critical loads (e.g., emergency shelters, hospitals) and disadvantaged communities	• Shift focus to stationary fuel cell development and demonstration efforts, including reversible fuel cells, for resiliency to support critical loads and for long duration energy storage to meet Administration priorities for a clean grid by 2035.
• Analysis efforts will focus on new applications and assessment of hydrogen and fuel cell targets as well as status to guide future R&D.	• Analysis efforts will continue to focus on assessment of hydrogen and fuel cell targets for various applications as well as status to guide future RD&D.	• No change.

Description
The Hydrogen Technologies subprogram supports RD&D to enable clean, low-cost, and environmentally sustainable hydrogen production, storage, and infrastructure technologies to achieve the DOE Hydrogen Shot goal of $1/kg clean H_2 by 2031. Hydrogen can play a pivotal role as an energy carrier, particularly for long-duration energy storage; a valuable feedstock for chemical processes (e.g., steel manufacturing and ammonia production); and versatile fuel for both transportation and stationary applications. The dispensed cost of hydrogen is a key focus area, and the target cost is application specific. Hydrogen must become more cost competitive for transportation applications in order to be commercially viable. This includes all costs related to hydrogen production, transport, and dispensing to a fuel cell vehicle while meeting all performance and quality requirements. The cost is broken down to hydrogen production and the remainder of the pathway, including delivery and dispensing. In the long term, to offer the highest impact potential and to enable widespread use of hydrogen, the subprogram will focus on achieving the DOE Hydrogen Shot stretch goal of $1/kg clean hydrogen production by 2031. This will enable its use for energy storage and chemical processes, where lower quality and lower pressure hydrogen is utilized, and production can occur onsite. The subprogram focuses on innovative strategies for highly efficient, sustainable, carbon-free hydrogen production from diverse domestic resources; high-density hydrogen storage and transport technologies; and low-cost, durable, and safe infrastructure technologies. The subprogram will also encourage diversity, equity and inclusion through fostering STEM outreach and fellowships/internships, including collaboration at user facilities affiliated with the lab-led consortia. Selected activities will also support international collaborations, particularly to leverage global resources, such as developing uniform protocols for testing hydrogen technologies and gathering data from global deployments to guide the subprogram's RD&D.

<u>Production R&D</u>: The Production R&D activity area addresses advanced water splitting RD&D, with electrolysis activities shifting to programs funded through the BIL's Clean Hydrogen Electrolysis Program. The key focus is a reduction in modeled cost for carbon-free hydrogen production. This effort is aligned with the Administration's focus on meeting aggressive climate goals and achieving the DOE's Hydrogen Shot goal. This important activity will focus on the following key areas: (1) direct photo-electrochemical (PEC) hydrogen production, and (2) high-temperature, thermochemical hydrogen production. Efforts leverage the capabilities within the DOE National Laboratories through the multi-laboratory consortium HydroGEN, which includes initiatives to encourage partnerships with industry and academia and focuses on innovative materials development to advance performance across direct water splitting technologies.

In addition to advanced water splitting, this activity includes support for technologies with the potential to leapfrog those available commercially today, such as 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 nuclear, and renewable resources – including technologies that use biomass or industrial waste streams.

<u>Storage R&D</u>: The Storage R&D activity area supports RD&D on advanced technologies to enable efficient, high-density, safe, and cost-effective hydrogen storage for stationary and mobile applications. Today, most hydrogen storage systems rely on either high-pressure, all-metal or carbon fiber composite tanks or vacuum-insulated cryogenic liquid hydrogen tanks. Costs are too high (e.g., $16/kWh for vehicular applications, even at high manufacturing volumes) for carbon fiber composite tanks and vacuum insulation presents limitations for certain applications. This activity area includes RD&D to reduce the cost of carbon fiber composite tanks, and on advanced, innovative liquid hydrogen storage technologies. In contrast to compressed and liquid hydrogen storage technologies, materials-based storage technologies have potential to provide high energy density storage at significantly lower pressure and at near ambient temperature. In FY 2023 the activity area will initiate industry-led demonstration activities of innovative bulk hydrogen storage technologies that provide high-density, low-cost, efficient hydrogen storage with superior performance over incumbent technologies. The hydrogen storage activity area will continue support of RD&D on innovative hydrogen storage materials (e.g., sorbents, chemical carriers, metal hydrides) with potential to significantly surpass performance of high pressure and cryogenic liquid tanks. These RD&D efforts will be supported through the Hydrogen Materials Advanced Research Consortium (HyMARC), leveraging capabilities of the National Laboratories.

Infrastructure R&D: The hydrogen infrastructure RD&D activity area supports RD&D on materials, components, and processes to enable a low-cost, safe, and efficient hydrogen infrastructure. The overall objective of this activity area is to enable achieving the overall cost target for produced, delivered, and dispensed hydrogen. These targets are application-specific, such as for delivery, bulk storage, and dispensing into vehicles. In FY 2023 emphasis will be on advanced hydrogen liquefaction technologies that are scalable with higher energy efficiency and low-cost. RD&D investigating and developing materials (e.g., metals, polymers) compatible for operation in hydrogen and hydrogen/natural gas blends will continue. Efforts will be carried out in collaboration with the H-Mat consortium, leveraging capabilities of the National Laboratories.

Hydrogen Technologies

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Hydrogen Technologies $71,000,000	**$71,000,000**	**$0**
Production R&D $30,000,000	$15,000,000	-$15,000,000
• Fund early-stage advanced water splitting projects through the HydroGEN National Laboratory consortium, high-temperature electrolyzer manufacturing R&D and new biological approaches to hydrogen production through competitively selected projects.	• Continue advanced water splitting R&D through HydroGEN and shift electrolysis efforts including H2NEW to BIL.	• BIL-provided funding will support electrolysis activity in FY 2023.
Storage R&D $16,000,000	$24,000,000	+$8,000,000
• 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 and initiate bulk liquid hydrogen storage R&D to enable efficient and cost-effective hydrogen storage.	• Continues developing technologies to enable hydrogen use in medium and heavy-duty transportation. Initiate activities for onboard liquid hydrogen storage and refueling for MD/HD applications.	• Initiate activities for onboard liquid hydrogen storage and refueling for MD/HD applications to help enable decarbonization of the transportation sector.

Hydrogen Technologies

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Infrastructure R&D $25,000,000	$32,000,000	+$7,000,000
• 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.	• Continue H-Mat materials compatibility RD&D, with inclusion of impact of hydrogen blending on performance.	• No change.
• Continue to support National Laboratory R&D within HyMARC on priority hydrogen carriers with potential to reduce the cost of hydrogen infrastructure.	• Refocus HyMARC with a greater emphasis on higher TRL materials and system-level consideration.	• Shifts emphasis to higher TRL activities.
• Competitively select new industry led projects on component R&D for high throughput refueling components for heavy-duty applications (e.g., marine, rail, trucks).	• Continue R&D on advanced, scalable hydrogen liquefaction technologies to accelerate progress on meeting needs for industrial and heavy-duty transportation applications.	• No change.
• 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).	• No funding requested. Continuing funded activities.	• No change

Hydrogen and Fuel Cell Technologies
Systems Development & Integration

Description

The Systems Development and Integration subprogram is focused on technology acceleration, including integrating, developing, and demonstrating hydrogen end use technologies needed to expedite the commercialization of hydrogen and fuel cell systems, produce low cost, clean hydrogen in support of Hydrogen Shot and realize the H2@Scale vision from a wide array of domestic resources. This includes focusing on key applications including integrating clean energy systems (i.e., grid energy storage and power generation), decarbonizing industrial and chemical processes, and demonstrating medium and heavy-duty transportation applications. In addition, the subprogram aims to demonstrate novel technologies related to the production, delivery, storage, and end use of hydrogen and provide feedback to the R&D sectors. Finally, the subprogram will enable the development of codes and standards with an emphasis on large-scale hydrogen applications, developing and sharing best practices on hydrogen safety, and supporting workforce development.

The goal of the Systems Development and Integration subprogram is to meet the Hydrogen Shot goals and enable the H2@Scale vision by demonstrating and de-risking the novel integration of hydrogen with diverse domestic sectors including energy storage, industrial and chemical sectors, and transportation. To achieve this goal, the subprogram aims to demonstrate safe, efficient, and low-cost hydrogen and fuel cell technologies with significant potential for greenhouse gas emission reduction and life-cycle cost parity when compared with incumbent and emerging technologies.
The subprogram also recognizes the essential role that state and local governments play in the transition to a clean energy economy and will work in a unified and coordinated way with state and local partners on activities such as workforce development and analyses, wherever possible to accelerate a just, equitable transition.

The Systems Development and Integration activities are focused on innovative concepts and solutions that can accelerate the transition from R&D to commercial viability. These activities 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 several application-specific parameters must be considered. Depending on the application (e.g., heavy duty trucks, marine, rail, or industrial/stationary use such as steel manufacturing, ammonia production, power for critical loads, and energy storage), the generation, storage, and dispensing technology for providing hydrogen may vary and must be addressed.

Transportation: Transportation activities will focus on demonstrating medium- and heavy-duty fuel cell trucks and on low-cost, high-flow hydrogen fueling infrastructure that can be deployed in zero-emissions transportation corridors. RD&D will accelerate medium and heavy-duty fuel cell electric trucks operating on clean hydrogen to reduce emissions and improve the energy and operational efficiency of moving freight while still providing operating range and fueling times on par with incumbent technologies. This will include hybridization strategies such as fuel cell range extenders as well as the associated high-flow hydrogen fueling and onboard hydrogen storage that will be required. In addition, new market opportunities for hydrogen and fuel cells in heavy-duty transportation sector such as marine, rail, and agricultural/excavating equipment will continue to be evaluated. Transportation activities will be coordinated with EERE's Vehicle Technologies Office (VTO).

Industrial and Chemical Applications: Within hard-to-decarbonize industrial and chemical processes, this activity will focus RD&D on demonstrating the ability of clean hydrogen to be used as a feedstock (e.g., ammonia production) or direct reducing agent (i.e., steel production) or to provide heat (i.e., steel and cement production). The activity will coordinate these activities with EERE's Advanced Manufacturing Office (AMO), FECM, and NE.

Grid Energy Storage and Power Generation: Grid Energy Storage and Power Generation RD&D will focus on hybrid systems, grid integration, and energy storage of hydrogen to enable grid stability/resiliency, avoid curtailment, and produce low-cost, clean hydrogen. This work will involve the integration of multi-megawatt water electrolyzers coupled with clean sources (e.g., nuclear baseload power and intermittent renewable power generation) to produce clean hydrogen. Demonstration of a grid-scale electrolyzer, along with storage technologies, will enhance the economics of baseload nuclear plants and accelerate adoption of renewable energy technologies by providing additional revenue streams for electricity generated during off-peak hours. In addition, the grid energy storage and power generation work will evaluate various end use applications, such as providing micro-grids and backup power for underserved communities (e.g., remote/rural communities). The activity will coordinate these activities with the Wind Energy Technologies Office (WETO) and NE.

Safety, Codes and Standards: This 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, industrial use, energy storage, etc.), specific issues such as the amount of hydrogen that may be stored in a given location, required hydrogen metering/flow rates, transport of hydrogen in tunnels, or the footprint restrictions onsite, must be addressed. 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.

This activity also ensures safety considerations are incorporated into RD&D projects, best practices are developed, and lessons learned are shared. Diversity, equity, and inclusion is a key feature of these activities particularly through fellowships/interns and encouraging engagement at Historically Black Colleges and Universities (HBCUs) and other minority serving institutions.

Systems Development & Integration

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Systems Development & Integration $51,000,000	**$87,000,000**	**+$36,000,000**
Hybrid Systems and Grid Integration $71,000,000	$0	-$71,000,000
• Fund competitively selected industry-led projects for grid-integration with hydrogen technologies, including hybrid approaches, to enhance the stability of the power grid through responsive load and energy storage, in support of H2@Scale. • Continue support for National Laboratory and competitively selected industry 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. • Fund National Laboratory first-of-a-kind systems integration and validation projects to guide R&D, in support of H2@Scale. • Establish research projects, including industry led teams, focused on improving the energy and operational efficiency of moving freight with medium and heavy-duty fuel cell electric trucks in support of SuperTruck as well as pursuing other heavy-duty transportation sectors such as marine, rail, and agriculture equipment. • Fund manufacturing related projects to help reduce the cost and improve the durability of fuel cells, electrolyzers, and other hydrogen components. Through responsive load and energy storage enable. • Fund National Laboratory first-of-a-kind systems integration and validation projects to guide R&D, in support of H2@Scale.		• Activity reorganized by end use: Transportation; Industrial and Chemical Applications; Grid Energy Storage and Power Generation.

Systems Development & Integration

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Transportation $0	$45,000,000	+$45,000,000
	• Continue funding industry-led teams focused on improving the energy and operational efficiency of moving freight with medium and heavy-duty fuel cell electric trucks in support of SuperTruck as well as pursuing other heavy-duty transportation sectors such as marine, rail, and off-road equipment.	• Previously funded under Hybrid Systems and Grid Integration. No change.
• No funding requested.	• Demonstrate low-cost, high-flow hydrogen fueling infrastructure and zero-emission transportation corridor.	• Initiates a new activity to support the build-out of heavy-duty hydrogen fuel cell electric truck infrastructure corridor demonstration.
Industrial and Chemical Applications $0	$16,000,000	+$16,000,000
	• Continue industry-led projects to demonstrate use of clean hydrogen as a feedstock or direct reducing agent to decarbonize ammonia and steel production, in support of H2@Scale in collaboration with the Advanced Manufacturing Office (AMO), FECM and NE.	• Previously funded under Hybrid Systems and Grid Integration. Increases focus on demonstrating clean hydrogen as a feedstock to decarbonize steel and ammonia production.
	• Continue manufacturing related projects to help reduce the cost and improve the durability of fuel cells, electrolyzers, and other hydrogen components.	• Previously funded under Hybrid Systems and Grid Integration. No significant change.

Systems Development & Integration

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Grid Energy Storage and Power Generation $0	$16,000,000	+$16,000,000
	• Continue industry-led projects for grid-integration with hydrogen technologies, including hybrid approaches, to enhance the stability/resiliency of the power grid and enable production of low cost, clean hydrogen, in support of H2@Scale, and Energy Storage Grand Challenge. Specific focus will be placed on developing micro-grids for underserved communities.	• Previously funded under Hybrid Systems and Grid Integration. Increased focus on developing micro-grids for underserved communities.
	• Continue first-of-a-kind systems integration and validations to guide R&D, in support of H2@Scale and DOE's Energy Storage Grand Challenge. Support NREL's Advanced Research on Integrated Energy Systems (ARIES) effort and net zero campus RD&D.	• Previously funded under Hybrid Systems and Grid Integration. No change.
Codes and Standards $10,000,000	$10,000,000	$0
• 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.	• Continue R&D to enable the development of codes and standards (e.g., sensor R&D, risk assessment) with an emphasis on large-scale novel hydrogen end use applications, and ensure activities include safety considerations.	• No change.
• Develop and share best practices and lessons learned by expanding education and training activities.	• Further develop and share best practices and lessons learned by pursuing education, training, and workforce development activities.	• Emphasizes focus on workforce development and diversity.

Hydrogen and Fuel Cell Technologies
Data, Modeling, and 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 assessing impacts of hydrogen and fuel cell technologies on sustainability metrics, 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 potential end-users' requirements 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. Modeling and analysis within this subprogram can elucidate the total cost of ownership of hydrogen and fuel cell technologies in specific sectors, regional impacts of deployment on criteria pollutant emissions and water resources, potential for job creation, and impacts of hydrogen and fuel cells on global sustainability. Specific sectors of interest include medium- and heavy-duty transportation, industrial uses of hydrogen, and integration of hydrogen and fuel cell technologies with regional grids for energy storage, nuclear power plants, and natural gas networks (e.g., blending). In FY 2023, the subprogram will increase emphasis on environmental justice, job creation, and energy storage to inform targeted R&D and deployments. The subprogram will support approximately nine projects for these activities with National Laboratory, 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 relevant legislation, including analyses supporting the federal advisory committees and the interagency working group on hydrogen and fuel cells which has been coordinated by the subprogram over a decade.

Data, Modeling and Analysis

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Data, Modeling & Analysis $3,000,000	**$3,000,000**	**$0**
• 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.	• Continue to perform analytical research supporting national roadmap, that assesses regional impacts of hydrogen and fuel cell technologies (e.g., criteria pollutants, water), to support 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 regional sustainability impacts to inform environmental justice goals, and supplement previously completed work on technology cost.
• 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.	• Continue analysis of hydrogen for industrial applications, long-duration energy storage, synthetic fuels, and export opportunities, jobs, and address decarbonization and global sustainability impacts.	• Includes a focus on long duration energy storage to meet Administration priorities for a clean grid by 2035, and jobs analyses.
• Conduct National Laboratory project to assess program milestones and technology readiness goals.	• Continue 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.	• Continue to assess cost and benefits of hydrogen and fuel cell technology deployments (e.g., job creation, regional emissions reduction), to inform first-of-a-kind demonstrations.	• Broaden focus from nuclear hybrid energy systems to include industrial and heavy-duty transportation sectors.

Renewable Energy Grid Integration

Overview

Achieving the nation's goals of a carbon pollution-free electricity sector by 2035 and a net zero economy by 2050 will require unprecedented increases in generation from renewable energy resources, with the bulk of this new generation likely to come from wind and solar power.[1] In order to ensure the long-term reliability and resilience of the electricity system as so much new wind and solar comes online, the planning and operations of the power system must evolve to rely more heavily on resources that are variable rather than dispatchable, and based on power electronics rather than physically synchronized with the grid.

Integrating large amounts of variable renewable energy into the power system involves addressing a number of technical and operational challenges in parallel. These include:

- Power system planning*:* ensuring grid planning tools accurately represent the characteristics of wind and solar and the flexibility of dispatchable resources at relevant time scales to ensure resource adequacy and plan reserves, as well as incorporate evolving load projections as the transportation and industrial sectors electrify.
- Power system operations*:* developing new hardware and operational practices to operate a power system where frequency is established safely and reliably by variable renewable energy sources based on power electronics rather than rotating turbines, to accommodate increased generation from distributed resources, and to ensure new generation protects against evolving natural and man-made threats.
- Market designs and business models*:* supporting the development of market products and regulations that can support the integration of variable renewable energy by facilitating the mutual matching of generation and load, allow for the optimization of energy storage, and ensure long-term incentives for power system flexibility and resource adequacy.

Addressing these challenges involves a mix of new technologies, improved data, tools, and models, and new analysis that directly supports decision-makers responsible for the planning, operation, regulation, and policies of the grid as a whole. To support system-wide decisions, it is critical that EERE's efforts mirror the integration of the grid and themselves be developed and implemented in a way that integrates across technologies and offices. While renewable integration work must be based in a deep understanding of the design and characteristics of specific renewable generation resources, effective R&D and analytical products must be designed at a system-wide level rather than from the perspective of any single technology, and provide solutions that are optimized for the performance of the entire power system rather than the adoption of any single generation resource.

For that reason, EERE's Renewable Energy Grid Integration program-supported projects will be coordinated across the Renewable Power sector, leveraging staff and expertise within the wind, solar, geothermal, and water program offices, and coordinated closely with the grid-focused R&D in EERE's Sustainable Transportation and Energy Efficiency pillars and the Office of Electricity (OE). EERE's RE Grid Integration work will contribute to the Grid Modernization Initiative, focused specifically on technologies and tools that directly facilitate the integration of variable renewables and the value of dispatchable renewables like hydropower and geothermal.

In partnership with other EERE Offices, this Request funds new initiatives that aim to develop, validate, and deploy technologies addressing charging and refueling of Heavy Duty ZEVs and the associated grid requirements. Efforts will address the unique fueling needs of heavy-duty trucks operating in large scale depots, ports and the corridors that connect them. REGI support will focus particularly on integrating renewable electricity as a primary source of power for charging and refueling.

[1] Solar Futures Study: www.energy.gov/sites/default/files/2021-09/Solar%20Futures%20Study.pdf

Highlights of the FY 2023 Budget Request

The Renewable Energy Grid Integration program will pursue the following major activities in FY 2023:

- Analysis and assistance for renewables integration: To achieve the Administration's 2035 and 2050 climate goals, a wide range of actors and institutions will need to make a variety of decisions that shape the evolution of the U.S. electricity grid. It Is critical to develop and disseminate the data, modeling and simulation tools, and critical analysis required to support power system planning, operation, and regulation as systems transition to higher levels of variable, power-electronic based resources, distributed generation, and electrification of load. This program will be coordinated closely with other technical assistance (TA) efforts in EERE, OE, the Office of Cybersecurity, Energy Security, and Emergency Response (CESER), and across the Department.

- Community clean energy transitions: Communities across the country seek to transition part of or all of their local consumption to renewable energy, whether to reach emissions reduction goals, reduce their dependence on external power supplies, or drive local jobs and environmental benefits. Successfully integrating larger amounts of renewable energy into a local power system requires both deep technical expertise and local knowledge, and this project will provide detailed planning support, simulated operations through national laboratory facilities, and direct engagement with local community organizations to help realize affordable, equitable pathways that meet local renewable energy objectives.

- Renewable energy integration demonstration: Field demonstrations are needed to show the robustness of grid services provided by wind and solar plants in power systems across a range of geographic regions with various regulatory and market structures, and the flexibility that can be provided by renewable dispatchable resources and different energy storage systems. EERE will work directly with utilities to demonstrate new operational parameters of wind and solar under various operating conditions and understand the capabilities of variable resources to provide grid services, informing asset investment and system operations and reducing risks associated with new technology deployment.

Contributions to DOE-wide Crosscutting Investments

Renewable Integration is involved in several crosscuts, including the following:

- Energy Storage ($10,000,000) ─ supports cross-office activities that address system-level challenges with integrating variable, power-electronics based generation with energy storage; and
- Grid Modernization ($57,000,000) ─ expands power system planning and operations support to communities looking to deploy larger amounts of renewable energy, provide analysis-based technical assistance to power system operators and regulators, demonstrate expanded provision of reliability services from wind and solar generation, and support the integration of renewable generation into zero-emission truck corridor demonstrations.

EERE Program Priorities

In FY 2023, REGI continues to support an investment strategy aligned to the following programmatic priority area that is a central pillar to the U.S. greenhouse gas (GHG) profile:

Funding ($K)

	FY 2021 Enacted	FY 2022 Annualized CR[1]	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted
Decarbonizing the electricity sector	0	0	57,730	+57,730

[1] The FY 2022 Annualized CR amounts reflect the P.L. 117-95 continuing resolution level annualized to a full year.

Renewable Energy Integration
Funding ($K)

	FY 2021 Enacted	FY 2022 Annualized CR[1]	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted
Renewable Energy Integration	0	0	57,730	+57,730
Total, Renewable Energy Integration	**0**	**0**	**57,730**	**+57,730**

Explanation of Major Changes ($K)

	FY 2023 Request vs FY 2021 Enacted
Renewable Energy Grid Integration This program was established in the Consolidated Appropriations Act, 2022 (P.L. 117-103) to focus on system-level challenges to the reliable integration of renewable energy into the power system. FY 2023 investments will focus on work that directly supports decision-makers responsible for the planning, operation, regulation, and policies of the grid as a whole. This includes improved data, tools and models, new analysis, and local demonstrations, with projects focused both on common high priority technical areas and local-level system objectives. Specific projects include analysis-based technical assistance, demonstrations of grid services from renewable energy, support for community-level grid planning, and the integration of renewables into sustainable trucking corridors.	**+57,730**
Total, Renewable Energy Integration	**+57,730**

[1] The FY 2022 Annualized CR amounts reflect the P.L. 117-95 continuing resolution level annualized to a full year. These amounts are shown only at the congressional control level and above, below that level, a dash (-) is shown.

Renewable Energy Integration

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Renewable Energy Integration $0	**$57,730,000**	**+$57,730,000**
• No funding requested	• Develop improved data, modeling and simulation tools, and provide new critical analysis required to support power system planning, operation and regulation with high levels of renewables.	• Support for RE grid integration in power system planning and operations is currently spread across all four Renewable Power offices, and as a result focused on the advancement of individual technologies rather than system-wide optimization. This project will leverage individual office expertise but explicitly support system-level analysis and objectives.
• No funding requested	• Work directly with utilities to demonstrate new operational parameters of wind and solar under various operating conditions and understand the capabilities of variable resources to provide grid services, informing asset investment and system operations and reducing risks associated with new technology deployment.	• Same as above.
• No funding requested	• Provide detailed planning support, simulated operations through national laboratory facilities, and direct engagement with local community organizations to help successfully integrate larger amounts of renewable energy into a local power system.	• Same as above.

Solar Energy

Overview

EERE's Solar Energy Technologies Program (SETO) accelerates the development and deployment of solar technologies while supporting the reliability, resilience, and security of the U.S. electric grid and solar supply chain, as well as the Administration's goal to reach a carbon pollution-free electricity sector by 2035, supported by good-paying, green jobs. The FY 2023 Request reflects an increased focus on the complete roadmap of solar energy implementation: advanced research and development (R&D); validation of solar technologies to invigorate American technological leadership; supporting industry's development of a robust American supply chain; ensuring that there is a trained American workforce employed in the industry; reducing regulatory burdens; contributing to the decarbonization of the energy and industrial sectors; supporting community resilience; and working to ensure the benefits of the transition to clean energy are shared with historically marginalized communities and those most affected by environmental justice inequities.

The solar resource is vast, and solar energy has the potential to be a substantial source of clean, affordable, and reliable electricity across the country. Estimates suggest that meeting the 2035 goal for a carbon pollution-free electricity sector is likely to require solar to supply approximately 40 percent of U.S. electricity.[1] While photovoltaic (PV) deployment has grown rapidly over the past decade; however, solar energy supplies only 4 percent of U.S. electricity today. To reach a carbon pollution-free electricity sector, solar generation will have to expand from 80 GWac cumulatively deployed at the end of 2020 to approximately 1 terawatt (TWac) by 2035. To accomplish this level of cumulative deployment, annual deployment needs to grow by 20 percent each year for the rest of the decade. Annual deployment rates may need to increase even further if deployment in the near term is not able to scale or maintain its recent deployment rates due to challenges in the solar supply chains. Yet today, less than twenty percent of solar modules deployed in the US are domestically made and solar hardware installed in the U.S. averages only 40 percent of domestic hardware content, mostly in the form of the support structures (racking and trackers), not active components (e.g., PV modules and inverters). The lack of a full and robust domestic supply chain makes the US susceptible to global supply chain disruptions due to issues ranging from needing to verify the source of module components to avoid forced labor concerns, to tariffs stemming from non-competitive trade practices by other nations, and leaves the US reliant on China and Southeast Asia for many solar components. The Request's Solar Manufacturing Accelerator initiative will help build the domestic manufacturing capacity needed for the Nation to meet its climate goals and will ensure an ethical and responsible supply chain. This, in combination with the portfolio of SETO programs, will create good-paying, stable manufacturing jobs with the option to join a union and bargain collectively, while also increasing domestic energy security.

Currently, solar technologies can be deployed cost-effectively at both the large, utility-scale and at a smaller scale on the distribution system where they offer opportunities for consumer choice, energy bill savings, local jobs, community health and quality-of-life improvements, and enhanced community resilience. Further unlocking solar energy's potential as an electricity source requires continued cost reductions, developing technologies to open new markets, removing barriers to deployment, establishing the full domestic supply chain, and enabling solar technologies to actively support the reliability, resilience, and security of the grid. Solar technology also has the potential to contribute to the decarbonization of the broader energy system through increased electrification, the direct production of industrial process heat, and solar fuels. Harnessing innovation, coupled with appropriate policy incentives, also supports growth of the U.S. solar manufacturing sector.

Continued reductions in the cost of solar electricity are essential to enabling growth in solar deployment and greater electricity affordability for consumers in diverse regions and communities. As the supply of solar electricity increases in a given region, pairing solar with energy storage and other technologies becomes increasingly important to address the temporal mismatch between the supply of sunlight and shifting peak electricity loads. Pairing solar with energy storage and other technologies adds the flexibility needed for solar to supply large shares of U.S. electricity, but costs of solar must continue to fall to make this broadly affordable. Accordingly, DOE recently accelerated its cost targets for utility-scale PV and Concentrated Solar Power (CSP) systems without subsidies – targets which could make solar electricity the lowest cost form of electricity in the U.S. given cost reductions of 50-60 percent from 2020 benchmarks for PV and CSP.[2] SETO has a

[1] DOE Solar Futures Study. www.energy.gov/eere/solar/solar-futures-study

[2] V. Ramasamy et al., "U.S. Solar Photovoltaic System Cost Benchmark: Q1 2021," NREL Technical Report, November 2021.

history of success in enabling solar energy cost reduction with its previous top-line cost reduction goal met years ahead of schedule.

As PV deployment becomes a larger share of electricity generation, it becomes critical that PV systems actively contribute to the reliability, resilience, and security of the electric grid. Already today, there are times in the year when solar and wind supply more than half of the demand for electricity in some regions. PV and wind technologies operate differently than conventional electricity generators due to their resource variability and fast power electronics. Learning to plan and reliably operate a grid with high penetrations of these resources requires research and demonstration. Further, PV technologies, and other distributed energy resources (DERs), are fundamentally changing the distribution system. There are 3 million PV systems on the grid today, representing 95 percent of distributed generators. These PV systems are creating new challenges related to forecasting, real time situation awareness, control coordination, as well as system protection and cyber-security for both distribution systems and bulk power systems to which they are connected. They also present new opportunities when coupled with energy storage and other distributed energy resources, to provide grid services and enhance community resilience.

It is critical that cost reductions and other benefits from solar energy extend to all Americans. Many of the challenges to achieving affordable, equitable deployment of solar across the country are a result of non-hardware costs (known as "soft costs"). Barriers to solar deployment raise soft costs.[1] These barriers can include lack of affordable and accessible financing, burdensome permitting, complex, lengthy, and expensive interconnection processes, lack of available knowledgeable workers, enabling legislation, consumer awareness, and competition for land. In addition, nearly 50 percent of the population does not have the option to install their own solar energy system because they lack adequate roof or land space for placement or rent their housing. Addressing these barriers requires engaging with state and local governments, utilities, the solar industry, local communities, and other stakeholders on research, improved processes, workforce training programs, streamlined permitting, and innovative siting strategies.

Today over 120 GW_{DC} of solar technology have been deployed across the U.S.,[2] a nearly 50-fold increase since 2010. This increase in deployment has been a source of significant job growth, with the industry employing 317,000 workers in 2021.[3] Rapid declines in solar costs have, in large part, made these increases possible. Nevertheless, significant work remains before solar realizes its full potential. With continued innovation to drive down solar electricity costs, improve solar technology's ability to support the reliability and resilience of the grid, and remove market barriers and open new markets, solar energy is capable of being a foundational source of the Nation's electricity supply. As a foundational energy source, solar will contribute to greater electricity affordability for all Americans, while invigorating and supporting an equitable pathway to economic growth, job creation, and opportunity within the American innovation ecosystem.

SETO also supports the key emphasis areas of energy justice, workforce, diversity in STEM and State and local partnerships. Investments associated with Workforce Development will support training and develop good paying clean energy jobs for the American people -- especially workers and communities impacted by the energy transition and those historically underserved by the energy system and overburdened by pollution. Investments associated with Diversity in STEM support outreach and will raise awareness of clean energy research and job opportunities at minority-serving institutions and minority professional organizations and ensure that organizations receiving EERE funding are thinking through diversity and equity in their own work. Investments in support State and Local partnerships will enable state and local governments to be more effective in facilitating the nation's (and their own) affordable and resilient clean energy and efficiency goals. Investments associated with Energy and Environmental Justice will support approaches and process to reach new groups of Americans historically underserved by the energy system.

[1] D. Feldman et al. "Shared Solar: Current Landscape, Market Potential, and the Impact of Federal Securities Regulation," NREL Technical Report NREL/TP-6A20-63892 (April 2015). https://www.nrel.gov/docs/fy15osti/63892.pdf.

[2] Wood Mackenzie/SEIA U.S. Solar Market Insight® https://www.seia.org/us-solar-market-insight.

[3] "US Energy Employment Report," Department of Energy. USEER 2021 Main Body.pdf (energy.gov) .

Highlights of the FY 2023 Request

The Solar Energy Technologies Program will support a portfolio of research, development, demonstration, and deployment (RDD&D) activities in FY 2023, including:

- Growing the domestic solar manufacturing value chain as well as the domestic solar industry through the Manufacturing and Competitiveness subprogram. Highlights include:
  - In partnership with the Advanced Manufacturing Office, launch the new Solar Manufacturing Accelerator that will help establish domestic manufacturing capabilities of advanced PV technologies that rely less on foreign sourced materials, in particular those materials where one country controls the market and where unfair labor practices may exist. Domestic supply chains are critical to ensuring the U.S. has access to the volume of solar energy cells, modules, and system components to meet decarbonization goals. The overall focus will be on reducing solar manufacturing costs while solidifying domestic material, equipment, and product supply chains.
  - Initiating new rounds of the American-Made Challenges solar hardware and software prize competitions. In addition to the development of a new prize to accelerate technology transitions to private sector support.
  - Continuing support for the development and demonstration of PV and grid technologies across the full supply chain with strong potential to be competitively manufactured in the U.S. as well as opening new market segments through innovative product development.
  - Initiating new solar manufacturing workforce training programming to help aid the expansion of domestic manufacturing capacity.
- Accelerating development and demonstration of solar energy's ability to support the affordability, reliability, resilience, and security of a carbon-free electric grid through the Systems Integration subprogram and in partnership with DOE's Grid Modernization Initiative. Highlights include:
  - Continuing and expanding demonstration projects, with strong community engagement, to identify and display the potential beneficial impacts of solar, storage and other assets in disadvantaged communities and impacts on their energy and resilience needs.
  - Initiating support for new tools for grid planning and grid operation to understand and control a power system with increasing amounts of solar power, including the interaction with other variable renewables, electric vehicles, and smart loads.
  - Continuing RDD&D of new cybersecurity technologies to keep up with a rapidly evolving threat landscape.
- Accelerating cost reductions toward the 2030 goal of $0.02/kWh PV electricity with systems lasting 50 years or more through PV system R&D. Highlights include:
  - Continuing to invest in projects which leverage core expertise at the National Laboratories to increase the efficiency and energy yield of a portfolio of PV technologies and advance PV characterization and testing capabilities, while developing the knowledge base to enable 50-year system lifetimes
  - Continuing programming that investigates and works to improve the durability of PV assets deployed in current and emerging market segments such as the co-location of solar and agriculture and the integration of PV into building materials.
  - Increasing evaluation efforts focused on risks to materials availability for long term PV deployment, and the development of recycling, materials reuse and other materials processing and handling methods to maximize material availability and mitigate end of life environmental impacts.
- Scaling up efforts to decrease soft costs and ensure the benefits of solar energy are available to all Americans through the Balance of System Soft Costs Reduction subprogram. Data collection, analysis, tool and resource development, technical assistance, stakeholder engagement, and workforce training efforts are critical to enabling increased solar deployment, access to the benefits of solar for all, and meeting the President's goal of a carbon-free power sector by 2035. Highlights include:
  - Contributing to new, EERE-wide workforce efforts that will provide expanded recruitment to include frontline communities, former fossil fuel workers, and military veterans; industry-led and employee-centered training opportunities; and immediate career placement in the clean energy industry. This includes developing new partnerships, refining training curricula, providing technical assistance on labor standards and classifications, catalyzing prevailing wage jobs, and highlighting opportunities for union membership.
  - Expanding efforts, in partnership with the Wind Energy Technologies Office, to reduce barriers and costs to interconnecting solar and wind resources to the grid.

    - Initiating new program that provides technical assistance to states and local governments on siting of large-scale solar and other renewable energy technologies, with the goal of reducing siting costs and timelines while ensuring equitable and environmentally friendly deployment.
    - Releasing competitive solicitations to enable increased solar energy access for members of tribal nations and low-income households nationwide through technical assistance, financial and business innovation, and tool creation.
- Accelerating the commercial use of concentrated solar thermal power in the electricity and industrial sectors through the Concentrating Solar Power subprogram. Highlights include:
    - Increasing support for research, development, and demonstration (RD&D) of pathways to decarbonize industrial processes to like cement, steel, and chemicals production. FY 2023 efforts will emphasize the development of promising technologies towards more mature demonstrations to accelerate deployment, as well as the development of technologies for solar thermochemical production of fuels that can be readily incorporated into existing industrial heating processes. This work is in line with the Administration priority on achieving a net zero economy by 2050.
    - Maintaining support for long-duration thermal energy storage technologies, aligned with the Long Duration Storage Energy Earthshot. These efforts will advance 'Generation 3 CSP' RD&D to develop and mature solar particles as a heat transfer and thermal storage medium, as well as exploring other thermal storage media well suited to long duration solar-heated thermal energy storage.

The Program closely coordinates activities with other EERE Programs, the Office of Electricity (OE), the Office of Cybersecurity, Energy Security and Emergency Response (CESER), the Advanced Research Projects Agency – Energy (ARPA-E), the Office of Fossil Energy and Carbon Management (FECM), the Office of Nuclear Energy (NE), and the Office of Science (SC) to ensure the most efficient use of taxpayer dollars, while maximizing the Department-wide impact of solar energy.

Contributions to DOE-wide Crosscutting Investments

SETO is involved in several crosscuts, including the following:

- Advanced Manufacturing ($179,200,000): SETO supports the research, development, and demonstration (RD&D) of advanced manufacturing relevant technologies to help the development of holistic domestic supply chains for solar system components with a focus on PV modules, new products for domestic manufacture, new technologies to drive down domestic manufacturing costs, and to mitigate issues related to material availability;
- Critical Minerals and Materials ($16,000,000): SETO supports the analysis of potential PV deployment limitations related to materials scarcity and the research, development, and demonstration of materials alternatives, techniques to use materials more efficiently and recycling methods to further utilize existing materials;
- Energy Storage ($26,800,000): SETO supports analysis related to the integration of solar plus storage at the bulk and distribution levels of the grid and at the individual building level. This support focuses on the (RD&D) of technologies to integrate energy storage with PV systems and thermal energy storage systems, which can be used either in concentrating solar power systems or as standalone storage assets to deliver electricity to the grid or process heat for industrial applications;
- Energy Water Nexus ($750,000): SETO supports analysis and RD&D of technologies that leverage heat generated by concentrating solar power to desalinate water;
- Grid Modernization ($83,500,000): SETO supports analysis and RDD&D of grid integration technologies at the bulk power and distribution system levels to allow reliable, resilient, and secure grid planning and operation with increasing amounts of solar, energy storage, hybrid systems, and other inverter-based assets;
- Industrial Decarbonization ($32,675,000): SETO supports RD&D of concentrating solar power technologies that can directly provide carbon-free heat to industrial facilities or generate carbon free fuels through thermochemical processes; and
- Hydrogen ($7,500,000): SETO supports the RD&D of concentrating solar thermal power systems that can be used for hydrogen production or in conjunction with hydrogen as a chemical feedstock for decarbonized industrial processes.

EERE Program Priorities:
In FY 2023, SETO continues to support an investment strategy aligned to the following programmatic priority areas that are central pillars to the U.S. greenhouse gas (GHG) profile:

Solar Energy
Funding ($K)

	FY 2021 Enacted	FY 2022 Annualized CR[1]	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted
Decarbonizing the electricity sector	270,000	270,000	504,575	+234,575
Decarbonizing energy-intensive industries	10,000	10,000	30,000	+20,000

[1] The FY 2022 Annualized CR amounts reflect the P.L. 117-95 continuing resolution level annualized to a full year.

Solar Energy
Funding ($K)

	FY 2021 Enacted	FY 2022 Annualized CR[1]	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted
Solar Energy				
Concentrating Solar Power Technologies	60,000	-	70,000	+10,000
Photovoltaic Technologies	72,000	-	77,575	+5,575
Systems Integration	53,000	-	85,000	+32,000
Balance of Systems Soft Cost Reduction	35,000	-	77,000	+42,000
Manufacturing and Competitiveness	60,000	-	225,000	+165,000
Total, Solar Energy	**280,000**	**280,000**	**534,575**	**+254,575**

FY 2021 Transferred: SBIR $8,024,640; STTR: $1,128,465
FY 2022 Annualized CR: SBIR $7,387,000; STTR: $1,039,000
FY 2023 Request: SBIR: $14,237,000; STTR: $2,002,000

[1] The FY 2022 Annualized CR amounts reflect the P.L. xxx-yyy continuing resolution level annualized to a full year. These amounts are shown only at the congressional control level and above, below that level, a dash (-) is shown.

Solar Energy
Explanation of Major Changes ($K)

	FY 2023 Request vs FY 2021 Enacted
Concentrating Solar Power Technologies: The Request includes funding to support the development of high temperature components for next generation CSP systems with thermal energy storage. The increase will support scale up efforts to develop and demonstrate solar-thermal-driven technologies to help decarbonize industrial processes such as cement, steel, and chemical production. CSP funding will also continue to support high-efficiency, reliable thermal energy storage technologies to support the Energy Storage Grand Challenge and Long Duration Storage Energy Earthshot, with a particular focus on technologies using solid particles as the heat transfer medium, leveraging the SETO-funded megawatt-scale Gen3 CSP test facility currently under construction.	**+10,000**
Photovoltaic Technologies: The Request includes funding to continue core efforts at the National Laboratories that advance emerging and commercially available PV materials and devices, improve the lifetimes of PV systems, and inform industry standards. The increase will allow the program to launch research topics evaluating and addressing potential materials availability limitations that could impede the scale up of PV technologies, including recycling and materials recovery techniques for PV systems. PV funding will also augment ongoing work related to PV system and component durability, with a particular focus on new applications such as the co-location with agriculture and the integration of PV in buildings.	**+5,575**
Systems Integration: The increase reflects SETO's greater emphasis on demonstration activities to provide real-world data on how solar and other DERs can improve the reliability and resilience of the grid, with an emphasis on under-resourced communities. The Request will also support the development of grid planning and controls tools that more effectively represent solar power, and trains grid operators in use of these new tools. Funding is also provided to advance solar energy cybersecurity. FY 2023 funding maintains core efforts at the National Laboratories to advance power system modeling and simulation, interconnection standards, data analytics, and other solar grid integration technologies. SETO will coordinate its efforts with offices across EERE and OE.	**+32,000**
Balance of Systems Soft Cost Reduction: The increase will support activities that will address critical soft cost barriers to solar deployment and ensure the benefits of solar energy are available to all Americans. The Request will support competitive solicitations and technical assistance to reduce system interconnection times, in cooperation with the Wind Energy Technologies Office. The program will continue to support soft costs research and analysis at the National Laboratories activities that bring together stakeholders to address siting and interconnection barriers to solar deployment, as well as provide technical assistance to stakeholders such as local governments, Tribes, utilities, and public utility commissions. The Request continues support for the National Community Solar Partnership, which provides technical assistance, stakeholder engagement, and programming that recognizes innovative approaches to developing systems to expand access to the benefits of community solar.	**+42,000**
Manufacturing and Competitiveness: The increase reflects the establishment of the new Solar Manufacturing Accelerator program for advanced technologies that avoid reliance on foreign supply chains that may use unfair labor practices in current production, including foreign-sourced polysilicon. The program will also continue to support American-Made Solar Prizes in hardware and software and develop new prize programming. The Request includes funding to continue support for the Incubator program to accelerate the prototyping of new solar energy technologies and speed commercialization efforts. The program will also support the development of innovative product ideas that can substantively increase U.S. domestic manufacturing across the full solar supply chain and expand private investment in America's manufacturing sector.	**+165,000**
Total, Solar Energy	**+254,575**

Solar Energy
Concentrating Solar Power Technologies

Description

The Concentrating Solar Power Technologies (CSP) subprogram works toward decarbonization of the electric power and industrial sectors by supporting RD&D of technologies that convert sunlight into thermal energy, which can be efficiently stored until it is needed for the production of electricity or for direct use in an industrial process. Because they can efficiently incorporate long durations of thermal energy storage, CSP technologies offer a path to supplying affordable and reliable solar power on demand.

Today there are nearly 2 GW of CSP technology deployed for electricity production in the U.S. To significantly increase deployment requires cutting the costs of CSP electricity through technology improvements in the solar collector, thermal systems, and power cycles, as well as component integration and demonstrations of these advances at scale. The CSP subprogram aims to reduce the cost of CSP electricity at utility scale to help make CSP electricity cost competitive with electricity from other dispatchable sources.

CSP technologies can also provide an alternative to conventional fuels to drive industrial processes. Solar industrial process heat can be used for a range of applications including low temperature processes such as water desalination and food processing, and high temperature processes such as cement production, ammonia synthesis, steel manufacturing, and thermochemical water splitting for fuel production, among others. This subprogram coordinates its work with the Advanced Manufacturing Office to align with their Industrial Decarbonization Roadmap.

Within the activities listed below, the Solar Energy fellowship program funds 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 will 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: This activity supports RD&D to test and integrate the components of a CSP thermal transport system capable of operation at substantially higher temperatures than today's commercial systems (i.e., 700 degrees Celsius or above), including the receiver, heat transport media, and thermal energy storage systems. 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. To support the development of the Gen3 CSP megawatt-scale test facility, this activity will primarily, though not exclusively, focus on solid particles as the heat transfer medium. This activity also includes RD&D of thermal energy storage technologies, in support of the Energy Storage Grand Challenge and Long Duration Storage Energy Earthshot, which includes work on a low-cost particle thermal storage media being developed for use in Gen3 CSP systems.

Power Cycles R&D: This activity supports RD&D of power cycles capable of net thermal-to-electric efficiency of 50 percent or greater. Support 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 FECM and NE. 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: This activity supports RD&D 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. The primary activity in this area is the continuation of a National Laboratory consortium for heliostat research, development, and validation.

Industrial Applications R&D: This activity supports RD&D of industrial processes driven by solar thermal energy. Activities include both low-temperature systems focused on low-cost embodiments of existing technologies, and the development components and system designs for high-temperature systems that are difficult to decarbonize through electrification. Low temperature systems, in the range of 100 to 300 °C target a levelized cost of heat (LCOH) of 1 cent per kWh-thermal or lower, which would constitute at least a 50 percent decrease in current LCOH. This includes the development of thermal processes, including thermal desalination, which can efficiently couple with a solar thermal energy input. High temperature systems work includes the development of solar thermal pathways for the carbon-emission-free production of energy-intensive chemicals, commodities, and fuels, like ammonia, steel, cement, and hydrogen.

Concentrating Solar Power Technologies

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Concentrating Solar Power Technologies $60,000,000	**$70,000,000**	**$10,000,000**
Thermal Systems R&D $29,000,000	$16,140,000	-$12,860,000
• Support existing, merit-reviewed R&D work at the National Laboratories to develop and analyze high-temperature, 'Gen3 CSP,' components and integrated thermal systems for CSP technology with long-duration thermal energy storage.	• Funding to maintain FY 2022-24 projects for National Laboratory research programs that were initiated in FY22. Work focuses on developing and analyzing high temperature components and systems related to Gen3 CSP and long-duration thermal storage among other projects.	• No significant change
• Fund competitively selected projects on improving the performance and reliability of both current and next-generation CSP systems to enable the deployment of low-cost CSP by 2030.	• Funding will focus on continued development of CSP systems and components, with a focus on long-duration thermal energy storage and development of solid particle-based heat transfer.	• Reduced funding reflects FY 2023 focus on decarbonization of industrial applications.
• Fund competitively selected projects to develop high-efficiency, long-duration pumped thermal energy storage (PTES) technologies, that can be charged using electric-driven heat pumps, in either standalone or CSP-hybridized configurations.	•	•
• 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.
• Funding for FY 2022 broad solicitation on 1-year innovative seedling projects for CSP research.	• Funding for FY 2023 broad solicitation on 1-year innovative seedling R&D projects for CSP research. All topics in thermal systems are eligible.	• No significant change.
Power Cycles R&D $13,000,000	$8,800,000	-$4,200,000
• Support existing, merit-reviewed R&D work at the National Laboratories to develop primary heat exchangers for advanced supercritical CO_2 power cycles.	• Funding to maintain FY 2022-24 projects for National Laboratory research programs that were initiated in FY22. Work focuses on	• No significant change.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
	developing primary heat exchangers for advanced CO_2 power cycles.	
• Fund competitively selected projects to integrate high-efficiency, long-duration pumped thermal energy storage (PTES) technologies with advanced supercritical CO2 power cycles.	• No funds requested. Continue managing competitively selected projects from prior years to integrate high-efficiency, long-duration pumped thermal energy storage (PTES) technologies with advanced supercritical CO2 power cycles.	• Projects will continue using prior year funds until complete. Analysis of results from existing projects will inform whether new projects are initiated in FY 2024.
• Funding for FY 2022 FOA topic on 1-year innovative projects for CSP research.	• Funding for FY 2023 broad solicitation on 1-year innovative seedling R&D projects for CSP research. All topics in power cycles are eligible.	• No significant change
Solar Collector R&D $6,000,000	$12,385,000	+$6,385,000
• Support existing, merit-reviewed R&D work at the National Laboratories to develop optical components and improved optical characterization methods for CSP collector fields.	• Funding to maintain FY 2022-24 projects for National Laboratory research programs that were initiated in FY22. This work will focus on developing optical components and improved optical characterization methods for CSP collector fields.	• No significant change
• Funding to initiate a test facility at the National Laboratories that can validate novel heliostat designs, particularly including wireless, reliable control systems, at commercially relevant scales.	• Continue funding of a National Laboratory consortium test facility on heliostat development and validation.	• Funding is increased to support the ramping up of activities and the issuance of a request for proposals to support research by industry and academia.
• Funding for FY 2022 FOA topic on 1-year innovative projects for CSP research.	• Funding for FY 2023 broad solicitation on 1-year innovative seedling R&D projects for CSP research. All topics in solar collectors are eligible.	• No significant change.
Industrial Applications R&D $12,000,000	$32,675,000	+$20,675,000
• Support an existing, merit-reviewed R&D project at the National Laboratories to research novel pathways for the solar thermal production of ammonia and hydrogen as a means to progress towards decarbonization of the chemical industry.	• Funding to maintain FY 2022-24 projects for National Laboratory research programs that were initiated in FY22. Work focuses on researching novel pathways for the solar thermal production of ammonia and hydrogen as a means to progress towards decarbonization of the chemical industry.	• No significant change.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
• Fund a prize competition for developing innovative advanced solar thermal desalination technologies.		
• Fund competitively selected project to develop solar thermochemical reactors for the production of solar-derived chemicals and fuels to enable decarbonization of the full energy sector.	• Continue the development of solar-thermal-driven industrial processes for the decarbonization of the industrial sector. FY 2023 efforts will emphasize more mature demonstrations, to accelerate deployment, in line with the Administration priority on achieving a decarbonized industrial sector by 2050.	• Funding is increased to reflect that demonstration projects require significantly more funding than R&D.
• Funding for FY 2022 FOA topic on 1-year innovative projects for CSP research.	• Funding for FY 2023 broad solicitation on 1-year innovative seedling R&D projects for CSP research. All topics in industrial applications are eligible.	• No significant change.

Solar Energy
Photovoltaic Technologies

Description

Achieving the President's 2035 goal for a carbon pollution-free power sector requires a large growth in total U.S. photovoltaic (PV) capacity and annual deployment rate. The Photovoltaic Technologies subprogram works to enable this acceleration by reducing the costs of PV electricity while also ensuring that deployed PV systems perform as expected and last up to 50 years. In support of these goals, the PV subprogram supports RD&D that advances foundational knowledge and tackles scale-up and fabrication challenges for technologies that increase efficiency and durability while simultaneously reducing cost. Furthermore, the PV subprogram aggregates and analyzes performance data from PV systems deployed across the Nation to identify trends and best practices. Over the last decade, the cost of PV electricity has declined over 80 percent, yet significant opportunity remains to continue to reduce costs to reach SETO's cost target for unsubsidized, utility-scale systems from today's current utility-scale benchmark. Reaching such a cost target would enable greater electricity affordability in addition to increased PV deployment.

The PV R&D subprogram advances state-of-the-art and emerging PV cells, modules, systems, and their components, spanning work from early-stage solar cell research up to commercialization. Specifically, the subprogram seeds research to advance materials processes and device design approaches that enable higher PV performance and reduced cost, as well as better predictability and understanding of long-term reliability with the ultimate goal of accelerating PV deployment. Key thrusts include the development and validation of perovskite technologies, a national research consortium to improve cadmium telluride (CdTe) efficiency, new tools to predict system performance through monitoring and data analysis, and a portfolio of research at the National Laboratories advancing PV cell efficiencies, understanding PV system degradation rates and lifetime performance, and developing new characterization techniques. Furthermore, the PV subprogram identifies and works to overcome material and environmental constraints that could inhibit the rapid acceleration of PV deployment such as the availability of silver (Ag), as well as the disposal and recycling of PV systems.

Within the activities listed below, the Solar Energy fellowship program funds emerging leaders in the field that will pursue breakthrough solar energy technologies at universities, National Laboratories, and other research facilities. In addition, funds will 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: This activity supports R&D to increase the power conversion efficiency and reduce the manufacturing costs of PV cells and modules, spanning established (e.g., silicon and CdTe) and emerging materials (e.g., perovskites and tandem structures). Two solar cell absorber materials that are particularly well suited for U.S. manufacturing receive specific focus in this research area – cadmium telluride (CdTe) and perovskites. Cadmium telluride (CdTe) is the largest domestically manufactured PV technology and the second most deployed technology, behind silicon based solar modules. Perovskites are a promising next-generation PV technology currently being researched in labs across the country with the potential to achieve high efficiencies at low costs. Strategic investments in these technologies now can reduce PV costs and position the United States to be a global leader in solar manufacturing for years to come. This activity also includes research in improved PV system design to increase energy production in real world operating conditions. Efforts include development of new characterization tools and techniques to build materials and device knowledge and connect with analysis of fielded systems and key performance metrics.

Durability R&D: This activity supports R&D to better understand and mitigate performance degradation of PV systems to enable 50-year lifetimes, resilience to extreme weather conditions, and application in dual-use settings, such as PV on agricultural land and building integrated PV systems (BIPV). Activities include 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. The subprogram's support has a strong emphasis on developing test conditions that accurately reproduce degradation observed in fielded modules, and therefore includes destructive testing of harvested modules and comparison of accelerated test results.

Materials Availability R&D: This activity supports R&D to better understand how the availability and environmental impacts of key materials used in PV systems could constrain domestic PV manufacturing and deployment, and R&D to mitigate these materials constraints to enable rapid scale-up of the domestic solar industry. Activities include efforts to 1) reduce the use of silver (Ag), tellurium (Te), and indium (In) in modules; 2) advance materials recovery techniques; 3) develop PV systems to that are easily recycled; and 4) improve long-term reliability and manufacturing of lead-free modules.

Photovoltaic Technologies

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Photovoltaic Technologies $72,000,000	**$77,575,000**	**+$5,575,000**
Conversion Efficiency R&D $30,000,000	$23,075,000	-$6,925,000
• Support to continue the third year of FY 2019-2021 National Laboratory projects to advance PV cell and module performance.	• Funding to maintain FY 2022-24 projects to advance PV cell and module performance for National Laboratory research programs that were initiated in FY 2022.	• No significant change.
• Funding for FY 2021 FOA topic on 1-year innovative projects for PV research.	• Funding for 1-year innovative seedling R&D projects focused on material constraints and reducing PV system waste at end of life.	• No FOAs on high-performance and low cost III-V requested in FY 2023.
• Initiate a CdTe research and industrial consortium executed by a National Laboratory that will bring together domestic companies, multiple National Laboratories, and academic researchers to advance the performance of CdTe PV systems.	• Funding for additional competitive projects to augment the CdTe consortium and maintain CdTe consortium research support at NREL.	• No significant change.
Durability R&D $42,000,000	$38,500,000	-$3,500,000
• Maintain DuraMat consortium led by NREL to perform research dedicated to modeling and measuring durable materials for PV modules including advanced encapsulants and flexible packaging concepts.	• Funding to maintain DuraMat consortium under new scope of work for FY 2022 – FY 2024. In FY 2023, the consortium will run an external solicitation for external participation, validate an accelerated testing approach using fielded module data, and develop a new analytical technique to support the planned work in FY 2024.	• No significant change.
• Support to continue the last year of National Laboratory FY 2019-2021 research projects to understand PV degradation pathways and develop standard tests.	• Funding to maintain FY 2022-24 projects for National Laboratory research programs that were initiated in FY 2022. Work focuses on researching PV degradation pathways, develop standard tests, and mitigation strategies.	• No significant change.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
• Funding for FY 2021 FOA PV topic on reducing system degradation pathways resulting from balance of system degradation such as wiring and interconnects as well as efforts to develop more resilient systems.	• Funding to support research building on durability work and expanding into non-destructive balance of material testing, durability of dual-use PV systems (BIPV, co-location of PV and agriculture, etc.), and PV system power-electronics durability	• Reduction in funding because FY 2022-funded projects remain underway. Limited funds will add work on emerging markets and address non-module related failures that increase Levelized Cost of Energy (LCOE) by reducing PV output.
• Additional support for the new CdTe research and industrial consortium to support tasks on increasing the long-term durability of the CdTe systems to enable greater LCOE reduction.	• Additional competitive projects that augment the existing CdTe consortium will be funded. Furthermore, funding requested to maintain CdTe consortium research support at NREL under the FY 2022-2024 core agreement.	• No significant change.
Materials Availability R&D: $0	$16,000,000	+$16,000,000
• No funding requested.	• Research on reducing the use of silver (Ag) and other limiting materials in modules, materials recovery techniques for PV systems, developing systems that are easily recycled, and long-term reliability and manufacturing of lead-free modules.	• Increase will expand efforts to remove barriers to PV deployment by mitigating long-term material availability issues and addressing environmental and end-of-life issues.

Solar Energy
Systems Integration

Description

The Systems Integration (SI) subprogram, in coordination with the DOE Grid Modernization Initiative (GMI) and Energy Storage Grand Challenge (ESGC), funds RD&D of technologies that better enable solar energy to support the reliability, resilience, and security of the electric power system. Solar deployment has been growing rapidly over the past decade, with solar producing just over three percent of the U.S. electricity supply in 2021. Meeting the President's goal for a carbon-free power sector will likely require solar to provide 30 to 50 percent of U.S. electricity by 2035. PV technologies cause challenges for power system operation due to their variable nature, fast-responding power electronics, and deployment on both the bulk power and distribution systems. There are three million PV systems connected to the distribution system today, and this number is growing steadily. At the same time, the power system itself is also evolving rapidly with the deployment of digital sensors and communication networks and the integration of new technologies such as electric vehicle charging infrastructures, resulting in increased connectivity and complexity. As PV deployment becomes a larger share of electricity generation, it becomes critical that PV systems actively contribute to the reliability, resilience, and security of the electric grid.

Solar, wind, and battery storage technologies operate fundamentally differently than conventional power generators owing to the power electronics that are their interface with the grid. Already today, there are regions of the U.S. that have times where wind and solar can supply over half of the instantaneous power. As these levels increase, it will be critical that these technologies can provide essential grid services such as voltage and frequency regulation. These capabilities have been demonstrated in isolated testing, but much more R&D is needed for grid operators and regulators to have confidence in their ability to rely on these technologies to support all aspects of grid reliability.

The SI subprogram addresses the key technical challenges in solar grid integration focusing on power system planning, generation variability, system inertia, operational flexibility, voltage and frequency control, real time situational awareness, system protection, cybersecurity, black start capability, and optimal power flow control. In addition, the subprogram advances the opportunities for PV, coupled with energy storage and other distributed energy resources (DERs) to enhance community resilience through reconfiguration to supply critical loads in the event of an outage. Further, the SI subprogram supports the development of industry standards and best practices on solar 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 utility-scale solar and DERs. The portfolio supports activities under the broad areas of SI subprogram research as listed below.

The subprogram has aligned all proposed work with grid activities across EERE and OE necessary to enable an economically and environmentally just transition to a grid that supports a decarbonized power system by 2035 and a zero-emission economy by 2050 while maintaining the reliability, affordability, security, and resilience of the energy system.

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

<u>Planning and Modeling R&D</u>: As more solar energy is added onto the electric grid every day, it's important for utilities and power system operators to plan for a variety of scenarios to balance electricity generation from solar and other sources with customer demand. Research in this topic area will focus on modeling and simulation methodologies and software tools for medium- to long-term planning for solar grid integration under various deployment scenarios, including optimal placement of PV and energy storage, the potential need for transmission and distribution upgrade, and interconnection requirements and reliability standards. This activity will support projects that will address challenges in solar generation variability and uncertainty, resource forecasting and adequacy, system control stability, system flexibility, and co-optimization.

Operation and Control R&D: With increasing amounts of solar energy connected to the grid, it's important for utilities and power system operators to have real-time information about and control capabilities for the amount of generation that's occurring at any given moment, in order to reliably operate the grid with high solar generation contributions. Research in this topic area will focus on hardware and software technologies to enable real-time situation awareness and coordinated control that ensure system reliability during normal and abnormal operating conditions. This activity will support projects that will address challenges in power electronic devices, sensing and communication, system protection and fault recovery, dynamic power flow control, grid services, and data analytics using artificial intelligence and machine learning.

Resilience and Security R&D: The deployment of distributed solar PV and other DERs can provide greater resilience to energy infrastructures and community services by integrating them into emergency response and recovery procedures. Research in this topic area focuses on technologies and solutions that integrate distributed solar PV, energy storage, and other DERs to provide continuity of electric power service for critical infrastructures and critical loads and reduce the magnitude and/or duration of disruptive events such cyberattacks and physical hazards such as hurricanes, floods, and wildfires. This activity will support projects that will advance the detection and situation awareness of threats and enhance solar PV and power system's capabilities of anticipating, absorbing, adapting to, and/or rapidly recovering from a potentially disruptive event.

Systems Integration

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Systems Integration $53,000,000	**$85,000,000**	**+$32,000,000**
Planning and Modeling R&D $13,000,000	$30,000,000	+$17,000,000
• Fund the third year of FY 2019-2021 SETO lab call projects to completion.	• Funding to maintain FY22-FY24 lab call projects and support new lab projects. Work will focus on dynamic models for PV and power systems, high-resolution measurement data, solar resource forecast and integration, reliability standards, and testing and validation.	• Increased funding for analysis of high-resolution measurement data, grid event pattern recognition, and grid reliability codes and standards development.
• Support the third year of FY 2019-2021 Grid Modernization Laboratory Consortium (GMLC) Lab Call projects to completion.		
Operation and Control R&D $32,500,000	$35,000,000	+$2,500,000
• Support the third year of FY 2019-2021 GMLC Lab Call projects.	• No further funding requested.	• Prior year obligations will continue to fund these projects.
• 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. Funding will also support projects to develop low cost, efficient, secure methods for real time data management to enhance visibility and controllability of distributed PV systems.	• Funding to develop better tools for grid operators to reliably monitor and control a power system that has high amounts of solar generation at the distribution and bulk grid levels. This includes the better incorporation of weather forecasts and real-time measurements for predicting solar irradiance and other variable renewables generation as well as loads. This is an EERE and OE collaboration.	• Increased funding to build upon insights from previous research and industry feedback with more emphasis on demonstration and deployment of technologies to support accelerated renewable integration and grid modernization.
• No funding requested.	• Funding to support competitively selected projects to develop better methodologies and software tools for grid planners to conduct long-term power system planning for integration of high amounts of solar at the distribution and bulk grid levels. This includes the better incorporation of weather models for resource adequacy assessment during extreme events. This effort	• New solicitations that will build upon insights from previous research and industry feedback with more emphasis on demonstration and deployment of technologies to support accelerated renewable integration and grid modernization.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
	will also support innovations in grid planning process. This is an EERE and OE collaboration.	
Resilience and Security R&D $7,500,000	$20,000,000	+$12,500,000
• Fund the third year of FY 2019-2021 SETO lab call projects.	• Funding to maintain FY22-FY24 lab call projects and support new lab projects. Work will focus on addressing cybersecurity challenges in solar grid integration including technology development, standard development, testing and validation, and information sharing.	• Increase in funding to address emerging cybersecurity challenges in solar PV.
• Support the third year of FY 2019-2021 GMLC Lab Call projects.	• Funding to expand upon activities to demonstrate how solar and other DERs can improve reliability and resilience of the grid in under-resourced communities.	• Increase funding to build upon insights from previous research and stakeholder feedback with a focus on under-resourced communities.

Solar Energy
Balance of Systems Soft Cost Reduction

Description

The Balance of Systems Soft Cost Reduction (BOS) subprogram focuses on reducing the non-hardware costs of solar electricity, enabling the benefits of solar energy to reach all Americans, and developing a skilled and diverse workforce with access to good-paying jobs with the free and fair option to join a union and bargain collectively. The non-hardware, or soft costs, of solar energy include siting, permitting, inspection, interconnection, installation labor, project development, customer acquisition, financing, and other related costs. Taken together, soft costs constitute about 65 percent of total system prices for residential PV systems, 57 percent of commercial PV systems, and 36 percent of utility-scale systems.[1] Reaching the DOE 2030 solar cost targets of $0.05/kWh, $0.04/kWh, and $0.02/kWh for the residential, commercial and utility-scale market segments, respectively, will require significant reductions in soft costs without impacting the wages, benefits, safety and quality of work.

Reducing soft costs like siting, permitting, inspection, and interconnection requires engaging with community organizations, state and local governments, Tribes, developers, utilities, and other stakeholder groups to understand barriers, develop collaborative research, tools, and processes, and broadly disseminate results and best practices to enable replication. For example, improving permitting sites for large-scale solar development and their host communities requires collaborative research and engagement on a wide range of topics, such as solar planning and zoning, environmental impacts and benefits, land use competition, and innovative siting practices (e.g., agrivoltaics, floating solar).

Rooftop solar offers opportunities across the country for consumers to save money on electricity bills. However, about half of U.S. households cannot access rooftop solar due to roof shading, financing barriers, or lack of home ownership.[2] Community solar has the potential to overcome these barriers. BOS has a target to enable enough community solar deployment to power 5 million households with one billion dollars in savings by 2025.

The solar industry has been one of the fastest growing employment sectors over the past decade, providing 317,000 jobs in 2021. To meet the President's 2035 carbon pollution-free electricity goals, EERE is committed to supporting a nationally representative workforce of sufficient size, skill, compensation, and other support needed to carry out EERE's mission. To enable this vision, SETO is working on stakeholder engagement efforts to build partnerships across the clean energy workforce, support strong skills development among those that make clean energy deployment possible, and increase the ease for new people to enter the clean energy workforce, with a particular focus on frontline communities, military veterans, returning citizens, and those currently or formerly working in fossil fuel industries. By building on ongoing work with labor unions, trade associations, and educational institutions, both EERE's and SETO's efforts will increase access to all clean energy workforce careers, including pathways to family-sustaining wage positions and labor organization membership. Wherever possible, SETO will work collaboratively across technology offices to coordinate funding opportunities, educational programs, and regional technical assistance, as well as coordinate with Department of Labor and Department of Education on shared priorities.

Within the activities listed below, the Solar Energy fellowship program funds 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 will be used to support efforts such as merit/peer reviews, data collection and dissemination, technical assistance, and technology to market activities.

Data, Modeling, and Analysis: This activity focuses on foundational data collection, modeling, and analysis to benchmark soft costs, understand barriers to solar and solar plus storage deployment, and evaluate the effectiveness of proposed solutions. Activities include data aggregation and analysis to increase market transparency, assess solar plus storage value

[1] V. Ramasamy et al., "U.S. Solar Photovoltaic System Cost Benchmark: Q1 2021," NREL Technical Report, November 2021.

[2] D. Feldman et al. "Shared Solar: Current Landscape, Market Potential, and the Impact of Federal Securities Regulation," NREL Technical Report NREL/TP-6A20-63892 (April 2015). https://www.nrel.gov/docs/fy15osti/63892.pdf.

providing reliability and resiliency, expand access to solar energy, evaluate alternative siting approaches, and open new markets.

Technical Assistance and Stakeholder Tools: This activity supports technical assistance to help solar stakeholders reduce soft costs and overcome barriers to solar and solar plus storage deployment. Activities include providing technical assistance to stakeholders on solar siting, interconnection, community solar, and financing solar for low-income households. Stakeholders include state, local and tribal governments, the solar industry, utilities, community-based organizations, and others. This activity also includes competitive funding to address barriers to interconnection and to develop and demonstrate financing models for low-income households, as well as funding the development of an online enrollment platform to facilitate low-income participation in community solar.

STEM and Workforce Development: This activity supports cross EERE STEM and workforce programs to enable diverse workers to benefit from the clean energy economy. Activities include support for new EERE wide workforce efforts to develop training partnerships, update and develop new training programs, communicate clean energy career opportunities and pathways to enter the workforce, and engage on labor standards and job classifications. In addition to support for EERE-wide workforce communications efforts and technical assistance related to job standards and classifications, this activity also includes a program to support placement of selected participants at public utility commissions, electric utilities or grid operator organizations to conduct research and stakeholder engagement activities that facilitate the deployment and the integration of solar energy onto the electric grid, as well as a competition that helps to prepare college students with various academic expertise for careers in clean energy.

Balance of Systems Soft Cost Reduction

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Balance of Systems Soft Cost Reduction $35,000,000	**$77,000,000**	+$42,000,000
Data, Modeling, and Analysis $14,000,000	$18,000,000	+$4,000,000
• Fund the first year of the National Laboratory FY 2022-24 projects that advance data, modeling, and analysis for the reduction of solar soft costs.	• Maintain National Laboratory FY 2022-24 projects to advance data, modeling, and analysis for the reduction of solar soft costs.	• No significant change.
• No funding requested	• Support EERE and cross-DOE data, tools, and analysis projects to facilitate the widespread integration of renewables in a resilient, reliable power system.	• New funding for holistic approaches to grid modernization and understanding pathways to decarbonize the power system.
Technical Assistance and Stakeholder Tools $18,000,000	$50,000,000	+$$32,000,000
• Use a FOA to support the extension of the SolSmart program that assists local governments to improve processes for solar energy development.	• No further funding requested.	• Program fully funded.
• Fund the National Community Solar Partnership, a congressionally directed program that provides technical assistance to businesses, non-profit organizations, and state, local and tribal governments to expand access to affordable community solar.	• Expand the National Community Solar Partnership and continue the operation of the five technical assistance, research, and tool-development initiatives created by community solar stakeholders to reduce barriers to rapid deployment while meeting the target of increased access to low-income households, increased energy savings, increased job creation, increased consumer awareness, and resiliency. To facilitate low-income household access to community solar this includes the development of an online platform to improve and make easier enrollment in community solar programs.	• Increased funding to develop an online platform to help with low-income household enrollment in community solar by leveraging data present in other low income programming to identify eligible households for community solar.
• No funding requested.	• Support additional multi-stakeholder team participation in the Solar Energy Innovation	• Increased funding expands the Solar Energy Innovation Network, a program that supports

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
	Network and the replication of solutions developed in previous rounds of the program.	communities to develop solutions that overcome barriers to solar energy deployment.
• No funding requested.	• Provide local governments, utilities, and other stakeholders with technical assistance on solar siting, permitting, and interconnections.	• New activity to focus on reducing soft cost barriers to solar deployment.
• No funding requested.	• Projects and technical assistance to develop, test, and replicate successful solar financing models for low-income households, especially in underserved communities.	• New activity enabling the equitable access to solar energy.
• No funding requested.	• Projects and technical assistance for Tribes to evaluate solar technologies, design programs, and develop solutions to facilitate solar deployment on Tribal lands.	• New activity enabling the equitable access to solar energy.
STEM & Workforce Development $3,000,000	$9,000,000	+$6,000,000
• Support solar workforce training programs for veterans and other talent pools.	• No further funding requested.	• Funding reprioritized toward other activity areas.
• Fund the Solar District Cup, a competition that helps to prepare college students with different academic expertise for careers in clean energy.	• Funding to support an additional round of the Solar District Cup, a competition that helps to prepare college students with different academic expertise for careers in clean energy.	• No significant change.
• No funding requested.	• Establish multiple regional workforce partnerships that provide workforce training, placement with local employers, and other support services to help people build careers in the clean energy industry.	• The increase establishes an activity to assist the transition of individuals into the clean energy workforce, creating pathways to union membership, and supporting energy and environmental justice goals.

Solar Energy
Manufacturing and Competitiveness

Description

The Manufacturing and Competitiveness (MC) subprogram supports entrepreneurs and companies in developing and commercializing new and advanced solar technologies that can complete, grow, and diversify the U.S. solar industry, increase U.S. competitiveness in solar energy manufacturing and advance progress toward the carbon-free power sector by 2035. The MC subprogram helps companies with promising solar technologies survive the funding gaps that often emerge in the development cycle of new technologies.

Today less than 20 percent of modules installed in the US are manufactured domestically, leaving the domestic industry and energy consumers beholden to foreign-dominated supply chains. The lack of domestic supply to fulfil domestic industry needs presents challenges to ensuring there is adequate access to products to meet national decarbonization goals. Increasing domestic content and supply chains for PV hardware and product components, such as ingots and wafers for silicon modules, will keep more value in the U.S. economy and create valuable, good-paying manufacturing jobs with the free and fair option to join a union and bargain collectively. Decreasing reliance on imported goods also reduces supply uncertainty and cost sensitivity to international supply chain disruptions or cyber-security concerns while also increasing domestic energy security. The MC subprogram supports proof-of-concept development, technology demonstration and validation, and technology transfer of innovative solar technologies across the value chain.

The MC subprogram utilizes prize programming and the American Made Network to catalyze new businesses pursuing innovative technologies. Manufacturing and value chain RD&D efforts aim to advance and validate technology progress to enable subsequent private sector funding to scale into production. This includes the 18th round of the successful Incubator program, which provides early-stage assistance to small businesses developing and validating technology prototypes. The new Solar Manufacturing Accelerator initiated in this Request focuses on advanced solar technologies to reduce the dependence on foreign controlled supply chain segments, particularly those utilizing unacceptable labor practices. This effort is a new partnership between SETO and the Advanced Manufacturing Office that will help establish domestic manufacturing capabilities of advanced PV technologies that rely less on foreign sourced materials. Domestic supply chains are critical to ensuring the U.S. has access to the volume of solar energy cells, modules, and system components to meet decarbonization goals. The overall focus will be on reducing solar costs while solidifying domestic material, equipment, and product supply chains. Programming could address advanced versions of industry-leading technologies like crystalline silicon and cadmium telluride and emerging technologies like perovskites, while also including support for upstream and downstream components.

Within the activities listed below, the Solar Energy fellowship program funds emerging leaders in the field that will pursue breakthrough solar energy technologies or analysis at universities, National Laboratories, and other research facilities. In addition, funds will be used to support efforts such as merit/peer reviews, data collection and dissemination, technical assistance, and technology to market activities.

<u>American-Made Challenges</u>: This activity supports prize programming and associated support structures such as the American Made Network to seed new solar technologies and increase America's market share for added-value manufacturing. The work focuses on incentivizing the development of solutions by a diverse set of individuals and new entrants to the solar technology development space in addition to connecting these people to a network of experienced commercialization partners 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.

<u>Manufacturing and Value Chain</u>: This activity supports cooperative agreements and grants focused on developing and validating new and advanced solar technologies with a focus on those which can be domestically manufactured. Funding targets the full value chain, from innovative approaches to producing solar cell components, cells, and module materials to new tracking technologies to power electronics to technologies to reduce maintenance costs. This activity also aims to supports efforts to bring more private capital funding into solar energy technology development and ensuring well trained workers are ready to enter the workforce as the opportunities grow. Overall, the goal is to help companies de-risk

technologies and commercial approaches sufficiently to enable investment and commercialization by private sector entities and develop a holistic domestic supply chain that is not dependent on foreign controlled supply chains.

Manufacturing and Competitiveness

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Manufacturing and Competitiveness $60,000,000	**$225,000,000**	**+$165,000,000**
American-Made Challenges $11,200,000	$15,000,000	+$3,800,000
• 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.	• Continue to run the American-Made Solar Prize (Hardware & Software) to support innovators in launching new products that advance the solar industry and support U.S. manufacturing.	• No significant change.
• Begin Perovskite Prize to establish innovative perovskite companies.	New Signal Prize to provide additional support to SETO awardees who are hitting critical R&D milestones to accelerate the transition to private sector funding. Funding reflects the need for additive funding to promising technologies in SETOs portfolio to speed the transition of that technology from federal to private funding which is best of ultimate technology commercialization.	• Increased funding for the development of the new Signal Prize for providing resources to expedite promising technologies to the market.
• Begin additional prizes to accelerate solar cost reduction solutions.	• Continue support for the American Made Network which provides support to applicants, participants and awardees that are part of SETO funding programs via access to technical expertise, help with application construction, access to tools and equipment and more.	• Increased funding for the expansion of the American Made Network to support SETO prize participants and funding applicants
Manufacturing and Value Chain R&D $48,800,000	$210,000,000	+$161,200,000

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
• Fund competitively selected projects focused on accelerating the commercialization of innovative product ideas that can substantively increase U.S. domestic manufacturing across the solar industry supply chain and expand private investment in America's solar manufacturing sector. These products and solutions will lower the cost of solar technologies and facilitate the secure integration of solar electricity into the Nation's energy grid.	• Continue support for projects focused on accelerating the commercialization of innovative product ideas that can substantively increase U.S. domestic manufacturing across the solar industry supply chain and expand private investment in America's solar manufacturing sector. This includes supply chain development for advanced versions of industry leading technologies, such as silicon and cadmium telluride, the transition of new technologies from the lab to manufacturing, such as Perovskites, and support for scaling complimentary and supporting supply chain technologies like equipment and other PV module and system components.	• The increase establishes the new Solar Manufacturing Accelerator program aimed at advanced technologies to significantly reduce the dependence on imported solar components and develop a robust and competitive domestic solar technology supply chain.
• No funding requested.	• Support targeted work in emerging sectors of the solar industry to include, but not exclusive to, the manufacturability and demonstration of building integrated PV, use of robotics technologies in system construction and manufacturing, floating PV, the co-location of PV with agriculture, virtual power plants, and PV applications in the transportation sector.	• The increase supports new efforts in emerging sectors of the solar industry value chain.

Wind Energy

Overview

In support of the President's clean energy goals, by 2035 the U.S. may require new additions to wind energy development of at least 500 GW[1], and perhaps up to 900 GW[2], to achieve a robust economy supported by carbon pollution-free electricity. Meeting this development goal would require annual installation rates of nearly 50 GW per year by 2030, three times the highest annual installation rate the U.S. has experienced to date. Wind energy is poised to meet this demand, as it is a proven technology that can rapidly scale if near-term barriers to deployment are addressed, and technologies continue to innovate and drive down costs. Wind expansion would create tens of thousands of good-paying jobs in domestic manufacturing across the supply chain, deployment/installation, operations, and maintenance.[3] Wind power expansion holds the hope of revitalizing communities throughout the U.S. and along the coastlines, with significant benefits for improved environmental quality, public health, and economic justice.

Accordingly, the U.S. Department of Energy's (DOE's) Wind Energy Technologies Office (WETO) will execute a comprehensive RDD&D plan to accelerate offshore wind and land-based wind energy innovation, cost reduction, and deployment, including on federal lands and at federal facilities. This work will include a major expansion of offshore wind efforts to accelerate development of fixed-bottom offshore wind and unlock floating offshore wind development in U.S waters, with the aim of realizing the Administration's goals of 30 GW deployed by 2030 and 110 GW by 2050. For land-based wind, WETO will increase efforts in developing siting solutions and removing barriers to deployment through investments in multiple mitigation technology pathways for wildlife deterrence, wind turbine-radar interference, and community impacts. To support these deployment acceleration efforts, WETO will actively participate with community engagement teams and invest in workforce development programs.

WETO's FY 2023 Budget Request supports a diversified portfolio of applied RDD&D activities designed to advance innovation and accelerate deployment of offshore, land-based, and distributed wind energy technologies and their integration with the electric grid. These priorities reflect a broad range of stakeholder inputs and support the Administration's energy and climate goals, namely, to achieve 100 percent carbon pollution-free electricity by 2035 and put the U.S. on a path to a net-zero carbon economy by 2050. Additionally, WETO's body of work emphasizes the underpinning principles of energy equity and environmental justice, the creation of good-paying jobs in a diversified U.S. wind workforce, diversity and inclusivity in STEM skills development, and increased engagement with states, local communities, and universities, including HBCUs and minority serving institutions, across all its planned activities in fiscal year 2023.

With continued innovation, wind energy has the potential to cost-competitively contribute 35 to 45 percent of U.S. electricity in less than two decades, up from the 8.3 percent of all U.S. electric power in 2020. Beyond electricity, wind energy can also contribute to grid reliability and resiliency, as well as the generation of clean fuels to help transition the U.S. economy to net-zero emissions in the transportation, buildings, industrial, and agricultural sectors, supporting growth in good-paying jobs and domestic manufacturing across all regions of the country. Progress on these fronts, arising from continued innovation in technology, grid systems integration, and unique solutions to deployment challenges, can position the United States to regain its position as a global leader in wind energy development at home and abroad.

Across all its wind energy development objectives, WETO emphasizes three common and overarching themes:

- Reduce the cost of wind energy for all wind applications (offshore, land-based utility-scale, and distributed);
- Enable and facilitate the interconnection and integration of substantial amounts of wind energy into the dynamic and rapidly evolving energy system, that is cost-effective, cyber-secure, reliable, and resilient, and includes systems integrated with other energy technologies, energy storage, and offshore and inter-regional transmission planning; and
- Accelerate the deployment of wind energy through siting and environmental solutions to reduce environmental impacts, minimizing timetables for wind energy project development, and facilitating responsible, sustainable, and equitable development and delivery of wind energy resources.

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[1] 2035 Report | Renewable Energy Costs & Our Clean Electricity Future - 2035 The Report
[2] Achieving 100% Clean Electricity by 2035: Ten Key Findings, NREL (forthcoming, Q3, 2022)
[3] 2015 Wind Vision, Executive Summary, Jobs Analysis, p.18, U.S. DOE

WETO also supports the key emphasis areas of energy justice, workforce, diversity in STEM, and state and local partnerships. Investments associated with Workforce Development will support training and develop good paying clean energy jobs for the American people – especially workers and communities impacted by the energy transition and those historically underserved by the energy system and overburdened by pollution. Investments associated with Diversity in STEM support outreach and will raise awareness of clean energy research and job opportunities at minority-serving institutions and minority professional organizations and ensure that organizations receiving EERE funding are thinking through diversity and equity in their own work. Investments in State and Local partnerships will enable state and local governments to be more effective in facilitating the nation's (and their own) affordable and resilient clean energy and efficiency goals. Investments associated with Energy and Environmental Justice will support approaches and processes to reach new groups of Americans historically underserved by the energy system.

Highlights of the FY 2023 Request

- New and expanded RD&D investments will support the Administration's goal of deploying 30 GW of offshore wind by 2030 and 110 GW or more by 2050 through two primary areas of focus: 1) accelerating the near-term deployment of fixed-bottom offshore wind through research to lower costs, address barriers to siting and permitting, and address offshore wind transmission challenges through an initiative called NOW (Near-term Offshore Wind); and 2) unlocking floating offshore wind in U.S. waters through a broad portfolio of integrated research to significantly reduce wind turbine, floating platform, and electrical connection costs, while advancing technological readiness across an array of associated systems. To help accomplish the latter, the program will initiate a Floating Offshore Wind Accelerated Research and Development (FORWARD) initiative, a major body of R&D aimed at unlocking floating offshore wind in U.S. waters. FORWARD will also help ready the West Coast, Gulf of Maine, and other relevant regions for floating offshore wind development through transmission planning, cable technology R&D, and efforts to address siting, environmental, and community acceptance issues.
- Expanded R&D targeting solutions to reduce environmental and siting barriers to land-based wind development including emphasis on: 1) wildlife impact assessment and deterrent tools and technologies, specifically for bats, eagles, and grouse species; and 2) wind turbine-radar interference mitigation activities. WETO efforts in these areas will be coordinated with other EERE offices, including the Solar Energy Technologies Office.
- New research to assess offshore wind transmission infrastructure requirements for broad coastal regions, improve offshore wind interconnection processes, advance offshore transmission technologies, and maintain overall system reliability and resilience in view of substantial additions from offshore wind.
- New social research, community engagement, and technical assistance support to identify and understand impacts of land-based and offshore wind energy development on inland and coastal communities, and to help those communities overcome barriers to siting wind energy projects.
- New investments through two new, distinct subprograms, proposed in the FY 2023 Request: Systems Integration, and Data, Modeling, and Analysis. These programs are in line with the expanded goals of the program that focus on enabling cost-effective, cyber-secure, reliable, and resilient operation of the power grid, as well as developing capabilities and analysis to identify wind technology needs for wind in multiple 2035 and 2050 decarbonization pathways. The subprograms will replace the Grid Integration and Analysis subprogram.

Contributions to DOE-wide Crosscutting Investments

WETO is involved in several crosscuts, including the following:

- Advanced Manufacturing ($26,000,000): WETO uses Advanced Manufacturing methods and technologies to address the issues and challenges associated with turbine scaling for both land-based and offshore wind. These activities will enable wind turbine technologies that address transportation constraints, allow for larger and lighter turbine components through novel designs and materials, and increase material and component production throughput;
- Critical Minerals and Materials ($24,000,000): WETO supports analysis and technology innovation efforts both to understand the vulnerabilities of the wind energy supply chain to critical materials and to mitigate those vulnerabilities by reducing dependence on, and improving recovery of, critical materials within wind energy components;
- Energy Storage ($6,000,000): WETO supports Energy Storage through multi-office collaboration on hybrid system design, hardware, control, and demonstration to hybrid systems involving multiple technologies such as wind, hydropower, solar, battery storage, or hydrogen; and
- Grid Modernization ($42,000,000): WETO prioritizes RD&D in transmission analysis and technology advancement, grid reliability and resilience, wind control and wind cybersecurity research, and crosscutting demonstrations in grid

enhancing technologies and hybrid energy systems. This body of work, which emphasizes offshore wind aspects, but is not limited to offshore wind, aligns with grid activities across EERE and OE necessary to enable a just transition to a grid that supports a decarbonized power system by 2035 and a net-zero-emission economy by 2050, while maintaining the reliability, affordability, security, and resilience of the energy system.

EERE Program Priorities
In FY 2023, WETO continues to support an investment strategy aligned to the following programmatic priority areas that are central pillars to the U.S. greenhouse gas (GHG) profile:

Wind Energy
Funding ($K)

	FY 2021 Enacted	FY 2022 Annualized CR[1]	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted
Decarbonizing the electricity sector	110,000	110,000	345,390	+262,890

[1] The FY 2022 Annualized CR amounts reflect the P.L.117-95 continuing resolution level annualized to a full year.

Wind Energy
Funding ($K)
(Comparable)

	FY 2021 Enacted	FY 2022 Annualized CR[1]	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted
Wind Energy				
Offshore Wind	63,200	63,200	197,792	+ 134,592
Land-Based Wind	31,800	31,800	77,848	+ 46,048
Distributed Wind	10,000	10,000	17,750	+7,750
Systems Integration	3,517	3,517	42,000	+ 38,483
Data, Modeling, and Analysis	1,483	1,483	10,000	+8,517
Total, Wind Energy	**110,000**	**110,000**	**345,390**	**+235,390**

Wind Energy
Funding ($K)
(Non-Comparable)

	FY 2021 Enacted	FY 2022 Annualized CR	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted
Wind Energy				
Offshore Wind	63,200	63,200	197,792	+ 134,592
Land-Based Wind	31,800	31,800	77,848	+ 46,048
Distributed Wind	10,000	10,000	17,750	+ 7,750
Grid Integration & Analysis	5,000	5,000	0	-5,000
Systems Integration	0	0	42,000	+ 42,000
Data, Modeling, and Analysis	0	0	10,000	+ 10,000
Total, Wind Energy	**110,000**	**110,000**	**345,390**	**+235,390**

FY 2021 Transferred: SBIR $4,007,232; STTR $354,965
FY 2022 Annualized CR: SBIR $2,837,000; STTR $399,000
FY 2023 Request: SBIR $7,487,866; STTR $1,052,981

[1] The FY 2022 Annualized CR amounts reflect the P.L. 117-95 continuing resolution level annualized to a full year. These amounts are shown only at the congressional control level and above, below that level, a dash (-) is shown.

Budget Structure Crosswalk ($K)

	Proposed FY 2023 Budget Structure					
	Offshore Wind	**Land Based Wind**	**Distributed Wind**	**System Integration**	**Data Modeling, and Analysis**	**Total**
FY 2021 Budget Structure						
Offshore Wind	197,792	0	0	0	**0**	**197,792**
Land Based Wind	0	77,848	00	0	**0**	**77,848**
Distributed Wind	0	0	17,750	0	**0**	**17,750**
Grid Integration & Analysis	0	0	0	42,000	10,000	**52,000**
Total, Wind Energy Technologies Office	**197,792**	**77,848**	**17,750**	**42,000**	**10,000**	**345,390**

Wind Energy Explanation of Major Changes ($K)	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Wind Energy **Offshore Wind:** Increased funding within the OSW portfolio will focus on two primary areas: 1) R&D to accelerate near-term deployment of offshore wind through research to lower costs, address barriers to siting and permitting, and address offshore wind transmission challenges to reach 30 GW by 2030 (NOW – Near-term Offshore Wind), and 2) initiation of the Floating Offshore Wind Accelerated Research and Development (FORWARD) program, a major body of R&D aimed at unlocking floating offshore wind in U.S. waters, which will be critical to achieving or exceeding 110 GW or more by 2050. Targeted funding will support a wide range of RDD&D activities, including an emphasis on: a) design, development, testing, and validation of floating offshore wind turbines to unlock U.S. offshore development in deep waters; b) cost reduction through innovations that capture economies of scale and component design for high-volume manufacturing; c) supply chain design and development for domestic manufacturing capability; d) addressing technical challenges to offshore installation, inspection, and repair methods, with an emphasis on remote turbine monitoring; e) solutions to environmental and radar impacts to accelerate and inform siting, permitting, and development; f) identifying offshore wind workforce needs and addressing gaps in educational and training programs; g) research and solutions development for impacts on coastal communities and ocean co-users; and h) state and local engagement to support coastal community energy planning.	**+134,592**
Land-Based Wind: The increase in funding for this subprogram reflects the prioritization of siting and environmental solutions to drive cost effective land-based wind deployment to contribute to achieve the Administration's goals of 100 percent carbon pollution-free electricity by 2035 and a net-zero carbon economy by 2050. Increased funding will target a wide range of RDD&D activities, including focus on: a) solutions for land-based wind environmental and siting challenges with an emphasis on improving bat mortality mitigation solutions through a bat "Grand Challenge" and characterization of impacts to prairie grouse species; b) wind-radar interference mitigation options emphasizing the validation and commercialization of mitigation tools and measures; c) support for university-level curriculum development, wind fellowship programs, and internships, emphasizing diversity, equity, and inclusion and expanded engagement with HBCUs and MSIs; and d) research on impacts of land-based wind development on communities to inform strategies to mitigate deleterious effects and enhance energy equity and environmental justice. Research on land-based wind plant optimization, wake interaction and wind plant controls are to be continued but deemphasized, with a shift of resources and similar skill sets to offshore wind atmospheric science and wind turbine interactions.	**+46,048**

Wind Energy
Explanation of Major Changes ($K)

	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Distributed Wind: Funding in this subprogram will continue to prioritize RDD&D innovations to drive down overall system cost and affect accelerated distributed wind deployment to achieve the Administration's goals of 100 percent carbon pollution-free electricity by 2035 and a net-zero carbon economy by 2050. The funding will support: a) efforts to advance small- and medium-scale wind turbine technology through cost reduction, performance improvement, grid support capability, and turbine testing to national standards; b) development of community-based zero-carbon power plans and utility business and regulatory models that enable markets to incentivize zero-carbon distributed energy resource aggregation; and c) data collection, analysis, and model development to accurately and reliably represent wind as a distributed energy resource in decision support tools used by energy transition stakeholders.	**+7,750**
Grid Integration & Analysis: No funding is requested for this Grid Integration & Analysis subprogram in FY 2023. Support for Grid Integration and Analysis activities will transition to the new Systems Integration subprogram, and the Data, Modeling, and Analysis subprogram, as outlined below.	**-5,000**
Systems Integration: The Systems Integration subprogram will prioritize activities to ensure cost-effective, reliable, cyber-secure, and resilient operation of the power grid with increasing levels of wind energy deployment. FY 2023 funding will support: a) cost-effective and reliable offshore transmission access in broad coastal regions, including comprehensive transmission planning analysis, research to advance offshore transmission technologies (including subsea cables and high-voltage direct current technology), models, and tools to support reliable and resilient grid operation with large amount offshore wind; b) Wind CyberShield initiative to significantly expand wind cybersecurity research to systematically identify solutions that address wind specific cybersecurity challenges; and c) multiple crosscutting efforts including grid-enhancing technology development and demonstration to unlock transmission capacity, hybrid system design, control, analysis and demonstration involving combinations of technologies including wind, solar, battery storage, and hydrogen. In FY 2021, support for area of work was provided under the Grid Integration and Analysis subprogram.	**+42,000**
Data, Modeling, and Analysis: This subprogram will evaluate and prioritize wind energy technology innovation opportunities for offshore, land-based, and distributed applications, based on objective analysis with a solid understanding of techno-economic conditions as well as state-of-the art systems engineering, cost and deployment models, and tools. FY 2023 funding will focus on a) expanding collection of data sources; b) enhancing modeling capabilities and level of resolution and accuracy to enhance utility; and c) conducting wind technology design analysis, future scenarios analysis, and impacts analysis. In FY 2021, support for area of work was provided under the Grid Integration and Analysis subprogram.	**+10,000**
Total, Wind Energy	**+235,390**

Description

A nascent offshore wind (OSW) industry is just beginning to develop in the United States, driven by the attraction of robust OSW resources, falling OSW wind turbine costs, technological advances, accelerated Federal OSW lease auctions, and complementary state policies and commitments. Several challenges have slowed OSW development in U.S. waters, however, including its comparatively high-cost, an array of unique weather, wildlife, environmental, radar and other siting challenges, and no clear path yet for integrating vast amounts of new power onto an existing shore-based grid. Fixed-bottom technology, as developed abroad, can be adapted to U.S. waters, but the technology for floating OSW is a “new frontier”.

In March 2021, DOE announced a joint-agency goal to deploy 30 GW of OSW by 2030, which, if realized, could unlock a pathway to 110 GW or more by 2050. Achieving these OSW goals requires a concerted effort on behalf of the Federal government, including critical R&D efforts by WETO in multiple areas with an increased emphasis on floating OSW technologies to unlock the 58 percent of the nation’s OSW resource found in deep waters.

In FY 2023, the OSW sub-program will support two areas of focus. The first will be a body of R&D to accelerate near-term deployment of OSW to lower costs, address barriers to siting and permitting, and address OSW transmission challenges, which is discussed in more detail in the Systems Integration subprogram narrative. Through these activities, the OSW subprogram aims to achieve breakthroughs in reducing the levelized cost of energy (LCOE) from a 2019 benchmark of $.08/kWh to $.05/kWh by 2030 without subsidies. Reaching this 2030 goal will make OSW energy a cost-competitive option. The approach for realizing cost reduction goals is to identify the top-most cost-contributing elements and find ways to reduce capital costs, improve energy output and operating efficiency, and reduce operating and maintenance costs over the life of the investment. The subprogram will develop and build national capabilities for cost-effectively manufacturing, installing, and maintaining OSW plants in the United States. The subprogram will also seek to address the most impactful barriers to OSW deployment through a portfolio of activities designed to ensure sustainable OSW development, promote co-use of ocean space, derive benefits to coastal communities, and result in a thriving domestic supply chain supported by a diverse, domestic workforce.

In FY 2023, WETO will launch the Floating OSW Accelerated Research and Development (FORWARD) program, a major body of R&D aimed at unlocking the 58 percent of the nation’s OSW resource accessible only through the development and commercialization of affordable floating OSW technologies. Significant development of floating OSW in the United States will require a reduction in costs from the current LCOE of $.135/kWh for floating turbines. The goal requires investments in sustainable and community-compatible development; further refinement of supply chain and workforce development requirements; and advancements in transmission planning and HVDC cable technology. FORWARD will be comprised of a body of expanded and new integrated competitively awarded and laboratory research to significantly reduce wind turbine, floating platform, and electrical connection costs, while advancing technological readiness across an array of associated systems and to help ready the West Coast, Gulf of Maine, and other relevant regions for floating OSW development through transmission planning, cable technology R&D, and efforts to address siting, environmental, and community acceptance issues..

Science and Technology Innovation: This activity seeks to reduce cost and risks to OSW development through advances in OSW technology and scientific understanding, and will focus on three major areas: resource characterization, OSW technology innovation, and research to reduce operations and maintenance (O&M) costs. The first of these activities, resource characterization, is critical to predicting OSW resources to inform wind farm siting and predict and optimize wind farm energy production. It is also critical to predicting potential structural loading impacts that will be experienced by future U.S.-based OSW systems, which will inform turbine design tailored to unique U.S. conditions, including hurricane risk. The OSW Resource Science project will improve predictions of wind/wave resources in OSW energy development areas along the U.S. coastline, with particular focus on improving the characterization of ocean-wave-atmospheric coupling necessary to capture variations and turbulence in rotor-level winds that are critical to understanding the wind energy resource and predicting turbine survivability.

This activity also seeks to develop OSW technology innovations to open new markets, such as deep-water markets on the West Coast of the U.S., by developing floating technologies, enabling economies of scale with resultant reductions in cost, developing designs optimized for domestic supply chains, and advancing turbine and farm controls to increase output and improve predictability. For floating OSW, the industry has demonstrated technology feasibility but still requires significant cost reductions to achieve full commercial viability. With many competing designs and an undeveloped project pipeline, R&D is focused on the significant technology challenges to enabling commercial-scale projects; foremost among these are investments that reduce the levelized costs of floating platforms, increase the certainty of the predicted performance, and enable manufacturing at domestic facilities.

Efficiency and usability of wind technology depends on the reliability and lifetime of components, and OSW O&M are major drivers of both floating and fixed-bottom OSW system costs. Proper tools and data to decrease unplanned maintenance and extend the lifetime of components can optimize operations and thus decrease O&M costs. The harsh offshore environment introduces significant challenges to maintenance, which increases the importance of investments in this area. Also, as wind turbines get larger and more flexible, O&M costs and reliability issues become more critical to the performance of the entire wind system and its economic competitiveness. The activity uses prognostic health management tools to optimize O&M practices driven by AI, automated fault detection, and remote, autonomous inspection and repair methods that will benefit both offshore and land-based wind plant operations.

Manufacturing and Materials R&D: This activity aims to develop and build domestic capabilities for cost-effectively manufacturing, installing, and maintaining OSW plants in the United States, resulting in domestic manufacturing opportunities in support of Buy American and creating well-paying jobs with the option to join a union. The complexity of OSW installation and maintenance activities require specialized infrastructure not yet available in the United States. Identifying and implementing 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, WETO will conduct technology R&D to ease the technical challenges of installation by reducing turbine weight, finding turbine installation methods that do not require large installation vessels, as seen in Europe, and using advanced materials and manufacturing technologies to reduce the fabrication costs of floating offshore turbine foundations. Activities include investigating and prototyping new manufacturing methodologies using additive manufacturing (3D printing) techniques coupled with automated assembly approaches to reduce fabrication costs and mitigate transportation challenges of large and complex wind turbine components. Automation will significantly reduce the manual labor typically involved in manufacturing wind components, allowing for manufacturing of components at larger scales at lower costs, leading to global economic competitiveness and technology leadership.

Environmental and Siting R&D: Siting of OSW projects in the United States has been a challenge for the last two decades and has proven to be a significant barrier to the development and expansion of this renewable energy technology. This activity will focus on developing solutions to key environmental and siting barriers to OSW development through research to understand impacts, development of technical solutions, and engagement with coastal communities to facilitate ocean co-use and aid in energy planning. WETO's approach is to identify and focus on the highest-priority concerns, which are primarily related to the environment, radar interference, community impacts, and ocean co-use. In FY 2023, WETO will focus on addressing near-term barriers to OSW development on the East Coast, as well as efforts to help prepare the West Coast and other regions for significant floating OSW development in coming years.

To facilitate the sustainable deployment of OSW, the program will help fill data gaps associated with OSW siting, environmental impact assessment, minimization, and mitigation. First-generation OSW projects will provide data on issues causing permitting uncertainty and risks for the first U.S. OSW projects, including questions regarding impacts on marine mammals and 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 OSW development. The subprogram will focus research on developing and validating 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 continued innovation of tools to minimize impacts of construction noise on protected species.

WETO will collaborate with the interagency Wind Turbine Radar Interference Mitigation Working Group to characterize and address the unique impacts of OSW development on critical agency missions and operations, which are less understood than the impacts of land-based wind plants. Efforts will focus on both leveraging work in the land-based wind space for radar systems that will likely be impacted by both land-based and OSW development, such as long-range air surveillance radars, and on work focused on systems where OSW is likely to have a greater effect, such as coastal high-frequency systems for ocean wave and current measurement, and marine navigation radars. Activities will include modeling and field testing and evaluation to characterize wind turbine interference and develop and deploy mitigation measures to increase the resilience of existing radar systems to OSW turbines, with a particular focus on high-Technology Readiness Level (TRL) development and deployment of mitigation technologies; and continuing interagency engagement to encourage development of next-generation radar systems that are resistant to interference from wind turbines.

Finally, this activity will support social science and socioeconomic research to understand impacts of wind energy on communities and ocean co-users and provide technical assistance to communities considering OSW development. Research will aid in the understanding of impacts of OSW development on communities and ocean co-users and allow for strategies that reduce impacts and increase environmental justice for wind energy development. In coordination with EERE offices supporting energy technologies deployed in the ocean, WETO will design programming to ensure communities have access to objective information regarding the benefits and costs of OSW energy development. Activities will aid in proactive, place-based community engagement and planning processes that include consideration of OSW energy development, in the context of broader energy options, to both ensure that wind development works for communities and increase siting certainty for future development.

<u>STEM and Workforce Development</u>: Growth of the American OSW industry has the potential to provide tens of thousands of well-paying, union-eligible job opportunities by 2030. Ensuring there is a well-trained and ready workforce available to meet those jobs requires new training and education programs to prepare workers with applicable skills and knowledge. Workforce education and training needs will be linked to the growth of the industry. WETO will support OSW STEM and workforce development activities, including national-scale analyses to systematically identify future workforce needs, university engagement and other programming to catalyze solutions to those needs, and efforts to convene industry and educational institutions to develop workforce development solutions. WETO will increase support for the development of OSW curriculum, fellowships, and internships at universities and colleges, with a strong emphasis on ensuring the diversity of the future OSW workforce.

Offshore Wind

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Offshore Wind $63,200,000	**$197,792,000**	**+$134,592,000**
Science & Technology Innovation $27,166,000	$108,032,000	+$80,866,000
• Support for offshore wind energy technology demonstration projects to advance offshore wind development by demonstrating innovative technologies not previously commercially used in the United States for offshore wind.	• Continued support for offshore wind energy technology demonstration projects to advance offshore wind development by demonstrating innovative technologies not previously commercially used in the United States for offshore wind with emphasis on new component demonstrations.	• No significant change.
• Continue DOE National Laboratories' support of offshore wind resource characterization and forecasting. No funding is requested for new competitively selected projects.	• The Request includes funding for National Laboratory work that will leverage existing core capabilities and facilities available through the National Laboratory network. Targeted research areas include offshore wind resource characterization and forecasting.	• Increase will support the start of a field campaign to characterize offshore marine boundary layer physics.
• Deploy lidar buoys off the coast of California in conjunction with the Bureau of Ocean Energy Management to characterize the wind energy resource. Analyze current and previous buoy data to develop improved air-sea interaction physics governing the variation of the winds and improve numerical weather prediction models.	• Deploy a buoy off the coast of Hawaii in conjunction with the Bureau of Ocean Energy Management to characterize the wind energy resource and inform potential future leases. Integrate new buoy instrumentation in support of OSW Resource Sciences campaign. Begin buoy preparations for the first major OSW measurement and validation campaign on the East Coast to develop reliable resource forecasts and design basis data.	• Increase will support additional buoy deployments. California buoy deployment completed; one buoy will be redeployed to Hawaii to develop improved resource forecasting and design basis data for that region.
• Support National Laboratory-led projects to advance fully-coupled turbine/foundation engineering design tools for fixed-bottom and floating foundations.	• Advance fully-coupled turbine/foundation engineering design tools for fixed-bottom and floating foundations.	• No significant change.
• New effort in Offshore Integrated Systems Engineering to develop analysis and research capability to improve system-level performance	• Expanding upon existing Offshore Integrated Systems Engineering efforts to develop analysis and research capability to improve system-level	• Extend design tools to support model-based turbine/mooring/cabling layout optimization,

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
and achieve system-level cost reductions. The effort incorporates advances in computational algorithms, simulation methods, physics-based improvements, cost and performance modules to assess new technology opportunities and advance the state-of-the-art, and best practices in multidisciplinary design analysis and optimization (MDAO) for wind energy applications.	performance and achieve system-level cost reductions. The effort incorporates advances in computational algorithms, simulation methods, physics-based improvements, cost and performance modules to assess new technology opportunities and advance the state-of-the-art, and best practices in multidisciplinary design analysis and optimization (MDAO) for wind energy applications.	array-wide mooring/cabling design, and array-level performance optimization.
• Fixed foundation farm-level control design and physics understanding associated with wake steering and hybrids.	• Expansion of Floating Platform Innovation & Industrialization and Floating Platform Sensitivity analyses. Develop designs suitable for U.S. manufacturing facilities, decrease costs of floating platforms, and provide seed funding for improvements until bulk orders are available.	• Increased funding to exploit FY2022 efforts which identified platform and facility concept designs to enable mass domestic production of floating platforms. The additional effort will allow continued development of floating platforms industrialization technologies and begin risk reduction efforts of key technologies identified by FY22 efforts.
• No significant efforts.	• Advanced planning and design for expansion of existing test facilities to handle 20MW+ class turbines (blade, drivetrain) and for other offshore test facilities (such as hybrid OSW/hydrogen, offshore research, and offshore structures).	• Increase initiates a new effort to define future test facilities needs and requirements for OSW
• Support National Laboratory led project to develop OSW full-farm controller using consensus control methodology.	• Continue efforts to develop OSW full-farm controller using consensus control methodology.	• No significant change.
• Fixed foundation farm-level control design and physics understanding associated with wake steering and hybrids.	• Expansion of Floating Platform Controls & Hydro/Aerodynamics with focus on advanced flow measurement, increased degrees of freedom & high-Reynolds number aerodynamics for performance and load predictions	• Increase will support expanded efforts to develop controls optimized for floating applications as part of FORWARD.
• No significant efforts.	• Develop, test, and demonstrate large-component replacement techniques including innovative crane concepts, vessel concepts, and process concepts (e.g., tow-in to port). Traditional approaches to accomplish large-component replacement (e.g. turbine blades or generators)	• Increase initiates a new program under FORWARD.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
	are infeasible for floating platforms in the open ocean because the turbine is moving as well as the maintenance vessel. New techniques or technologies need to be developed which allow for safe and reliable replacement	
• No significant efforts.	• Establishment of an Anchoring & Mooring Development effort to demonstrate new concepts applicable to deep-water locations at scale. Approximately 60% of the US OSW resource is in deep waters suitable for floating platforms (>60m). Anchoring & mooring technology for wind needs to significantly cheaper than that employed in other industries. This is especially true in very deep waters (>600m) found off the West Coast.	• Increase initiates a new program under the Floating Earth Shot (FORWARD).
• No significant efforts.	• Floating Platform Industrialization development, testing, and demonstration. Floating platform development efforts to date have focused on one-off demonstrations. Building and deploying platforms in large quantities requires industrialization efforts to modify designs and processes.	• Increase initiates a new program under the Floating Earth Shot (FORWARD).
• No significant efforts.	• Advanced planning for an OSW atmospheric sciences validation campaign on the Pacific coast.	• Increase initiates a new program under the Floating Earth Shot (FORWARD) to greatly expand the scientific knowledge and forecast modeling capability for the Pacific coast wind resource.
• No significant efforts.	• Establishment of Dynamic Cable development and test effort. Electrical cables that connect floating turbines to a collector point and the shore are subjected to cyclical motions induced by wind and waves. These motions cause significant recurring loads on the cables and dynamic cables need to be developed which can accommodate those loads cost effectively.	• Increase initiates a new program under the Floating Earth Shot (FORWARD).
Manufacturing and Materials R&D $23,640,000	$33,500,000	+$9,860,000

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
• No significant efforts	• Research effort to analyze existing available infrastructure for application to OSW manufacturing, assembly, logistics and port facilities. Anticipated outcome will identify required infrastructure upgrades necessary to enable OSW supply chain development.	• Increase will identify manufacturing and infrastructure needs, gaps, and methods of filling those gaps.
• No significant efforts	• Expansion of Operations & Maintenance Research to increase the technological maturity of advanced inspection, maintenance, and repair techniques.	• Increase will support expanding O&M efforts with the goal of increasing safety, increasing turbine availability, and decreasing cost, specifically by developing O&M technologies that reduce personnel actions at-sea and increase the range of sea states during which maintenance actions may be achieved (as part of FORWARD).
• No significant efforts.	• Emphasized Advanced materials and manufacturing R&D to reduce full lifecycle costs and accelerate blade/tower/nacelle factory throughput. 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.	• Increase will support a new floating platform effort aimed at increasing their size and designing common components for high-volume manufacturing.
• No significant efforts.	• Wind Re-design for Recycling: Emphasize recycling for existing components and re-design for future components; novel materials and manufacturing ("design for recycling") to extend life and make it economically more cost effective to recycle in the future. Goals include reducing demand for critical materials in wind turbines.	• Increased funding with a focus on new materials and design approaches to reduce reliance on critical minerals.
• Continue the manufacturing and additive design of electric machines enabled by three-dimensional printing (MADE3D) project to additively manufacture every part of the generator including the coils/windings, electrical insulation, stator/rotor, magnetic core packs and	• Manufacturing and additive design of electric machines enabled by three-dimensional printing (MADE3D) project to additively manufacture every part of the generator. A kW-scale generator will be fabricated using the multi-material manufacturing suite and a detailed performance	• Continued funding at current levels with a focus on prototype fabrication and validation.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
permanent magnets, structural/mechanical and thermal management components and enabling new design degrees of freedom in terms of shape complexities and materials not previously available.	test and validation will be conducted. Project concludes in FY 2023.	
• Continue 3D Printed Blade Core Material project to design and manufacture a 3D printed blade core structure which outperforms current solutions in terms of strength, stiffness, mass, cost, and durability.	• Manufacture and test full scale 3D printed blade cores for static structural strength. Project concludes in FY2023.	• No significant change.
• Support for National Laboratory research to develop improved carbon fiber material mechanical properties using non-circular, hollow fibers with larger surface areas (for bonding) and larger inertia for bending and buckling resistance.	• No funding requested.	• Scope of work completed, and the project concluded in FY2022
• Building on FY 2020 activities, initiate National Laboratory led analytical studies for additive design and feasibility of prospective additive processes.	• No funding requested.	• Analytical study was completed in FY 2021
• FOA award down-select to build and test a prototype of a high-efficiency, ultra-light low temperature superconducting generator (SCG) on a wind turbine.	• No funding requested.	• Fully funded in FY 2021. The prototype test is expected to start in late FY 2023 or early FY 2024 and all required funding has been provided.
Environmental and Siting R&D $11,282,000	$38,260,000	+$26,978,000
• OSW environmental research and instrumentation validation FOA to increase understanding of environmental impacts of OSW, as well as projects that advance and validate tools to monitor and minimize impacts.	• Research on siting environmental impacts of floating and fixed-bottom OSW projects.	• No significant change.
• 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, including support for validation of monitoring tools capable of being deployed on buoys to lower baseline data collection costs and provide more robust baseline and post-construction data.	• Increased focus on validation of autonomous monitoring capabilities for areas where there are current performance gaps.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
• Continue international research sharing and dissemination through IEA Wind Energy Task 34 (WREN) and the Tethys database.	• Continue international research sharing and dissemination through IEA Wind Energy Task 34 (WREN) and the Tethys database.	• No significant change.
• Co-fund National Laboratory research and development to address wind/radar challenges unique to OSW and facilitate the definition of next-generation radar requirements and technology development with industry partners. Key funded partnerships with Department of Defense (DOD), Department of Homeland Security (DHS), Department of Transportation (DOT), Department of the Interior (DOI) and Department of Commerce (DOC).	• Address wind/radar challenges associated with radar systems of mutual interest to land-based and OSW, while continuing to build understanding of impacts unique to OSW. Continue to facilitate the definition of next-generation radar requirements. Key partnerships with DOD, DHS, DOT, DOI and DOC.	• Increased emphasis on final development and radar agencies to develop mitigation measures for their systems.
• Maintain WINDExchange to ensure use of the best available science to support wind energy policy and deployment decisions.	• Maintain WINDExchange, to ensure use of the best available science-based technical, economic, and development information to support wind energy policy and deployment decisions.	• Increased focus on partnerships to maximize the dissemination of national and technical information.
• No significant efforts.	• Provide local and regional technical assistance and knowledge sharing to coastal communities considering OSW development to ensure access to science-based information during planning processes. Expand collaboration with NOAA National Sea Grant Program and other community organizations to support regional or state-level engagement with ocean users.	• Develop a community engagement network to provide science-based information, user tools, and other informational and decision-making resources to coastal communities considering OSW.
• No significant efforts.	• Support research on social and socioeconomic impacts of wind energy on communities to support project permitting and identify ways to make wind development work more effectively for coastal communities and ocean users, through expanded collaboration with NOAA National Sea Grant Program.	• Expand on collaboration initiated on a pilot basis in FY 2022.
• Continue support for the National Wind Turbine Database and research on community impacts.	• Continue support for the National Wind Turbine Database to provide authoritative geospatial data on wind deployment to support project permitting and inform research on wind impacts.	• No significant change.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
STEM and Workforce Development $1,112,000	$18,000,000	+$16,888,000
• Support for the Collegiate Wind Competition (CWC), an annual event that challenges teams of undergraduate students to develop solutions to complex wind energy projects.	• Support the Collegiate Wind Competition (CWC), an annual event that challenges teams of undergraduate students to develop solutions to complex wind energy projects, as well as other OSW STEM educational opportunities.	• Broaden the CWC to include an OSW focus. including an emphasis on ensuring diversity of the future OSW workforce. Develop workforce training programs in collaboration with states and labor organizations.
• No significant effort.	• Initiate programs to increase OSW curriculum, fellowships, and internships at universities and colleges, including an emphasis on ensuring diversity of the future OSW workforce.	• The increase will support the first year of funding for this investment to help create a solid pathway for more diverse professionals in clean energy industries.
• No significant effort.	• Initiate national-scale analyses to systematically identify future workforce needs and programming to catalyze solutions to those needs.	• The Increase will support more detailed understanding of OSW workforce needs to help target program investments in workforce development.
• Support National OSW Workforce Development Roadmap and Network.	• Support the National OSW Workforce Development Roadmap and Network which supports analysis of workforce development needs and convenes a network of relevant stakeholders to meet those needs.	• No significant change.

Wind Energy
Land-Based Wind

Description

The Land-Based Wind subprogram emphasizes efforts to reduce the cost of wind energy to enable nationwide cost-competitiveness and to develop siting and environmental solutions to accelerate land-based wind energy development, comprising most of the country's wind resource. Rotor blade innovation in support of "Tall Wind" turbine technology is motivated by economies of scale. The quality of the wind resource (e.g., wind speed, wind shear, and wind profile) varies significantly based on location, but is almost uniformly better at higher heights above the ground. Key opportunities include taller towers with larger generators, longer blades, and larger rotor diameters, which all lead to greater energy capture and lower cost per unit of energy output and represent significant opportunities for cost reduction, as well as opportunities for domestic manufacturing in support of Buy American and well-paying jobs with the option to join a union.

Through these efforts, the subprogram seeks to reduce the levelized cost of energy (LCOE) for land-based wind from a 2015 benchmark of $.06/kWh to $.02/kWh, without subsidies, by 2030. Achieving this 2030 goal would represent a 50 percent reduction from today's LCOE and make wind electricity cost-competitive nationwide.

Science and Technology Innovation: The approach to achieving the Wind Program's LCOE goal is to address the highest cost-contributing elements of today's land-based wind technology and operations and significantly reduce them through science, research, and innovation. 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 activity will shift focus to executing field experiments to validate the physics knowledge and design tools developed under the Atmosphere to Electrons (A2e) project.

Manufacturing and Materials: 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. Very long, highly flexible blades 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. They also allow wind plants to operate at a higher capacity factor, with less variability in power production.

The activity will focus efforts on research to recover critical minerals from wind turbine components. The activity will also advance materials science, developing technology to mitigate bearing and gear failures through advanced lubricants, composite materials, and metallic coatings that are resistant to damage in operating conditions that benefit both land-based and OSW applications.

Environmental and Siting: Meeting the President's climate goals will likely require deployment of land-based wind on a scale and at a pace not seen in the U.S. to date. Such development will require focused and concerted investments in addressing the associated siting and environmental challenges that will increase in scale and import as deployment accelerates. This activity focuses on the development of solutions, impact mitigation, and enabling the efficient siting and operation of land-based wind facilities. WETO's approach is to identify and focus on the highest-priority siting concerns, which are primarily related to wildlife, radar interference, and communities.

The activity will focus on developing solutions for environmental impacts of land-based wind by supporting research that informs siting decisions. Characterization of impacts will be used in the development of mitigation tools and technologies, and further research will focus on evaluating and addressing impacts on wildlife, including bats, eagles, and grouse species. Building off earlier foundational investments relating to bat impact characterization and mitigation tool development, FY 2023 bat projects will take parallel paths to validate near-commercial solutions across a broad species and geographic range to enable viable, accepted, and cost-effective bat impact minimization solutions for any given wind plant location in the U.S. Additionally, there is increasing interest in wind energy development in the sagebrush (western) region of the U.S, on both public and private lands. However, many areas that are promising for wind energy development overlap with prairie grouse habitat, such as the greater sage grouse as well as greater and lesser prairie chicken. This activity will accelerate its research effort to characterize prairie grouse behavior around wind energy facilities to inform siting of wind plants in these wind-rich areas. Ultimately these research findings could be used to inform policies and practices regarding wind development on grouse habitat and could provide developers the tools to minimize and offset impacts to aid future development. This increase in emphasis on grouse augments prior-year investments in bat and eagle research and solution development.

Through this activity, WETO will collaborate with other agencies through the interagency Wind Turbine Radar Interference Mitigation Working Group to address the impacts of land-based wind development on air surveillance and weather radar missions. Activities will include modeling and field testing and evaluation to characterize wind turbine interference to develop and deploy high-TRL mitigation technologies to increase the resilience of existing radar systems to wind turbines. WETO will continue interagency engagement to encourage development of next-generation radar systems that are resistant to interference from wind turbines.

Finally, this activity will support social science and socioeconomic research to understand impacts of wind energy on communities and provide technical assistance to communities considering land-based wind development. Research will aid in the understanding of impacts of wind development on neighbors and communities and enable innovation for siting and participatory outcomes that reduce impacts and promote equitable outcomes for wind energy development. WETO will also continue support for WINDExchange, the online database of technical, economic, and development information and data, which provides key access to wind energy information. In coordination with other land-based renewable energy offices, including EERE's Solar Energy Technologies Office, WETO will support proactive technical assistance and support to help communities overcome barriers to siting wind and other renewable energy. Through this activity, WETO will also provide technical assistance to States interested in developing state-level programs that help local governments understand and manage renewable energy siting in their communities. Such programming will help to provide critical siting information and increase siting certainty for future development.

<u>STEM and Workforce Development</u>: Wind energy provides significant domestic job opportunities and the rapid development of additional, substantial wind energy integral to achieving the President's energy targets will provide substantially more. New education programs, like university fellowships, to prepare workers with applicable skills and knowledge require a well-trained and ready workforce available to meet these jobs. To target workforce development programming, there's a need to understand both the patterns of development driven by the President's energy targets, as well as potential gaps in educational and training programs. This activity will support STEM and workforce development activities, including national scale analyses to systematically identify future workforce needs, programming to catalyze solutions to those needs, and efforts to convene industry and educational institutions to develop workforce development solutions. The work will also place a strong emphasis on ensuring the diversity, inclusion, equity, and accessibility of the future land-based wind workforce.

Land-Based Wind

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Land-Based Wind $31,800,000	**$77,848,000**	**+$46,048,000**
Science & Technology Innovation $21,611,000	$11,407,000	-$10,204,000
• Support to maintain mission readiness and operational expertise of DOE's specialized research facilities and capabilities at the NREL Flatirons Campus and Sandia Scaled Wind Farm Technology (SWiFT) facility.	• Maintain mission readiness and operational expertise of DOE's specialized research facilities and capabilities for the NREL National Wind Technology Center at Flatirons and Sandia Scaled Wind Farm Technology (SWiFT) facility.	• No significant change
• 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.	• Conclude the AWAKEN field campaign and demobilize instrumentation. In the next phase of the project data collected during the field campaign will be analyzed and used for numerical model validation.	• Maintain funding level. Initial validation studies of observations from field will be completed.
• Continue the A2e atmospheric science research to develop, test, refine, validate, and disseminate specific mesoscale to microscale coupling strategies and technologies as well as provide basic research results and enable low order modeling to support new high-performance-computing-based multiscale wind plant simulation tools that couple a broad range of scales.	• No funding requested.	• Scope of project has been completed and work concluded in FY 2022. Funding priority under land-based wind shifted to Environmental and Siting R&D.
• Continue the A2e High-fidelity modeling (HFM) and simulation development, ExaWind, to dramatically improve the understanding of the fundamental physics governing whole wind plant performance, including wake formation, complex-terrain impacts, and turbine-turbine-wake interaction.	• No funding requested.	• Scope of project has been completed and work concluded in FY 2022. Future HFM efforts moved to Offshore subprogram. Funding priority under land-based wind shifted to Environmental and Siting R&D.
• Continue A2e Rotor Wake Measurements & Predictions for Validation efforts to enable the validation of cross-application simulation tools in the context of wind turbine and plant modeling, and to further our understanding of wind turbine flow physics and wake management.	• The Rotor Aerodynamics Aeroelastics, and Wake (RAAW) experiment will conclude. Validation of high- and mid-fidelity numerical aerodynamic and wake models will be completed using the data gathered. The RAAW experiment is focused on the inflow, turbine response, and the resulting	• Focus on validation of cross-application simulation tools in the context of wind turbine and plant modeling, and to further our understanding of wind turbine flow physics and wake management.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
	wake and the results will be used to inform the AWAKEN field campaign.	
• 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.	• No funding requested.	• Scope of project has been completed. Funding priority under land-based wind shifted to Environmental and Siting R&D.
• High Fidelity Modeling Toolkit project augments the ExaWind capabilities developed under the high-fidelity modeling effort to include a multi-fidelity approach for wind characterization and allow it to specifically address problems related to farm blockage and site/pad-level wind variations.	• No funding requested.	• Scope of project has been completed Funding priority under land-based wind shifted to Environmental and Siting R&D.
• Continue the A2e Integrated Systems Design and Analysis – Systems Engineering and Optimization (ISDA-SEO) initiative to develop analysis and research capability to improve system-level performance and achieve system-level cost reductions. The effort incorporates advances in computational algorithms, simulation methods, physics-based improvements, cost and performance modules to assess new technology opportunities and advance the state-of-the-art, and best practices in MDAO for wind energy applications.	• No funding requested	• Systems Engineering efforts moved to Offshore Wind subprogram.
Manufacturing and Materials R&D $3,112,000	$6,500,000	+$3,388,000
• Build upon previous National Laboratory activities and advanced materials science research on quantifying the effect of numerous contact conditions as well as the effectiveness of potential mitigation methods on white etching cracks failures in bearings and gears.	• Continue to investigate the effects of stray electrical currents on white etching cracks failures in bearings and gears, and initiate new research focused on material characterization of main bearing and pitch bearing failures.	• New research focus toward the material characterization of main bearing and pitch bearing failures in order to address the predominant failure modes which are not accounted for in design standards, not attributable to material deficiencies nor manufacturing quality control, are complex in nature and generally independent of specific component suppliers.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
• Support for National Laboratory led Big Adaptive Rotor (BAR) 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.	• Continue Big Adaptive Rotor (BAR)program support. Field experiments to demonstrate the design concepts and collect validation data for the new suite of advanced non-linear engineering design tools necessary for aeroelastic analysis of very flexible blades including loads and stability analysis will be conducted.	• Maintain funding level. Focus of the project will evolve toward field experiments to validate technoeconomic analyses of the concepts and design tools developed in FY 2022.
• Design, implementation, and validation of fusion joining of thermoplastic composites applied to wind turbine blades.	• No funding requested.	• Project completed. Funding priority under land-based wind shifted to Environmental and Siting R&D.
Environmental and Siting R&D $5,961,000	$47,941,000	+$41,980,000
• Build upon National Laboratory research to characterize the environmental performance of 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.	• Conduct research to understand the behavioral drivers of bat collision risk to improve efficacy of existing technologies, expand validation efforts across species and geographies to increase consumer confidence and support the development of novel solutions.	This is an enhanced effort that expands focus to bat behavior and further technology validation across species and technologies.
• Development and validation of environmental monitoring and mitigation technologies, with an emphasis on developing and optimizing bat monitoring and deterrent technologies.	• Applying research findings to large-scale field studies to test and validate improvements to deterrent and curtailment technologies across a range of geographies and bat species.	• Increase will shift focus to field validation and commercialization of mitigation technologies across geographies, turbine models, and species.
• No significant effort.	• Research impacts and evaluating impact mitigation options related to prairie grouse species Grouse represent a growing deployment barrier as there is significant uncertainty about the nature and scope of grouse impacts from wind facilities. Grouse-wind interactions are of growing concern given the potential listing of the lesser prairie chicken under ESA, and the Administration’s goal to expand wind energy on BLM lands (which include the majority of remaining sage grouse habitat).	• This is a new effort to be initiated in FY 23. and more informed permitting decisions
• Continue international research sharing and dissemination through IEA Wind Energy Task 34 (WREN) and the Tethys database, including	• Continue international research sharing and dissemination through IEA Wind Energy Task 34 (WREN) and the Tethys database.	• No significant change

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
population of a wind impact mitigation tools database.		
• 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.	• Develop and deploy wind turbine radar interference mitigation for both land based and OSW. In partnership with DOD, DHS, DOT, DOI and DOC, test and validate one or more mitigation measures at a radar site where the mission is currently impacted by wind turbine interference.	• Increased funding shifts emphasis to final validation and deployment of mitigation technologies.
• Maintain WINDExchange to ensure use of the best available science based technical, economic, and development information to support wind energy policy and deployment decisions.	• Maintain WINDExchange to ensure use of the best available science based technical, economic, and development information to support wind energy policy and deployment decisions.	• Increased funding to focus on partnerships to maximize the dissemination of national and technical information.
• No significant efforts.	• Technical assistance and support to help communities overcome barriers to siting wind and other renewable energy. Provide funding and technical assistance to States interested in developing state and local government programs to understand, share experiences, and manage renewable energy siting in their communities.	• New effort to help develop frameworks, resources, and user tools to share among states and tailor to meet state and local regulations, laws, and processes.
• Continue support for research on community impacts.	• Expand research on impacts of wind development on wind farm neighbors with an emphasis to innovate siting and participatory outcomes to promote greater equity and benefits from wind energy development especially for disadvantaged communities.	• Funding increased and focus shifted to emphasize understanding of wind's effects in disadvantaged communities.
• Support for the National Wind Turbine Database.	• No funding requested	• Continued work under Offshore subprogram.
STEM and Information Resources $1,116,000	$12,000,000	+$10,884,000
• Support for the Wind for Schools (WFS) project.	• No funding requested	• Transfer funding of WFS to non-profit entity established for this purpose through an FY 2016 National Renewable Energy Lab Request for Proposals.
• Continue support for the Collegiate Wind Competition (CWC), KidWind, and the North American Wind Energy Academy.	• Support the Collegiate Wind Competition (CWC), an annual event that challenges teams of undergraduate students to develop solutions to complex wind energy projects, as well as other OSW STEM educational opportunities such as	• Expand CWC to include part-time support for associated faculty and staff.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
	KidWind, and the North American Wind Energy Academy.	
• No significant effort.	• Identify future workforce needs, programming solutions for those needs, and opportunities to convene industry and educational institutions to develop workforce development solutions.	• New effort will help meet the future workforce needs of the industry.
• No significant effort.	• Support for new wind energy fellowships and internships, with an emphasis on promoting diversity in the future wind workforce.	• New effort will help meet the current workforce needs of the industry including the need for diversity and equitable inclusion.

Wind Energy
Distributed Wind

Description
The Distributed Wind subprogram focuses on achieving breakthroughs in reducing the levelized cost of energy (LCOE) from $.09/kWh today to $0.05/kWh for a reference 100-kilowatt system. Achieving this goal would enable distributed wind to cost-effectively complement and integrate with other distributed energy resources (DERs), such as solar PV and storage, in hybrid plants and microgrids. The subprogram invests in activities to reduce soft costs (i.e., permitting and interconnection processes); increase system power production and grid support capabilities; improve decision support tools for distributed wind project and decarbonization planning and execution; and test next generation technology to national standards to verify performance and safety. Activities to reduce high-cost market barriers, such as permitting and interconnection, will provide targeted technical assistance to support rural, disadvantaged, and isolated communities with planning for decarbonization and evaluating the opportunities and benefits of standalone and hybrid distributed wind energy systems.

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

Testing and Reliability: This activity supports efforts for distributed wind that will support U.S. small and medium wind turbine manufacturers through the Competitiveness Improvement Project to reduce turbine costs, improve system performance and grid support capabilities, and test turbine designs and balance of plant components to national and international safety and performance standards to achieve certification. Efforts will also include U.S. and international stakeholder engagement to improve and harmonize national and international wind turbine performance and safety standards to ease export market access.

Balance of Systems: This activity will focus support on reducing capital costs through standardization of project assessment, permitting, interconnection, system design, and installation of distributed wind systems. New efforts under this activity will include crosscutting EERE grid integration activities for DERs including Communities to Clean Energy (C2C), enhancing DER aggregation into grid system operations, and demonstrating resilience to underserved communities through microgrids powered by renewable DERs. This new crosscutting work aligns with grid activities across EERE and OE necessary to enable a just transition to a grid that supports a decarbonized power system by 2035 and a net-zero-emission economy by 2050 while maintaining the reliability, affordability, security, and resilience of the energy system. The activity will also continue to fund R&D that enhances the capabilities of wind technology, as distributed energy resource, to provide valued grid support services. Efforts will also focus on accurately representing the capabilities and value of wind as a DER in decision-support tools and providing technical assistance to communities and industries transitioning to carbon free energy sources.

Distributed Wind

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Distributed Wind $10,000,000	**$17,750,000**	**+$7,750,000**
Science and Technology Innovation $3,238,000	$4,000,000	+$762,000
• Tools Assessing Performance (TAP) 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.	• No funding requested	• The Tools Assessing Performance project will be completed in FY 2022.
• No significant efforts	• New work will build on prior year efforts under the Tools Assessing Performance project by refining and integrating validated wind resource models and datasets with lab based and commercially available opportunity assessment and decision support tools.	• As Tools Assessing Performance project ramps down, shift in emphasis to from early-stage R&D to refinement of models and datasets and integration with user facing tools decision support tools.
• Defense and Disaster Deployable Turbine work will complete design guideline and model procurement specifications for military applications.	• No new funding requested	• The Defense and Disaster Deployable Turbine project will be completed in FY 2022.
• No significant efforts under Science & Technology Innovation. Previously completed efforts under Testing & Reliability.	• New techno-economic and deployment scenario analysis to resolve promising high impact opportunities for cost reduction and deployment acceleration. Work will include data collection, analysis, and model development which are critical for accurately representing wind technology as a distributed energy resource in decision support tools used by state energy offices, communities, utilities, financiers, project developers, and other stakeholders.	• Increased funding will focus on addressing gaps in data collection, modeling megawatt scale wind technology as DERs, and representing energy equity and environmental justice considerations as related to distributed wind deployment in decision support tools.
Testing & Reliability $4,273,000	$6,750,000	+$2,477,000
• Support for the Competitiveness Improvement Project (CIP) to reduce turbine costs, improve performance and grid support capabilities, and	• Continue Competitiveness Improvement Project with 2023 Request for Proposals to reduce small and medium scale wind turbine costs, improve	• No significant change.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
test designs to national safety and performance standards for achieving certification.	small and medium scale turbine performance and grid support capabilities, and test designs to national safety and performance standards for achieving certification. Efforts to advance small and medium scale wind turbine designs will enable wind technology, as a distributed energy resource, to provide onsite and community-based carbon-free power solutions.	
• Strategic and technical analysis and engagement activities in support of distributed wind R&D to increase the economic and technical viability of distributed wind energy installations.	• Continue strategic and technical engagement activities in inform distributed wind R&D, increase the economic and technical viability of distributed wind energy systems, and increase understanding for equitably and justly accelerating deployment.	• The increase supports a new focus on engagement to better resolve opportunities to equitably and justly expand market opportunities and access to distributed wind systems. Data collection, modeling & analysis work has moved under Science and Technology Innovation.
Balance of System R&D $2,387,000	$7,000,000	+$4,613,000
• Microgrids, Infrastructure Resilience, and Advanced Controls Launchpad (MIRACL) work develops advanced system control capabilities for enhanced resilience and grid support and improves modeling and valuation tools.	• No funding requested	• Microgrids, Infrastructure Resilience, and Advanced Controls Launchpad work will be completed in FY 2022.
• No significant efforts.	• New work will build on prior year efforts under the Microgrids, Infrastructure Resilience, and Advanced Controls Launchpad project by supporting development and demonstration of advanced power electronics, controls, and monitoring for wind hybrid plants and microgrids applications.	• As the Microgrids, Infrastructure Resilience, and Advanced Controls Launchpad project ramps down, shift in emphasis from early-stage research to development and demonstration.
• No significant efforts.	• Launch Wind Innovations for Rural Economic Development (WIRED) Networks to support the development of permitting and interconnection best practices for wind and wind hybrid projects, new business models, and other work to reduce soft costs and overcome barriers to wind deployment in rural communities.	• Shift in focus to providing technical assistance to new FOA awardees.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
• No significant efforts.	• New funding to support the expansion and inclusion of wind in the EERE-funded Energy Transitions Initiative Partnership Project (ETIPP).	• Support expansion of EERE-led National Laboratory technical assistance program to remote communities to aid in energy transition planning and implementation.
• No significant efforts.	• New funding will enable WETO to contribute to EERE cross-cutting projects providing communities and electric utilities with technical assistance for development and implementation 100 percent clean power plans, development of business and regulatory models that enable markets to incentivize zero carbon distributed energy resources, and demonstration zero carbon distributed energy resources providing reliable and resilient power in microgrids for remote and isolated communities.	• The increase supports this new crosscutting work, which aligns with grid activities across EERE and OE. The activities are critical to enable a just transition to a grid that supports a decarbonized power system by 2035 and a net-zero-emission economy by 2050 while maintaining the reliability, affordability, security, and resilience of the energy system.
STEM and Information Resources $102,000	$0	-$102,000
• Maintain WINDExchange to ensure use of the best available science to support wind energy policy and deployment decisions.	• No funding requested.	• Funded under the Land-Based and OSW Environmental & Siting R&D.

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. The subprogram aims 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 ensure cost-effective and reliable transmission access for wind energy deployment at scale, maintain and increase grid reliability and resilience through the provision of grid services from wind and wind-hybrid systems, address wind-specific cybersecurity needs, and improve the understanding of electricity market operation with high penetrations of wind energy.

Considerations for wind energy systems integration include:

- Increased Variability and Uncertainty: The future generation mix is anticipated to have higher shares of variable generation sources, including wind. Changes in energy demand due to increasing electrification are also anticipated. The combined variability and uncertainties from both generation and load require wind and wind hybrid systems to be designed to provide more system flexibility.
- Growing Demand for Increased Grid Reliability and Resiliency Capabilities: Wind power and many energy storage options are connected to the grid through inverters. These inverter-based resources respond differently to grid balancing requirements and disturbances than conventional synchronous generators and interact rapidly with other renewable generation systems' power electronics.
- Demand for Transmission Adequacy and Flexibility: wind deployment at scale require cost-effective transmission access to deliver the wind energy to the end users. Facilitating collaborative, long-term transmission planning can increase the certainty and pace of wind deployment. Transmission capacity can also be effectively utilized through a set of grid-enhancing technologies.
- Cybersecurity: Virtually all modern sources of power depend on integrated control systems, data, monitoring, communications, and related technologies, whose security has become increasingly important. Wind energy cybersecurity will need to be strengthened to ensure a cyber-secure energy system today and in the future.

Transmission constraints, including both land-based interconnections and transmission and offshore transmission, is one of the central challenges to achieving the Administration's OSW deployment goals of 30 GW by 2030 and 110 GW by 2050. For example, existing cable routes, landing points, and points of interconnection will quickly be exhausted if current project-by-project process continues. Major onshore transmission upgrades are also likely. To maximize the value of OSW while minimizing environmental and community impacts, comprehensive and proactive transmission analysis across multiple projects, states, transmission planning regions is critical to evaluate transmission options for both near- and long-term OSW energy deployment. Further advancements in cost-effective and reliable offshore transmission technologies, especially for floating offshore that connects through high voltage direct current transmission lines, requires additional R&D. Maintaining a reliable and resilient power grid with significant amount of OSW is always a high priority.

<u>Grid Integration</u>: This activity aims to enable cost-effective, cyber-secure, reliable, and resilient operation of the energy system with increasing levels of wind in all regions. Progress in these areas will mitigate barriers to transmission access for offshore and land-based wind. With progress, advanced technologies will enable cost-effective wind hardware and controls that will be secure, enhanced, and transformed to provide a full range of grid services for reliable and resilient grid operation.

The subprogram aligns with grid activities across EERE and OE necessary to enable a just transition to a grid that supports a decarbonized power system by 2035 and a net-zero-emission economy by 2050 while maintaining the reliability, affordability, security, and resilience of the energy system.

Systems Integration

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Systems Integration $0 (Previously Grid Integration and Analysis > Grid Integration $3,517,000)	**$42,000,000**	**+$38,483,000**
• In support for cross-cutting Grid Modernization Initiative and Energy Storage Grand Challenge activities, continue the research and development in renewable hybrid energy storage systems and provide technical assistance to ISOs/RTOs.	• No funding requested.	• Project concludes in FY 2022.
• No significant effort	• Conduct a series of OSW transmission research and development to enable cost effective transmission access for OSW while maintaining reliable and resilient grid operation with large amount of OSW.	• Increase supports new planned activities, including OSW transmission analysis for broader coastal areas, transmission interconnection reform, subsea cable and HVDC technology advancement, and new models and tools to monitor and control OSW connected HVDC systems for grid reliability and resilience.
• No significant effort.	• Research and development to increase dispatchability of wind energy and improve wind power forecast for grid services.	• Increase supports initiating this R&D effort.
• Wind cybersecurity research to compare and evaluate various hardening mechanisms to secure wind power plant.	• Launch Wind CyberShield research initiative to systematically identify solutions that effectively address wind cybersecurity challenges and increase wind energy system's cybersecurity awareness, preparedness, and responsiveness.	• Increase will support activities that will focus on developing wind cybersecurity standards, further advance cyber protection and intrusion detection for wind plant and identifying effective mechanisms to secure wind supply chain.
• No significant effort.	• Co-fund Grid Enhancing Technologies (GETs) development demonstration in partnership with industry to accelerate industry adoption of GETs and unlock transmission capacity.	• Increase will support the expansion from single Grid Enhancing Technology to multiple GETs. Through analysis, tools development, and sensor installation, the project will demonstrate the effectiveness of GETs at different geographic regions with different market environment or transmission ownership.
• No significant effort.	• The Renewable Hybrid System initiative will fund partnerships with industry to include design and control development, analysis, and field	• Increase supports the joint effort with multiple DOE offices to prioritize broader hybrid system analysis, design, and control, which will lead to

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
	demonstration of hybrid systems involving combinations of technologies such as wind, hydropower, solar, battery storage, or hydrogen,	field demonstration that de-risk the industry adoption of renewable hybrid as grid service provider and renewable fuel producer.
• Develop and prototype grid forming control for wind.	• No funding requested.	• Fully funded in FY 2021.

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 offshore, land-based, 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. Subprogram activities of data collection, modeling, and tools development, and analysis collectively form an integrated and coherent information system, with an on-demand capability that is connected to ongoing and emerging trends. This work informs, guides, and enables the Wind Program to efficiently plan, prioritize, execute, and deliver on its research and innovation mission. Specific fiscal year 2023 priorities include:

- Continued and expanded collection and dissemination of data on wind technology cost and performance trends to support GPRA reporting, Energy Act of 2020 reporting, and other analytical efforts to inform stakeholders.
- Continued development of capabilities to evaluate the impacts of innovations in land-based, distributed, and OSW technologies, with a focus on supporting capabilities to assess wind-to-X and other hybrid applications, and the impacts of innovation in wind technologies at a high degree of spatial resolution.
- In collaboration with other EERE and DOE offices, expanded development of linkages between electricity system models and models of other energy production and use sectors.
- In collaboration with other EERE and DOE offices, expanded scenario analysis focusing on potential future wind contributions for deep decarbonization pathways across sectors and assessment of related impacts, including on land and ocean space use, impacts to wildlife, radar and communities, and the sensitivity of wind's contributions to decarbonization to different wind technology evolution pathways.

Data, Modeling and Analysis

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Data, Modeling, and Analysis $0 (Previously Grid Integration and Analysis > Analysis $1,483,000)	**$10,000,000**	**+$8,517,000**
Data, Modeling, and Analysis $1,483,000	$10,000,000	+$8,517,000
• Collect and disseminate data on wind technology cost and performance trends to support GPRA reporting, support other analytical efforts and inform stakeholders.	• Market data collection, analysis and reporting; including establishing technology baselines and industry benchmarks, tracking progress to goals and evaluating return on investment.	• Funding increase reflects a consolidation of activities from other subprograms into Data, Modeling, and Analysis. No significant change in scope.
• Develop and maintain capabilities to evaluate the impacts of innovation in land-based, distributed, and OSW technologies.	• Conduct techno-economic analysis; including impact evaluations of wind innovations, spatial and temporal supply curve analysis, decarbonization impacts analysis, and cost and performance analysis. Emphasis on assessing the impact of infrastructure investments and innovative operations and maintenance strategies in OSW and expanding land-based wind supply chain analysis.	• Funding increase reflects a consolidation of activities under other subprograms into Data, Modeling, and Analysis. Increase in analysis of infrastructure and maintenance innovations, and supply chain needs.
• Through collaboration with other Renewable Power offices, conduct electricity system analysis to better understand wind energy's role in the electricity system, both today in the future.	• Strategic wind energy futures analysis; including electric sector modeling, wind value to the grid for energy and grid services, and capacity expansion model development. Emphasis on developing linkages between electricity and other energy sector models to capture interactions between sectors in deep decarbonization scenarios, further developing spatial analysis capabilities to evaluate the impact of siting and land use constraints on wind's role in the electricity sector.	• Funding increase reflects a consolidation of activities under other subprograms into Data, Modeling, and Analysis. Increase in emphasis on capability development for evaluation of wind in decarbonization pathways and spatial analysis.

Water Power

Overview

The Water Power Technologies Office (WPTO) administers a broad portfolio of research activities to strengthen the body of technical knowledge and support industry efforts to develop and deploy new hydropower and marine energy technologies at all scales. These efforts are directly aligned with the Administration's goal of a carbon pollution-free electricity sector by 2035. America has vast marine energy and hydropower resources and there remains enormous potential to both expand into new markets and applications and to increase generation and flexibility across the nation's sizable hydropower and pumped storage fleet. Areas of opportunity include existing hydropower facilities and non-powered dams that can utilize new technologies to cost-effectively increase generation and flexibility; innovating on flexible and more rapidly deployable pumped energy storage systems; and advancing marine energy technology to support new and growing industries utilizing waves, currents, tides, and gradient differentials (ocean thermal, pressure, and salinity). The program supports applied research, development, demonstration, and deployment (RDD&D)-focused projects across industry, academia, and the National Laboratories through a wide variety of mechanisms and other innovative partnership approaches to accomplish its objectives.

Hydropower, which currently provides almost seven percent of the electricity on the Nation's grid, offers flexibility in both the short and long-term to support and complement variable renewable energy (VRE), and pumped storage systems are one of the most scalable, cost-effective, and long-lived grid-scale storage assets, both now and likely in the future. The pumped storage hydropower (PSH) fleet provides 22 gigawatts (GW) of capacity and 550 GW hours (GWh) of energy storage, making it by far the largest source of long-duration storage currently available. The Program's HydroWIRES (Water Innovation for a Resilient Electricity System) initiative invests in research and development (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 integrating additional VRE resources while maintaining a reliable and resilient grid. The program also supports DOE-wide Energy Storage investments to validate and demonstrate promising approaches to long-duration energy storage that can help provide the necessary flexibility to operate a high-renewables power system. This includes working closely with other EERE and DOE offices to refine storage performance metrics, validate technologies in the field, and develop new storage demonstration and pilot programs.

Marine energy, with its potential to provide power through precisely predictable tides and the large technical resources in waves, currents, and gradient differentials, offers both a future opportunity to supply electricity to a deeply decarbonized national grid and is a near-term solution for distributed energy for isolated and islanded communities, where marine energy might serve as the only viable substitute for fossil fuels. In addition, wave-powered desalination system, designed to harness the power of waves to produce potable water, holds promise to offer solution to water shortages for off-grid, coastal communities and in support of providing water to communities struck by natural disasters. However, marine energy technologies are still relatively nascent and face significant challenges in engineering and operations to fully unlock their potential at both small and large scales to provide power to centralized and decentralized grids.

In addition to its value to grid integration, water power has important benefits across multiple infrastructure sectors and to the people who depend on them. There are opportunities to evaluate how to harness and deliver water power, including through building more resilient infrastructure, providing power to produce clean water, unlocking the full potential of all ocean resources (Powering the Blue Economy or PBE), and better-aligning technology development with end-users and communities.

Community-centric development is an increasing emphasis of WPTO's work, particularly in the instances of remote, underserved, tribal, and/or isolated communities. These communities are deeply reliant on and connected to their water systems as part of their economy and culture. Recognizing and being respectful of these factors, WPTO endeavors to build connections to communities and the industries who use the technologies developed through the program's R&D. The program does this through leveraging the larger innovation ecosystem to support entrepreneurship and technology development, incorporating end-user requirements in solicitations, and by working with community-based organizations. Building on research in FY 2021 and FY 2022, WPTO will expand the Energy Transitions Initiative Partnership Project to include demonstrations with communities in hydro and marine energy and building on alternative values for hydropower beyond serving as power for the grid. This includes work to support irrigation modernization, working with municipal utilities and cooperatives to expand their ability to manage systems like storage and hybrid systems, and building out strategies to address multipurpose existing water infrastructure like dams. In FY 2023 the program will build out partnerships with local irrigation districts and municipalities to deploy digital planning tools developed in FY 2022 and initiating activities at multiple sites to demonstrate benefits including saving water, decreased pumping costs for farmers, decreased nutrient loading downstream, and increased on-farm productivity.

Realizing the potential of water power requires understanding how it is changing with the climate. Water power technologies can serve as invaluable assets in a decarbonized future and serve the energy needs of climate-impacted communities, but it is necessary to understand how water systems themselves are impacted by changing weather patterns and societal needs. Climate change will affect water control, storage, management, and multiple uses of water by reservoirs, resulting in critical risks and unique opportunities for these water systems. In FY 2023 the program will dramatically expand efforts to quantify hydrologic and climate change impacts to hydropower by working with local communities demonstrating and deploying advanced hydrologic sensors in watersheds across the U.S. to better characterize climate change variations on watersheds and improve ecological resilience and energy-water security. The oceans can also serve as assets for resilience against climate change. WPTO plans to explore the potential for how oceans can be an environmentally appropriate sink for carbon, offer pathways to decarbonization through the maritime sector, and explore how marine energy can power emerging markets like kelp farming and other climate mitigation strategies.

The hydropower sector has an aging workforce but offers pathways to well-paying, stable jobs. This potentially includes veterans and the workforce from other industries impacted by a shift to a clean energy economy, particularly since many hydropower plants are operated by utilities who can shift operations away from fossil fuel systems to renewables. Marine energy holds promise for new jobs from ports to remote communities, to developing solutions far out at sea, as well as being an interdisciplinary hard technology field for emerging researchers and scientists. However, both the marine and hydropower industries currently face challenges, such as a lack of diversity in the workforce, as well as the public's lack of awareness of workforce opportunities within these industries.

Support for both deep tech and near-term deployable solutions to address climate change requires increased support for the broader innovation ecosystem that is critical to ensuring commercialization, adoption, and diffusion of climate technologies to address the key challenges to commercialization, adoption, and diffusion of technologies. WPTO will work with other offices across the Renewable Power portfolio to support an effort to align activities and with the Office of Technology Transitions (OTT) to support the regional, local, and national innovation ecosystem. Specific activities under consideration include: supporting incubators/accelerators in the private sector to support commercialization of a broad range of technologies and entrepreneurs; identifying options to build on National Laboratory-focused commercialization opportunities; and developing metrics to measure, track, and evaluate commercialization strategies.

In support of the Administration's goals of achieving a 100 percent carbon pollution-free electricity system by 2035 and a 100 percent net-zero emission economy by 2050, WPTO will support increased cross-EERE and cross-DOE efforts to provide data, tools, and analysis to support the widespread integration of renewables in a resilient, reliable power system. This includes partnering with the Office of Strategic Programs and the Office of Electricity to expand significantly upon current technical assistance for stakeholders faced with making data-driven decisions and investments, including evaluating technologies, designing clean energy deployment programs, developing market and policy solutions, and planning transmission and distribution upgrades to facilitate the transition to a 100 percent clean electricity system.

WPTO also supports the key emphasis areas of energy justice, workforce, diversity in STEM, and state and local partnerships. Investments associated with Workforce Development will support training and develop good paying clean energy jobs for the American people - especially workers, communities impacted by the energy transition, and those historically underserved by the energy system and overburdened by pollution. Investments associated with Diversity in STEM support outreach and will raise awareness of clean energy research and job opportunities at minority-serving institutions and minority-focused professional organizations, and ensure that organizations receiving EERE funding are thinking through diversity and equity in their own work. Investments in State and Local partnerships will support state and local governments with the necessary resources to be more effective in facilitating affordable and resilient clean energy and efficiency goals. Investments associated with Energy and Environmental Justice will support approaches and processes to reach new groups of Americans historically underserved by the energy system.

Highlights of the FY 2023 Request

The Water Power Program will pursue the following major activities in FY 2023 to support the EERE strategic priority of initiating a path to achieve a carbon pollution-free electricity sector no later than 2035:

- Initiate a new national-scale study, through the HydroWIRES initiative, to quantify the emission and cost reduction potential of new PSH deployment and enhanced hydropower flexibility, as well as enhance ongoing technical assistance efforts by expanding the recently released PSH Valuation Guidebook methodology to include non-power values. The Program will also contribute to the DOE-wide Renewable Energy Grid Integration effort to fund demonstrations of hybrid systems.
- Increase efforts to develop technologies designed to lower costs while increasing the efficiency of low-head hydropower. The subprogram will engage both the National Laboratories and the private sector in developing new designs and demonstrations of new and cost-effective technologies necessary for powering non-powered dams, particularly marginal dams where developmental costs currently outweigh the power benefits.
- Develop tools to assist the Nation’s irrigation districts in using hydropower as a “building block” toward irrigation modernization, partnering with local irrigation districts to expand its FY 2022 demonstration efforts to additional sites by converting canals to pressurized pipes; enabling electrification of farm equipment and elimination of diesel pumps; and helping decarbonize the agricultural sector.
- With respect to climate change effects on watersheds and hydropower, develop a suite of climate and hydrologic models, advanced hydrologic sensors, and decision-making tools to provide accurate state-of-the-art climate information and diagnostic capabilities for predicting and managing water and power systems. This will also include collaborative efforts with the Bureau of Reclamation, NOAA, and TVA improve sub-seasonal and seasonal flow forecasting.
- Continue its effort to develop technologies to ensure safe and effective fish passage for migratory species by partnering with the National Laboratories and the private sector to develop higher Technology Readiness Level (TRL) systems through field demonstrations and deployment. In addition, the subprogram will partner with Indian tribes to offer technical assistance with respect to management of fish species of cultural significance with migratory pathways historically blocked by dams.
- Increase support for cross-EERE and cross-DOE efforts to provide data, tools, analysis, and technical assistance to support the widespread integration of renewables in a resilient, reliable power system, in partnership with the Office of Strategic Programs and the Office of Electricity.
- Support the design, fabrication, and testing of marine energy conversion devices at a range of sizes (including grid-scale and PBE technologies); continued investigation into marine powered Carbone Dioxide Removal (CDR) and aquaculture opportunities; demonstrations of marine energy powered ocean observing systems; and demonstrations of novel concept (including flexible material) marine energy device designs.
- Continue support of the Testing Expertise and Access for Marine Energy Research (TEAMER) initiative, a rolling test campaign developed in collaboration with U.S. universities and National Laboratories to provide technology developers with quick and economical access to marine energy testing facilities and capabilities across the U.S.
- Continue support for the Energy Transition Initiative Partnership Project (ETIPP), a program launched in 2020 to establish a new mechanism to both engage with underserved remote and islanded communities and deliver technical assistance to enable these communities to leverage expertise in evaluation of energy systems. ETIPP provides on-the-ground assistance on resource assessment (water, solar, wind, geothermal), grid integration analyses, and vetting of technology fit to help communities chart pathways to energy resiliency.

Contributions to DOE-wide Crosscutting Investments

WPTO is involved in several crosscuts, including the following:

- Advanced Manufacturing Crosscut ($12,000,000) – WPTO will support development of a program that will allow for access to manufacturing facilities at the Manufacturing Demonstration Facility (MDF) at Oak Ridge National Laboratory

(ORNL) or other facilities to support advanced manufacturing, as well as launch a solicitation focused on advanced manufacturing techniques applied to hydropower;

- Carbon Dioxide Removal ($3,000,000) – In FY 2023, WPTO will fund National Laboratory research to explore which marine energy sources are best suited to support and power CDR;
- Energy Storage Crosscut ($29,500,000) – In FY 2023, through the HydroWIRES initiative, WPTO will provide funding for hydropower hybrid demonstrations through the HydroWIRES initiative, a comprehensive Hydropower Futures Study to quantify emission and cost reductions enabled by increased hydropower flexibility and new PSH development, and expansion of the PSH Valuation Guidebook to include non-power values;
- Grid Modernization Crosscut ($27,500,000) – WPTO will provide funding for hydropower hybrid demonstrations through the HydroWIRES initiative, a comprehensive Hydropower Futures Study to quantify emission and cost reductions enabled by increased hydropower flexibility and new PSH development, and expansion of the PSH Valuation Guidebook to include non-power values;
- Energy Water Nexus ($25,000,000) – WPTO will build on prior work in Irrigation Modernization to launch a larger demonstration and deployment program, fund Multi-stakeholder Planning Grants to help diverse communities of hydropower operators, water resource managers, NGOs, state agencies, and local and Tribal governments meet key energy and water resilience issues, and prepare for a technical assistance program to support municipalities and localities in deploying hydropower in managed water systems; and
- Hydrogen ($1,000,000) – As part of a HydroWIRES funding opportunity, demonstrate multi-resource configurations such as floating PV and hydrogen storage.

EERE Program Priorities

In FY 2023, WPTO continues to support an investment strategy aligned to the following programmatic priority areas that are central pillars to the U.S. greenhouse gas (GHG) profile:

Water Power
Funding ($K)

	FY 2021 Enacted	FY 2022 Annualized CR[1]	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted
Decarbonizing the electricity sector	147,425	147,425	178,560	+31,135
Decarbonizing the agriculture sector, specifically focused on the nexus between energy and water	2,575	2,575	16,000	+13,425

[1] The FY 2022 Annualized CR amounts reflect the P.L. 117-95 continuing resolution level annualized to a full year.

Water Power
Funding ($K)

	FY 2021 Enacted	FY 2022 Annualized CR[1]	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted
Water Power				
Hydropower Technologies	41,000	-	80,530	+39,530
Marine Energy Technologies	109,000	-	109,970	+970
Total, Water Power	**150,000**	**150,000**	**190,500**	**+40,500**

SBIR/STTR:

- FY 2021 Transferred: SBIR $9,741,982; STTR $619,056
- FY 2022 Annualized CR: SBIR $4,627,000; STTR $651,000
- FY 2023 Request: SBIR $5,860,382; STTR $824,116

[1] The FY 2022 Annualized CR amounts reflect the P.L. 117-95 continuing resolution level annualized to a full year. These amounts are shown only at the congressional control level and above, below that level, a dash (-) is shown.

Water Power
Explanation of Major Changes ($K)

	FY 2023 Request vs FY 2021 Enacted
Water Power	
Hydropower Technologies: The hydropower technologies subprogram is building on its efforts through optimization of the existing hydropower fleet by: (1) increasing funding of its HydroWIRES Initiative to demonstrate hybrid systems of hydropower with other resources; improving valuation tools to fully capture power and non-power value provided by PSH; and quantifying emission benefits associated with new PSH and expanded hydropower flexibility; (2) expanding its scope of work in new, low-impact hydropower by investing in demonstration of technologies to power nonpowered dams or infrastructure, including demonstrating and deploying irrigation modernization to serve agricultural end-users; and (3) increasing work to analyze hydrologic and climate change impacts to hydro now and through 2050, as well as investing in the environmental systems to keep the fleet online.	**+39,530**
Marine Energy Technologies: Major changes in this subprogram's portfolio are driven primarily by an increased need for demonstration and deployment funding to support current and tidal power technologies and increasing funding for at-sea applications like aquaculture, carbon dioxide removal monitoring, and building systems tested through the Ocean Observing Prize. The Request continues to support DOE-wide Energy Storage efforts such as remote communities use case, supporting device design and fabrication to serve remote coastal and islanded communities based on outcomes of the ETIPP cohorts. The subprogram continues to provide funding for desalination technologies and systems and is provided for controls, advancements in materials and manufacturing, access to testing facilities for marine energy developers, and the design, fabrication, and testing of marine energy devices at a range of sizes, including PBE and grid-scale technologies.	**+970**
Total, Water Power	**+40,500**

Water Power
Hydropower Technologies

Description

As the Nation's first renewable source of electricity, hydropower has provided clean, low-cost electricity for over a century. Today's evolving power system has created new opportunities for hydropower to play an important role in a 100 percent clean energy future, using existing and new technologies and infrastructure. In 2020, hydropower provided 7.3 percent of the electricity on the grid and accounted for 36.7 percent of U.S. renewable electricity generation. Hydropower, including pumped storage hydropower (PSH), provides flexibility, inertia, storage, and grid services to support the integration of variable renewable energy (VRE) such as wind and solar energy. And while hydropower is well-positioned to serve this integrating role, there are urgent needs to better quantify the value hydropower provides, understand tradeoffs (both power and non-power) associated with hydropower operations, and develop new technologies and operational strategies to enhance hydropower's flexible capabilities.

PSH is the largest contributor to U.S. energy storage with an installed capacity of 21.9 GW, or roughly 93 percent of all commercial storage capacity in the U.S. PSH also provides over 550 gigawatt-hours of U.S. energy storage, making it by far the largest source of commercially available long-duration energy storage. While most PSH plants were built decades ago, multiple new large-scale PSH projects have progressed in the development pipeline in recent years.

The vision of the Hydropower Technologies subprogram is a U.S. hydropower and pumped storage industry that modernizes and safely maintains existing assets; responsibly develops new low-impact hydropower; supports grid reliability and the integration of other energy resources; promotes environmental sustainability; and supports energy-water systems resilience. Through modernization of the existing U.S hydropower fleet, adapting to the changing needs our Nation's power system, and meeting the challenges of climate change head-on, hydropower can be the keystone to a fully decarbonized power system by 2035.

New Low Impact Hydropower: Most new hydropower facilities will be smaller scale than existing systems since limited opportunities exist to develop new, large-scale conventional hydropower due to high costs and environmental concerns. These new facilities—including low-impact, small hydropower facilities or with technologies for existing conduits and canals—can integrate multiple social, environmental, and energy benefits, while realizing value and revenue from a variety of sources. Hydropower Technologies subprogram activities support the deployment of these systems with an explicit focus on modernizing irrigation systems and developing technologies that will more cost-effectively power non-powered dams and develop new stream reaches, particularly in remote communities. Scientific advances associated with these technologies can allow developers and operators to more effectively identify and mitigate potential environmental impacts, ultimately allowing for more effective utilization of existing hydropower and reduced regulatory costs.

There are more than 90,000 existing dams across the Nation, of which about 2,500 have hydropower facilities for electricity generation. Retrofitting existing dams and adding generation at non-powered dams can increase renewable energy production. Over the last four years, the Hydropower Technologies subprogram has developed design criteria for more standardized, modular hydropower development that capitalizes on advanced manufacturing and materials, while preserving and enhancing stream functionality for greenfield development and powering non-powered dams.

Dams serve many roles besides power generation, such as flood control, water supply, irrigation, and recreation. Because hydropower occupies a unique position at the intersection of the energy/water nexus, it offers unique benefits through connections to the water supply and associated infrastructure. For example, cost-savings from hydropower project developments have allowed irrigation districts to modernize their irrigation systems[1]. The process of converting unlined, open canals to pressurized pipes saves water, decreases pumping costs for farmers, decreases nutrient loading downstream, and increases on-farm productivity. Facilitating this effort requires partnerships with irrigations districts to inform development of digital planning tools and demonstration sites.

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[1] https://www.energy.gov/eere/water/articles/new-way-modernize-irrigation-infrastructure-and-generate-renewable-energy

Grid Integration: Both hydropower and PSH can adjust 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, along with the ability to absorb excess generation during the pumping mode and provide long-term power storage for when it is needed most. As part of DOE-wide Energy Storage investments, 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, addressing critical technical barriers to effective operation of hydropower resources, and identifying technology solutions that will preserve or enhance hydropower capabilities to deliver services or system benefits competitively. The activity 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 incentivizing private investment.

HydroWIRES will expand its efforts to develop new strategies that can enhance hydropower's flexibility for facilitating deployment of wind and solar onto the U.S. electric grid—including faster and more frequent ramping, more frequent starts and stops, and enhanced frequency and voltage control to optimize the highest-value services crucial for the transition to a primarily renewable power system. HydroWIRES will also increase support for PSH valuation and associated technical assistance efforts to capture the full range of values that PSH plants can provide to power grids, river basins, and nearby communities. HydroWIRES will support demonstration of hydropower hybrid energy storage configurations, such as hydropower plus batteries or floating solar PV.

Existing Hydropower: The existing U.S. hydropower fleet faces key challenges including asset modernization, operations optimization, and cybersecurity threats. The average hydropower plant is 64 years old,[1] and as the fleet continues to age, maintaining efficient and cost-effective operations and ensuring the security – including cybersecurity – of our critical energy infrastructure becomes increasingly challenging. Modernization of the existing hydropower fleet represents a significant opportunity to restore reliability and performance and add new cutting-edge technologies that can mitigate high operation and maintenance costs as well as addressing the hydropower fleet's unique cyber vulnerabilities, which were catalogued and assessed in the subprogram's FY 2021 "Cybersecurity State of the Hydropower Fleet."

In addition to supporting research to address the challenges faced by the U.S. hydropower fleet, the Hydropower Technologies subprogram also supports the hydropower industry and its stakeholders through its activities to assess and address climate change impacts, environmental sustainability, and relicensing. Hydropower generation is both impacted by climate change and has an important role in climate change mitigation. Climate change will disproportionally impact regional water supplies across the U.S. and pose challenges for the multipurpose demands of reservoirs. The subprogram's work on hydropower reservoir management can create opportunities to enhance climate resilience and adaptation for remote or socioeconomically vulnerable communities by advancing climate science and adaptation, analyzing infrastructure design and water management, enhancing environmental sustainability, and ultimately building socioeconomic resilience in communities challenged by climate change.

Environmental sustainability is another critical challenge, requiring fundamental research to understand hydropower's effects on the environment, as well as novel monitoring and mitigation technologies. Hydropower's long-term value depends on maintaining a high level of environmental performance across the fleet. Improving the environmental performance of hydropower facilities requires new technologies, particularly on issues related to fish passage. Since 2005, the Federal Energy Regulatory Commission (FERC) has ordered mandatory fishway prescriptions for project relicenses for upstream or downstream passage in approximately 27 percent of hydropower facilities. To meet this order, WPTO has

[1] https://www.eia.gov/todayinenergy/detail.php?id=30312#

initiated high priority research on fish passage at hydropower dams to understand fundamental research in fish behavior, movement, and lifecycles; and information and tools to increase fish survival through turbines and other hydropower structures.

Finally, non-federally owned hydropower facilities require a license from the FERC to operate, and license terms typically last for 30-50 years. At the time of licensing or relicensing, the environmental impacts of a hydropower facility are rigorously evaluated. Relicensing provides an opportunity for communities to (1) establish goals for the environment, recreation, energy, and other benefits; (2) evaluate site- and basin-level potential impacts in relation to goals; and (3) define measures to avoid, minimize, or mitigate impacts. In the next decade, approximately 30 percent of U.S. hydropower will need to go through relicensing. Environmental measures can account for up to 30 percent of the federal wholesale rate, and solutions for effective environmental outcomes and cost reductions are essential. Over the past five years, the Hydropower Technologies subprogram has taken an active role in developing tools and analyses that can assist applicants for FERC licenses and other hydropower stakeholders navigate the FERC licensing process and assess the environmental effects of proposed projects.

Data, Modeling, & Analysis: Throughout the course of its funded R&D activities, the Hydropower Technologies subprogram, the National Laboratories, and funding recipients identify and aggregate large amounts of data from across the hydropower industry and hydrologic science disciplines. Non-proprietary data are validated and made publicly 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, policymakers, and regulatory agencies. The activity also supports a portal which features hydropower educational resources and will continue to build on its workforce development and STEM activities, including initiation of an updated hydropower workforce report and launching a new hydropower-focused collegiate competition.

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

Hydropower Technologies

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Hydropower Technologies $41,000,000	**$80,530,000**	**+$39,530,000**
New Low Impact Hydropower $8,000,000	$26,500,000	+$18,500,000
• Develop an opportunities strategy for advanced manufacturing technologies to support standard modular hydropower and modernize the hydropower fleet.	• Support access to the MDF at ORNL, or other facilities, to support advanced manufacturing, as well as launch. Launch a solicitation focused on advanced manufacturing techniques applied to hydropower.	• Continued funding will support use of the advanced manufacturing opportunities strategy to support access to the MDF in order to demonstrate its capabilities leading to cost reductions in the manufacturing of new hydropower technologies.
• Complete design criteria for standard modular hydropower development at non-powered dams (NPD).	• Support designs for powering NPDs, with the intent of leading into a demonstration funding opportunity to support the advancement of these designs. Assess costs and benefits of adding hydropower to non-powered dams. Partner with private sector developers and municipalities to implement demonstration projects.	• Expand on past work in conceptual designs for non-powered dam technologies and establishing framework for assessing costs and benefits of adding hydropower to non-powered dams, partner with private sector developers and municipalities to implement concepts to real-world hydropower projects. Shift focus toward demonstrations.
• Continuation of National Laboratory projects investigating where small, modular hydropower technologies could complement other water-related objectives like irrigation systems modernization or groundwater recharge.	• Fund additional demonstrations of small, modular hydropower systems to support irrigation modernization, building on the IrrigationViz tool that enables communities to evaluate opportunities for adding hydropower for modernizing systems.	• Expand digital tools developed in FY 2021 to support demonstration and deployment of irrigation modernization and small hydropower.
• Complete National Laboratory work on identifying non-energy benefits of small hydropower.	• Expand technical assistance to small hydropower developers to create awareness of non-energy benefits of small hydropower.	Develop technical assistance program for developers to better capture quantitative evidence of non-power benefits of hydropower, building on initial qualitative assessments of non-energy benefits scoped in FY21. This includes building tools and analysis to quantify benefits beyond power for hydropower. Sharing non-energy benefits will lead to deployment of hydropower technologies.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
• Complete National Lab scoping study of potential sites for federal hydropower test facility.	• Partner with Bureau of Reclamation and the Army Corps of Engineers to begin a 2 to 3-year effort to fund the construction of a hydropower test facility or facilities that will incentivize developers to design and develop new hydropower technologies by reducing financial risk and providing access to technical expertise inherent in the testing process.	• Increase will support the first year of support for construction of a hydropower test facility
• Not funded in FY 2021.	• With the Advanced Manufacturing Office, develop novel water infrastructure sensing capabilities for human-made water systems. The scope of this effort includes not only hydropower plants but also water conveyance systems, water treatment, and water storage facilities.	• Increase support for an effort with AMO to support better data and access to information on water availability, develop tools to demonstrate advanced sensing techniques to collect real-time hydrologic data from several watersheds across a wide geographic spectrum.
Grid Integration $15,000,000	$27,500,000	+$12,500,000
• Under the HydroWIRES initiative, continue National Laboratory-led hydropower value drivers quantification effort to understand the system conditions (e.g., generation mix, market structure, etc.) that provide the greatest value to a decarbonized power system and enable more flexible operation, as well as improve the representation of hydropower in power system models to more accurately capture its unique capabilities.	• Commence a comprehensive, national-scale study on hydropower and PSH's evolving role in the power system and future potential, taking advantage of significant modeling enhancements, and including technology opportunities. After the publication of the study, next steps would be the development of regional roadmaps—through state and local-scale stakeholder workshops—to map out the opportunities for hydropower in different geographic, hydrologic, and market regions of the U.S.	• Expand on modeling enhancements developed in the North American Renewable Integration Study and other efforts to quantify emission and cost reductions of additional hydropower flexibility, as well as new PSH deployment.
• The activity will continue support of component level technology R&D to enable increased flexibility of hydropower, including a competitive funding solicitation targeting manufacturers with owners/operators as partners focused on technology innovations that can improve hydropower and PSH flexibility and their value to a decarbonized power system.	• Continue PSH technology R&D to advance promising concepts to the testing phase.	• Continued funding for technical assistance and validation of technologies supporting flexibility enhancements to hydro and advanced PSH.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
• Develop an online PSH valuation tool, based on the PSH valuation guidance previously developed under HydroWIRES, to ensure ease of use by developers and other stakeholders.	• The Request includes funding to expand the PSH Valuation Guidebook framework to accommodate non-power values such as those resulting from water use for multiple purposes, and would include broader economic, health, and cultural values defined by relevant communities. Also demonstrate multi-resource hybrids for increased revenue, reduced cost, environmental mitigation, and other purposes, as well as configurations such as floating PV and hydrogen storage. Also demonstrate microgrids for underserved communities and provide technical assistance and tools for system operators and planners. Demonstrate multi-resource hybrids for increased revenue, reduced cost, environmental mitigation, and other purposes, as well as configurations such as floating PV and hydrogen storage.	• Expand existing work in HydroWIRES to demonstrate multi-technology hybrids managed through a cross-office process.
Existing Hydropower $6,000,000	$24,000,000	+$18,000,000
• Continuation of congressionally directed study to examine the risks from global climate change associated with water supplies for Federal hydroelectric power generation. Initiation of a national-scale analysis and visualization platform enabling utilities and system operators to evaluate water-related impacts and risks.	• Establish the tools and partnerships necessary to build toward an Intelligent Watersheds major initiative, which includes 1) advancing monitoring technology through SBIR Phase I funding of smart environmental sensors and sensor networks, 2) building capacity through Community Planning Grants that will seed future Intelligent Watersheds focused on environmental resilience, and 3) pursing joint work with the Office of Science that expands and applies research to watershed planning. Build on existing portfolio and expand partnerships to support climate diagnostics, including valuation of climate services, and developing responses to climate risk.	• Increased funding to develop tools to understand climate change effects on hydropower systems, with an eye towards demonstration of advanced sensing techniques to collect real-time hydrologic data from several watersheds across a wide geographic spectrum.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
• Continued development of a scientific framework and a user-friendly tool for identifying key factors contributing to environmental impacts of hydropower developed in prior years in a regulatory setting to assess its ability to minimize the time and costs for scientific studies needed for regulatory permitting.	• Launch demonstrations, like self-powered Fish Tag lab project and eDNA Demo for FERC relicensing lab project.	• Focus on demonstrations that help streamline environmental permitting and lower costs for hydropower developers.
• The activity initiated significant investments in digitalization and modernization of the existing hydropower fleet by scoping existing capabilities and mathematical methods and models leading to the development of hydropower turbine digital twins to understand the effects of variable dispatch on a decarbonized grid dominated by variable renewables.	• Develop and deploy a pilot program(s) of the digital twin capability developed focused on O&M reduction and market optimization in order to refine the concept and further develop industry confidence in the technology benefit and value.	• Moving from development of digital twins for hydropower turbines to partnering with industry to demonstrate effectiveness in reducing O&M costs and market optimization.
• Completion of a landscape study on the highest priority R&D needs of the hydropower industry to improve the industry's cybersecurity standing. Initiation of cybersecurity investment guidance with respect to the "value" of implementing cybersecurity measures.	• Leverage the SCADA mapping and controls monitoring capability of the Digital Twin effort to help detect abnormal activity in the OT network.	• Partnering with industry to leverage actual operational data to allow for physics-based monitoring for a more accurate assessment of network intrusion.
• Completion of work to develop turbine design and evaluation tools that improve both fish passage and turbine efficiency.	• Competitive funding opportunity on fish passage for restoration to support design and deployment of solutions to move fish above and below dams, evaluate environmental effects, or develop comprehensive technical restoration plans include partnering with tribal communities where species maintain economic and cultural importance.	• Utilizing fish passage R&D developed over previous 5 years to solve real-world problems associated with moving fish around dams with additional focus on deployment in partnership with tribal communities.
Data, Modeling, & Analysis $5,000,000	$2,530,000	-$2,470,000
• Updates to the Hydropower Vision Roadmap, which lays out strategic R&D needs to advance the hydropower industry towards a 100 percent clean energy economy.	• Monitor progress toward goals in the Hydropower Vision Roadmap.	• Shift from 2 years of comprehensive outreach and engagement of the hydropower community to low- level monitoring of efforts to make progress towards priorities and goals.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
• Support for the hydropower industry by building the educational infrastructure to identify and train future hydropower professionals through development of educator resources, water power career profiles, and a STEM portal within existing OpenEI pages for educators, students, and the public to learn about water power technologies and workforce development opportunities.	• Support certification programs, curricula sharing, and provide training and other development opportunities to minority workforce entrants, vets, and transitioning workers from adjacent sectors. Support and support a new hydropower collegiate competition as well as analysis to inform a new/updated hydro workforce report.	• Expansion of Workforce and STEM activities to actively engage the hydropower industry and college graduates/researchers to ensure a well-trained hydropower workforce for the future.
• Exploratory scoping work to assess stakeholder needs and value of improved access to many different types of river and water-related data.	• Continue to expand and improve HydroSource. Support, a publicly available database to support improved decision-making and basin-wide management of river resources.	• No significant change.
• Initiation of work on a user-friendly tool to search the FERC eLibrary database. Complete National Laboratory development of a user-friendly interface for U.S. Hydro fleet data and a competitive funding solicitation for hydro operational to modernize and optimize hydro to support a decarbonized grid dominated by variable renewables.	• Continue to maintain and update the RAPID database allowing public users to search the FERC eLibrary database. • Add more U.S. Hydro fleet data, improve automation of adding datasets, improve dissemination and sharing capabilities, expand Data Explorer, and refine use cases.	• No significant change. • Shift from inward focused development of new user interface to outward facing data collection and outreach.
EPAct Section 242 $7,000,000	$0	-$7,000,000
• Funding supports the Congressionally-directed implementation of the Energy Policy Act of 2005, Section 242, Hydropower Production Incentive Payments to owner/operators.	• No funding requested.	• Bipartisan Infrastructure Law (BIL)-provided funding will support this activity in FY 2023.

Water Power
Marine Energy Technologies

Description

Marine energy technologies convert the energy of waves, tides, river and ocean currents, ocean thermal gradients, and salinity and pressure gradients into electricity and have the potential to provide millions of Americans with locally sourced, clean, and reliable energy. Resource assessments show that the total marine energy technical resource in the 50 U.S. states is 2,300 TWh/yr, equivalent to 57 percent of the electricity generated by those states in 2019. The nation's Pacific and Caribbean territories and freely associated states add an additional 4,100 TWh/yr of ocean thermal energy resource.[1] Developing just one-sixth of the available wave energy in the five Pacific states could power more than five million homes. Marine energy – particularly tidal energy – can serve as a predictable, forecastable resource with a generation profile complementary 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.

Marine energy offers both a future opportunity to supply electricity to a deeply decarbonized national grid, and as a near-term solution for distributed energy for isolated and islanded communities. Through the Powering the Blue Economy (PBE) initiative, WPTO is demonstrating that marine energy technologies also have the potential to provide cost-effective energy for emerging at-sea and coastal distributed 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. Successfully serving these markets provides industry with opportunities to develop and deploy marine energy technologies in the near-term, while reducing costs for larger utility-scale markets that are still developing. These real in-water experiences allow the industry to drive down learning curves and increase near term investment in the sector.[2] 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.

However, marine energy 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 and face significant challenges in engineering and operations to fully unlock their potential at both small and large scales. High costs and lengthy permitting processes associated with in-water testing intensify these challenges. To address them, the program invests in RDD&D specific to marine energy applications to generate knowledge relevant for industry to develop innovative components, structures, materials, systems, and approaches to manufacturing. 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 marine energy RDD&D also focuses on those scientific and engineering challenges where breakthroughs likely have the broadest, industry-wide benefits. Industry deployment of marine energy technologies for bulk power generation is nascent, and significant RDD&D is still required to realize cost-competitiveness at the utility-scale for marine energy technologies and reduce levelized costs of energy.

Materials and Components R&D: Marine energy technologies have difficult engineering challenges specific and inherent to the marine energy environment. The activity works to support RDD&D to tackle these difficult engineering challenges to rapidly improve and reduce costs of marine energy generation technologies. Advanced controls research also 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. Programmatic research will continue to support DOE's commitment to a joint DOE-Navy project targeting

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[1] Kilcher, Levi, Michelle Fogarty, and Michael Lawson. 2021. Marine Energy in the United States: An Overview of Opportunities. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5700-78773. https://www.nrel.gov/docs/fy21osti/78773.pdf

[2] "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

advanced controls and continues with 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.

The activity is also continuing development of the first-ever national wave classification metrics and site-specific wave energy characterization. This work is similar to what DOE has provided historically for the wind and solar industries, including national level maps and dynamic resource predictions. These 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 to inform device design and DOE's own RDD&D priorities.

In addition, few materials are designed or optimized for use in the ocean at a practical cost for the marine energy industry. The activity supports research into cost-competitive materials and coatings designed to function in one of the harshest environments, providing a catalyst for the emerging industries that depend on it.

<u>System Integration and Validation</u>: This activity's strategy to help catalyze marine energy deployment focuses on technology research, design, testing, and validation to reduce cost and improve performance of marine energy technologies at a range of sizes and technology readiness. This work involves testing proof-of-concept systems in laboratory and ocean settings to understand performance characteristics, identifying and mitigate reliability risks, and providing data to inform future RDD&D to improve next-generation designs across the industry. The Marine Energy Technologies subprogram is committed to investment in RDD&D activities that will include a focus on design concepts that have the potential to serve existing or emerging ocean-based technologies that can advance the Nation's military, commercial, and scientific capabilities. These include power for remote coastal communities and Department of Defense 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.

The activity will continue to support the PBE initiative, including desalination systems for remote communities and disaster relief and recovery, demonstration of marine energy powered ocean observing systems, and through ETIPP provide on-the-ground assistance on resource assessment (water, solar, wind, geothermal), grid integration analyses, and vetting of technology fit to help communities chart pathways to energy resiliency. In addition, the activity continues to support deployable systems to address plastics waste in U.S. rivers and waterways and expanded investigation into marine powered CDR and aquaculture opportunities. Furthermore, the activity will demonstrate and deploy grid-scale marine energy projects to validate performance towards a fully decarbonized electric grid.

<u>Testing & Reliability</u>: The activity makes strategic investments to support infrastructure at the National Laboratories and other marine energy test sites to enable technology innovations and reduce barriers to testing and validation. Deploying marine energy for coastal and ocean-based applications is crucial towards accelerating marine energy technology development for the grid. These near-term deployments with existing applications will enable the industry to understand the effectiveness of marine energy technologies, their shortcomings, and to rapidly solve technical challenges, while also benefiting coastal communities and the other Blue Economy markets. With time, these deployments will improve the marinization of marine energy systems, i.e., better understand their survival in harsh, highly corrosive, energic environments, and utilize appropriate materials and technologies. In addition, siting marine energy technologies in an environmentally responsible manner through partnerships between coastal communities, the government, private industry, and technical experts can lead to sustainable and resilient energy technology. For industry to expand deployment of marine energy technologies, in-water validation of prototype performance, efficiency, and reliability across a wide range of sea states including extreme conditions, is needed. The activity partners with industry to enable the development and testing of these prototypes, through programs such as TEAMER (Testing Expertise and Access for Marine Energy Research), as well as enable access to dedicated testing infrastructure to reduce the inefficiency associated with each developer investing in testing cables and permits. The activity also supports modeling and predicting of the environmental effects of marine energy devices through research that simulates device-ecosystem interactions and industry efforts to develop new technologies that more accurately monitor in-water devices.

Data, Modeling, & Analysis: Marine energy 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 activity 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 support is maximized. The activity also ensures access to STEM resources and opportunities for students to develop skills needed to enter the marine energy workforce. These efforts include the maintenance of the PRIMRE system (Portal and Repository for Information on Marine Renewable Energy). This knowledge management system centralizes databases, tools, and educational resources developed by the Marine Energy Technologies subprogram. The activity will continue to support student research fellowships and a collegiate competition for interdisciplinary teams to develop technical designs and Blue Economy business cases for marine energy.

Marine Energy Technologies

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Marine Energy Technologies $109,000,000	**$109,970,000**	**+$970,000**
Materials and Components R&D $27,500,000	$31,650,000	+$4,150,000
• Continued National Laboratory R&D into controls and power take-offs for MHK devices following up on the strategy developed in recent FYs to dramatically reduce costs and/or increase energy capture.	• Continued National Laboratory R&D into controls and power take-offs for marine devices following up on the strategy developed in recent FYs to dramatically reduce costs and/or increase energy capture R&D on controls and power take-offs for MHK devices.	• No change.
• Building on recent advances in materials and manufacturing and the completion of a significant systems engineering study, FY 2021 increased R&D focused on advanced materials and manufacturing, and initiated a new funding competition focused on generating novel device concepts and testing prototypes of wave energy systems, and partnered with the Navy on a study of emerging technologies with the potential to transform MHK designs.	• Design and develop flexible material Wave Energy Conversion (WEC) and support the WaveSparc prize to validate and demonstrate novel concepts. Continue to build on flexible material WEC design and development as well as continued WaveSparc work to develop novel concepts and execution of the WaveSparc prize (and prize support) launched in FY 2022 to validate and demonstrate the potential of novel concepts developed.	• 1-3 additional novel concepts in fluid-structure interactions use of advanced computational design tools and control strategies to develop new MHK device designs with improved energy extraction.
• Continued support for National Laboratory work on modeling tools and methodologies for device and array performance, R&D of advanced materials, and new approaches for operation and maintenance (O&M) of marine energy projects.	• Continue support with and increased focus on foundational R&D modeling tools and methodologies for device and array performance. R&D of advanced materials and components, and new. New approaches for O&M of marine energy projects.	• Increased support and funding for foundational R&D.
• Continued development of the first-ever national wave classification metrics and site-specific wave energy characterization.	• Continue development of the first-ever national wave classification metrics and site-specific wave energy characterization, with a focus on new sites and locations applicable to Powering the Blue Economy (PBE) technologies.	• Increased focus on characterization of new sites such as remote coastal communities. Increased focus on characterization of blue economy applications, like thermal gradients, salinity gradients, and more localized evaluation of resource characterization in remote communities.
Systems Integration & Validation $48,800,000	$51,650,000	+$2,850,000
• Support the testing of up to 4 existing wave energy conversion (WEC) devices and testing of	• Continue to advance the state of the art and push high potential designs of large WECs and	• Continue to support wave and current, though with an increased focus on current energy

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
up to 5 supporting systems (including components & devices) at PacWave. These projects will quantify WEC technology performance and costs, help validate numerical models in a realistic ocean environment, and help identify high priority R&D needs for the wave energy industry.	CECs (tidal, river, and ocean current) towards commercialization through 1-3 in-water testing and demonstrations of devices. Demos will leverage research, develop and demonstrate large WECs and current energy converters (tidal, river, and ocean current). Demos will leverage WPTO supported infrastructure (e.g. PacWave and the Mobile Test Vessel (MTV) under development).	technologies. Increased focus on current energy technologies. This work will help to lead to widespread utilization of agreed upon international standards and performance metrics for device performance and insurance certification, increasing private investment in and commercial demonstration of marine energy technology.
• To advance alternative applications for remote communities and other ocean markets, the Powering the Blue Economy initiative will begin to focus on the fabrication and testing of prototype systems for desalination and ocean observing. This includes moving to the next phase of both Waves to Water and OceanObs prizes, as well as the progression of phase II selections from 13 phase I ongoing SBIR awards. In addition, the program will begin implementation of the partnership with the ETIPP to support marine energy in remote communities and finalize the full PBE R&D Roadmap.	• Research potential marine energy solutions for aquaculture and CDR. Scope and develop a separate ETIPP track specific for water technologies, which will aim to identify communities looking to develop a strategy for incorporating water tech into their energy planning. Desal work will focus on multiple application and scales ranging from disaster relief to small communities.	• Increase in funding will continue to advance successful technologies from OceanObs prize and emerging power at sea areas (aquaculture and CDR). New work also includes WaterPACT, which builds on deployable systems to address plastics waste in U.S. rivers and waterways. Work will continue in wave powered desalination, though at a lower funding amount to allow for increased efforts in current energy technologies and power at sea applications.
• 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.	• With existing funds, support will continue for developers entering into non-grid-scale markets.
Testing & Reliability $23,700,000	$17,650,000	-$6,050,000
• Continued support of TEAMER, a rolling test campaign supported in collaboration with U.S. universities and National Laboratories for early stage marine energy systems.	• Continue support of TEAMER, a rolling test campaign supported in collaboration with U.S. universities and National Laboratories for early stage marine energy systems.	• No change.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
• Continued 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 National Laboratory work 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, resulting in reduced cost and timelines associated with permitting.	• No change.
• Continued support for upgrades to test infrastructure at marine energy technology testing sites, including the development of a testing needs roadmap.	• Continue support for upgrades to test infrastructure at marine energy technology testing sites based on the testing needs roadmap.	• No change.
• Continued funding for the newly established Atlantic Marine Energy Center (AMEC), focused on advancing marine energy technologies towards commercialization and to develop powering the blue economy (PBE) solutions.	• No funding requested.	• AMEC will continue to operate and support developer needs with prior year funds.
Data, Modeling, & Analysis $9,000,000	$9,020,000	+$20,000
• To advance diversity in STEM and clean energy industries, the subprogram continued the Marine Energy Collegiate Competition, an annual competition established in 2020, which engages student competitors to identify the most promising, near-term blue economy applications for marine energy and develop technically sound, tabletop-scale, marine energy prototypes that are designed based on the end-user needs in their selected market.	• Continue the Marine Energy Collegiate Competition to identify promising, near-term blue economy applications and develop tabletop-scale prototypes.	• No change.
• 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.	• Make program-funded research and testing results widely accessible through databases and tools such as PRIMRE.	• No change.
• Support National Laboratory analysis of R&D challenges and opportunities for remote and coastal communities (Powering the Blue Economy).	• Continue to support National Laboratory analysis of R&D challenges and opportunities for remote and coastal communities (Powering the Blue Economy).	• Increase in funding to expand focus into additional end-use markets.

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 and dispatchable energy source. Increasing the deployment of carbon-free, flexible geothermal energy in both the electric and non-electric sectors will help reach a carbon pollution-free electric grid by 2035, decarbonize the commercial and residential sectors and the agriculture sector, and achieve a net-zero economy by 2050, while ensuring that the benefits accrue equitably to all Americans. Geothermal addresses environmental justice issues because its high-capacity factor, small physical footprint, and wide-ranging application in the built environment ensure that it can be utilized in urban centers, rural areas, and remote communities where geothermal has high technical and economic potential and can reduce dependence on fossil fuels.

The current domestic installed geothermal capacity is over 3.8 gigawatts (GW). The 2019 DOE study, *GeoVision: Harnessing the Heat Beneath Our Feet* (GeoVision), showed that with improved technologies, reduced permitting timelines, and increased public awareness of geothermal and its benefits, geothermal power capacity could reach 60 gigawatt electricity (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. The mission of the Geothermal Technologies Office (GTO) is to drive increased deployment of geothermal energy through research and development (R&D) in innovative technologies that enhance exploration and production.

GeoVision analysis indicates that the majority of the modeled 60 GWe geothermal growth by 2050 results from enhanced geothermal systems (EGS) deployment. Relative to other geothermal resources, EGS has the potential to provide the most growth in the electric sector, and EGS technology can also support significant growth within the non-electric sector for district heating and other direct-use applications. Without significant and sustained investment in EGS technology development and demonstrations, however, the 60 GWe target will not be met by the U.S. To ensure the U.S. stays on track to meet this substantial deployment goal, the FY 2023 EGS Subprogram Budget Request reflects an increase of $52,000,000 over FY 2021 Enacted. This additional funding will support field demonstration projects in two areas: Subsurface Accessibility R&D, including directed efforts on EGS focused drilling and well completion, which comprise a major portion of overall geothermal development costs; and Subsurface Enhancement & Sustainability R&D, including reservoir creation, which remains the most challenging technological hurdle limiting widespread EGS deployment. Investments in large-scale geothermal field demonstrations in these critical areas will facilitate a step-change in geothermal deployment; demonstrations allow real-time innovation, flexibility to repeatably test high-risk techniques and technologies in a variety of geologic settings and conditions, and an invaluable opportunity to learn-by-doing. This scale of innovation-led research, which can lead to transformative changes in our energy sector, is only possible with government intervention.

GTO's technology portfolio prioritizes research, development, demonstration, and deployment (RDD&D) in three closely related geothermal categories: Hydrothermal Resources, Enhanced Geothermal Systems (EGS), and Low Temperature Resources. This portfolio addresses technology barriers in RDD&D that industry may not have the technical capabilities or institutional knowledge to address. 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 supports RDD&D in the geothermal sector to develop innovative technologies that will help harness American geothermal energy resources safely and efficiently.

GTO also supports the key emphasis areas of energy justice, workforce, diversity in STEM, and state and local partnerships. Investments associated with Workforce Development will support training and develop good paying clean energy jobs for the American people, especially workers, communities impacted by the energy transition, and those historically underserved by the energy system and overburdened by pollution. Investments associated with Diversity in STEM support outreach and will raise awareness of clean energy research and job opportunities at minority-serving institutions and minority-focused professional organizations, and ensure that organizations receiving EERE funding are thinking through diversity and equity in their own work. Investments in State and Local partnerships will support state and local governments with the necessary resources to be more effective in facilitating affordable and resilient clean energy and efficiency goals.

Investments associated with Energy and Environmental Justice will support approaches and processes to reach new groups of Americans historically underserved by the energy system.

Highlights of the FY 2023 Request

The Geothermal Technologies Program will pursue the following major activities in FY 2023:

- EGS Greenfield Demonstration: EGS Greenfield Demonstrations will target shallow to mid-depth geothermal anomalies for clean, renewable, geothermal power production. Projects will build on the zonal isolation/stimulation learnings of previous GTO initiatives such as Wells of Opportunity (WOO), Frontier Observatory for Research in Geothermal Energy (FORGE), and EGS Collab. WOO focused primarily on near-field EGS, while FORGE is set in a single geologic setting. This new set of EGS demonstrations will move beyond the near-field environment to get closer to greenfield EGS in multiple environments to continue to hone our understanding of what is required, especially in zonal isolation and stimulation, to scale up EGS and ensure its viability throughout the U.S.
- EGS Drilling and Well Construction: The EGS Drilling and Well Construction initiative builds on the work of the FY 2022 Hydrothermal Resources Drilling Demonstration projects, and this initiative targets drilling and completion technologies that will enhance exploration and development specific to EGS resources. These methods and technologies will focus on the unique characteristics and barriers to EGS drilling, completion, and production to unlock 60 GW of geothermal energy and decarbonize the electric grid by 2035.
- Frontier Observatory in Research in Geothermal Energy (FORGE): This flagship initiative, started in FY 2014, has drilled several major wells on the Utah site, including the first-ever highly deviated geothermal well, drilled at 8000+ foot depth at a rate twice the industry standard. In FY 2022, Utah FORGE kicked-off 17 research and development awards selected competitively via its first R&D solicitation. In addition, the Utah team performed a series of multi-stage stimulation experiments in a highly deviated well drilled in FY 2020. In FY 2023, GTO will drill a third, long-reach horizontal well, providing an opportunity to further advance drilling improvements and enable additional stimulation and zonal isolation testing. These represent the most impactful areas toward lowering operational and construction cost of EGS and conclusively demonstrating the viability of EGS as a scalable technology and enabling 60 GWe of geothermal power by 2050.
- Wells of Opportunity (WOO): GTO has funded near-field EGS demonstration projects through Wells of Opportunity FOAs for several years. In FY 2023, GTO will issue an additional WOO funding opportunity to continue to spur the rapid development of EGS power generation, including a focus on shallow heat located near existing hydrothermal fields, enabling 15-20 GWe to be deployed from these untapped geothermal resources.
- Geothermal Energy from Oil and Gas Demonstrated Engineering (GEODE): This is a new consortium in FY 2022 designed to leverage oil & gas subsurface assets, technologies, and expertise to help solve geothermal energy's toughest challenges while providing clean energy employment opportunities and environmental benefits for communities adversely impacted by the fossil energy sector decline. GEODE provides an organizational framework to effectively transition the oil and gas technologies and workforce into geothermal. In FY 2023, the GEODE Team will prepare solicitations and other activities focused on each GEODE facet listed above, building off the GEODE Roadmap developed in FY 2022 to make immediate progress in modernizing geothermal drilling, deploying O&G technologies to lower geothermal development costs, and standing up workforce development programs to attract, train, and utilize highly skilled workers displaced from O&G.
- Hybrid EGS/Deep Direct Use (DDU) Demonstration: GTO will work with rural communities and Tribes from regions with elevated geothermal temperatures to demonstrate and validate EGS hybrids as a resilient power source, while providing excess heat to the local community for direct use. Best practices will serve as a model for future expanded deployment of EGS hybrids across the U.S. to provide EGS power and/or heat to communities across the nation.
- FedGeo Power: Building on the success of the FY 2022 Federal-Geothermal (FedGeo) Partnerships for geothermal heating and cooling at Federal sites, GTO will conduct feasibility studies and site characterization for geothermal power generation opportunities at Federal and military installations with a large electricity demand and/or strong energy security and resiliency mandates. Out of 7,000+ U.S. federal facilities, approximately 450 campuses make up over 75% of the 889 trillion BTU total energy use. Converting even a few of these large campuses to geothermal power will have an impact of decarbonizing trillions of BTUs of energy as well as increase resilience and energy security for key Federal sites.
- Community Geothermal Heating & Cooling Deployments: This new initiative in FY 2022 funds demonstrations of geothermal heating and cooling systems as the district- and community-scale. In addition to building on FY 2022 efforts, the FY 2023 initiative will deploy systems with agricultural applications that can address local energy scarcity and/or

food security needs in underserved areas of the U.S. This program's goal is to double the over 3,000 terajoules/year of geothermal heat that is already used in the U.S. agricultural sector. The projects will prioritize building local coalitions that include state and local partnerships and developing a vocational workforce to deploy and install geothermal heating systems.

- Reservoir Thermal Energy Storage (RTES): In this initiative aimed at unlocking the terawatt-scale thermal energy storage of using the Earth as our battery, GTO will conduct new pilots and demonstrations that build on prior years of early-stage research to demonstrate technical feasibility, grid integration, and long-term storage opportunities for renewable energy systems. These projects will consider where geothermal energy storage can be used in combination with other renewable energy generation and energy efficient technologies to create industrial and community energy systems that are fully decarbonized.

Contributions to DOE-wide Crosscutting Investments

GTO is involved in several crosscuts, including the following:

- Critical Minerals and Materials ($5,000,000): In FY 2023, GTO will address technology and process gaps that still exist following the results of the Geothermal Lithium Extraction Prize to generate technical solutions to our Nation's critical minerals supply through geothermal brine and produced water extraction and processing. This may include efforts to scale up technical solutions developed as part of the Geothermal Lithium Extraction Prize to successful demonstration in the Salton Sea area of California. In the Salton Sea alone, there is an estimated lithium resource potential of 600,000 tons per year of lithium carbonate, corresponding to a value of $7.2 billion[1].
- Energy Storage ($12,000,000): In FY 2023 GTO will fund new pilots and demonstrations of Reservoir Thermal Energy Storage that will build on prior years of early-stage research to demonstrate technical feasibility, grid integration, and opportunities for systems that leverage more than one type of renewable energy or energy storage. The goal of this initiative is to unlock the terawatt-scale potential of thermal energy storage by using the Earth as our battery; and
- Subsurface Energy Innovations Crosscut ($202,000,000): All of GTO's portfolio contributes to this effort.

EERE Program Priorities

In FY 2023, GTO continues to support an investment strategy aligned to the following programmatic priority areas that are central pillars to the U.S. greenhouse gas (GHG) profile:

Geothermal Technologies
Funding ($K

	FY 2021 Enacted	FY 2022 Annualized CR[2]	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted
Decarbonizing the electricity sector	89,000	89,000	159,500	+70,500
Reduce the carbon footprint of the U.S. building stock	17,000	17,000	25,500	+8,500
Decarbonizing the agriculture sector, specifically focused on the nexus between energy and water	0	0	17,000	+17,000

[1] https://www.energy.ca.gov/publications/2020/selective-recovery-lithium-geothermal-brines

[2] The FY 2022 Annualized CR amounts reflect the P.L. 117-95 continuing resolution level annualized to a full year.

Geothermal Technologies
Funding ($K)

	FY 2021 Enacted	FY 2022 Annualized CR[1]	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted
Geothermal Technologies				
Enhanced Geothermal Systems	65,000	-	117,000	+52,000
Hydrothermal Resources	20,000	-	34,000	+14,000
Low Temperature and Coproduced Resources	15,000	-	34,000	+19,000
Data, Modeling, and Analysis	6,000	-	17,000	+11,000
Total, Geothermal Technologies	**106,000**	**106,000**	**202,000**	**+96,000**

SBIR/STTR:

- FY 2021 Transferred: SBIR: $3,344,000; STTR: $470,250
- FY 2022 Annualized CR: SBIR: $3,146,000; STTR: $442,000
- FY 2023 Request: SBIR: $6,107,260; STTR: $858,833

[1] The FY 2022 Annualized CR amounts reflect the P.L. 117-95 continuing resolution level annualized to a full year. These amounts are shown only at the congressional control level and above, below that level, a dash (-) is shown.

Geothermal Technologies
Explanation of Major Changes ($K)

	FY 2023 Request vs FY 2021 Enacted ($K)
Geothermal Technologies	
Enhanced Geothermal Systems: To ensure the U.S. stays on track for 60 GWe deployment of geothermal power by 2050, the FY 2023 EGS Subprogram Budget Request reflects an increase of $52,000,000 from the FY 2021 Enacted level. The Request targets field demonstration projects in both Subsurface Accessibility R&D, including directed efforts on EGS focused drilling and well completion, and Subsurface Enhancement & Sustainability R&D, including reservoir creation. Within Subsurface Enhancement and Sustainability R&D, the Request includes an increase to provide funding for the new EGS Greenfield Demonstration initiative to demonstrate EGS viability in green-field environments and continuing the Wells of Opportunity initiative. Within Subsurface Accessibility, EGS will provide significant funding for the new EGS Drilling and Well Construction initiative and the second year of GEODE, an initiative intended to help transition and transfer between the oil and gas and geothermal sectors. The Request includes funding for the highly successful Frontier Observatory for Research in Geothermal Energy (FORGE) initiative under the FORGE activity, which decreases by $5,553,000 from FY 2021 Enacted. The Request provides $11,000,000 for work with rural communities and Tribes for a Hybrid EGS/Deep Direct Use demonstration initiative within the Resource Maximization R&D (see below) activity.	**+52,000**
Hydrothermal Resources: The Request prioritizes funding for Exploration and Characterization R&D for a new initiative focused on working with Federal agencies to determine the feasibility of installing geothermal power production on Federal property and continuation of collaborative work with the U.S. Geological Survey. The increase includes funding for work for critical materials research, specifically follow-on research from the FY 2021 Geothermal Lithium Extraction Prize, under the Resource Maximization R&D activity, and the Subsurface Accessibility R&D Activity includes a focus on the GEODE initiative.	**+14,000**
Low Temperature and Coproduced Resources: The Request prioritizes funding for efforts under the Resource Maximization R&D Activity in the Low Temperature & Coproduced Resources subprogram with an increase of $19,000,000 from the FY 2021 Enacted, including a strong focus on technical assistance in the Community Geothermal Heating and Cooling for Food and Agriculture initiative, on demonstrating the potential of Reservoir Thermal Energy Storage, part of the DOE Energy Storage Grand Challenge, and technical assistance for direct use geothermal in community and sports facilities.	**+19,000**
Data, Modeling, and Analysis: The Request focuses on cross-EERE analysis and demonstration as well as continuing to stand up a significant analysis capability. The increase will provide funding for analytic support for streamlining geothermal permitting on Federal lands and improved data ingestion, processing, and dissemination. The Request also provides funding for Geothermal Grid Valuation Technical Assistance and for Technical Assistance to Support Community Capacity building, including activities to help a variety of communities transition to clean energy.	**+11,000**
Total, Geothermal Technologies	**+96,000**

Geothermal Technologies
Enhanced Geothermal Systems

Description

Enhanced Geothermal Systems (EGS) are engineered reservoirs created where there is hot rock but little to no natural permeability or fluid saturation present in the subsurface. Underpinning the EGS subprogram's major technical thrusts are fundamental geoscience challenges whose resolution hinge on collaborative Research, Development and Demonstration (RD&D). The focus of the EGS subprogram is to gain an evidence-based understanding of basic and applied 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 RD&D will enable industry to develop a baseload energy resource as shown in the GeoVision report, which will be the major contributor to achieving a potential geothermal power capacity of 60 GWe by 2050.

Technologies that facilitate characterization of local stress, chemical constituents, and evolution of fluid and thermal pathways through space and over time are critical to advancing EGS. A final overarching challenge is sustainable operation, which requires manipulation of the subsurface to maintain sufficient productivity for power generation without excessive flow localization or reduced flow rates.

EGS shares common challenges with other subsurface industries where collaboration across the government, academic, and private sectors is advantageous. This is typified in the EGS subprogram's flagship initiative, the Frontier Observatory for Research in Geothermal Energy (FORGE), where multidisciplinary collaboration has yielded exciting successes to date. In addition to FORGE, all other research in the EGS subprogram is focused on characterizing, accessing, creating, and sustaining EGS reservoirs and is therefore categorized into the following activities: Resource Characterization R&D, Subsurface Accessibility R&D, Subsurface Enhancement & Sustainability R&D, and Resource Maximization R&D.

Relative to other geothermal resources, EGS has the potential to provide the most relative, year-on-year growth in the electric sector, comprising much of the GTO 60 GWe goal by 2050, and can also support significant growth within the non-electric sector for district heating and other direct-use applications. Without significant and sustained investment in EGS technology development and demonstrations, however, GTOs 60 GWe by 2050 target is unlikely to be met by the U.S. To ensure the U.S. stays on track to meet this substantial deployment goal, the FY 2023 EGS Subprogram Budget Request reflects an increase of $52,000,000. This additional funding will support investments in large-scale geothermal field demonstrations in EGS Drilling and Well Construction and in EGS Greenfield Demonstrations that will facilitate real-time innovation, the flexibility to repeatably test high-risk techniques and technologies in a variety of geologic settings and conditions, and an invaluable opportunity to learn-by-doing not possible.

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

Resource 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. The EGS Near-Field Monitoring & Characterization R&D Partnerships with the National Laboratories and the U.S. Geological Survey (USGS), for example, address a critical gap in this space, where the team is focused on developing a state-of-the-art subsurface monitoring system for EGS to be deployed at the Near-Field EGS Demonstration (Amplify) project sites. Higher resolution subsurface characterization will reduce EGS costs, which will enable deployment of carbon pollution-free EGS energy production.

Subsurface Accessibility R&D: In FY 2023, the Budget Request includes a large investment in a new EGS Drilling and Well Construction initiative. 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. Work at the FORGE site, focused on improving drilling efficiency and transitioning methods from oil and gas to geothermal will directly enable deployment of carbon pollution-free EGS energy production, contributing 60 GWe by 2050.

Subsurface Enhancement & Sustainability R&D: Engineering the subsurface is paramount to the commercial and technological success of EGS. 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 needed 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, especially microseismicity as related to permeability enhancement. Research in these areas will reduce the costs and risks of EGS resulting in a lower ultimate LCOE. Addressing critical technology gaps in subsurface sustainability and enhancement through repeatable stimulation design and testing via the FY 2023 Wells of Opportunity (WOO) and a new FY 2023 EGS Greenfield Demonstration initiative. In the near term, the transition of relevant O&G technologies, workforce, and assets to geothermal energy production will also contribute to advances in this critical technology space.

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): FORGE is an essential step toward establishing the capability to improve our understanding of EGS concepts as it enables US science and engineers to conduct transformative and high-risk science and engineering and move EGS toward commercial viability. 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.

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Enhanced Geothermal Systems $65,000,000	**$117,000,000**	**+$52,000,000**
Frontier Observatory for Research in Geothermal Energy (FORGE) $30,552,700	$25,000,000	-$5,552,700
• FORGE Competitive R&D Solicitations: This R&D focus addresses developing alternative completion techniques, adoption of relevant unconventional oil and gas stimulation methods, and identifying links between completion techniques and reservoir development and operation. • FORGE Advanced Wellbore Completions for EGS Longevity: This R&D focus addresses developing alternative completion techniques, adoption of relevant unconventional oil and gas stimulation methods, and identifying links between completion techniques and reservoir development and operation.	• FORGE – R&D focused on developing alternative completion techniques, adoption of relevant unconventional oil and gas stimulation methods, and identifying links between completion techniques and reservoir development and operation. A portion of these funds will enable the drilling of an additional highly-deviated well. • FORGE Advanced Wellbore Completions for EGS Longevity: No funding requested.	• An additional well will enable simulation testing and downhole testing of tools and technologies funded via competitive research solicitations aimed at advancing EGS with respect to the Subsurface Enhancement activity area. Additional well will enable simulation testing and downhole testing. • Funding reprioritized for other EGS technology R&D areas that specifically cover wellbore completions in the Subsurface Enhancement & Sustainability R&D category.
Subsurface Enhancement & Sustainability R&D $26,700,000	$48,000,000	+$21,300,000
• Innovative Methods to Control Hydraulic Properties of Enhanced Geothermal Systems: This R&D focus addresses 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 stimulation and will aid in designing more efficient, sustainable reservoirs.	• Innovative Methods to Control Hydraulic Properties of Enhanced Geothermal Systems: No funding requested.	• Work on this important effort will continue with prior year appropriations; these technologies will be transitioned to the private sector and to demonstration projects when complete and GTO may pursue additional research into this technical via the FORGE effort.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
• Wells of Opportunity – Amplify Topic Area 1 – Amplify (EGS Near-Field RD&D): This field validation effort will culminate in new power production, adding to the commercial viability of existing geothermal fields. The goal of Amplify is to illustrate that near-field and in-field EGS can be successfully deployed now as a result of recent technology advancements and that low permeability/underproductive wells near and in existing hydrothermal fields can be turned into valuable assets using EGS techniques.	• Wells of Opportunity – Initiate additional near-field EGS demonstrations, including a focus on shallow heat located near existing hydrothermal fields.	• Additional demonstrations will add tens of MW of clean, geothermal energy to the electric grid and add to the commercial viability of existing geothermal fields.
• Wells of Opportunity - Topic Area 2 – ReAmplify (Geothermal production from hydrocarbon wells): The objective of this initiative is to establish the commercial viability of geothermal energy production from existing hydrocarbon fields. The goal of ReAmplify is to establish a pilot program where the production of geothermal heat from existing hydrocarbon fields can be demonstrated for electricity production or direct use applications.	• Wells of Opportunity – ReAmplify: No funding requested.	• ReAmplify will be incorporated into outyears of GEODE.
• EGS Workforce Training: FY 2021 includes engagement with the community to speed the adoption of advanced concepts and capabilities, including the subsurface workforce, into the EGS field. A major goal of this effort is engagement of a broader swath of the U.S. population to increase geothermal literacy – which can facilitate technically savvy workforce and also a community interested in advocating for geothermal energy as their clean-energy of choice.	• EGS Workforce Training: No funding requested.	• Work on this effort will be transitioned to the GEODE initiative.
• EGS STEM Early Career Awards: This effort includes a program for early career researchers to	• EGS STEM Early Career Awards: Issue small seedling grants that allow participants to develop	• No significant change.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
receive seed funding to explore EGS concepts and widen the breadth of contributors to the EGS community. A major goal of this effort is engagement of a broader swath of the U.S. population to increase geothermal literacy – which can facilitate technically savvy workforce and also a community interested in advocating for geothermal energy as their clean-energy of choice.	and pursue geothermal-relevant ideas. This will increase awareness of geothermal benefits and resources and attract researchers and other interested parties to the geothermal field.	
• No funds requested.	• EGS Greenfield Demonstration: EGS Greenfield Demonstration will target shallow to mid-depth, geothermal temperature anomalies for clean, renewable, geothermal power production. Projects will build on the zonal isolation/stimulation learnings of previous GTO initiatives such as WOO, FORGE, and EGS Collab. WOO focused primarily on near-field EGS, while FORGE is set in a single geologic setting.	• This new set of EGS demonstrations will move beyond the near-field environment and focus on drilling and development in greenfields (where no existing geothermal development exists) in varied geological environments to continue to hone our understanding of what is required to scale up EGS and ensure its viability throughout the U.S..
Subsurface Accessibility R&D $5,380,070	$33,000,000	+$27,619,930
• EGS Collab: The EGS Collab project continues stimulation and flow experiments in highly-monitored and well characterized intermediate-scale (~10-20 m) field test beds. In FY 2021 a new test bed, in a different rock type 4,100 feet below the surface will be developed. Fracture creation, stimulation, and interwell flow tests are repeatedly performed to better understand processes that control formation of effective subsurface heat exchangers useful in EGS. EGS Collab also provides a means of testing models, tools, and concepts that can later be employed under geothermal reservoir conditions at FORGE or other enhanced geothermal systems to improve reservoir creation and connectivity.	• EGS Collab: No funding is requested.	• Work to continue using prior year funds. The EGS Collab effort was designed with specific goals linked to a suite of intermediate scale reservoir creation and model validation tasks. The project team will have met these goals successfully at the end of FY 2022 and therefore the project will decommission the field site and end.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
• The intermediate scale field testing underway at EGS Collab is a critical step to enable full scale field deployment of EGS nationwide. Efforts culminating in FY 2022 at EGS Collab will directly enable deployment of carbon-free EGS energy production, contributing 60 GWe by 2050, facilitating 516 million (MMT) of avoided CO2e and creating 262,000 "gross" full-time jobs.	• No funding requested.	• Work to continue using prior year funds. The EGS Collab effort was designed with specific goals linked to a suite of intermediate scale reservoir creation and model validation tasks. The project team will have met these goals successfully at the end of FY 2022 and therefore the project will decommission the field site and end.
• No funding requested	• Geothermal Energy from Oil and gas Demonstrated Engineering (GEODE): Select GEODE Team and prepare solicitations to modernize geothermal drilling, deploy O&G technologies to lower geothermal development costs and stand up workforce development programs to attract, train, and utilize highly skilled workers displaced from O&G. • EGS Drilling and Well Construction: Research, develop and demonstrate drilling and completion technologies that will enhance exploration and development specific to EGS resources.	• New initiative will leverage technical, physical and workforce assets from the oil and gas industry. This initiative started in FY 2022. • New initiative to help unlock 60 GW of geothermal energy and decarbonize the electric grid by 2035.
Exploration and Characterization R&D $2,367,230	$0	-$2,367,230
• EGS Near-Field Monitoring & Characterization R&D: Partnerships with the National Laboratories and USGS will continue R&D to develop a state-of-the-art subsurface monitoring system for Enhanced Geothermal Systems (EGS) to be deployed at the Near-Field EGS Demonstration (Amplify) project sites. A successful outcome of this effort will include lower-cost, faster deployed wells that are capable of monitoring in situ reservoir evolution and properties at higher resolution than existing systems. The EGS Near Field Monitoring goals, as stated above, impact the economics of EGS deployment dramatically, and when successful will enable reduction of one	• EGS Near-Field Monitoring & Characterization R&D: Support new near-field EGS demonstrations through the WOO effort.	• Focus on developing more cost-effective methods for developing sustainable, economic EGS reservoirs. The Near-Field project will be fully instrumented with prior year funding and therefore additional funds are not necessary.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
portion of the EGS deployment costs (monitoring for regulatory compliance).		
Resource Maximization R&D $0	$11,000,000	+$11,000,000
• No funding requested.	• Hybrid EGS/Deep Direct Use Demonstration: Demonstrate and validate EGS hybrids (EGS + Solar thermal, CSP, etc.) as a resilient power source in regions with elevated geothermal temperatures.	• New demonstration will serve as a model for future expanded deployment of EGS hybrids across the U.S. and help validate systems and costs modeling underway across EERE with field data.

Geothermal Technologies
Hydrothermal Resources

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. Hydrothermal resources can also be utilized to hit the nearer-term Administration goal of a carbon pollution-free electricity sector by 2035. The program sponsors RD&D that can lower cost and risk throughout the lifecycle of a hydrothermal project to bring more hydrothermal power online, 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 resource development, many of the biggest opportunities for advancement relate to the exploration and drilling phases 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, reducing delays, 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 wells that are required as well as reducing the cost for each well, 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 energy applications and business models, e. g. mineral recovery, grid-scale energy storage, and dispatchable power generation. The subprogram also supports R&D for extracting critical materials or other strategic minerals from geothermal brines to maximize the ancillary benefits of geothermal resources. 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 but are of high interest for technology transfer efforts. 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 for all geothermal applications.

Subsurface Enhancement and Sustainability R&D: 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. 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 the challenges of proving extraction technologies and scaling them up to commercial levels; R&D can improve tools and techniques for characterizing provenance and sustainability of these types of mineral resources.

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Hydrothermal Resources $20,000,000	**$34,000,000**	**+$14,000,000**
Subsurface Accessibility R&D $3,500,000	$12,000,000	+$8,500,000
• Drilling Technology Demonstration Campaign: R&D on drilling technologies over the past decade has resulted in several technologies and methods ready for field demonstration that can reduce the costs and risks of drilling and, therefore, lead to increased deployment of geothermal. GTO will fund a major drilling technology demonstration campaign to prove the utility and efficacy of innovative well construction technologies and to attract future private investment. DOE-sponsored field development is needed, because thinly-capitalized geothermal developers will not accept risks associated with the implementation of such innovative well construction technologies, including those adapted from the oil and gas industry. This will directly enable deployment of carbon-free geothermal energy production, contributing toward the goal of 60 GWe by 2050. • No funding Requested	• Drilling Technology Demonstration Campaign: No funding requested. • Geothermal Energy from Oil and gas Demonstrated Engineering (GEODE): Select GEODE Team and prepare solicitations to modernize geothermal drilling, deploy O&G technologies to lower geothermal development costs and stand up workforce development programs to attract, train, and utilize highly skilled workers displaced from O&G.	• Effort will continue under the new EGS Drilling and Well Construction initiative. • New initiative will leverage technical, physical and workforce assets from the oil and gas industry. This initiative started in FY 2022.
Exploration and Characterization R&D $16,500,000	$17,000,000	+$500
• No funding Requested	• FedGeo Power: Conduct feasibility studies and site characterization for geothermal power generation opportunities at Federal and military installations with a large electricity demand	• This is a new initiative. Out of 7,000+ U.S. federal facilities, approximately 450 campuses make up over 75% of the 889 trillion BTU total energy use. Converting even a few of these large

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
	and/or strong energy security and resiliency mandates.	campuses to geothermal power will have an impact of decarbonizing trillions of BTUs of energy.
• Machine Learning for Geothermal: Projects awarded under the FY 2018 Machine Learning for Geothermal Energy FOA will undergo a downselect. 1-3 projects will continue into the next phase of research which will focus on scaling up from early-stage R&D and may involve expanded study areas, new data acquisition, and additional market transformation activities. Further leveraging machine learning research to identify geothermal resources and improve hydrothermal operations and methods will help meet Administration carbon pollution-free goals by directly enabling deployment of carbon-free geothermal energy production, contributing 30 GWe by 2050. • Hydrothermal Lab R&D – Dark Fiber: Pending the outcome of a Go / No Go review, the next phase of work for a Lawrence Berkeley National Lab project, which explores the use of dark fiber (unused optical fiber that has been laid but is not currently being used in fiber-optic communications) and distributed acoustic sensing to map and monitor geothermal resources in the Imperial Valley, will begin. This project will provide unique insights into the Imperial Valley in California, where known geothermal resource areas exist, which will directly enable deployment of additional carbon-free geothermal energy production in the Imperial Valley. It will also provide a method for increased discovery of hidden geothermal resources in the U.S.	• Machine Learning for Geothermal: Identify hidden geothermal resources in the U.S. using machine learning in conjunction with data gathered through geophysical surveys in partnership with USGS (GeoDAWN; GeoFlight). • Hydrothermal Lab R&D – Dark Fiber: No funding requested.	• No significant change. • This project is in its final stages using funding from prior years. No new funding needed.

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
• Hidden Systems Award: To stimulate the continued discovery and development of hidden geothermal resources in the Basin and Range Province of the western U.S. by expanding the public body of exploration tools and knowledge, the project selected will design, apply, and validate a complete workflow for discovering hidden geothermal resources in the selected study area. The team will optimize the allocation of award funds across the project activities, with the concurrent goals of maximizing the identification of undiscovered resources, lowering risk and uncertainty for the overall resource portfolio, and validating the specific exploration methods and approach for the study area through some level of site-specific drilling. This award will directly enable identification of geothermal systems that will lead to deployment of carbon-free geothermal energy production, contributing 30 additional GWe by 2050, and aiding the U.S. transition to 100 percent clean energy economy.	• Hidden Systems Award: No funding requested.	• The Request prioritizes RDD&D in other areas within Hydrothermal Resources to continue to harness hydrothermal resources toward a carbon-free grid for 2035. Work on Hidden Systems will continue in FY 2023 with prior year appropriations.
Resource Maximization R&D $0	$5,000,000	+$5,000,000
• Critical Materials: No funding was requested in FY 2021 through the Hydrothermal Resources subprogram; until FY 2022, critical materials research was funded through Low-Temperature and CoProduced Resources.	• Critical Materials: Scale up technical solutions for geothermal brine and produced water extraction and processing. Demonstrate technologies in the Salton Sea area of California.	• This new critical mineral extraction effort can have vast potential toward administration priorities in critical minerals. In the Salton Sea alone, there is an estimated annual lithium resource potential of 600,000 tons, which currently exceeds the annual U.S. demand for lithium.

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 energy designs, that can be co-developed with other clean energy technologies. Low-temperature resources used for power production have a lower power conversion efficiency than other geothermal resources so, while these resources are abundant throughout the country, EGS tools and techniques will help unlock their full potential. The subprogram also supports R&D on the direct use of thermal resources for process and space heating applications, district-scale geothermal heating and cooling systems, and deep direct use geothermal resource development. These technologies have the potential to provide cost-effective, renewable thermal energy in large portions of the U.S.

A 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 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, the U.S. has an opportunity to leverage existing HVAC and piping infrastructure for low-temperature resources, 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 direct use applications and power production, including temperature gradients at varying depths and in varying environments (urban/rural, residential/industrial, etc.), will help the geothermal industry better understand 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 online and facilitate nationwide deployment of low-temperature power production.

Subsurface Accessibility R&D: Drilling wells and boreholes, along with trenching, enables 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 outside of the West where higher temperature resources are concentrated, 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 online and facilitating nationwide deployment of low-temperature power production.

Subsurface Enhancement and Sustainability R&D: Enabling cost-effective subsurface engineering technologies, specifically the ability to increase permeability at depth, can facilitate geothermal district heating and cooling throughout 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 online.

[1] https://www.usgs.gov/programs/energy-resources-program/science/geothermal#overview.

Coupled thermal, hydraulic, mechanical, and chemical (THMC) modeling and testing help 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 online 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. District- and community-scale geothermal heating and cooling systems make use of near-constant year-round temperatures in the shallow subsurface to heat communities and infrastructure in the winter and cool them in the summer. There is ubiquitous thermal energy storage available in the Earth for a variety of direct-use and grid applications that can significantly enable new, more resilient energy services that not only provide an effective alternative to grid-dependent heating and cooling but that also add resilience to the broader energy system. GTO continues to support this potential in partnership with the DOE Energy Storage Grand Challenge and through standalone funding opportunities for large-scale resource assessment and feasibility research across a diverse group of institutions pursuing geothermal system installation. This program includes maximizing the benefits of coproduced energy sources, such as coproduction of oil/gas and geothermal energy using heated fluids sourced from nearby oil and gas fields. The geothermal component of these systems may generate power/electricity, or it may be directly used for heating applications.

Low Temperature and Coproduced Resources

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Low Temperature and Coproduced Resources $15,000,000	**$34,000,000**	**+$19,000,000**
Resource Maximization R&D $15,000,000	$34,000,000	+$19,000,000
• Energy Storage Grand Challenge: The selected project in Direct Use Applications will enable new, more resilient energy services that not only provide an alternative to grid-dependent heating and cooling but that also add resilience to the larger energy system. The engineering design and testing of low-temperature geothermal fluids in district heating and cooling systems will enable the development of needed low-temperature system components and infrastructure resulting in the next generation of district heating and cooling in America. This initiative will help transition the U.S. to a 100 percent clean energy economy as well as develop technology that will transition underserved communities to clean, geothermal energy through the addition of 17,500 district heating systems nationwide by 2050.	• Energy Storage Grand Challenge: Develop pilots and demonstrations of Reservoir Thermal Energy Storage to demonstrate technical feasibility, grid integration, and opportunities for systems that leverage more than one type of renewable energy or energy storage.	• Transition from early-stage research to pilots and demonstrations.
• Energyshed Management System: This effort includes the development and demonstration of an "energyshed" management system that addresses a discrete geographic area in which renewable sources currently provide a large portion of electric energy needs, where grid capacity constraints result in curtailment of renewable generation, and with very substantial existing deployment of interactive smart meters. The "energysheds" design should achieve a high level of integration resilience and reliability among all energy uses, including both on-demand and long-time energy scales, transmission and distribution of electricity. “Energysheds” will	• Energyshed Management System: No funding requested.	• The Energyshed Management System effort has moved to the Renewable Energy Integration line of the FY 2023 Budget Request.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
provide information and transparency to key stakeholders and the public regarding the sources, reliability, and sustainability of their electricity to encourage accountability and environmental justice as we move towards a future with 100 percent clean energy.		
• No funding requested.	• Community Geothermal Heating & Cooling Technical Assistance & Deployment: Build on FY 2022 initiative to provide demonstrate geothermal heating and cooling for communities in a variety of living environments. Demonstrate community-scale agricultural heating systems that use geothermal energy to address local energy scarcity and/or food security needs in underserved areas. Build state and local partnerships to develop a vocational workforce to deploy and install geothermal heating systems.	• Building on the existing initiative to develop technologies that will transition underserved communities to clean, geothermal energy through the addition of 17,500 district heating systems nationwide by 2050.
• No funding requested.	• Direct Use for Recreational Facilities: Provide financial assistance to community organizations to retrofit sports and recreation facilities with direct use geothermal technologies such as district heating or geothermal heat pumps. Initiative focuses on underserved populations and includes an outreach campaign promoting the organization's contribution of clean energy to the community and its advantages (resiliency, emissions reductions, savings).	• New initiative will leverage the innate relationship between community organizations with recreational facilities and the regions in which they reside to promote early adoption of geothermal technologies.

Geothermal Technologies
Data, Modeling, and Analysis

Description

The goal of the Data, Modeling, and Analysis (DMA) 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 R&D from early stage to technology demonstration and deployment. DMA 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 enable further deployment of geothermal resources.

DMA conducts analyses in the following areas: the environmental impacts of geothermal, the policy and regulatory barriers to geothermal development and deployment, geothermal grid value and integration, techno-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 R&D direction from early stage to technology demonstration and deployment. DMA 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, DMA 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, the program published a Multi-Year Program Plan in FY 2022. The Multi-Year Program Plan provides additional RD&D objectives and associated performance goals through FY 2026 for accelerating towards the outcomes identified in the GeoVision analysis.

Data, Modeling, and Analysis

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Data, Modeling, and Analysis $6,000,000	**$17,000,000**	**+11,000,000**
Data, Modeling, and Analysis $6,000,000	$17,000,000	+11,000,000
• Techno-Economic Tools & Data: Funding supports continued maintenance of techno-economic tools, data, and National Laboratory expertise. Geothermal Electricity Technology Evaluation Model (GETEM): In its current form, GETEM is a robust open-source techno-economic analysis tool used by industry and DOE to evaluate the levelized costs of prospective geothermal power generation developments. There are opportunities to improve and enhance GETEM's capabilities by incorporating relevant datasets that are rigorously tied to the underlying physics and thermodynamics of geothermal systems. Through a multi-lab collaboration, a framework of enhancements will upgrade model sophistication, minimize data uncertainties, and expand data inputs leveraging the results of key initiatives such as FORGE. These improvements will allow GETEM to better directly represent technology advancements and their ability to lower geothermal LCOE accurately value geothermal project costs and provide critical inputs for a variety of energy system planning models to better accurately capture geothermal's important deployment potential in the transition to a 100 percent clean energy economy. Geothermal Data Repository (GDR): GDR is the submission portal for data generated by GTO funded projects. Data collected will continue to be collected and curated, and NREL will continue to maintain the repository as well as implement	• Techno-Economic Tools & Data: Conduct critical analysis, modeling, and facilitate the storage of project data. The FY 2023 Request includes funding for the second year of development of major analytic capacity building for geothermal at NREL and other laboratories. Major focus areas of analytic capacity building are in modeling capacity, power sector analysis at NREL, and heating and cooling sector analysis.	• This increase will leverage the increased analytic capacity building at NREL and other laboratories which started in FY 2022 and will continue in FY 2023 and beyond.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
improvements that can streamline submission practices to enable new GTO analysis capabilities. Data is accessible to everyone in order to fuel innovation, promote scientific discovery in the geothermal sector, and empower a diverse group of stakeholders to engage with cutting-edge geothermal data. Technical Monitoring Team (TMT): Independent expertise will continue to be provided by the DOE National Laboratories on the Program's major investments.		
• Feasibility of Geothermal on Federal Installations: In collaboration with the DOE Federal Energy Management Program (FEMP), the Program will conduct feasibility analyses and research to identify promising Federal installations (e.g., DoD, National Park Service, the Department of Veterans Affairs) for developing on-site geothermal projects. This effort will leverage existing data and analytical tools, identify approaches to enhance analytical tool capabilities, as well as leverage FEMP Federal partnerships and networks. The result of this collaboration will be a suite of sites with demonstrated promise for additional research and characterization activities for developing on-site geothermal projects that can provide significant contributions to Federal clean energy goals and highlight Federal leadership in transitioning to a 100 percent clean energy economy.	• Feasibility of Geothermal on Federal Installations: No funding requested.	• Transitioned to the Hydrothermal Resources Fed Geo Power initiative.
• Closed-loop Geothermal System Performance Modeling: A multi-laboratory working group will numerically investigate the potential of closed-loop type geothermal systems, considering variations in well geometries, geothermal reservoirs working fluids, enhancement	• Closed-loop Geothermal System Performance Modeling: No funding requested.	• Analysis will be completed by the end of FY 2022; no further research is necessary at this stage.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
technology, and other operational parameters. Results will focus on quantifying thermal power generation, heat quality yields across these variations, and system longevity among other considerations. This analysis project represents continued focus from GTO on a variety of geothermal technologies that can support transitioning to a 100 percent clean energy economy.		
• No funding requested	• Cross-EERE Analysis, Technical Assistance, and Demonstration: In support of the Administration's goals of achieving a 100 percent clean electricity system by 2035 and a 100 percent net-zero emission economy by 2050, GTO will continue supporting increased cross-EERE and cross-DOE efforts to provide data, tools, analysis to support the widespread integration of renewables to an evolving grid that ensures a resilient, reliable power system. This includes partnering with other Energy Efficiency and Renewable Energy Offices, the Office of Strategic Programs, and the Office of Electricity to significantly expand upon current technical assistance for stakeholders faced with making data-driven decisions and investments, including evaluating design and control development, analysis, and field demonstration of hybrid geothermal technology applications, designing clean energy deployment programs, evaluating effective electrification and decarbonization pathways, developing market and policy solutions, and planning transmission and distribution upgrades to facilitate the transition to a 100 percent clean electricity system. Laboratory capabilities will include analysis, demonstrations, evaluation, measurement, and verification; and direct	• Cross-EERE Analysis and Demonstration: The Request includes funding to build on analysis and demonstration programs started in FY 2022 to initiate these high-priority FY 2023 analysis, technical assistance, and demonstration programs. This work aligns with Renewable Energy Grid Integration Action Plan, developed to align grid activities across EERE and OE necessary to enable a just transition to a grid that supports a decarbonized power system by 2035 and a zero-emission economy by 2050 while maintaining the reliability, affordability, security, and resilience of the energy system.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
	technical assistance, tailored to the needs of individual cities and communities.	
• No funding requested	• Communities to Clean Energy (C2C): Over 170 cities have committed to power their communities with 100% renewable energy, and these city-focused goals represent a bottoms-up approach that will support achieving a 100 percent clean electricity system by 2035. Meeting these goals will require understanding how renewable generation technologies can work together with energy storage, advanced distribution management systems, electrified transportation, and energy efficient loads. Through C2C, GTO will contribute towards cross-DOE and national laboratory assistance to help cities and communities in achieving these goals. C2C will provide a variety of support mechanisms including analysis to highlight effective decarbonization strategies, laboratory demonstrations of technologies and best practices, developing measurement and verification processes, building out workforce development pipelines, and disseminating outcomes and lessons learned.	• Communities to Clean Energy (C2C): The Request includes funding to continue this high-priority set of cross-DOE activities that was begun in FY 2022 to support reaching a 100 percent clean energy system by 2035 and a 100 percent net-zero emission economy by 2050.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
• No funding requested.	• Cross-EERE Analysis, Technical Assistance, and Demonstration: Support increased cross-EERE and cross-DOE efforts to provide data, tools, analysis to support the widespread integration of renewables to an evolving grid. Expand upon current technical assistance for stakeholders faced with making data-driven decisions and investments, including evaluating design and control development, analysis, and field demonstration of hybrid geothermal technology applications, designing clean energy deployment programs, evaluating effective electrification and decarbonization pathways, developing market and policy solutions, and planning transmission and distribution. Laboratory capabilities will include analysis, demonstrations, evaluation, measurement, and verification; and direct technical assistance, tailored to the needs of individual cities and communities.	• This work aligns with grid activities across EERE and OE necessary to enable a just transition to a grid that supports a decarbonized power system.
• No funding requested.	• Communities to Clean Energy (C2C): Provide a variety of support mechanisms to cities and communities including analysis to highlight effective decarbonization strategies, laboratory demonstrations of technologies and best practices, developing measurement and verification processes, building out workforce development pipelines, and disseminating outcomes and lessons learned.	• New initiative to enable cities and communities to meet important decarbonization targets in line with Administration goals.

Advanced Manufacturing

Overview

The Biden Administration is committed to revitalizing domestic manufacturing, and a resilient and competitive American manufacturing sector is critical for the economy and our national security. Manufacturing generates 11 percent of U.S. gross domestic product (GDP)[1] and employs more than 12 million Americans[2]. Significant decarbonization of the manufacturing sector and scale-up of clean energy and climate technology manufacturing is essential to achieving the Administration's goal of economy-wide decarbonization by 2050, while creating good paying jobs with a fair and free chance to join a union and collectively bargain. Manufacturing composes three-quarters of the U.S. industrial sector, which has an annual energy bill of about $200 billion[3], consumes roughly one-third of primary energy in the U.S., and produces 28 percent of the Nation's carbon emissions.[4] Innovation in the manufacturing sector is required to reduce greenhouse gas (GHG) emissions from U.S. manufacturers and support U.S. manufacturers to be more competitive in the global marketplace.

The Advanced Manufacturing Office (AMO) plays a leading role in decarbonizing and revitalizing the industrial sector. It addresses the climate crisis by driving the innovation and deployment that can lead to a more resilient, robust, and competitive domestic clean energy manufacturing sector that provides economic opportunities across diverse communities. Manufacturing can deliver the technologies needed to decarbonize other sectors of the economy, including transportation, buildings, and the electric grid. AMO accomplishes its goals by supporting applied research, development, and demonstration (RD&D) in crosscutting, platform technologies to reduce GHG emissions, and promote the development and growth of advanced manufacturing in multiple emerging energy fields. AMO actively partners with industry to lower barriers that would otherwise limit the subsequent demonstration, adoption, and use of the new knowledge and practices gained through RD&D. This ensures that new technologies invented in the U.S. are manufactured in the U.S. as well, all in support of the Administration priority to deliver an equitable, clean energy future for all Americans. Through its technical assistance and workforce development programs, AMO ensures that tools and resources are available to diverse manufacturing organizations. These tools help manufacturers increase energy and water efficiency and decrease waste and GHG emissions. AMO's workforce development activities focus on creating the next generation of manufacturing workers and fostering career opportunities for a diverse workforce. With this approach, AMO will drive the manufacturing innovations needed to support the Biden Administration goal of net-zero GHG emissions, economy-wide, by 2050, while also investing in the economic engine of American-made energy technology that brings economic prosperity and high-quality jobs to communities across the country.

Through strategic investments in RD&D activities, as well as technical assistance and workforce training, AMO works with universities, laboratories, companies (for-profit and non-profit), state/local governments, and consortia. AMO activities depend on merit-based selection and peer-reviewed results.

In the FY2022 Budget, AMO developed and proposed a new budget structure in response to feedback from stakeholders and program peer reviewers. The historical subprogram structure through FY 2021 was based on operational categories – R&D Projects, R&D Consortia, and Technical Partnerships. The FY 2023 Budget Request further refines the new structure across four updated technical subprograms: Industrial Efficiency and Decarbonization; Clean Energy Manufacturing; Material Supply Chains; and Technical Assistance and Workforce Development.

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[1] "GDP by Industry / VA, GO, II, EMP," 2021, Bureau of Economic Analysis; available from: https://apps.bea.gov/industry/factsheet/factsheet.cfm.
BEA : BEA Industry Facts

[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] U.S. Energy Information Administration. State Energy Data System (SEDS): 1960-2019 (complete), 2021, https://www.eia.gov/state/seds/seds-data-complete.php?sid=US.

[4] Annual Energy Outlook 2022: Reference Case Data, U.S. Energy Information Administration, available from: http://www.eia.gov/forecasts/aeo/data.cfm.

The Industrial Efficiency and Decarbonization subprogram focuses on reducing GHG emissions from industry by targeting high emitting sectors and pursuing crosscutting technologies that are relevant across multiple sectors. The Clean Energy Manufacturing subprogram focuses on solving key manufacturing challenges for clean energy technologies that are critical for achieving economy-wide decarbonization. The Material Supply Chains subprogram focuses on secure and sustainable supply chains, including critical materials, as well as material recycling and recyclability. The subprogram also focuses on solving foundational materials and manufacturing challenges for both decarbonization and clean energy by developing novel materials with improved properties. Finally, the Technical Assistance and Workforce Development subprogram focuses on making knowledge and transformational tools accessible across manufacturing organizations and developing the future manufacturing workforce with an emphasis on benefiting disadvantaged communities and underrepresented populations. The technical subprograms will support secure and resilient decarbonized manufacturing supply chains and drive improvements in energy and resource efficiency in manufacturing. Moreover, AMO supports the Administration's commitment to ensuring the future is Made in America by workers who have a fair and free choice to join a union and collectively bargain.

Within each subprogram, AMO focuses on technical areas with high potential for impact. The AMO technical focus areas are developed through engagement with stakeholders, informed by strategic analysis, and guided by roadmaps to target knowledge gaps and barriers that, if addressed through R&D or other investments, can be further developed by industry to improve productivity through advanced manufacturing processes.

Examples of AMO focus areas within the technical subprograms include:

Industrial Efficiency and Decarbonization

- Energy-intensive industries: Applied research, development, and pilot-scale demonstration activities to accelerate the commercial readiness of emerging, net-zero emissions technologies for the most carbon-intensive industrial sectors such as cement, chemicals, and steel.
- Chemical and Thermal Process Intensification: R&D to reduce the equipment size and energy intensity for manufacturing processes through higher reaction efficiency, novel mixing and separations, and low thermal budget heating and cooling.
- Energy-Water Nexus: R&D to enable non-traditional water sources, such as sea, brackish, municipal, industrial, and agricultural water, to be treatable at a levelized cost compared to today's marginal water supplies (fresh water) and to recover valuable resources, such as embedded energy and other nutrients, from municipal, industrial, and agricultural wastewater.

Clean Energy Manufacturing

- Clean Energy Technology Manufacturing: Application of manufacturing innovations to clean energy technologies, such as energy storage systems and power electronics. Includes the new Solar Manufacturing Accelerator to advance domestic solar manufacturing.
- Advanced Manufacturing Processes: Foundational manufacturing processes that can be applied across multiple clean energy technologies, including additive processes capable of direct net-shape formation of metals, polymers, and ceramic materials and smart manufacturing technologies that leverage advanced sensors, controls, artificial intelligence, platforms, and models to facilitate real-time, secure, agile, operational improvements in materials, manufacturing processes, and systems.

Material Supply Chains

- Critical Materials and Supply Chains: RD&D supporting diversification of supply, recycling, more efficient use, and substitution for critical materials (e.g., rare-earth materials) essential to manufacturing energy technologies for which there is potential for supply chain disruption.
- Materials for Improved Performance: Development of advanced materials broadly applicable to energy technologies and/or reduction of lifecycle energy requirements, including energy conversion materials, materials for extreme or harsh conditions, high conductivity materials, and high strength-low weight materials.
- Sustainable Manufacturing: Advances in sustainable product design, including design for recyclability, and the efficient use, recycling, and reuse of raw materials in manufacturing.

AMO will closely coordinate its RD&D efforts with the Manufacturing and Energy Supply Chains Office that supports modernization, scaleup and deployment of manufacturing facilities critical to the Energy Industrial Supply Base

Technical Assistance and Workforce Development

- Technical Assistance: Assistance for diverse manufacturers in reducing their carbon emissions, adopting energy management programs, incorporating resilience into their operating systems, and providing targets for energy efficiency, electrification, clean fuels, productivity, waste reduction, carbon reductions, and water use reduction practices. The new Better Climate Challenge program supports manufacturers as they pursue decarbonization goals through a focus on energy efficiency measures, fuel switching (electrification, moving from higher carbon to lower carbon fuels, etc.), onsite renewables, grid interactivity, and offsite renewables.
- Stakeholder Engagement: A robust two-way engagement program with industry stakeholders to inform future investments and program activities in the areas of decarbonization, workforce development, underserved communities, energy storage, and others.
- Workforce Development: A multi-level manufacturing workforce development program that engages participants at varying career levels and integrates activities across AMO programs and partner offices to expand impact, especially in energy communities, underserved communities, and tribal communities.

AMO also supports the key emphasis areas of energy justice, workforce, diversity in STEM, and state and local partnerships. Investments associated with Workforce Development will support training and develop good paying clean energy jobs for the American people, especially workers, communities impacted by the energy transition, and those historically underserved by the energy system and overburdened by pollution. Investments associated with Diversity in STEM support outreach and will raise awareness of clean energy research and job opportunities at minority-serving institutions and minority-focused professional organizations, and ensure that organizations receiving EERE funding are thinking through diversity and equity in their own work. Investments in State and Local partnerships will support state and local governments with the necessary resources to be more effective in facilitating affordable and resilient clean energy and efficiency goals. Investments associated with Energy and Environmental Justice will support approaches and processes to reach new groups of Americans historically underserved by the energy system.

Highlights of the FY 2023 Request

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

- The Solar Manufacturing Accelerator in partnership with the Solar Energy Technology Office. This initiative will produce technologically-advanced solar energy components that avoid supply chains that may be reliant in part on unethically sourced materials or vulnerable foreign supply chains. The Accelerator will include technology and manufacturing demonstration across the solar supply chain.
- A second year of funding for a new Manufacturing USA institute focused on industrial decarbonization.
- Industry-specific decarbonization investments, with initiatives focusing on the chemicals, iron and steel, cement, and other high carbon-emitting industries such as food products.
- Priority cross-cutting technologies for decarbonization based on industrial decarbonization roadmap potentially including thermal-process electrification, electrochemical processes, innovative separations, circular economy approaches, and carbon dioxide (CO_2) reuse.
- Expanded funding RD&D for high priority critical materials, including pilot and demo projects and testbeds to reduce supply risk and improve supply resilience for materials and technologies necessary for the clean energy transition. Manufacturing innovations to address technical challenges and manufacturing barriers to achieve lower manufacturing cost, higher performance, and accelerated demonstration and deployment of clean energy technologies, such as energy storage systems, wide bandgap semiconductors, hydrogen systems and wind turbine blades and components.
- Resources and training to increase the impact of existing workforce related programs, including within energy communities, underserved communities, and tribal communities. Training for clean energy innovators and manufacturing energy management workforce of the future. Expanded programs targeting community colleges and technical schools, apprenticeship programs, and resources focused on reskilling and upskilling existing workers.
- Technical assistance to increase the adoption of decarbonization technologies and advanced energy and water efficiency technologies and practices across the industrial sector. Expanded programs include DOE's Better Climate Challenge: a national public-private partnership that calls on organizations across the country to set bold, portfolio-

wide GHG reduction targets and share their innovative solutions and best practices. Leveraging the success of the Better Buildings, Better Plants Challenge, DOE will provide technical assistance and convene peer-to-peer exchanges to identify pathways and key areas for collaboration and improvement Through the Better Climate Challenge, DOE will provide technical assistance and national recognition to partners that share innovative and cost-effective GHG reduction implementation strategies and replicable pathways to decarbonization.

DOE-wide Crosscutting Investments

Highlights include support for the following Departmental Crosscuts:

- Advanced Manufacturing ($582,500,000) – Advanced manufacturing will increase energy and material efficiency in manufacturing to drive energy productivity and economic growth. AMO will place a significant emphasis on industrial decarbonization, clean energy manufacturing, foundational materials and processes, technical assistance and workforce development;
- Carbon Dioxide Removal ($10,000,000) – AMO will support manufacturing innovations that enable pathways of CO_2 removal such as emerging decarbonization technologies in the cement sector.
- Critical Minerals and Materials ($60,000,000) – AMO will continue to support an integrated and coordinated RD&D program for high priority critical materials;
- Energy Storage ($30,000,000) – AMO will collaborate with multiple offices, including the Office of Electricity (OE), and EERE's Vehicle Technologies Office and Hydrogen Fuel cell Technologies Office (HFTO), on projects to overcome the manufacturing barriers of innovative integrated energy storage systems;
- Energy-Water Nexus ($40,000,000) – AMO is supporting lower cost, lower energy intensive water treatment technologies to create a more modern, equitable, climate-adaptive, and sustainable water infrastructure from both freshwater and non-traditional water sources, such as brackish groundwater, seawater and wastewater for use and reuse in industry, power utilities, municipalities, agriculture, and resource extraction;
- Industrial Decarbonization ($315,700,000) – AMO will invest in RD&D to decarbonize energy intensive industries including the iron and steel, chemicals, food products, cement sectors, as well as other energy intensive sectors. In addition, technical assistance will be provided to decarbonize the industrial sector; and
- Hydrogen ($20,000,000) – AMO will collaborate with HFTO to develop and deploy hydrogen and fuel cell technologies to advance the economic use of low-carbon hydrogen for industrial processes.

EERE Program Priorities

In FY 2023, AMO continues to support an investment strategy aligned to the following programmatic priority areas that are central pillars to the U.S. greenhouse gas (GHG) profile:

Advanced Manufacturing
Funding ($K)

	FY 2021 Enacted	FY 2022 Annualized CR	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted
Decarbonizing the electricity sector	10,000	20,000	80,000	+70,000
Decarbonizing transportation across all modes: air, sea, rail, and road	10,000	101,500	90,000	+80,000
Decarbonizing energy-intensive industries	42,958	411,941	513,857	+470,899
Decarbonizing the agriculture sector, specifically focused on the nexus between energy and water and food products	20,000	20,000	45,000	+25,000

Advanced Manufacturing
Funding ($K)
(Comparable)

	FY 2021 Enacted	FY 2022 Annualized CR[5]	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted
Advanced Manufacturing				
Industrial Efficiency and Decarbonization	156,312	–	261,000	+$104,688
Clean Energy Manufacturing	117,721	–	157,000	+39,279
Material Supply Chains	86,618	–	110,000	+23,382
Technical Assistance and Workforce Development	35,349	–	54,500	+19,151
Total, Advanced Manufacturing	**396,000**	**396,000**	**582,500**	**+186,500**

SBIR/STTR:
FY 2021 Transferred: SBIR $11,232,000; STTR: $1,580,000
FY 2022 Annualized CR: SBIR: $ 11,238,000; STTR: $ 1,580,000
FY 2023 Request: SBIR: $15,745,000; STTR: $2,214,000

Advanced Manufacturing
Funding ($K)
(Non-Comparable)

	FY 2021 Enacted	FY 2022 Annualized CR	FY2023 Request	FY 2023 Request vs FY 2021 Enacted
Advanced Manufacturing				
R&D Projects (2021)	217,672	–	0	0
R&D Consortia (2021)	133,328	–	0	0
Technical Partnerships (2021)	45,000	–	0	0
Industrial Efficiency and Decarbonization (2023)	0	–	261,000	+$261,000
Clean Energy Manufacturing (2023)	0	–	157,000	+157,000
Material Supply Chains (2023)	0	–	110,000	+110,000
Technical Assistance and Workforce Development (2023)	0	–	54,500	+54,500
Total, Advanced Manufacturing	**396,000**	**396,000**	**582,500**	**+186,500**

[5] The FY 2022 Annualized CR amounts reflect the P.L. 117-95 continuing resolution level annualized to a full year. These amounts are shown only at the congressional control level and above, below that level, a dash (-) is shown..

	FY 2023 Request Level vs FY 2021 Enacted
Industrial Efficiency and Decarbonization: Increased funding for this subprogram will focus on reducing GHG emissions from industries through new manufacturing technologies. Key activities include the development and demonstration of decarbonization solutions for energy-intensive industries and crosscutting decarbonization technologies including second year of funding for a new Manufacturing USA Institute. In FY 2023, AMO will prioritize decarbonization efforts on four key industries – chemicals, iron and steel, cement, and food products – to address large opportunities and enable an accelerated timeline for achieving carbon emission reductions, while continuing crosscutting decarbonization technology efforts.	+$104,688
Clean Energy Manufacturing: Increased funding for this subprogram will focus on solving key manufacturing challenges for clean energy technologies that are critical for achieving economy-wide decarbonization. In FY 2023, AMO will prioritize R&D to address manufacturing innovation needs to drive down the cost, improve the performance, and accelerate the path to commercialization of innovative clean energy technologies such as energy storage, power electronics, wind, solar and hydrogen.	+39,279
Material Supply Chains: Increased funding for this subprogram will focus on research, development and demonstration to support secure and sustainable supply chains and high performance materials. AMO will address supply, substitution, and reuse solutions for critical materials. The subprogram will also advance circular economy work and develop novel materials with improved properties, as well as new production processes for those materials. In FY 2023, AMO efforts will prioritize critical materials and supply chains, high performance materials, and recyclable materials. AMO will closely coordinate its RD&D efforts with the Manufacturing and Energy Supply Chains Office that supports modernization, scaleup and deployment of manufacturing facilities critical to the Energy Industrial Supply Base. Please see the relevant sections of the DOE Budget Request for additional information.	+23,382
Technical Assistance and Workforce Development: Increased funding for this subprogram will focus on providing technical assistance for the implementation of decarbonization technologies and water efficiency projects and practices; making transformational tools accessible across manufacturing organizations; and developing the future manufacturing workforce. Technical assistance areas include energy and water efficiency, waste reduction, onsite clean power generation, workforce development, cybersecurity, and energy management. In FY 2023, AMO will increase funding for multi-level workforce development activities and focused assistance to energy-intensive manufacturing sectors, including those in energy communities, underserved communities, and tribal communities.	+19,151
Total, Advanced Manufacturing	**+186,500**

Advanced Manufacturing
Industrial Efficiency and Decarbonization

Description

The Industrial Efficiency and Decarbonization subprogram will focus on reducing GHG emissions from the industrial sector in support of a net zero emission economy by 2050. Key activities include the research, development and demonstration of decarbonization solutions for energy-intensive industries and cross-cutting decarbonization technologies. These RD&D projects will be selected through a combination of merit-based, competitive solicitations and peer-reviewed National Laboratory-based activities (in partnership with industry). Example topic areas include molten oxide electrolysis of steel, zero carbon cement production, integration of renewable feedstocks, electrification of process heat, high-performance computing for manufacturing, and process intensification. The subprogram will identify a set of specific RD&D challenges based on stakeholder input, alignment with the program's technology thrust areas, and potential energy, carbon, and economic impacts.

Energy-Intensive Industries: Energy-intensive industries, including iron, steel and other metals, chemicals, food & beverage, and cement, emit over one-half of the GHG emissions in the industrial sector. Significant opportunities exist to address major sources of energy consumption and carbon emissions by process operations such as heating, melting, drying, and calcining. Improved reactions and separations can enable energy and cost savings, reduced water usage and a lower carbon footprint. This activity will support RD&D initiatives that will include industry-specific technologies that improve energy efficiency, eliminate process emissions, pursue electrification, and integrate clean fuels, feedstocks, and energy sources.

Cross-Cutting Technologies: Cross-cutting technologies enable decarbonization in multiple industrial sectors. Informed by analysis and stakeholder engagement, this activity will invest in a suite of targeted technology RD&D for highest decarbonization impact. For example, advances in process intensification that contribute to improvements in energy efficiency, as well as electrification and other advancements for thermally intensive operations, especially those that are difficult to decarbonize due to high temperatures. Additionally, hydrogen or other clean fuels may be used to decarbonize combined heat and power technologies. High performance computing-based solutions can enable improved energy performance and substantially reduce carbon emissions throughout industry. A strong analytical program will conduct assessments based on findings from the forthcoming industrial decarbonization roadmap to identify additional priority cross-cutting opportunities for decarbonization.

Energy-Water Nexus: The water sector has GHG emissions from methane, as well as from energy use. In addition, regions with limited water resources depend increasingly on non-traditional water sources, which are more energy intensive to treat. R&D supporting energy-efficient, low-carbon, low–cost, electrified desalination technologies through the Energy-Water Desalination Hub managed by the National Alliance for Water Innovation (NAWI) will help to reduce costs, energy use, and the carbon footprint for the provision of nontraditional water. This activity will support efforts that will include development of technologies that treat seawater, brackish water, and produced waters, for use in municipal, industrial, agricultural, utility, and other water supply needs. In addition, the activity's investments in RDD&D of energy and resource recovery from municipal, agricultural, and industrial wastewater will contribute to reduced methane emissions, lower energy requirements, and reduced energy costs.

Industrial Efficiency and Decarbonization

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Industrial Efficiency and Decarbonization $156,312,000	**$261,000,000**	**+$104,688,000**
Energy Intensive Industries $44,740,000	$160,000,000	+$115,260,000
• Support industrial sector decarbonization through competitively selected, merit-reviewed R&D focused on transformative zero-carbon production technologies, novel chemical and steel manufacturing processes, and other opportunities in energy- and carbon- intensive sectors.	• Support industrial decarbonization activities, including research, development and pilot-scale demonstrations, to rapidly advance technologies and enable an accelerated timeline for achieving carbon emission reductions. Focus on decarbonization of the chemicals, iron and steel, cement, and food products industries.	• Substantial increase in funding to address large decarbonization opportunities in energy- and carbon-intensive industries, particularly the chemicals, iron and steel, cement, and food products industries.
Cross-cutting Technologies $66,572,000	$61,000,000	-$5,572,000
• Support competitively selected, merit-reviewed R&D focused on cross-cutting industrial decarbonization technologies such as process heating, electrification, and other opportunities, including a new Manufacturing USA Institute	• Pursue priority cross-cutting technologies for decarbonization based on industrial decarbonization roadmap and analyses, potentially including electrochemical processes, innovative separations and CO2 reuse. This includes the second year of funding for a new Manufacturing USA Institute.	• Decrease represents a shift in focus to efforts on energy intensive industry technology opportunities for industrial decarbonization.
• R&D and technical assistance for hydrogen or renewably fueled CHP that enables flexible manufacturing.	• Decarbonized combined heat and power: RD&D and technical assistance for hydrogen or renewably fueled CHP for industry.	• No significant change.
• 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; and conduct quantitative analysis research.	• Support high performance computing-based solutions that apply modeling, simulation, and data analysis to industrial processes and products to improve energy performance and substantially reduce carbon.	• No significant change.
Energy-Water Nexus $45,000,000	$40,000,000	-$5,000,000
• Fund the first year of the second and final five-year phase of the Energy Water Hub. Fund up to 10 competitively selected, merit-based research projects to achieve energy efficiency and energy recovery at water and wastewater treatment	• Fund the third year of the final five-year phase of the Energy Water Hub. Fund competitively selected, merit-based research projects to decarbonize water and wastewater treatment, with a focus on agricultural waters.	• Moderate decrease in competitive projects to enable greater focus on energy intensive industry decarbonization opportunities.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
plants, with a focus on decarbonization of water infrastructure.		

Advanced Manufacturing
Clean Energy Manufacturing

Description

The Clean Energy Manufacturing subprogram will focus support on solving key manufacturing challenges for clean energy technologies that are critical for achieving economy-wide decarbonization, with an emphasis on manufacturing processes that benefit multiple technologies. It also focuses on smart and agile manufacturing technologies that will enable value chains to be nimble, responsive, and adaptive to disruption, change, and opportunity. The Clean Energy Manufacturing subprogram will support applied R&D projects, cost-shared with companies and research organizations, that focus on generating solutions to specific technology challenges to advance domestic manufacturing while reducing our Nation's carbon footprint. These RD&D projects will be selected through a combination of merit-based, competitive solicitations and peer-reviewed, National Laboratory-based activities (in partnership with industry. The results of these RD&D efforts will support industry development and manufacturing of next-generation advanced materials and manufacturing processes to supply our clean energy economy. Efforts include advanced manufacturing processes for technologies such as energy storage, semiconductors, heat pumps, wind, solar and hydrogen. The subprogram will identify the specific research challenges based on stakeholder input, alignment with the program's technology thrust areas, and potential energy, carbon, and economic impacts.

Advanced Processes: This activity will support foundational manufacturing processes such as additive manufacturing and the manufacture of carbon fiber from low-cost precursors. These manufacturing process innovations can improve U.S. competitive advantage across a variety of industries important to clean energy manufacturing. In addition, hardware and software system innovations will be supported to enable manufacturing systems and supply chains to be responsive to be nimble, responsive, and adaptive to disruption, change and opportunity.

Energy Technology Manufacturing: This activity will support efforts focused on advancements in manufacturing RD&D for technologies such as energy storage systems, hydrogen for industrial decarbonization, and composite materials for wind energy and other clean energy applications. Investments will focus on manufacturing innovations to improve performance and address barriers to achieve lower manufacturing cost to that can accelerate the path of these technologies to market. Investments will be prioritized based on analysis and cross-DOE planning to enable robust deployment and accelerate decarbonization throughout the economy. AMO will collaborate on the Solar Manufacturing Accelerator, a new initiative in partnership with the Solar Energy Technologies Office. This Accelerator will seek to diversify and strengthen the supply chain for solar energy technologies and will work to enhance the domestic capability to produce technologically advanced solar energy components that avoid supply chains that may be reliant in part on unethically sourced materials or vulnerable foreign supply chains. The Accelerator will include technology and manufacturing demonstration across the solar supply chain.

Clean Energy Manufacturing

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Clean Energy Manufacturing $117,721,000	**$157,000,000**	+$39,279,000
Advanced Processes $71,845,000	$30,000,000	-$41,845,000
• Conduct high-priority public-private projects related to additive manufacturing and carbon fiber materials research through the MDF/CFTF.	• Continue additive manufacturing and carbon fiber materials research through the MDF/CFTF.	• Shift focus from the MDF/CFTF to an increase emphasis on energy technology manufacturing.
• Fund competitive opportunity for innovative advanced manufacturing technologies to enable manufacturing supply chains to be nimble, responsive, and adaptive to disruption, change and opportunity; and support competitively selected, merit-based projects addressing innovations in emerging industries and advanced tooling for lightweight automotive components.	• Support new methods for manufacturing products such as agile manufacturing, additive manufacturing, and the manufacture of carbon fiber from low-cost precursors, and support innovative advanced manufacturing technologies to enable manufacturing supply chains to be nimble, responsive, and adaptive to disruption, change and opportunity	• Shift focus to an increase emphasis on energy technology manufacturing.
Energy Technology Manufacturing $45,876,000	$127,000,000	+$81,124,000
• No funding requested.	• Support the Solar Manufacturing Accelerator initiative, a joint effort with the Solar Energy Technology Office, to produce technologically advanced solar energy components that avoid supply chains that may be reliant in part on unethically sourced materials or vulnerable foreign supply chains. The Accelerator will include technology and manufacturing demonstration across the solar supply chain.	• Significant increase to support the launch of the Solar Manufacturing Accelerator initiative.
• Collaborate with the Wind Energy Technologies Office on additive manufacturing work on large offshore wind blades and other wind turbine components including thermoplastic resin systems; Collaborate with HFTO on a funding opportunity to increase focus on electrolyzer manufacturing.	• Clean energy manufacturing R&D in collaboration across EERE and DOE for technologies including efficient motors, pumps, generators; highly efficient semiconductors, power electronics, wind, and hydrogen.	• Significant increase to support competitively selected R&D projects to enable robust deployment and accelerate decarbonization throughout the economy. Develop roadmap across DOE applied offices to identify highest need priorities for additional investments.
• Strengthen the domestic production of energy storage technologies by designing new technologies, enhancing materials used in energy	• Develop manufacturing innovations to improve performance of energy storage systems and to address technical challenges and manufacturing	• No significant change.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
storage systems, and improving the manufacturing methods for system components.	barriers to achieve lower manufacturing cost to make storage systems more accessible.	

Advanced Manufacturing
Material Supply Chains

Description

The Material Supply Chains subprogram supports RD&D enable a secure and reliable supply chain of critical materials for clean energy technologies; material and product sustainability through advances in recycling and recyclability; and high performance materials. These activities will be supported through a combination of merit-based, competitive solicitations and peer-reviewed National Laboratory-based activities (in partnership with industry). Example topic areas include critical materials supply, recycling, and substitution; material recycling and the circular economy; and high-performance materials. The subprogram will identify the specific challenges based on stakeholder input, alignment with the program's technology areas, and potential energy, carbon, and economic impacts. AMO will closely coordinate its RD&D efforts with the Manufacturing and Energy Supply Chains Office that supports modernization, scaleup and deployment of manufacturing facilities critical to the Energy Industrial Supply Base.

Critical Materials: This activity will support RD&D investments to reduce supply risk and improve supply resilience for materials and technologies necessary for the clean energy transition (including rare earths, lithium, cobalt, and gallium), which applications such as magnets in electric vehicles and wind turbines, batteries, efficient lighting, and semiconductors require. Strategies include diversifying supply, developing substitutes, and improving reuse/recycling. The activity will also support pilot projects and testbeds that verify economics of continuous operations in real world conditions. Areas of interest for these projects include highly selective separation, metal reduction, magnet manufacturing, materials recovery from secondary and unconventional sources, material reuse, more efficient use, and balanced coproduction.

Sustainable Materials and Products: This activity will support efforts to apply principles of materials reuse and recycling across material classes such as metals, plastics, and fiber reinforced polymer (FRP) composite materials to reduce carbon emissions and environmental impact. Efforts include design for recyclability, new material development, and reuse and recycling technologies.

High Performance Materials: This activity will focus on support for improved performance for materials necessary for decarbonization and clean energy. Specific RD&D will address topics such as advancements in materials used in extreme or harsh conditions such as the high temperature and pressure environments for manufacturing processes, heat exchangers, and hydrogen storage. The activity will also support R&D to enable advancements such as high performance materials for clean energy technologies, including high conductivity metals, nanomaterials, and high-strength and low-weight materials.

Material Supply Chains

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Material Supply Chains $86,618,000	**$110,000,000**	**+$23,382,000**
Critical Materials $54,488,000	$60,000,000	+$5,512,000
• Continue funding high priority critical materials RD&D and de-risk and support consortium to validate successful technology innovations for critical minerals including test bed facilities to address gaps in domestic supply chains in an integrated and coordinated program. Lithium ion extraction for designing a commercial scale facility to extract and convert lithium from geothermal brines.	• Expanded funding RD&D for high priority critical materials, including pilot projects and testbeds to reduce supply risk and improve supply resilience for materials and technologies necessary for the clean energy transition.	• Increase funding to support Investments that will be prioritized based on analysis and cross-DOE planning to enable robust deployment and accelerate decarbonization throughout the economy.
Sustainable Materials and Products $10,601,000	$15,000,000	+4,399,000
• Support efforts to apply principles of materials reuse and recycling with emphasis on plastics as part of Plastics Innovation Challenge activities, including the continuation of the BOTTLE Consortium and R&D projects to recycle and upcycle plastics films; along with efforts to apply circular economy principles to polymers and fiber reinforced polymer (FRP) composite materials.	• Continuation of the BOTTLE Consortium and the expansion of R&D projects to recycle and upcycle plastics films; along with efforts to apply circular economy principles to polymers and fiber reinforced polymer (FRP) composite materials	• Increase funding to accelerate progress in plastics and polymers.
High Performance Materials $21,529,000	$35,000,000	+$13,471,000
• Fund competitively selected, merit-based applied R&D projects at National Laboratories, universities, and companies focused on increasing durability and capability, and reducing the cost of materials and components operating in harsh and extreme environments found in industrial operations.	• Fund competitively selected R&D projects to increase focus on advance improved performance for materials necessary for decarbonization and clean energy, such as high conductivity metals and industrial materials that can operate in harsh service environments.	• Increase funding for a larger selection of the best R&D projects to advance improved performance for materials necessary for decarbonization and clean energy, such as high conductivity metals and industrial materials that can operate in harsh service environments.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
• Support CABLE prize activities to help build an equitable, clean-energy future.	• Expand funding support for CABLE prize activities to help build an equitable, clean-energy future.	• Increase funding to increase the number of top-rated R&D projects for high performance materials research.

Advanced Manufacturing
Technical Assistance and Workforce Development

Description

The Technical Assistance and Workforce Development subprogram will focus on making knowledge and transformational tools accessible across manufacturing organizations; developing the future manufacturing workforce with an emphasis on benefiting disadvantaged communities and underrepresented populations; and enabling value chains to be nimble, responsive, and adaptive to disruption, change, and opportunity. The subprogram will support technical assistance and stakeholder engagement to encourage the deployment of energy and water efficient technologies and processes. Through a combination of merit-based, competitive solicitations and peer-reviewed, National Laboratory-based activities (in partnership with industry), the technical assistance efforts will support manufacturers in increasing their operational efficiency so they can save money and reduce carbon emissions. Technical assistance areas include technologies for flexible and adaptable manufacturing, waste reduction, water efficiency, workforce development, secure digital and cyber-physical systems, and energy management. Example programs include Better Plants Challenge, Energy Management Programs (50001 Ready and Superior Energy Performance), and Lab Embedded Entrepreneurship Programs. The subprogram will identify the specific research and deployment challenges based on stakeholder input, alignment with the program's technology areas, and potential energy, carbon, and economic impacts.

Technical Assistance: Increasing the adoption of decarbonization technologies and advanced energy and water efficiency technologies and practices across the industrial sector requires technical assistance. Opportunities exist to provide resources to assist manufacturers in reducing their energy use intensity by promoting the adoption of energy management programs and providing targets for energy efficiency, productivity, carbon reductions, and waste/water use reduction practices. This activity will support efforts that include the expansion of the Better Plants Challenge to include new initiatives related to energy-intensive manufacturers, carbon reduction, technology validation, and training opportunities. Additional activities include the expansion of existing tools like the 50001 Ready Navigator and MEASUR tool suite to address emerging topics such as carbon reduction, resiliency, and cybersecurity, and enable manufacturing companies to easily access state-of-the-art tools to conduct analysis. By focusing on disadvantaged communities, this technical assistance work will also support the Justice40 initiative.

Workforce Development: Advanced manufacturing processes are demanding more from workers in the form of technical skills, experience with computer-automated processes, and expertise in energy information management systems. This activity will include a multi-level manufacturing workforce development program that supports participants at varying career levels, engages underserved communities, and integrates activities across AMO programs and partner offices to expand impact. Opportunities exist to provide educational resources for students at primary and high schools, community colleges, and universities. The activity will also provide support to provide opportunities for mentoring and on-the-job training to increase the number of qualified technical employees in advanced manufacturing. All educational and workforce development activities will include a focus on diversity and inclusion, and reskilling programs will be specifically targeted toward underserved communities, energy communities, and tribal communities to aid in their transition to the clean energy economy. The activities will build partnerships with labor unions to create good paying jobs with the fair and free chance to join a union and collectively bargain. The activities will also improve industrial hygiene and reduce workplace exposures. By developing a more flexible and resilient manufacturing workforce, U.S. manufacturers can be more agile in reacting to market needs, while focusing on innovation. AMO is actively coordinating on workforce development activities with DOL and DOC, including a strong collaboration with DOC's Manufacturing Extension Partnerships.

Technical Assistance and Workforce Development

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Technical Assistance and Workforce Development $35,349,000	**$54,500,000**	**+$19,151,000**
Technical Assistance $11,704,000	$30,500,000	+$19,329,000
• Provide technical assistance to manufacturers on energy and water efficiency, waste reduction, technology validation, and energy management processes.	• Expand technical assistance for the implementation of energy and water efficiency projects and practices, including increased technical assistance to disadvantaged communities, Equity, Environmental and Energy Justice communities, and areas with high industrial emissions.	• Increased technical assistance to energy intensive manufacturing sectors and to disadvantaged communities, EEEJ communities, and areas with high industrial emissions.
• Provide focused technical assistance to energy intensive manufacturing sectors related to energy and carbon reduction.	• Expand the Better Plants Challenge to include new initiatives related to energy-intensive manufacturers, carbon reduction, technology validation, and training opportunities.	• Increased funding for expansion of Better Plants Challenge to provide technical assistance to energy-intensive manufacturers.
• Technical assistance to support screening analyses for resiliency systems and development of educational resources to support technology deployment.	• Provide technical resources, tools, and implementation guidance to manufacturers that are pursuing onsite renewable energy generation or energy storage projects.	• Increased funding to focus on energy intensive industries to support the deployment of emerging decarbonization technologies and operational practices.
Workforce Development $23,645,000	$24,000,000	+355,000
• Fund multi-level training program that supports participants at varying career levels (i.e. Students, skilled trades workers, energy managers, corporate managers, etc.).	• Train the clean energy innovators and manufacturing energy management workforce of the future. Provide additional resources and trainings to increase the impact of existing workforce-related programs, including within energy communities, underserved communities, and tribal communities. Expand programs targeted at community colleges and technical schools, apprenticeship programs, and resources focused on reskilling and upskilling existing workers.	• Shift focus to energy communities, disadvantaged communities, and building partnerships with labor unions.
• Support educational resource development to encourage energy/water efficiency, waste reduction, and carbon reduction technologies and practices, especially in energy communities,	• Support projects led by early-career post-doctoral researchers to address fundamental manufacturing decarbonization challenges.	• Increase early-career post-doctoral researchers to address fundamental manufacturing decarbonization challenges.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
underserved communities, and tribal communities.		
• Fund competitively selected partnerships between National Laboratories, universities, and the private sector that emphasize student-led projects to develop new tools and processes that address energy management and advanced manufacturing challenges	• The FY 2023 Request for EERE does not include funding for the Industrial Assessment Centers. This activity is realigned to the Office of Manufacturing and Energy Supply Chains (MESC) in the Office of the Undersecretary of Infrastructure	• No funding requested.

Building Technologies

Overview

The Building Technologies Office's (BTO) goal is to reduce the energy intensity and related carbon emissions resulting from homes and commercial buildings through the application of cost-effective technologies and practices. Throughout the stages of a building's lifecycle, there are multiple opportunities to work towards emission reductions. Increasing energy efficiency and encouraging demand flexibility enables the convergence of decarbonized buildings with on-site renewable energy, electric vehicles and a rapidly decarbonizing electric grid. In addition, improvements in new building design and construction, ongoing building management, maintenance, and appliance replacements provide further opportunities for emission reductions in buildings. Lastly, building shell renovation and improvements, as well as real estate transactions, provide opportunity to further integrate energy efficiency measures and reduce the energy use and emissions of buildings. BTO is focused on maximizing impact in each of these stages through strategic investment in research, development, demonstration, and deployment (RDD&D). According to the U.S. Census (2011-2015), the national average energy burden for low-income households is over 8 percent, and 47 percent of U.S. households, or about 50 million homes, are defined as low-income.[1] With the belief that all Americans can/should be able to benefit from affordable and high-performing homes and buildings, BTO's activities across technologies and sub-sectors to lower the cost of no/low-carbon solutions. In addition, these highly efficient technologies and market transformation programs can help reduce energy burden, especially on low-income households. In FY 2023, BTO-sponsored activities will have an increased focus on supporting low-income households, which on average have three times the energy burden of non-low-income households and small businesses, and typically receive a lower quality of energy services.[2] For example, DOE is actively working on projects that seek to reduce costs and increase accessibility for new, more-efficient manufactured homes by looking at innovative manufacturing practices for more-efficient designs, consumer education, and accessibility.

Acceleration of building sector technology innovation and deployment plays an essential role towards a U.S. net-zero emission economy by 2050. The U.S.'s 130 million residential and commercial buildings are the single largest energy-consuming sector in the U.S. economy, representing approximately 40 percent of total national energy consumption, 75 percent of the Nation's electricity use, and are responsible for some 35 percent of energy-related carbon dioxide emissions[3]. It is estimated that one-third or more of the energy used by buildings is wasted, and with it as much as $150 billion[4] annually. Total building energy use in 2021 was 21 quads and energy-related CO_2 emissions from buildings is approximately 1,700 million metric tonnes (MMTons), with residential and commercial buildings contributing approximately 55 percent and 45 percent, respectively. Today, 65 percent of CO_2 emissions from buildings result from electricity consumption; therefore, closely linking decarbonization of the building sector to the decarbonization of the electricity supply.[5] In addition to reducing emissions resulting from electricity consumption, reducing direct emissions of building end uses, primarily space heating and water heating, is essential. Reducing energy demand and having the ability to shift building loads through demand flexibility and storage are important supportive roles to renewable integration as the power sector continues to reduce emissions from the electricity supply. Collectively these strategies can lower energy demand and cost related to home and commercial building operations, as well as reduce the cost of overall grid

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[1] According to DOE's **Low-Income Energy Affordability Data (LEAD) Tool** the national average energy burden for low-income households is 8.6%, three times higher than for non-low-income households which is estimated at 3%. Of all U.S. households, 44%, or about 50 million, are defined as low-income. Low-Income Community Energy Solutions | Department of Energy

[2] https://www.energy.gov/eere/slsc/low-income-community-energy-solutions#:~:text=According%20to%20the%20U.S.%20Department,which%20is%20estimated%20at%203%25

[3] U.S. Energy Information Administration. Monthly Energy Review, 2022, https://www.eia.gov/totalenergy/data/monthly/index.php.

[4] Derived from residential and commercial expenditures given in U.S. Energy Information Administration. State Energy Data System (SEDS): 1960-2019 (complete), 2021, https://www.eia.gov/state/seds/seds-data-complete.php?sid=US.

[5] U.S. Energy Information Administration. Monthly Energy Review, 2022, https://www.eia.gov/totalenergy/data/monthly/index.php.

decarbonization by decreasing the need for further transmission and distribution congestion pricing and investments. Energy efficiency and demand flexibility benefits become even more critical as the buildings and transportation sectors rely more heavily on a decarbonized grid.

Energy reductions across building electric end uses (e.g., cooling, commercial ventilation, lighting, and refrigeration) are an important part of the transition to a net-zero emission economy. Deep decarbonization of the electricity grid also puts an emphasis on onsite building emissions reduction opportunities from space and water heating. In addition to a focus on the equipment directly responsible for reducing energy and emissions, it is also important to incorporate the role building envelope upgrades can play in reducing the overall heating and cooling loads for buildings, especially when considering increased electric grid needs and peak times of power use. Heating and cooling equipment in the built environment has a long lifespan, so building equipment that is replaced in the next decade will impact the long-term emissions reduction trajectory, potentially out to 2050. As a result, BTO's FY 2023 funding is aligned with greatly accelerating progress on the building end uses most impactful to reducing carbon emissions, placing an increased emphasis on space heating, cooling, and water heating, and increasing the focus on market priming and cost suppression for the accelerated adoption of these technologies.

BTO also supports the key emphasis areas of energy justice, workforce, diversity in STEM, and state and local partnerships. Investments associated with Workforce Development will support training and develop good paying clean energy jobs for the American people, especially workers, communities impacted by the energy transition, and those historically underserved by the energy system and overburdened by pollution. Investments associated with Diversity in STEM support outreach and will raise awareness of clean energy research and job opportunities at minority-serving institutions and minority-focused professional organizations and ensure that organizations receiving EERE funding are thinking through diversity and equity in their own work. Investments in State and Local partnerships will support state and local governments with the necessary resources to be more effective in facilitating affordable and resilient clean energy and efficiency goals. Investments associated with Energy and Environmental Justice will support approaches and processes to reach new groups of Americans historically underserved by the energy system.

Highlights of the FY 2023 Budget Request

In FY 2023, BTO will increase support for the Administration's climate and clean energy objectives by focusing broadly on three areas that allow for strategic implementation of these priorities across BTO including:

- Appliance & Equipment Standards: Develop new and amended test procedures and energy conservation standards to decrease energy and water use, and related carbon emissions, from appliances, lighting, and equipment used in buildings. The increased funding requested will strengthen the program's analytical and economic capacity to implement cost-effective Appliance and Equipment Standards and accelerate the realization of societal net benefits.
- Building Energy Codes: Develop and advance building energy codes to decrease energy use and reduce carbon emissions in new and existing residential and commercial buildings with a specific emphasis on technical support to states and local governments. for the increased funding requested will help localities and States to adopt the latest codes or stretch codes, increase cope compliance, and support workforce training.
- Heat Pump Initiative for Better Energy, Emissions, and Equity (E3): The E3 Initiative aims to accelerate the adoption of heat pump technologies and provide compelling high-performance alternatives to fossil-fueled building equipment. E3 will advance both research innovation and market adoption of highly efficient cost-effective heat pumps for both space heating and water heating systems in residential and commercial buildings, working to make these technologies easy to install and affordable for all Americans. The initiative prioritizes advancing research on low- to no-global warming potential (GWP) refrigerants; reducing space and water heating costs through system optimization; validating, and accelerating cold climate heat pump performance; and grid-interactive and storage capabilities that enable demand flexibility of heating and cooling loads. In addition to research, a key focus for E3 is partnering with critical market actors and stakeholders including equipment manufacturers, utilities, state and local governments, commercial building owners, local community organizations, and labor-related organizations to initiate new deployment

opportunities, market transformation support, and developing workforce training that will address new and expanded skills required for heat pump installation and maintenance.

- Advanced Building Construction (ABC) Initiative: The ABC Initiative is helping lay the foundation for the U.S. to become a leader in modernized, low-carbon building construction and renovation, by scaling highly efficient modular new construction and manufactured housing, and developing easy to install, appealing retrofit solutions. BTO's ABC Initiative includes RD&D and strategic partnerships aimed at integrating new technologies and approaches for quickly deploying high efficiency and low-carbon solutions into both new building construction and renovation. BTO's investments focus on developing efficiency-related building technologies that require significantly reduced onsite construction and installation time, are affordable and appealing to the market, and leverage related efforts to increase the productivity of the construction and renovation industry.
- Better Buildings Initiative: The Better Buildings Initiative is a broad DOE platform that engages with private and public sector partners to accelerate the adoption of energy efficient products and practices as well as pathways to decarbonize our nation's commercial, residential, and industrial buildings. There are more than 250 commercial partners working with BTO on the Better Buildings Initiative, representing more than 13 percent of the U.S. commercial building space. More than 100 of these partners committed to the Better Buildings Challenge goal of a 20% reduction in energy use intensity within 10 years. Through the Better Climate Challenge, launched in FY 2022, BTO is working with more than 90 inaugural partners, comprised of public and private sector building owners to reduce the carbon footprint their portfolio. Partners commit to a portfolio wide reduction target of at least 50% less scope 1 and 2 GHG emissions in the next 10 years.

Additionally, the Request will support the following major activities in FY 2023:

- Buildings to Grid Integration: BTO's RDD&D on advanced and grid-interactive technologies, such as controls, interoperability, and energy storage, will partner with industry stakeholders to develop and deploy grid-interactive efficient buildings related systems. These systems will be capable of connecting with the power grid in new and increasingly adaptive manners to help with overall energy system efficiency, reliability, resilience, environmental performance, and energy affordability. These capabilities are an integral and necessary part of a decarbonized power system that maximizes use of renewable resources and can significantly reduce energy use at times when this provides a valuable option for utilities and their customers.
- Workforce Development & Education: BTO will support efforts to prepare the next generation of tradespersons, professionals, and other workers needed to create a low-carbon, modernized U.S. building stock. BTO will build interest in these careers among underrepresented groups, augment training programs to improve the skills of existing tradespersons and professionals and streamline pathways from education and training to viable careers. BTO is committed to providing opportunities to those in communities with greatest employment needs.

BTO implements its activities through partnerships with National Laboratories and competitively selected, cost-shared projects. In addition, FY 2023 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.

Contributions to DOE-Wide Crosscutting Investments

BTO is involved in several DOE-wide crosscuts:

- Advanced Manufacturing ($5,000,000) – In its Emerging Technologies portfolio, BTO will continue support for advanced manufacturing especially in the areas of new refrigerants and heat pumps to support decarbonization technologies.
- Energy Storage ($25,000,000) – BTO will continue its support for energy storage research, both thermal and electric storage, such as cost reductions and deployment of heat pumps with thermal energy storage and building technologies and architectures that enable electrical storage to provide load management and customer resilience, especially in disadvantaged communities.
- Grid Modernization ($20,000,000) – BTO will continue RDD&D on advanced and grid-interactive technologies, including the integration of behind the meter solar, solar+storage and V2B (Vehicle to Building) technologies, including controls, interoperability, and emerging load management technologies to enable the future low carbon, high renewable electric

grid, in close coordination with Office of Electricity and EERE offices including the Solar Energy Technologies Office and the Vehicle Technologies Office.

EERE Program Priorities:
In FY 2023, BTO continues to support an investment strategy aligned to the following programmatic priority areas that are central pillars to the U.S. greenhouse gas (GHG) profile:

Building Technologies
Funding ($K)

Funding ($K)

	FY 2021 Enacted	FY 2022 Annualized CR[1]	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted
Reduce the carbon footprint of the U.S. building stock	290,000	290,000	392,000	+102,000

[1] The FY 2022 Annualized CR amounts reflect the P.L. 117-95 continuing resolution level annualized to a full year.

Building Technologies
Funding ($K)

	FY 2021 Enacted	FY 2022 Annualized CR[1]	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted
Building Technologies				
Emerging Technologies	145,000	-	100,000	-45,000
Commercial Buildings Integration	50,000	-	95,000	+45,000
Residential Buildings Integration	40,000	-	122,000	+82,000
Equipment and Buildings Standards	55,000	-	75,000	+20,000
Total, Building Technologies	**290,000**	**290,000**	**392,000**	**+102,000**

SBIR/STTR:

- FY 2021 Transferred: SBIR: $11,149,904; STTR: $1,595,612
- FY 2022 Annualized CR: SBIR: $5,830,000; STTR: $820,000
- FY 2023 Request: SBIR: $7,999,000; STTR: $1,125,000

[1] The FY 2022 Annualized CR amounts reflect the P.L. 117-95 continuing resolution level annualized to a full year. These amounts are shown only at the congressional control level and above, below that level, a dash (-) is shown.

Building Technologies
Explanation of Major Changes ($K)

	FY 2023 Request vs FY 2021 Enacted
Emerging Technologies (ET): The Request will strategically invest in R&D to support the next generation of building technologies to enable decarbonization. BTO will prioritize and significantly expand R&D activities supporting heat pumps, low to no global warming potential refrigerants, and energy storage to help develop and commercialize the next generation technologies needed for building decarbonization, while also putting an emphasis on reducing costs for equipment used in the residential, multi-family, manufactured housing, and commercial sectors. ET will conduct performance validation and verification of near market ready technology to understand their market readiness before scaling to demonstration and deployment. For portfolios that are now focused on demonstration and deployment, solid state lighting for example, BTO has transitioned those investments into other BTO subprograms to strengthen integration with other BTO investments in market transformation and deployment. In addition, BTO will reduce early-stage R&D investment in those technologies that do not support or that have a negligible impact on building energy efficiency and decarbonization.	**-45,000**
Commercial Buildings Integration (CBI): The Request increases emphasis on energy efficiency and decarbonization of commercial buildings. CBI will support the strategic deployment of decarbonization technologies and solutions, such as heat pumps, building controls, and grid-interactive storage, to reduce the carbon footprint of the existing commercial building stock. BTO will expand its investment in the Better Buildings Initiative, including developing implementation pathways for the decarbonization of existing buildings. Additionally, CBI will significantly grow its portfolio of efficiency investment with small businesses, as well as small- and medium-sized buildings, through testing, demonstration, and deployment of turnkey energy efficiency and climate-responsive technology packages, scaled in partnership with community-level organizations.	**+45,000**
Residential Buildings Integration (RBI): The Request increases strategic investment in residential building energy efficiency and decarbonization. BTO will support a combination of systems integration development, demonstrations, technical assistance, partnerships, modeling, and analysis aimed at creating a U.S. residential building stock–both existing and new construction – that is affordable, decarbonized, high-performing, and grid-interactive. In partnerships with state and local governments and industry, RBI will focus on dramatically expanding use of high efficiency equipment (e.g., heat pumps, low-e windows) in single family, and multifamily buildings through vast expansion of market transformation support, including partnerships such as a heat pump consortium with industry. In addition, improving the affordability of energy efficient manufactured housing through innovative manufacturing practices for more-efficient designs, consumer education, and accessibility.	**+82,000**

Equipment and Buildings Standards (EBS): The Request strengthens BTO's analytical and economic capacity for to implement cost-effective Appliance and Equipment Standards and accelerate the realization of societal net benefits. DOE's commitment to the appliance and equipment standards program, which is a fundamental building block to improving efficiency in buildings that contributes to DOE's decarbonization goals. BTO is focusing on meeting its statutory obligations for the appliance and equipment standards program, including developing new or amended test procedures and energy conservation standards. In addition, BTO will continue its work toward clearing a backlog of missed statutory deadlines and expanding coverage to new products to help reduce energy use and emissions from appliances and equipment. BTO will maintain a level playing field for all manufacturers by enforcing its minimum performance standards relating to appliances and equipment. BTO will continue to amend and develop ENERGY STAR test procedures while participating in industry verification programs of ENERGY STAR equipment and verifying the performance of ENERGY STAR equipment through testing. The Request also increases investment in activities that will help state and local jurisdictions to maximize the impact of building energy codes. New BTO activities will emphasize the development of national building energy codes, increase and faster adoption of building energy codes through technical assistance to states and local governments, as well as support for "stretch" codes for those localities looking for additional energy and carbon savings, including a focus on low-carbon solutions. BTO will also expand support for technical assistance activities supporting code compliance, with an emphasis on research, technical analysis, and workforce development, including education and training initiatives which help states, local governments, and construction professionals embrace evolving technologies and construction practices.	**+20,000**
Total, Building Technologies	**+102,000**

Building Technologies
Emerging Technologies

Description

The Emerging Technology (ET) program focuses on R&D projects that can support building technology developments in energy-efficiency, demand-flexibility, low-carbon, and cost reductions to help support building sector decarbonization and strategic analysis to inform future R&D directions. ET's work enables innovation and job creation in a range of U.S. industries, including building equipment and component manufacturing and building equipment development. ET conducts research, development and performance verification at the material, component, and building system levels in the following technology areas: heating, ventilation, and air conditioning (HVAC), water heating, refrigeration, energy storage, buildings-and-grid integration, lighting, building envelope, and building energy modeling. FY 2023 activities are focused on R&D to help address deployment challenges, such as cost and footprint, on the most impactful technologies for reducing carbon emissions, especially surrounding heat pumps. As a result, ET is placing an increased emphasis on R&D advancements in space heating & cooling and water heating to lower the cost and reduce the installation barriers associated with these technologies to help accelerate adoption. The ET program plans significant support for the E3 Initiative with a focus on new research supporting low- to no-GWP refrigerants, cold climate Heat Pump performance validation, advanced controls, and electric optimization solutions to address control panel upgrades. The ET program also supports the buildings-and-grid integration work in conjunction with other offices. This ET applied RD&D portfolio collaborates with industry and academia and leverages the National Laboratories' researchers, computing capabilities, and other unique facilities that are critical for BTO to support efforts to significantly reduce carbon emissions from buildings.

<u>HVAC, Water Heating, and Refrigeration (HVAC&R) R&D</u>: This activity focuses on fundamental and applied R&D on reducing the cost and footprint and advancing the performance of energy-saving, low-emission heating, cooling, water heating, and refrigeration technologies. The portfolio will support the E3 cross-program initiative aimed at advancing heat pumps. This investment will support innovative technologies such as variable speed drives and sophisticated controls to help tailor the equipment usage to the load being delivered in an efficient manner. This activity will prioritize critical R&D needs such as: cold climate heat pumps; heat pumps for affordable housing that address energy use, indoor air quality and comfort issues; Central and 120V heat pump water heaters; low GWP and natural refrigerants for refrigeration systems, both packaged as well as for large warehouses.

<u>Thermal Systems and Energy Storage R&D:</u> This activity focuses on management of the building load to enable better operation of the HVAC&R systems and integration with the electricity system, while also enhancing occupant comfort and indoor air quality. This activity includes investments in building envelopes, including air and duct sealing, insulation, and windows, both opaque and glazing, as well as thermal energy storage and battery energy storage. These investments seek to reduce and shift major energy loads, especially around heating, that will help us overcome electric infrastructure constraints, both within the building and on the grid. Building envelope R&D supports the development of next-generation technologies and solutions that reduce the energy required to heat and cool a building, contribute to improved occupant comfort, building flexibility, and resilience, and have reduced costs and installation challenges to enable widespread market adoption.

<u>Electrical and Whole Building System R&D:</u> This activity includes Building Energy Modeling, analysis, large building controls, lighting and integration of buildings with the grid. In lighting, the focus will be on implementation and new applications of solid-state lighting, such as connected lighting and indoor lighting. Building Energy Modeling R&D focuses on physics-based whole-Building Energy Modeling (BEM) for integrated, performance-driven design in new construction and major retrofits. We will continue work in buildings to grid R&D with a focus on demand flexibility of end uses systems and optimizing energy use at the building level and the overall electricity system.

Emerging Technologies

Activities and Explanation of Changes

In the FY 2023 the Emerging Technologies Subprogram is proposing to restructure from five distinct activities to three to better address system challenges and opportunities while supporting the decarbonization of the building sector. The elements of each of these categories are identified and explained below.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Emerging Technologies $145,000,000	**$100,000,000**	**-$45,000,000**
HVAC, Water Heating, and Refrigeration R&D $28,320,000	$46,000,000	+$17,680,000
• 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 research to accelerate performance improvement and field validation of cold climate heat pumps, technology advancements to reduce heat pump soft costs, and advanced fault detection and diagnostics that improves heat pump operational performance.	• Increased focus on building decarbonization, and support for heat pumps resulting in an increased budget for this activity.
• Award FOA projects on innovative heating, ventilation, air conditioning, and refrigeration (HVAC&R) technologies that push the state of the art for energy cascading (the process of using the waste heat from one process as the energy source for another).	• Support research to advance heat pump water heaters that can be "ready" replacements for existing water heaters and boilers such as low power (120V) and central heat pump water heaters.	• No significant change in activities, technical focus shifted towards emissions reductions and demand flexibility.
• Award FOA projects to develop refrigeration technologies that reduce the energy consumption and cost of refrigeration equipment while improving demand flexibility and resilience to power interruptions.	• Conduct projects that accelerate development and validation of non-HFC low-GWP refrigeration technologies for comfort and product refrigeration to reduce energy use, improve safety and support future regulations.	• Increased funding to evaluate low Global Warming Potential (GWP) refrigerants supporting the AIM Act.
Thermal Systems and Energy Storage $27,650,000	$22,000,000	-$5,650,000
• Support three to five national laboratory projects in thermal energy storage materials research for advanced salt hydrate and	• Advance building energy storage by launching Thermal Energy Storage (TES) National Laboratory Consortium and support work to integrate electric	• Increased investment in an integrated storage portfolio focused on both thermal and electric storage.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
advanced phase-change materials development to enable load shifting and climate resilience.	storage and thermal energy storage at equipment and building levels.	
• Award FOA projects that focus on advanced envelope retrofit technologies, particularly those that can be mass produced and applied to existing facades and robotics.	• Support projects to reduce heating and cooling load through advanced envelope retrofit technologies, such as thin triple pane, high efficacy retrofit windows, geospatial identification of thermal leakage, and robotic construction of retrofit facades.	• Reallocation of windows investments towards more deployment activities in the building integration subprograms.
Electrical and Whole Building Systems $89,030,000	$32,000,000	-$57,030,000
• Fund National Laboratories to continue development and maintenance of physics-based whole building modeling engine and large-scale analysis to support evaluation of technologies, systems, and strategies by BTO itself, utilities, states, and other organizations. • Competitively select 1-2 Connected Communities projects focused on advancing the next generation of grid interactive efficient buildings. Issue a competitive prize for next generation efficient and connected lighting.	• Continue development and maintenance of open-source physics-based whole building modeling engine and large-scale analysis to support evaluation of technologies, systems, and strategies by BTO itself, utilities, states, and other organizations. • Support research on controls for whole buildings, as well as connected plug loads, and lighting and how these can enable greater demand flexibility for grid integrated buildings in a future variable zero carbon grid.	• No significant change • Controls related research work will be substantially supported through BTO residential and commercial buildings integration (RBI & CBI) subprograms and technology-specific controls R&D, which is substantially HVAC&R controls, is integrated into the HVAC&R activities. Solid state lighting work shifted to deployment.

Building Technologies
Commercial Buildings Integration

Description

The U.S. commercial building sector represents 5.9 million buildings, over 200 billion square feet of real estate and $170 billion in energy expenditures each year. Commercial buildings consume roughly 18 percent of the Nation's total primary energy consumption, account for 35 percent of all U.S. electricity consumption and 16 percent of the Nation's CO_2 emissions.[1] As a result, commercial buildings represent a large building decarbonization and energy reduction opportunity for BTO strategic investments. The Commercial Building Integration (CBI) program works to increase voluntary adoption of energy efficient technologies and practices in commercial buildings, serving as a critical "market stimulation" and "market feedback" link between BTO's Emerging Technologies and Codes and Standards programs. CBI demonstrates and deploys replicable and scalable solutions that will enable U.S. businesses and organizations to reduce U.S. building GHG emissions to net zero by 2050.

In FY 2023, CBI will prioritize investments in demonstrations, deployment, and the associated market transformation work necessary to help support commercial building decarbonization. As part of DOE's Better Buildings Initiative, DOE is working with almost 1,000 organizations to highlight successful strategies, highlight innovation and develop new resources that contribute to lower costs and a cleaner, more resilient and decarbonized energy system. There are more than 250 commercial partners working with BTO on the Better Buildings Initiative, representing more than 13 percent of the U.S. commercial building space. Through the Better Climate Challenge, launched in FY 2022, CBI is working with public and private sector building owners to reduce the carbon footprint of their portfolio. CBI will work with more than 50 leaders in the commercial sector to identify the barriers and highlight the best practices necessary to reduce emissions across the entire commercial building stock, with a focus on streamlining and scaling adoption through technology demonstrations, purchasing support resources, adoption campaigns, and recognition of exemplary practices.

In addition, small buildings that are 50,000 square feet or less represent more than 94 percent of all commercial buildings and consume almost 50 percent of energy.[2] CBI will invest in programs to accelerate deployment of decarbonization technologies and retrofits in small and medium commercial buildings, leveraging the work of the cross-cutting E3 initiatives and the RBI deployment initiatives, as applicable. Lastly, CBI will place a renewed focus on translating applicable insights to reducing emissions in high rise multi-family housing and lowering energy burdens for low-income consumers.

In partnership with other EERE Offices, this Request funds new initiatives that aim to develop, validate, and deploy technologies addressing charging of Heavy Duty Zero Emission Vehicles (ZEVs) and the associated building and grid requirements.

Systems Integration and Technology Deployment: This activity works across a broad group of industry representatives to identify, demonstrate, and deploy solutions that enable and scale pathways to meet energy efficiency and decarbonization goals in new and existing commercial buildings, including harder-to-reach markets such as small and medium buildings, small portfolios, and rural buildings. CBI supports a broad technology demonstration portfolio with third party verification. Technology deployment activities include challenges, demonstrations, technical specification, bulk purchasing, and adoption campaigns to de-risk and streamline broad adoption for maximum energy, carbon, and cost savings and to ensure value-stack benefits are documented, shared, and realized. CBI will expand the portfolio of deployment work with multi-family housing and schools to focus on climate-responsive, turnkey technology solutions, integrated packages to enable buildings that can participate in a clean grid and clean, low-carbon commercial heating and cooling technologies. CBI demonstrates and deploys energy efficiency and decarbonization solutions via voluntary partnerships under the Better Buildings Initiative and through multi-agency collaboration with the Federal Energy Management Program (FEMP), the General Services Administration (GSA), the Environmental Protection Agency (EPA), the Department of Education and the Department of Defense (DOD) to enable Federal lead-by-example activities

[1] https://www.eia.gov/outlooks/archive/aeo19/pdf/aeo2019.pdf
[2] Commercial Buildings Energy Consumption Survey (CBECS) 2012, U.S. Energy Information Administration.

Technical Assistance: CBI actively provides technical assistance to commercial building stakeholders to identify and scale best practices by market leaders through the Better Buildings Initiative as well as in support of disadvantaged and underserved communities. CBI's efforts in this area include technical assistance, resources, and support to deploy easy-to-install and use decarbonization technologies, building envelope upgrades, renewables integration and demand response technologies in market sectors including efficient healthy schools, especially Title 1 schools and in rural, Tribal, and other disadvantaged communities. Through this work, CBI will highlight the best practices and pathways to strategically overcome technical and structural barriers and to leverage other drivers to accelerate adoption. This effort feeds directly into rapid R&D within BTO and other EERE organizations to help solve critical technical and cost barriers. Additionally, CBI will continue support for growth in skilled building efficiency and decarbonization jobs through capacity building activities targeted at underserved and diverse stakeholders. CBI will further support the development and implementation of building performance standards through software and analysis, demonstration of decarbonization pathways, and technical assistance for local governments.

Modeling and Analysis: CBI maintains and continuously improves a suite of user-accessible, packaged tools to enable the affordable evaluation of commercial building energy, emissions reduction, demand flexibility, and performance investments. This work is founded on the physics-based computational simulations supported through the BTO BEM portfolio, bringing complicated simulation activities where they can be easily used by the designer and engineer. In addition, CBI's design and decision support tools and resources can be used to evaluate efficiency investments for one building or across a portfolio of buildings at various phases of a building's life cycle–design, operation, renovation, and resale.

Commercial Buildings Integration

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Commercial Buildings Integration $50,000,000	**$95,000,000**	**+$45,000,000**
Systems Integration & Tech Deployment $16,902,000	$33,000,000	+$16,098,000
• FOA awards to support pilot small commercial assessment centers (inspired by Industrial Assessment Centers) and turnkey upgrade solutions in small commercial buildings. • Continue National Laboratory projects that test and document the deployment opportunity for simplified, accessible technology upgrades in small and medium commercial buildings. • No funds provided.	• Support for the deployment of heat pumps and grid flexible technologies to reduce the carbon footprint of the existing commercial building stock. • Expansion of portfolio of efficiency work with small and medium businesses through demonstration, and deployment of turnkey efficiency and climate-responsive technology packages, scaled in partnership with community-level organizations. • Develop and deploy integrated technologies for Heavy-duty ZEV initiatives to support identified needs including, but not limited to, improved building energy management systems and connected grid projects to enable nationwide adoption of electric vehicles and charging infrastructure.	• Increase support for demonstrations, deployment, and market transformation support for low-carbon technologies and commercial building energy reductions. • Increase funding to expand portfolio and support small and medium businesses. • Increase funding to support Heavy-duty ZEV initiatives.
Technical Assistance $24,018,000	$47,000,000	+$22,982,000
• Fund technical engagement through the Better Buildings Initiative (via National Laboratories and other technical experts). • Fund technology field validation portfolio which includes voluntary hosting of technology pilots with third party verification.	• Increase emphasis on decarbonization of commercial buildings including support for implementing decarbonization policies and pathways in multiple commercial use cases. • Expand technology field validation to focus on validating technologies for decarbonization pathways in commercial buildings.	• Increase support for technical assistance to implement new work on low carbon goals and deploy pathways to achieve low carbon buildings. • Increase funding for field validation of technologies to achieve decarbonization use cases in commercial buildings.
Modeling and Analysis $9,080,000	$15,000,000	+$5,920,000

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
• Fund National Laboratories to continue development and maintenance of data tools for accessible and affordable systems-based evaluation of commercial building energy efficiency trade-offs. • Fund National Laboratories to conduct pathways analysis to support demonstrations of performance-based codes.	• Maintain and continuously improve suite of user-accessible, used, and useful packaged tools, to enable the affordable evaluation of commercial building energy, emissions reduction, demand flexibility, and performance investments. • Develop and maintain design and decision support tools and resources that can be used to evaluate efficiency and decarbonization investments for one building or across a portfolio of buildings at various phases of a building's life cycle.	• Increase support for tools that enable analysis and implementation of decarbonization pathways. • Increase support for maintain and designing decision support tools, analysis, and resources that stakeholders can use to implement decarbonization pathways.

Description
The U.S. residential building sector, representing 95 percent of U.S. buildings, consists of approximately 125 million residences, including single-family and multifamily units and manufactured housing, and accounts for about 21 percent of U.S. total energy consumption and 38 percent of U.S. electricity consumption, costing households some $240 billion in annual energy expenditures, and resulting in about 19 percent of the Nation's energy-related CO_2 emissions. Furthermore, residential energy use in certain regions accounts for 50 percent of peak electric power demand, making it an even more important target for improving energy efficiency, demand flexibility and grid reliability.

Through a combination of technology development, demonstration, technical assistance, partnerships, modeling, and analysis, RBI invests in residential solutions with the greatest promise for delivering energy, cost, carbon, and other benefits at scale. RBI's investments focus on developing building technologies and approaches that are affordable, require minimal onsite construction and installation time, appeal to a wide range of consumers and users, and can be broadly applied to the multitude of residential building types and climates in the U.S. In addition to funding development and testing of technologies, RBI partners with key building sector stakeholders to tackle challenges to scaling solutions, including training and expansion of the workforce, development of effective business models, and demand aggregation. RBI puts particular focus on developing efficiency solutions that can be enjoyed by all homeowners and tenants, regardless of income or social status, and creating long-term employment opportunities for those seeking new jobs or career advancement across the buildings sector, from architecture and engineering to manufacturing, construction, and residential trades. These efforts are designed to overcome barriers to residential building integration that inhibit achieving a net-zero carbon emission economy by 2050, while also developing a labor force with appropriate skills, and helping make housing more affordable, resilient, better able to integrate distributed energy resources, and more comfortable with improved indoor air quality.

Systems Integration: Through its Building America program and other efforts, RBI has a successful track record working with builders, contractors, manufacturers, program implementers and others to validate and demonstrate new efficiency technologies and integration approaches in real world (non-laboratory) homes; develop solutions to application and integration issues; disseminate resulting "best practice" technical guidance; and provide technical expertise to early adopters – all essential precursors to acceptance and uptake by builders and contractors and integration into advanced building energy codes. A complement and extension of the work done by the Emerging Technologies Program, RBI pressure tests systems in real world conditions to ensure that unexpected challenges not apparent in the lab are addressed before technologies are commercialized, promoted, and ultimately widely adopted. In terms of prioritizing these efforts, RBI focuses on developing and demonstrating innovative technologies and practices that meet low/no carbon goals, can be installed in existing residential buildings without disruption to tenants and homeowners (e.g., pre-fabricated facades/panels, insulated siding), and can be readily integrated into scalable construction practices, including modular construction and manufactured housing. Energy efficient manufactured housing and modular construction will be key areas of focus in FY23.

Technical Assistance: RBI works with industry, state and local governments, utilities, residential contractors (including home performance, HVAC, renovation, and other contractors), builders, building owners and operators, and training entities among other key stakeholders to both understand and address the barriers hindering widespread uptake of efficiency measures and decarbonization of new and existing single and multifamily homes, including manufactured homes. Through competitive awards, prizes, and other mechanisms, RBI supports the development, dissemination, and implementation of programs, tools, and materials dedicated to addressing other needs, beyond technology, that are essential to scaling efficiency and meeting decarbonization goals. These include, but are not limited to, workforce recruitment and training; building science and STEM education (e.g., Solar Decathlon); risk mitigation and financing; measurement and verification; and consumer information. RBI will further support the development and implementation of building performance standards through software and analysis, demonstration of decarbonization pathways, and technical assistance for local governments.
RBI will expand its collaborative work with the DOE's Weatherization and Intergovernmental Programs by providing technical assistance and guidance to state and local governments and others funded to carry out weatherization and

retrofit of American homes. This technical assistance will be aimed at empowering local decision-makers and implementers to effectively accelerate energy efficiency and decarbonization in the residential sector, while addressing local needs, particularly those of underserved communities. RBI also plans to continue to work closely with the Department of Housing and Urban Development to integrate efficiency solutions in relevant programs (e.g., HOME, Housing Trust Fund, Community Development Block Grant, Community Development Block Grant - Disaster Recovery) on new construction, existing homes, and financing with the goal of enhancing comfort and resiliency while reducing utility costs for occupants.

Modeling and Analysis: Given the complexity and diversity of the U.S. housing stock, as well as the challenges associated with ensuring affordable and decarbonized homes for all Americans, RBI relies on robust analysis and modeling to inform its work, tackle complicated questions, evaluate trade-offs, and ensure a no-regrets approach. In addition to using these capabilities to guide its work, RBI develops, refines, and applies building energy models, data systems, and other tools to assist builders, contractors, homebuyers, utilities, state and local governments, and other decision-makers to consistently and accurately estimate energy use, savings and costs; to inform investment decisions and maximize benefits; and, to apply best building science practices as well as the most up-to-date information on new technologies and approaches.

Residential Buildings Integration

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Residential Buildings Integration $40,000,000	**$122,000,000**	**+$82,000,000**
Systems Integration R&D $26,696,000	$48,000,000	+$21,304,000
• Invest in Advanced Building Construction (ABC) technologies and approaches, including state-of-the-art innovations that can dramatically scale deep energy retrofits to our Nation's 125 million residential buildings and can assist in meeting the Administration's goal for building or retrofitting 1 million sustainable and affordable housing units in four years. • Support field validation of highly efficient equipment, including heat pumps in non-moderate climates and other technologies that put the U.S. on track to achieving a 100 percent clean energy economy by 2050; support research to ensure efficient buildings maintain indoor air quality; support technical challenges and prizes to expand availability and affordability of higher efficiency products to all Americans (e.g., automated fault detection and diagnostics incorporated into standard systems, rather than only high end products).	• Continue investment in development and demonstration of deep energy retrofit solutions for all types of residential buildings, with a priority placed on approaches and technologies that offer additional value add (e.g., non-disruptive installation, greater resiliency) and can be readily scaled. • Expanded field validation of technologies and installation practices, particularly with greater emphasis on testing and improving these innovations in actual existing residential buildings. To create a better feedback loop between researchers, manufacturers, and the trades/contractors, field efforts will include greater collaboration and involvement of these key stakeholders who are integral to ensuring high performance and affordable retrofits of our nation's existing residences.	• Increase strategic investment in residential building decarbonization, given the tremendous opportunity to not only significantly cut carbon emissions associated with our nation's 125 million existing residences, but at the same time invest in modernizing these homes and making them more resilient, comfortable, and affordable to heat and cool. • Increase investment to validate new technologies and approaches and overcome contractor concerns.
Technical Assistance $7,922,000	$60,000,000	+$52,078,000
• Conduct 2021 Solar Decathlon Design Challenge and complete 2020 Solar Decathlon Build Challenge to help develop our Nation's next generation of building scientists, architects, engineers, and other experts needed to attain a clean energy economy. • Provide technical assistance to utilities, state and local governments, training facilities,	• Conduct 2023 Solar Decathlon Design Challenge as well as first-of-its-kind all local 2023 Solar Decathlon Build Challenge, to help develop our Nation's next generation of building scientists, architects, engineers, and other experts needed to attain a clean energy economy. • Expand technical assistance to program implementers for the scaling of heat pump	• No significant change. • Expand support to efficiency programs to ensure high performance upgrades of residences across U.S.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
residential contractors, builders, and others to (a) promote best practices in new construction and retrofit of existing buildings and (b) develop a sufficiently large and skilled workforce needed to construct new low-carbon, high-performance homes and dramatically reduce the energy use of the Nation's existing homes. Support field validation of highly efficient equipment, including heat pumps and other technologies that put the U.S. on track to achieving a 100 percent clean energy economy by 2050.	deployment as well as key energy-efficiency measures with particular emphasis on upgrades with available incentives.	• Increase support to communities and others to scale residential building decarbonization and modernization.
• Engage in partnerships with industry, federal, state, and local governments, architects and engineers, utilities, home efficiency contractors, and others; with a focus on wide adoption of priority technologies, aggregated demand for high efficiency solutions (e.g., workforce recruitment and training, and improved STEM capabilities across the entire buildings/construction workforce.	• Conduct a large-scale competitive prize for communities across the U.S. to spur and support innovative approaches aimed at scaling the use of highly efficient technologies in the residential sector and leverage outside investment.	• No significant change.
• Provide technical assistance to utilities, state and local governments, training facilities, residential contractors, builders, and others to (a) promote best practices in new construction and retrofit of existing buildings and (b) develop a sufficiently large and skilled workforce needed to construct new low-carbon, high-performance homes and dramatically reduce the energy use of the Nation's existing homes.	• Provide technical assistance to public and private organizations, including affordable housing organizations, state and local governments, builders, trades, and others to promote best practices in building construction and retrofit and support workforce recruitment and training.	
Modeling and Analysis $5,382,000	$14,000,000	+$8,618,000
• Invest in the development of UrbanOpt, EnergyPlus, ResStock, and other modeling and	• Continue refinement of analytical tools and models to accurately characterize the US	• No significant change.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
data tools that ensure accurate understanding of how individual buildings use energy as well as how communities can optimize energy use across buildings.	housing stock, to identify promising opportunities for cost compression, and to support utilities and other primary stakeholders in measuring the effectiveness of energy efficiency investments.	
• Apply these state-of-the art tools to analyze building typologies across the U.S. and prioritize areas of focus for the Advanced Building Construction Initiative.	• Apply analytical tools to assist state and local governments, utility programs and other efficiency program implementers in optimizing efficiency packages to meet the needs of their specific housing stock and their policy goals.	• Increase in funding to develop greater capabilities to assist state and local entities more directly.

Buildings Technologies
Equipment and Buildings Standards

The Equipment and Buildings Standards subprogram within BTO contains two critical activities for locking in energy savings and carbon reductions from buildings. Both are critical building blocks in DOE's decarbonization of efforts and furthering building efficiency in the U. S. These two activities include appliance and equipment standards and building energy codes. Both activities are discussed in detail below.

Description

The Appliance and Equipment Standards (AESP) develops new or amended energy standards and test procedures, as directed by statute. The Appliance Standards Program currently sets policy regulations for more than 60 products, representing about 90 percent of home energy use, 60 percent of commercial building energy use, and 30 percent of industrial energy use. The AESP has 4 core components. The Program develops and updates 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. The Program establishes Federal minimum energy efficiency standards based on DOE's prescribed test procedures to lock in energy savings for consumers. The Program enforces the energy conservation standards to prevent any manufacturer from undercutting those playing by the rules. The Program supports other Federal initiatives to help consumers make more energy-efficient purchasing decisions, including the ENERGY STAR program and EnergyGuide labeling program.

DOE is committed to meeting its legislatively mandated deadlines for covered appliances and equipment. The rulemaking schedule is directed by Congress, and thus the level of program activity is mostly determined by existing statute. In addition, DOE is placing an emphasis on investigating and developing the next generation of test procedures for heat pumps and heat pump water heating to support building decarbonization and other programs within BTO.

Energy Conservation Standards: The AESP develops and adopts energy conservation standards for all covered products and equipment in the program under a pre-determined cadence prescribed in statute for the purpose of saving the Nation energy and water. As part of its international engagement on standards, AESP participates in international programs and committees to minimize regulatory burden by ensuring regulatory harmonization to the greatest extent practicable and allowed by law.

Test Procedures: AESP 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, AESP 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. In addition to its regulatory work on test procedures, AESP supports the ENERGY STAR Program by amending and developing new test procedures for ENERGY STAR products and providing technical input on specification development. In support of the E3 Initiative, AESP will work with manufacturers and other stakeholders to develop the next generation of test procedures and metrics to help inform consumer about the benefits of advance technology heat pumps.

Certification, Compliance, and Enforcement: To ensure the energy savings are realized and a level-playing field is maintained for manufacturers, AESP actively enforces the energy conservation standards through certification, outreach, surveillance testing, and enforcement investigations. As part of its verification testing program, AESP also supports EPA by conducting product performance testing of ENERGY STAR products and working with the Association of Home Appliance Manufacturers on their ENERGY STAR verification program.

Building Energy Codes: BTO's Building Energy Codes (BECP) provides technical assistance supporting building energy efficiency, decarbonization and other emissions reductions, and increased resilience and comfort through the advancement and successful implementation of building energy 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. In addition, DOE is directed to review published editions of the International Energy Conservation Code (IECC) and ANSI/ASHRAE/IES Standard 90.1, and issue Determinations as to whether the updated edition will increase energy efficiency in residential and commercial buildings, respectively, which triggers state building energy code review and update activities. DOE is also directed to provide technical assistance to states to support code implementation, including technical analysis to assess energy and environmental impacts, research to support states in evaluating how their codes are applied in practice, as well as education, training, outreach, and tools to help increase compliance in the field and ensure the benefits of building energy codes are realized by American homes and businesses.

In fulfilling its statutory mission and other Departmental goals, BECP employs an array of strategies across the following subactivities:

Model Code Advancement: BECP participates in industry processes to develop national model energy codes, fulfilling DOE's statutory directive and Departmental goals. This directive includes seeking adoption of all technologically feasible and economically justified energy efficiency measures and identifying how building energy codes can enhance energy efficiency, resilience, and reduce carbon emissions from the building sector. In addition, BECP reviews published editions of the IECC and Standard 90.1 and prepares formal Secretarial Determinations as to whether the updated codes increase energy efficiency in residential and commercial buildings, respectively. BECP will bolster its technical analysis and support activities for state and local governments in this area, with an emphasis on advanced model codes, as well as stretch codes focused on low-carbon, grid-interactivity, advance energy-efficiency, and integrative solutions. Furthermore, BECP will provide technical support and guidance for federal, state, and local governments who are considering emerging and innovative concepts, including Building Performance Standards (BPS) to improve the energy efficiency in certain existing buildings. BECP's activities yield advanced codes and standards that can be considered by national code bodies or adopted by state and local governments, as well as directly support the Administration's goals. In addition, BECP conducts rulemakings as required by statute to advance cost-effective energy codes for Federal facilities, along with the development of a rulemaking to support the statutory directive of reducing and ultimately eliminating fossil fuel use in Federal buildings. Lastly, BECP will support the development of BPS for Federal buildings across agencies.

State and Local Technical Assistance: BECP fulfills the DOE statutory directive to provide technical assistance to states supporting implementation of their building energy efficiency codes. Traditional activities are focused on states and include technical analysis to quantify the impacts of building codes on energy, climate, and resilience. BECP will continue to expand these activities to support local governments more directly to the degree practicable, where strong alignment exists between federal and municipal goals supporting clean energy, mitigation of climate change, and in creating more equitable policy solutions that ensure the benefits of energy efficiency are realized by all Americans. As part of this expansion, BECP will place an emphasis on support for states, and local governments, pursuing stretch codes and integrated technological solutions that have the potential to increase energy efficiency and optimize cost effectiveness across the range of U.S. climates, building types, and construction practices. BECP will also support technical assistance forums that enable the effective exchange of information and successful practices surrounding code implementation (both adoption and compliance), as well as energy code education, training, and outreach initiatives that support states, local governments, and the range of industry stakeholders in embracing advanced design and construction practices.

Equipment and Buildings Standards
Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Equipment and Building Standards $55,000,000	**$75,000,000**	**+$20,000,000**
Energy Conservation Standards $22,990,000	$31,910,000	+$8,920,000
• 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, reduce regulatory burden for manufacturers and provide them with a larger national marketplace. Energy savings achieved through new or amended standards will contribute to reducing utility bills and carbon emissions as old appliances are replaced with more efficient products.	• Expand the development of 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, reduce regulatory burden for manufacturers and provide them with a larger national marketplace. Energy savings achieved through new or amended standards will contribute to reducing utility bills and carbon emissions as old appliances are replaced with more efficient products.	• The increases are directly related to the number of rulemakings and analytic support needed to address the backlog of missed statutory guidelines and keep pace with current statutory obligations.
Test Procedures $18,020,000	$24,100,000	+$6,080,000
• 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.	• 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.	• Increased funding to support test procedure development for heat pumps that will better characterize field operation over a range of conditions, better controls, and cold-climate performance. The increased funding also supports additional testing and development to better incorporate innovative technologies and designs introduced into the market by manufacturers to capture energy savings features in the test procedure and metric.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Certification, Compliance and Enforcement $3,990,000	$3,990,000	$0
• Ensure products sold in the U.S. meet energy and water conservation standards so that all Americans save money on their utility bills when purchasing new appliances and equipment.	• Ensure products sold in the U.S. meet energy and water conservation standards so that all Americans save money on their utility bills when purchasing new appliances and equipment.	• No significant change
Building Energy Codes $10,000,000	$15,000,000	+5,000,000
• Limit participation in industry processes to review and modify national model energy codes to the minimum required for compliance with statute.	• Continue participation in the industry code processes, including reviewing and modifying national model energy codes. Develop and implement building energy codes for the Federal building fleet, including analysis, rulemakings, and implementation support.	• Increase support of federal building-related analysis and rulemakings.
• Technical assistance will be limited to maintaining and updating DOE's REScheck and COMcheck software and the energycodes.gov website.	• Provide technical assistance and analysis (including REScheck and COMcheck software) to States and localities to support their building codes and building performance standards.	• Increase funding to support expanded technical assistance and the development of additional technical analysis to quantify the impacts of updated building energy codes (e.g., energy, cost, and greenhouse gas savings).

Program Direction

Overview

Program Direction enables EERE to maintain and support a world-class Federal workforce that supports EERE's mission to accelerate the research, development, demonstration, and deployment (RDD&D) of innovative technologies that will transition Americans to net-zero greenhouse gas emission, economy-wide, by no later than 2050 and ensure the clean energy economy benefits all Americans. The FY 2023 Program Direction Request provides 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.

Highlights of the FY 2023 Budget Request

The FY 2023 EERE Program Direction Budget Request will:

- Support 750 FTEs at Headquarters, the Golden Field Office, and the National Energy Technology Laboratory.
- Support strengthening EERE's overall performance, organization, budget, laboratory management, operations, human capital, and project management while achieving significant cost savings; and
- Support project management and procurement across EERE's full portfolio of projects, including closing out completed financial assistance awards.
- Build capacity to ensure American Jobs Plan programs are implemented efficiently and effectively.

Salaries and Benefits: The Request assumes a 4.6 percent federal staff pay increase, annualization of the 1.0 percent increase from 2022 as well as increased funding to support up to 750 FTE. This FTE level reflects the shift of the Federal Energy Management Program (FEMP) and the Weatherization and Intergovernmental Programs (WIP) to the new Undersecretary for Infrastructure and additional transfers of smaller programs from within Water Power Technology Office and the Advanced Manufacturing Office. The increase in FTE from FY 2021 is to address increasing funding and gaps in areas such as in the appliance standards development and building codes development, development of technologies to facilitate transitioning to carbon-free electricity and fleet electrification, and to support EERE's programmatic priorities.

Support Services: The Request includes additional funds for contract support to implement programmatic priorities. Hiring and retaining staff needed to achieve EERE's mission continues to be a priority, and the Request also provides increased funding for activities associated with attracting a diverse workforce and onboarding staff in an efficient manner.

Other Related Expenses: Improving the tracking and evaluation of EERE's investments to make sure every dollar is contributing to mission, with useful metrics and performance processes is a FY 2023 priority for EERE. The Request includes funding for information technology systems development to ensure EERE can collect and analyze data on its investments. The Request also provides an increase for information technology needs to support EERE's staffing planned for FY 2023 including support to ensure the EERE workforce can execute its mission in a hybrid fashion as needed.

Program Direction
Funding ($K)

	FY 2021 Enacted	FY 2022 Annualized CR[1]	FY 2023 Request
Program Direction			
Washington Headquarters			
Salaries and Benefits	76,617	-	114,600
Travel	1,780	-	3,500
Support Services	15,846	-	7,250
Other Related Expenses	36,570	-	40,000
Total, Washington Headquarters	**130,813**	**130,813**	**165,350**
Golden Field Office			
Salaries and Benefits	19,336	-	26,000
Travel	104	-	750
Support Services	1,331	-	5,000
Other Related Expenses	1,941	-	4,500
Total, Golden Field Office	**22,712**	**22,712**	**36,250**
National Energy Technology Laboratory			
Salaries and Benefits	6,047	-	9,000
Travel	115	-	250
Support Services	363	-	5,724
Other Related Expenses	4,950	-	7,900
Total, National Energy Technology Laboratory	**11,475**	**11,475**	**22,874**
Total Program Direction			
Salaries and Benefits	102,000	-	149,600
Travel	2,000	-	4,500
Support Services	17,539	-	17,974
Other Related Expenses	43,461	-	52,400
Total, Program Direction	**165,000**	**165,000**	**224,474**

[1] The FY 2022 Annualized CR amounts reflect the P.L. 117-95 continuing resolution level annualized to a full year. These amounts are shown only at the congressional control level and above, below that level, a dash (-) is shown.

	FY 2021 Enacted	FY 2022 Annualized CR	FY 2023 Request
Federal FTEs	**631**	**631**	**715**
Additional Office of Fossil Energy's FTEs at NETL	44	44	45
Total EERE-funded FTEs	**675**	**675**	**750**
Support Services			
Technical Support	11,648	-	9,250
Management Support	5,891	-	8,724
Total, Support Services	**17,539**	**17,539**	**17,974**
Other Related Expenses			
Other Services	20,714	-	28,918
Working Capital Fund (WCF)	22,747	-	23,482
Total, Other Related Expenses	**43,461**	**43,461**	**52,400**

Program Direction
($K)

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Program Direction $165,000	**$224,474**	**+$59,474**
Salaries and Benefits $102,000	$149,600	+$47,600
• Funding levels will support a Federal workforce of 675 FTE, provide resources for program and project management, administrative support, contract administration, and human capital management.	• The Request will support a Federal workforce of 750 FTE, provide resources for program and project management, administrative support, contract administration, and human capital management. S&B estimates take into consideration grade/step levels for the current workforce and the programmatic needs the FY 2022 workforce level.	• The request accounts for the realignment of FEMP and WIP to the Undersecretary for Infrastructure • The increase provides additional staff to address new and increasing areas of funding, as well as staff or skill gaps in areas such as appliance standards and building codes development; technology areas support transitioning to carbon-free electricity and fleet electrification; and to support EERE's programmatic priorities.
• Funding also supports Federal employees' salary and benefits, including health insurance costs and retirement allocations in the Federal Employees Retirement System (FERS).	• The Request also will support costs associated with Federal employee benefits, including health insurance costs and retirement allocations in FERS.	• The increase provides additional funding for anticipated workload increases in areas such as appliance standards development and building codes development, technology development to transition to carbon-free electricity and fleet electrification, and to support EERE's programmatic priorities. The increase also accounts for a 4.6 percent increase in Federal salaries and the annualization of the 2022 1.0 percent pay increase.
Travel $2,000	$4,500	+$2,500
• Funding supports only the most essential travel during the COVID-19 pandemic when telepresence and virtual meetings for oversight of EERE funded projects is impossible.	• The Request will support travel funding in support of project management and close-outs where the use of virtual meeting technologies or other telepresence is not practical for oversight of EERE funded projects.	• The increase in travel funding for FY 2023 reflects EERE's anticipated travel requirements at the FY 2023 staffing and programmatic funding levels assuming a safe return to normal operations.
Support Services $17,539	$17,974	+$435

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
• 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. This includes operation and maintenance costs associated with EERE's IT modernization project, EPIC.	• 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. This includes operation and maintenance costs associated with EERE's IT modernization project, EPIC.	• The increase provides funding for contract support to execute EERE priorities including funding to attract and support a diverse workforce, including increased funding to expedite onboarding staff.
Other Related Expenses $43,461	$52,400	+$8,939
• Other Related Expenses provides funds for overhead at DOE Headquarters and the Golden Field Office through EERE's contribution to the WCF and through direct payments in the field. Expenses covered include building operations, telecommunications, network connectivity, supplies/equipment, printing/graphics, mail, contract closeout, purchase card surveillance, computer equipment, utilities, postage, administrative expenses, security, and publications. Also includes funding for EERE's IT modernization project (i.e., EPIC).	• The Request will provide funds for overhead at DOE Headquarters and the Golden Field Office through EERE's contribution to the WCF and through direct payments in the field. Expenses covered include building operations, telecommunications, network connectivity, supplies/equipment, printing/graphics, mail, contract closeout, purchase card surveillance, computer equipment, utilities, postage, administrative expenses, security, and publications. Also includes funding for EERE's IT modernization project (i.e., EPIC).	• Increase reflects expenses associated with EERE's FTE projection of 740 including increased WCF contributions associated with a higher number of staff on board in FY 2023. The increase also includes additional funding to ensure that all EERE staff (federal and contract support) have the necessary information technology tools to work effectively whether at a DOE facility or remote location. The increase also reflects funding for information technology systems development to ensure EERE can collect and analyze data on its investments to make sure every dollar is contributing to its mission.

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 four principal subprograms:

- Technology-to-Market and Communities (formerly Technology-to-Market (T2M)): America's disadvantaged and hard to reach communities bear the brunt of energy cost volatility, energy burden. The T2M and Communities subprogram, publicly branded the Energy Transitions Initiative (ETI), an EERE led multi agency approach, brings crosscutting clean energy expertise to the communities to address high energy costs, reliability, and inadequate infrastructure challenges. 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 Analysis (formerly Strategic Priorities and 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 and the competitiveness of clean energy technologies to enable the transition to a net-zero carbon emission economy.
- 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 programs, communicated objectively and transparently across a range of traditional and online media. Supports and coordinates workshops, roundtables, and other manners of data exchange to inform crosscutting initiatives and executive priorities.
- International: This new function proposed in FY 2023 will support collaborative efforts with key partner countries to accelerate decarbonization efforts, improve energy security, and open markets for clean energy technologies. Catalyzes the development of international export markets for U.S. clean energy solutions with strategically important countries through technical and policy assistance, analysis, and the promotion of U.S.-based standards, test procedures, and certifications.

The program also includes support in the key emphasis areas of energy justice, workforce, diversity in STEM and state and local partnerships. Investments associated with Workforce Development will support training and develop good paying clean energy jobs for the American people – especially workers and communities impacted by the energy transition and those historically underserved by the energy system and overburdened by pollution. Investments associated with Diversity in STEM support outreach and will raise awareness of clean energy research and job opportunities at minority-serving institutions and minority professional organizations and ensure that organizations receiving EERE funding are thinking through diversity and equity in their own work. Investments in State and Local partnerships will enable state and local governments to be more effective in facilitating the nation's (and their own) affordable and resilient clean energy and efficiency goals. Investments associated with Energy and Environmental Justice will support approaches and processes to reach new groups of Americans historically underserved by the energy system.

Highlights of the FY 2023 Request
EERE's approach to integrated technology management requires sustained corporate analysis to develop a framework for investments. Strategic Analysis (SA) will continue to support robust analysis and impact evaluation efforts and expand technical assistance functions in support of EERE's program priorities and joint office partnerships.

EERE will leverage its communication and outreach functions to engage state and local policymakers, business leaders, community advocates, academics, utilities, transit agencies, and other partners to leverage their regions' unique strengths to tackle our climate emergency and to create healthy, safe, and thriving communities, including energy communities, with clean energy jobs that cater to different education and experience levels. This function will support EERE's programs in communicating their work and why it matters to communities and will help technology offices develop and execute effective communications campaigns that inform about EERE opportunities and resources and highlight EERE's accomplishments and successes. In addition, the Request includes increased support for collaboration and outreach to disadvantaged and energy communities in line with the objectives of the Justice40 Initiative. EERE will take a strategic approach to partnering with a broader array of system stakeholders across the RDD&D portfolio while expanding American clean energy innovation leadership.

The Request proposes reestablishing an international coordination function within EERE to complement the DOE International Affairs office with a specific focus on providing funding to facilitate bilateral and multilateral partnerships with the aim to address global energy decarbonization and facilitate technology transfer and market access for American clean energy solution providers through targeted technical assistance. This function will serve as a central coordination point between EERE and the DOE Office of International Affairs on issues pertaining to EERE's mission.

EERE Program Priorities

In FY 2023, Strategic Programs continues to support an investment strategy aligned to the following programmatic priority areas that are central pillars to the U.S. greenhouse gas (GHG) profile:

Strategic Programs Funding ($K)

	FY 2021 Enacted	FY 2022 Annualized CR[1]	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted
Decarbonizing the electricity sector	2,085	2,085	33,500	+31,415
Decarbonizing transportation across all modes: air, sea, rail, and road	395	395	12,000	+ 11,605
Decarbonizing energy-intensive industries	710	710	9,865	+ 9,155
Reduce the carbon footprint of the U.S. building stock	0	0	13,365	+13.365
Decarbonizing the agriculture sector, specifically focused on the nexus between energy and water	0	0	2,000	+ 2,000

[1] The FY 2022 Annualized CR amounts reflect the P.L. xxx-yyy continuing resolution level annualized to a full year.

Strategic Programs
Funding ($K)

	FY 2021 Enacted	FY 2022 Annualized CR[1]	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted
Strategic Programs				
Technology-to-Market and Communities (new name in FY 2023)	4,500	-	34,000	+ 29,500
Strategic Analysis **(formerly Strategic Priorities and Impact Analysis)**	7,000	-	12,385	+ 5,385
Communications and Outreach	3,000	-	5,500	+ 2,500
International (new subprogram in FY 2023)	0	-	7,500	+ 7,500
Total, Strategic Programs	**14,500**	**14,500**	**59,385**	**+44,885**

[1] The FY 2022 Annualized CR amounts reflect the P.L. xxx-yyy continuing resolution level annualized to a full year. These amounts are shown only at the congressional control level and above, below that level, a dash (-) is shown.

Strategic Programs
Explanation of Major Changes ($K)

	FY 2023 Request vs FY 2021 Enacted
Strategic Programs	
Technology-to-Market (T2M) and Communities: In FY 2023, the increase for T2M and Communities subprogram will continue coordinating and building upon Energy Transition Initiative (ETI) efforts. The increase will also support expansion of ETI's community-driven approach to deliver the benefits of EERE's integrated technology portfolio through technical and capacity building support in line with EERE principles to build a clean energy economy that benefits all Americans, prioritizing those communities disproportionately impacted by environmental injustices.	**+29,500**
Strategic Analysis (formerly Strategic Priorities and Analysis): In FY 2023, the increase will support the launch of new technical assistance efforts for renewable integration and grid modernization. The increase will also continue analysis and impact evaluation efforts and support technical assistance functions in support of key EERE programmatic priorities and key emphasis areas.	**+5,385**
Communications and Outreach: The increase will expand communications and outreach activities to achieve greater impact on target audiences, including outreach to disadvantaged and energy communities in line with the objectives of the Justice40 Initiative to the FY 2020 and prior levels. Communications and Stakeholder. The Request will significantly increase engagement activities in support of EERE's programmatic priorities.	**+2,500**
International: The increase will support coordination efforts between EERE and the DOE Office of International Affairs to ensure bilateral and multilateral partnerships with the goal to address global energy decarbonization and enable technology transfer and market access for American clean energy solution providers through targeted technical assistance. The subprogram will leverage the technical expertise of the national laboratory system and provide strategic planning guidance and technical assistance in the EERE pillars - sustainable transportation, energy efficiency, and renewable power. When targeting technical assistance in international engagement, EERE can partner with U.S. clean energy technology and service providers in project execution and demonstration.	**+7,500**
Total, Strategic Programs	**+44,885**

Strategic Programs
Technology-to-Market and Communities

Description

The Technology-to-Market and Communities subprogram fully supports efforts under EERE's Energy Transitions Initiative (ETI). ETI's core mission is to facilitate self-reliant communities by addressing high energy costs, reliability, and inadequate infrastructure challenges faced by islands and remote communities. These activities target both resiliency and first-market adopters of modular emerging technologies across the EERE portfolio in America's hardest to reach communities. To execute effectively, ETI engages a cross-sector set of organizations to include EERE's technology offices, DOE's Office of Electricity (OE), the U.S. Department of Agriculture, and the Department of the Interior to address energy challenges, build capacity, and accelerate the sharing of best practices and innovations to leverage specialized expertise into commercial opportunity, with a particular focus on supporting long-term recovery efforts in jurisdictions impacted by natural disasters.

The Request supports activities that are in line with EERE's commitment to environmental justice as these efforts will ensure that the clean energy economy benefits all Americans in a fair and equitable manner. In FY 2023, EERE will continue ETI activities and apply lessons learned from remote and island communities to a broader set of underserved, disadvantaged, and historically hard to reach communities. In support of the Administration's goals of achieving an equitable carbon-free electricity system by 2035 and net-zero emissions, economy-wide, by no later than 2050, the ETI team is working in close coordination with EERE technology offices and OE, to broaden the scope of ETI.

In FY 2023, in concert with DOE's cross organizational programs, 15 years of lessons learned from ETI in supporting energy transition in remote and islanded communities dramatically expand the impact of ETI to beyond islands and remote communities to leverage the cross organizational program in disadvantaged and hard to reach communities across the United States. The community driven, technology neutral, multi-agency collaboration enables streamlined support to communities disproportionately bearing the brunt of aging infrastructure, climate change, pollution, and high or volatile energy costs. The proposed FY 2023 program expansion will result in hundreds of additional communities supported in commercialization of clean energy technologies through this program that already has illustrated impact through the currently running technical program on islands and remote communities. These efforts will include the development of focused stakeholder engagement for development of on-the-ground partners in underserved communities, focused capacity building in underserved communities in the area of energy efficiency and renewable energy technologies and their applications, and direct technical assistance to traditional and non-traditional energy system stakeholders within communities to enable effective participation in the energy system.

In FY 2023, the Technology-to Market and Communities subprogram will continue to administer ETI activities and expand the scale and impact of ETI investments to apply the lessons learned from island and remote communities to a broader set of underserved, disadvantaged, and historically hard to reach communities. By leveraging activities in the technology offices and across DOE, as well as the full integration of on the ground partners and a focus on end user replicable friendly tools and models, ETI delivers commercial benefits of the R&D portfolio equitably across the American people. These efforts will focus on considering the unique challenges associated with remote and underserved communities, targeting additional remote communities (such as alternative Alaskan areas) and deepening engagement with Puerto Rico and similar island communities in the Caribbean and the Pacific. ETI will maintain its key relationships with partners like Hawaii (and others) to provide decision support tools and lessons learned for other locations in the U.S. looking to pursue resiliency and ambitious sustainable energy goals. ETI will broaden the tools and technical assistance provided to relevant stakeholders for clean and renewable energy technologies.

Technology-to-Market and Communities

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Technology-to-Market $4,500,000	**$34,000,000**	**+$29,500,000**
• Continued investment in Energy Transitions Initiatives ecology of models and activities. Expand upon the initial Energy Transitions Initiatives Partnership Program to include additional communities.	• Coordinate with new investments across EERE on new initiatives that leverage the existing successful Energy Transitions Initiative or the Energy Transition Initiative Partnership Program and to include building capacity in the energy and environmental justice communities.	• Increased funding to continue Energy Transitions Initiative activities to expand the base suite of models to account for a broader set of circumstances identified by the expanded communities brought into the portfolio.

Strategic Programs
Strategic Analysis (formerly Strategic Priorities and Impact Analysis)

Description

The Strategic Analysis (SA) subprogram supports EERE's cutting-edge, transformational research, development, and deployment activities 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. SA funds high-impact, crosscutting, integrative activities most efficiently executed by a single crosscutting organization in coordination with EERE technology programs and other DOE offices. This is accomplished by performing 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 2023, SA will support several key EERE and DOE priorities to place the Nation on an accelerated timeline to achieve net-zero carbon emissions as quickly as possible.

In support of the Administration's goals of achieving a carbon free electricity system by 2035 and net-zero emissions, economy-wide, by no later than 2050, SA, working in close coordination with the EERE technologies offices, OE, and the DOE Office of Policy, will fund analysis to identify interim milestones to meet key decarbonization goals across the electricity, buildings, industrial, transportation and agricultural sectors. This analysis will inform EERE R&D planning and serve as a resource for EERE stakeholders involved in the unprecedented deployment of clean energy technologies.

SA, in partnership with the Renewable Power offices and OE, will support EERE's "Comprehensive Technical Assistance for an Evolving Grid" program, which will systematically provide support across several critical topic areas: project valuation, resilience, energy planning, transmission and interconnection, grid operation, regulatory and policy support, and electricity markets. Program activities will include developing foundational capabilities (data, tools, analysis), indirect TA (best practices guides, workshops, etc.), as well as direct TA (tailored responses to specific stakeholder questions). To maximize efficacy, this program will be coordinated with other TA efforts in EERE, OE, the Office of Cybersecurity, Energy Security, and Emergency Response (CESER), and across the Department. The program will also develop formalized relationships with national-level stakeholder organizations to increase participation and access, help prioritize research that reflects the diversity of stakeholder needs and streamlines delivery. Ultimately, this subprogram will enable stakeholders to make data-driven decisions that can accelerate technology deployment and the implementation of policy, regulatory, and market structures necessary for planning and operating a reliable and resilient decarbonized grid. FY 2023 activities will focus on scaling up existing TA efforts, accelerating development of foundational capabilities, and large-scale program roll-out and stakeholder engagement.

Additionally, in FY 2023, SA will lead efforts to ensure that EERE is maximizing the impact of its research dollars, tracking the impacts of EERE investments relative to priority metrics, and striving to ensure that the clean energy economy benefits all Americans. Efforts will be coordinated with the Department's larger efforts to meet the goals of the Justice40 Initiative, address workforce needs, and examine the potential for good paying jobs.

Departmental Crosscuts:

SA is involved in several crosscuts, including the following:

- Energy Storage ($1,000,000): Continue analysis of pathways to a 100 percent clean electricity system inclusive of the Long Duration Storage Shot target. Support the Energy Storage Grand Challenge Policy & Valuation Track, which provides data, tools, and technical analysis that help policymakers and other energy system decision-makers maximize the value of energy storage to the power, industrial, and transportation systems.
- Industrial Decarbonization ($5,865,000): SA funded analysis of interim milestones to meet key decarbonization goals across the sectors will examine tradeoffs and opportunities to optimize approaches to reduce emissions for sectors and applications that are harder to decarbonize.

Strategic Analysis (formerly Strategic Priorities and Impact Analysis)

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Strategic Analysis $7,000,000	**$12,385,000**	**+$5,385,000**
• Conduct preliminary analysis of potential pathways to achieve a carbon pollution-free electricity sector by 2035, examining threats and solutions to ensure cost effective grid reliability and resilience.	• Finalize analysis of comprehensive nationwide analysis of pathways to carbon free electricity and integrate with analysis of pathways to decarbonize transportation, buildings, and industry.	• Increased funding will support additional focal areas informed by work in FY 2022.
• No funding requested in FY 2021.	• Fund technical assistance efforts for renewable integration and grid modernization to support stakeholders making data-driven decisions around clean energy pathways, transmission buildouts, and market as well as policy solutions.	• Increased funding to expand provision of technical assistance beyond initial offerings in FY 2022.
• Conduct analysis of renewable technology pathways for industrial processes, process heating, and fuels production that can help Americans transition to a 100 percent clean energy economy no later than 2050.	• Work will be completed in FY 2022.	• No funding is requested in FY 2023.
• Enhance modeling and workforce analysis tools to project clean energy job shifts and opportunities for equitable transitions within energy communities.	• Complete development of analytical tools to enable EERE programs and external stakeholders to maximize U.S. energy job creation and minimize job transitions.	• Increased funding to support development of analytical tools.
• Provide analytical support for the Energy Storage Grand Challenge and identify opportunities to integrate EERE technologies with storage and enhance grid integration to meet clean energy goals.	• Continue to provide analytical support for the Energy Storage Grand Challenge in coordination with cross sector analysis examining pathways to decarbonization.	• No significant change.
• No funding requested in FY 2021.	• Support Justice40 Initiative by developing tools to measure and inform EERE efforts to foster equity and environmental justice. Quantify progress against established EEERE priority metrics and collect qualitative information to help inform planning and decision making.	• Increased funding to support new activity. Efforts in FY 2023 will build upon foundation set in FY 2022.

Strategic Programs
Communications and Outreach

Description

The Communications and Outreach subprogram provides strategic communications leadership, coordination, and operation support for EERE and the Department by developing and disseminating information and associated impacts to media and the public on EERE programs, activities, and technologies. In addition, this subprogram supports investments to raise awareness and understanding of EERE technologies and inform key stakeholders and audiences of EERE resources and opportunities.

The Communications and Outreach subprogram activities in FY 2023 will focus on:

- Informing key EERE audiences and stakeholders about the work that EERE is doing to transition the Nation to a clean energy economy and fight the global climate crisis. This includes increased support for collaboration with disadvantaged and energy communities in line with the objectives of the Justice40 Initiative. In addition, EERE will increase outreach efforts to raise awareness of clean energy research and career opportunities at minority-serving institutions and minority professional organizations.
- Developing and implementing strategic communications plans and messages that reflect EERE's mission, vision, and goals.
- Supporting EERE's programs in communicating the impacts of their work and why it matters.
- Working across EERE technology offices and programs to develop and execute effective communications narratives and campaigns that inform about EERE opportunities and resources and highlight EERE's accomplishments and successes.
- Supporting EERE's senior leaders to communicate EERE's message through engagements with internal and external stakeholders as well as the public.
- Developing targeted stakeholder engagement and outreach campaigns that leverage a wide range of virtual and live event platforms and communications tactics to engage with a wide range of EERE audiences and stakeholders.
- Executing a wide range of events, conferences, workshops, roundtables, and other means of data exchange (both in-person and virtual) to inform crosscutting initiatives and organizational and executive priorities.
- Improving the functionality and effectiveness of EERE's digital, web-based, social media products with the end-user, the American people, in mind. These efforts will prioritize:
    - Improving the functionality of EERE's website and digital communications products to make them more user friendly and accessible;
    - Increasing engagement and effectiveness of EERE social media content and campaigns;
    - Improving the analysis and reporting of metrics to measure the effectiveness and engagement of communications products and campaigns; and
    - Utilizing videography, photography, animation, commercial art, and graphic design to tell EERE's story and more effectively engage with online audiences on social media and digital/web-based platforms.

Communications and Outreach

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Communications and Outreach $3,000,000	**$5,500,000**	**+$2,500,000**
• Support and coordinate workshops, roundtables, and other manners of data exchange to inform crosscutting initiatives and executive priorities. Conduct analysis and reporting of metrics to measure and improve the effectiveness and engagement of communications products and campaigns. Support the development and implementation of a wide range of digital, web-based, social media products to inform and engage target audiences of EERE's efforts and impact in advancing the transition to a clean energy economy and tackling the global climate challenge.	• Increase EERE's focus on strategic communications planning and implementation to have a greater impact on target audiences. Create new language and messaging that is easily accessible to audiences. Increase analysis and reporting of metrics to measure and improve the effectiveness and engagement of communications products and campaigns. Expand EERE's digital, web-based, graphic, video, and social media products to inform and engage target audiences of EERE's efforts and impact in advancing the transition to a clean energy economy and tackling the climate crisis. Support the development of virtual events and roundtables, strategic communications campaigns, and stakeholder engagement initiatives that highlight progress made towards EERE's strategic goals and tell the story of EERE's successes in an engaging, impactful, and meaningful way; provide information and resources on how to engage with EERE and the work the organization is doing; and convey why EERE's work matters.	• Increased funding to support activities to raise awareness and understanding of EERE technologies and inform key stakeholders and audiences of EERE resources and opportunities to support EERE goals, priorities, and objectives.

Strategic Programs
International

Description:
The International subprogram aims to increase the speed and scale of clean energy deployment to promote deep decarbonization through international collaboration with strategic partners. Project activities will lead to deep decarbonization efforts in partner countries to meet the climate challenge, with opportunities for exports of U.S. clean energy technology and services. While DOE's Office of International Affairs (IA) acts as the initial entry point for broad discussion with countries and organizations, this subprogram will support more substantive, technical, and policy engagement regarding EERE technologies. This subprogram will closely liaise with IA to respond to inquiries for targeted engagement, represent EERE equities in bilateral and multilateral meetings and coordinate with EERE technology offices regarding alignment and scope of work.

The subprogram's activities will fully coordinate with DOE's Office of International Affairs and the Departments of State and Commerce, implementing expert-driven technical assistance in the areas of sustainable transportation, renewable power, and energy efficiency that otherwise does not exist in the federal government. The subprogram will also coordinate and collaborate with U.S. clean energy technology manufacturers and service providers when appropriate. The International subprogram will prioritize partner countries and topic areas informed by Administration priority and by analysis of potential impacts. The subprogram will also consider policy and market insights from U.S. and international public and private-sector partners.

The International subprogram's market priming activities will likely focus on large emerging economies such as India, Indonesia, and South Africa, and regions such as ASEAN (Association of Southeast Asian Nations), that are significant emitters of greenhouse gases and have great opportunities for emissions reductions across major sectors: electric power, commercial buildings, residential buildings, industrial facilities, and transportation. Priming markets and building capacity in these countries through technical assistance on policy options — developing codes and standards, as well as evaluating and addressing technology product reliability from various sources — will help development occur with the cleanest energy profile possible. These activities also generate market pull for energy efficiency and renewable energy technologies, which can be met with U.S. clean energy exports. These activities include technical collaborations to establish business cases for adopting codes, standards, and advanced EERE technologies. The subprogram will also support targeted efforts to demonstrate and deploy emerging U.S. products and services in specific markets, enabling early commercial success and enabling U.S. companies to compete in global markets.

The International subprogram will also encourage and arrange coordination between the U.S. and developed nations (e.g., France, Japan, and Germany) to leverage clean energy technology research, development and innovation and conduct analyses to compare and contrast policy measures to encourage deployment of such technologies.

The International subprogram will measure impacts of collaborative engagement activities designed to deliver decarbonization solutions by tracking their effect on real or projected GHG emissions, investment in clean energy projects in partner countries, and renewable energy or energy efficiency policy changes (such as adoption of U.S. industry-preferred standards or rating systems for technologies such as windows or solar photovoltaics; successful development and implementation of more stringent building codes, etc.).

International

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
International Coordination $0	**$7,500,000**	**+$7,500,000**
• No FY 2021 funding for this activity.	• The Request will allow EERE to implement technical assistance projects with target countries, and to coordinate research, development, and innovation collaboration with developed countries, in consultation and coordination with DOE International Affairs to meet key Secretarial and Administration priorities and commitments to fight climate change.	• The increase provides funding for new activity in FY 2023 for technical assistance and laboratory support, to engage in technical assistance projects with key partner countries, and coordinate R&D exchanges with developed countries.

Facilities and Infrastructure

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 2023 Budget Request ensures that EERE maintains and upgrades NREL's existing research and support infrastructure in key areas to attract world-class research scientists, and develops cutting-edge, innovative solutions to the most challenging technology issues while ensuring the laboratory facilities and real property is resilient to foreseeable climate risks that may impact mission readiness.

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 Research and Development (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 2023 Request
To posture NREL's capabilities to support emerging technologies and future requirements, the FY 2023 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 provides funding that supports operations, maintenance, equipment, and a 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.

The Request reflects EERE's commitment to put in place the capabilities to advance the Administration priorities to achieve a carbon pollution-free electricity sector by 2035 and net-zero emissions, economy-wide, by no later than 2050. To that end, the Request prioritizes investment in the Advanced Research in Integrated Energy Systems (ARIES) initiative to address the challenges of designing and constructing future energy systems using the basic principles of operating large-scale hybrid energy systems that interconnect multiple generation, storage, and end-use technologies and solving the complex problem of controlling the interactions between millions of distributed assets. ARIES research focus areas include energy storage, power electronics, hybrid energy systems, future energy infrastructure, and cybersecurity. Further, EERE plans significant investments toward the decarbonization of the NREL South Table Mountain (STM) campus. EERE plans thermal energy conversion from natural gas to electric heating of eleven standalone facilities on the STM campus, not connected to the district heating and cooling system. EERE also reduces climate risks to property and infrastructure on the NREL campuses, as a "living laboratory", through investigation of alternative fuels for diversified renewable generation and exploration of microgrid feasibility for autonomous operation (islanding) of building operations.

The Request provides funding for the first segment of the construction phase of the Energy Materials and Processing at Scale (EMAPS) line-item construction project. EMAPS is envisioned to address the full lifecycle of our products, materials, and energy economy to enable partnerships with U.S. industry to incentivize waste reduction, reuse, and reduced persistence in the environment, as well as accelerate innovations to market viability. Such a capability will enable research activities critical for a more rapid transition to a circular economy for energy-relevant and energy-intensive materials and processes. The EMAPS project achieved Critical Decision 0 (CD-0), *Mission Need Statement,* on December 20, 2019. EMAPS is expected to achieve Critical Decision 1 (CD-1), *Alternate Selection and Cost Range,* in early FY 2023.

Additionally, this Request provides funding for the design and first segment of construction of the Carbon-Free District Heating and Cooling System on the South Table Mountain (STM) campus. Completion of the CD-0, *Mission Need Statement,* is expected in the third quarter FY 2023.

Facilities and Infrastructure
Funding ($K)

	FY 2021 Enacted	FY 2022 Annualized CR[1]	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted
Facilities and Infrastructure				
Operations and Maintenance	86,321	–	146,150	+ 59,829
Facility Management	43,679	–	63,950	+ 20,271
Construction				
21-EE-001, Energy Materials Processing at Scale (EMAPS)	0	–	60,000	+60,000
23-EE-TBD, STM Carbon Free District Heating/Cooling	0	–	31,500	+31,500
Total, Facilities and Infrastructure	**130,000**	**130,000**	**301,600**	**+171,600**

[1] The FY 2022 Annualized CR amounts reflect the P.L. 117-95 continuing resolution level annualized to a full year. These amounts are shown only at the congressional control level and above, below that level, a dash (-) is shown.

Explanation of Major Changes ($K)

	FY 2023 Request vs FY 2021 Enacted
Facilities and Infrastructure	
Operations and Maintenance: The Request continues to invest in ARIES infrastructure and equipment, STM campus laboratory upgrades and equipment, prioritizes a STM Power (Central) Plant Upgrade, and completes the Scalable Wireless Communications Platform. The Request also prioritizes NREL campus decarbonization efforts to include Distributed Energy Grid East STM campus and electric heating for all new buildings.	+59,829
Facility Management: The Request prioritizes ESIF ARIES infrastructure and equipment investments and provides funding that supports operations, maintenance, equipment, and a refresh/upgrade of the High-Performance Computer (HPC) at the ESIF.	+20,271
Construction: The Request provides funding for first segment of construction of EMAPS and initiates the design and first segment of construction of the new line-item construction project STM Carbon-Free District Heating and Cooling System.	+91,500
Total, Facilities and Infrastructure	**+171,600**

Facilities and Infrastructure
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 Minor Construction Projects (i.e., 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).

Minor Construction investments maintain and enhance the real property portfolio, renovate general science capabilities and buildings, and upgrade laboratories for technical advancements. Examples of Minor Construction Projects are laboratory refurbishments, laboratory reconfigurations, utility enhancements, facility additions, and small (<$20 million) projects to accommodate new research capabilities.

Major GPP activities:

- Design for the STM Central Plant upgrade that maximizes chilled water and heating water plant capacity at the Field Test Laboratory Building and Solar Energy Research Facility, extends underground utilities and roads to support the STM campus.
- Decarbonization of the STM campus to include converting buildings with standalone natural gas heating to electric heating and design of all-electric heating for all new buildings.

EERE and NREL aim to 1) leverage NREL research capabilities, 2) build upon the previous success of designing and constructing the net-zero energy Research Support Facility, 3) use over 10 years of data gathered by operating the NREL campus as a ‘living laboratory’ for energy solutions, and 4) lead by example to develop a roadmap to achieve near-term decarbonization of the NREL Flatirons and STM Campuses no later than 2025. The roadmap includes, but is not limited to, fleet electrification, fully electrify new facilities, and reduce embodied carbon in new construction. NREL will also partner with other DOE National Laboratories to develop an integrated roadmap across the DOE complex and to serve as a roadmap template, beyond, as applicable.

EERE and NREL also identify solutions to mitigate climate change impacts on mission-essential research at NREL facilities. For example, NREL is pursuing a microgrid on the South Table Mountain Campus for autonomous operation (islanding) of building operations. A past equipment failure at the Flatirons Campus that resulted in a full-campus power outage provided an opportunity to demonstrate the successful deployment of on-site research renewable energy assets, including solar arrays, battery energy storage, and wind turbines, minimizing the need for diesel generators and reducing the duration and impact of the outage. EERE successfully repowered the campus from black start using NREL’s ARIES assets. This experience highlighted the value of renewable assets for future consideration in campus planning and capital infrastructure activities to start campus power. NREL is mitigating wildfire risk with the Flatirons Campus Water Project to connect the campus to a local water supply and reduce NREL’s reliance on trucked-in water to meet ongoing site potable and increase firewater needs. Existing and future GPP investments are key to advancing climate and resilience goals and objectives.

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 activity:
The Request supports the Scalable Wireless Telecommunications Platform, which includes installation and commissioning of a field of wireless range capabilities for use in integrated research and development of operational and information technology application to energy system operations, cyber technologies, monitoring, and security.

The Request also supports additional high-priority Advanced Research in Integrated Energy Systems research platform GPE investments in support of the ARIES energy storage, power electronics, hybrid energy systems, future energy infrastructure, and cybersecurity research areas.

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 2023 Request ensures NREL will remain within the DOE control standard of two to four percent of Replacement Plant Value (RPV). This Request increases funding for M&R.

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. The Request slightly increases SW.

Operations and Maintenance

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Operations and Maintenance $86,321,000	**$146,150,000**	**+$59,829,000**
• Minor Construction and GPE reduces deferred maintenance and refurbishes laboratories at the NREL South Table Mountain Campus and provides ARIES infrastructure investments at the NREL Flatirons Campus that include design for a 34.5kV Grid Infrastructure upgrade project. Provides Other Project Costs for EMAPS.	• The Request prioritizes continued support GPE ARIES investments in the five research areas of the initiative: Cybersecurity, Future Energy Infrastructure, Energy Storage, Hybrid Energy Systems, and Power Electronics. Includes design for a STM Campus Central Plant and completes the Scalable Wireless Communications Platform. The Request also prioritizes NREL campus decarbonization efforts to include STM Distributed Energy Grid East and electric heating for all new buildings.	• Prioritizes support for ARIES Minor Construction and GPE investments and NREL campus decarbonization efforts.
• 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, with increased investments in M&R.	• Increased investments in M&R.
• Maintained operational readiness for S&S activities.	• Maintains operational readiness for S&S activities.	• No significant change.
• Maintains operational readiness for SW activities.	• Maintained operational readiness for SW activities, with increased investments for additional facility management, maintenance, chemical management, industrial hygiene, electricians, fire systems technicians, and health and safety initiatives as NREL’s two-campuses build-out to ensure the level of services necessary to keep the Laboratory running safely, securely, and effectively.	• Increased investments in SW activities.

Facilities and Infrastructure
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 2023 Request continues the research-readiness efficiency-charge for users of the ESIF.

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 investments continue relevance of ESIF laboratory facilities and capabilities, and advance multi-program focused cross-cutting integration research in Energy Storage, Cybersecurity, Hydrogen and Renewable Fuel Systems, Thermal Systems, Future Energy Infrastructure, Hybrid Energy Systems, Power Electronics, Transportation, Autonomous Energy Systems, and Buildings.

ESIF's High Performance Computer (HPC) supports research across nine EERE programs as well as the Advanced Research in Integrated Energy Systems research platform and produces computational experiments that advance critical NREL 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 2023 Request provides funding that supports operations, maintenance, equipment, and a refresh/upgrade of the ESIF HPC.

The FY 2023 Request emphasizes investments in ARIES equipment and infrastructure within ESIF. The Request supports the addition of Network and Security and Encryption components and add-on devices to enhance security and a High-Current 1MW Electrolysis DC Power Supply with Active AC Control to expand PV emulation capability necessary to support ESIF's 2 MW grid simulation.

ESIF investments also 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); the maintenance and safety envelope of the ESIF; and 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 support 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

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Facility Management $43,679,000	**$63,950,000**	**+$20,271,000**
• Supported the last year of a four-year refresh/upgrade of the ESIF Eagle High Performance Computer, upgraded the ESIF High Performance Computer infrastructure in preparation for the next refresh/upgrade cycle, and provided HPC equipment and continues HPC operations.	• Provides for a refresh/upgrade cycle of the Kestrel High Performance Computer.	• The increase provides additional funding to the HPC refresh/upgrade cycle.
• Provided Advanced Research in Integrated Energy Systems (ARIES) equipment and infrastructure investments.	• Increases ARIES equipment and infrastructure investments.	• Increased investments in ARIES equipment.
• Continued research-readiness efficiency-charge for users of the ESIF.	• Continues research-readiness efficiency- charge for users of the ESIF.	• No significant change.
• Provided for energy system security and resilience to ensure that activities at ESIF to 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.	• No significant change.
• Decreased support for site operating costs and utilities as these costs are transferred to indirect NREL funding.	• Continues charging prorated share of site operating costs and utilities to indirect funding.	• No significant change.
• Continued funding 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.

Facilities and Infrastructure
Construction

Description

This subprogram supports line-item construction projects associated with EERE's mission. The Request provides funding for the first segment of the construction phase of the Energy Materials and Processing at Scale (EMAPS) line-item construction project, and initiates support for the design and first segment of construction of the new line-item construction project, Carbon-Free District Heating and Cooling System on the STM Campus.

EMAPS is envisioned to address the full lifecycle of our products, materials, and energy economy to enable partnerships with U.S. industry to incentivize waste reduction, reuse, and reduced persistence in the environment, as well as accelerate innovations to market viability. Such a capability will enable research activities critical for a more rapid transition to a circular economy for energy-relevant and energy-intensive materials and processes. Construction segment 1 provides sitework, water and sewer taps, foundations, and construction of core and shell dried-in building. Segment 2 will provide completed interior and exterior finishes plus purchase and installation of long-lead equipment. Segment 3 will provide completion of hardscape/landscape, lab fit-out, test and balance, and building commissioning that will lead to Beneficial Occupancy and Certification of Final Completion.

The most recent DOE Order 413.3B Critical Decision (CD) is CD-0, Approve Mission Need, approved on December 20, 2019. The preliminary estimate for CD-1, Approve Alternative Selection and Cost Range, is anticipated in the first quarter of FY 2023. This project is pre-CD 2; therefore, schedule estimates are preliminary and subject to change. The current preliminary Total Estimated Cost (TEC) range for this project is $90,000,000 to $160,000,000 and the preliminary Total Project Cost (TPC) range of $95,000,000 to $165,000,000. These cost ranges encompass the most feasible preliminary alternatives currently.

The Carbon-Free District Heating and Cooling System on the STM Campus project represents NREL's strategic approach to decarbonizing the laboratory's footprint which will require the elimination of greenhouse gas (GHG) emissions from all campus facilities' energy use. Currently, NREL's STM Central Plant is at capacity and many of the chillers and boilers are reaching end of service life. Addressing these two very significant challenges is crucial to NREL's implementation strategy that must deliver infrastructure support to all mission critical facilities. The STM Campus has nine major facilities connected to the campus central plant. The central plant provides hot and chilled water for heating, cooling and research needs in these facilities. NREL intends to migrate these facilities to a carbon-free district heating and cooling system. Completion of the CD-0, *Mission Need Statement,* is expected in the third quarter FY 2023.

Construction

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Construction $0	**$91,500,000**	**+$91,500,000**
• Design for EMAPS started in FY 2021.	• Provides funding for the first segment of the construction phase for the EMAPS line-item construction project. • The Request supports the design and the first segment of construction for the STM Carbon-Free District Heating and Cooling System currently at pre-CD-0.	• Transitions from design to construction phase for EMAPS. • Increase is to fund the full design and the first segment of the construction phase.

Facilities and Infrastructure
Capital Summary ($K)

	Total[1]	Prior Years	FY 2021 Enacted	FY 2021 Actuals	FY 2022 Annualized CR	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted
Capital Summary (including Major Items of Equipment (MIE))							
Capital Equipment > $5M (including MIE)	-	0	20,262	20,262	14,400	38,775	+18,513
Minor Construction	-	1,200	69,421	69,421	13,100	51,925	-17,496
Major Construction	-	0	4,000	4,000	8,000	91,500	+87,500
Total, Capital Summary	**-**	**1,200**	**93,683**	**93,683**	**35,500**	**182,200**	**+88,517**
Capital Equipment > $5M (including MIE)							
Total Non-MIE Capital Equipment (< $5M)	-	0	20,262	20,262	13,400	35,675	+15,413
Scalable Wireless Communications Platform (DF)	5,000	0	0	0	1,000	3,100	+3,100
Total, Capital Equipment (including MIE)	**5,000**	**0**	**20,262**	**20,262**	**14,400**	**38,775**	**+18,513**
Minor Construction Projects							
Total Direct Funded Minor Construction Projects (TEC <$5M)	-	-	20,211	20,211	700	18,425	-1,786
Enhanced Grid/Energy Systems Control Center (DF)	10,500	0	10,500	10,500	0	0	-10,500
Research and Innovation Laboratory (DF)	24,910	0	19,910	19,910	5,000	0	-19,910
Flatirons Campus Water Line Project (IF)	12,400	1,200	11,200	11,200	0	0	-11,200
ARIES 34.5kV Infrastructure Upgrade (DF)	8,000	0	1,600	1,600	6,400	0	-1,600
ESIF HPC Data Center 7.5MW Upgrade (DF	6,000	0	6,000	6,000	0	0	-6,000
Waste Handling Facility (DF)	9,350	0	0	0	1,000	0	0
Flatirons Campus (FC) Infrastructure Upgrade (DF)	5,000	0	0	0	0	5,000	+5,000
STM Power Plant Upgrade (DF)	15,000	0	0	0	0	1,500	+1,500
Flatirons Campus Utility Distribution Duct Work (DF)	19,500	0	0	0	0	1,500	+1,500
Distributed Energy Grid East STM Campus (DF)	19,500	0	0	0	0	19,500	+19,500
Electric Heating for All New Buildings (DF)	6,000	0	0	0	0	6,000	+6,000
Total, Minor Construction Projects	**136,160**	**1,200**	**69,421**	**69,421**	**13,100**	**51,925**	**-17,496**

[1] Dashes (-) in the Total column indicates a broad category where totaling would not be applicable as it would be for an individual investment.

	Total[1]	Prior Years	FY 2021 Enacted	FY 2021 Actuals	FY 2022 Annualized CR	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted
21-EE-001, Energy Materials and Processing at Scale, TEC[1,2]	160,000	0	0	4,000	8,000	60,000	+56,000
23-EE-TBD, STM Carbon Free District Heating/Cooling, TEC[3,4]	62,000	0	0	0	0	31,500	+31,500
Total, Construction	**222,000**	**0**	**4,000**	**4,000**	**8,000**	**91,500**	**+87,500**
Total, Capital Summary	**363,160**	**1,200**	**93,683**	**93,683**	**35,500**	**182,200**	**+88,517**

[1] This project has not received CD-2 approval; therefore, preliminary estimates are shown for TEC.
[2] Indicates a project where the cost of the Conceptual Design Report is estimated to exceed $3 million.
[3] This project has not received CD-2 approval; therefore, preliminary estimates are shown for TEC.
[4] Indicates a project where the cost of the Conceptual Design Report is estimated to exceed $3 million.

Outyears ($K)

	FY 2024 Estimate	FY 2025 Estimate	FY 2026 Estimate	FY 2027 Estimate
Capital Summary (including Major Items of Equipment (MIE))				
Capital Equipment > $5M (including MIE)	64,500	46,300	41,500	25,800
Minor Construction	132,500	129,900	42,100	37,300
Major Construction	137,500	99,000	0	0
Total, Capital Summary	**334,500**	**275,200**	**83,600**	**63,100**
Capital Equipment > $5M (including MIE)				
Total Non-MIE Capital Equipment (< $5M)	64,500	39,800	41,500	25,800
Field-scale 5G Platform	0	6,500	0	0
Total, Capital Equipment (including MIE)	**64,500**	**46,300**	**41,500**	**25,800**
Minor Construction Projects				
Total Direct Funded Minor Construction Projects (Total Estimated Cost (TEC) <$5M)	58,000	14,100	27,600	19,000
Total Indirect Funded Minor Construction Projects (Total Estimated Cost (TEC) <$5M)	0	0	0	0
STM Power Plant Upgrade (DF)	13,500	0	0	0
Flatirons Campus Control Center II (DF)	1,000	18,500	0	0
Research and Innovation Lab II (DF)	1,000	18,500	0	0
Flatirons Campus Utility Distribution Duct Work (DF)	0	4,500	4,500	4,500
Substation Device Research Platform (DF)	5,000	0	0	0
IESS Infrastructure Expansion (DF)	5,000	5,000	5,000	0
Pilot Plant Revitalization - IBRF Remodel (DF)	10,000	0	0	0
Waste Handling Facility (DF)	8,350	0	0	0
NREL Campuses Digital Twin (DF)	0	5,000	0	0
Zero Carbon Wastewater Treatment Facility at Flatirons Campus (DF)	0	7,500	0	0
Monitoring-based Commissioning (DF)	0	5,000	0	0
Implement a Smart Labs Program (DF)	0	10,000	0	0
FC Carbon-free Backup Power Technologies (DF)	19,500	0	0	0
STM Carbon-free Backup Power Technologies (DF)	19,500	0	0	0
Onsite Renewable Energy (DF)	0	17,000	0	0
MVDC Microgrid Research Platform (DF)	0	5,800	0	0
3MW Wind Turbine (DF)	0	5,000	0	0
Future Tech Ready Interconnect Support Platforms (DF)	0	8,000	0	0
Power/Cooling Upgrade for ESIF HPC Datacenter Kestrel II (DF)	0	0	5,000	0
Metrology Laboratory (DF)	0	0	0	8,800
Time Scale Energy Storage Characterization Research Pad (DF)	0	0	0	5,000
Total, Minor Construction Projects	**140,850**	**123,900**	**42,100**	**37,300**

	FY 2024 Estimate	FY 2025 Estimate	FY 2026 Estimate	FY 2027 Estimate
Major Construction Projects				
EE-21-001, Energy Materials Processing at Scale[1][2][3] Total Estimated Cost (TEC)	57,000	31,000	0	0
23-EE-TBD, STM Carbon Free District Heating/Cooling	30,500	0	0	0
TBD, Distributed Energy Districts	30,000	0	0	0
TBD, Offsite Renewable Energy	0	68,000	0	0
TBD, 24/7 Carbon Free Energy Operations	20,000	0	0	0
Total, Construction	**137,500**	**99,000**	**0**	**0**
Total, Capital Summary	**342,850**	**269,200**	**83,600**	**63,100**

[1] This project has not received CD-2 approval; therefore, preliminary estimates are shown for TEC.
[2] Indicates where a project where the cost of the Conceptual Design Report is estimated to exceed $3 million.
[3] Other Project Costs (OPC) are funded through laboratory overhead.

Minor Construction Projects ($K)

Facilities & Infrastructure Operations & Maintenance	
Project Name:	Flatirons Campus Water Line Project
Project Site/Location:	NREL Flatirons Campus
Type:	Minor Construction (Indirect funded)
Total Estimated Cost:	$12,400
Construction Design:	$ 1,200
Project Start:	FY 2020
Design Complete:	FY 2022
Construction Complete:	FY 2023
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 potable and fire suppression purposes. The infrastructure investments include a water pipeline to supply raw water to the campus; a water treatment system producing potable water, storage tanks for fire suppression and domestic water demands; an onsite wastewater treatment 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. Useful segments: • Design (FY 2021 – 2022) $1,200 • Water Rights and Easements (FY 2022) $1,000 • Construction (FY 2021 – 2023) $10,200
Prior Year Accomplishments:	• The Integrated Project Teams (IPT) for NREL and DOE have been formed. • The Project Management Plan has been reviewed and approved by the NREL IPT. • The Project Charter has been reviewed and approved by the DOE IPT. • The NEPA for design has been reviewed. • DOE has contracted with WAPA to provide real estate services for the project on behalf of DOE. WAPA has started researching existing land rights on Section 16 of the wildlife refuge. • Discussions on the extension of the Right-of-Way on the wildlife refuge have started with the Fish and Wildlife Service. • The design phase is underway.
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:	Design completion changed from FY 2020 to FY 2022 and Project completion changed from FY 2022 to FY 2023 due to a delay in the start of design.

Minor Construction Projects ($K)

Facilities & Infrastructure Operations & Maintenance	
Project Name:	Enhanced Grid/Energy Systems Control Center
Project Location/Site:	NREL Flatirons Campus
Type:	Minor Construction (Direct funded)
Total Estimated Cost:	$10,500
Construction Design:	$800
Project Start:	FY 2020
Design Complete:	FY 2022
Construction Complete:	FY 2023
Project Description:	A central control center at the Flatirons campus serves a dual function for enabling remote data collection and analysis involving diverse research portfolios while also conducting grid integration research. The center would accommodate space to allow for multiple parallel project field campaigns; a visualization room capable of providing state of the art, high- resolution visual imagery that will illustrate research findings to stakeholders; a conference room and offices. This control center will serve as the hub for all grid/energy research at the site and coordinate multiple level energy integration and cybersecurity experiments with both local and remote facilities. The visualization room will be connected to the Energy Systems Integration Facility and other National Laboratories through a high-speed data connection. Useful segments: • Design FY 2020 – FY 2022 $800 • Construction FY 2021 – FY 2023 $9,700
Prior Year Accomplishments:	The Integrated Project Team (IPT) for NREL has been formed. • The PMP has been reviewed and approved by the IPT. • The design phase is underway. The building concept plan prepared by the design team isnearing completion. • The NEPA for design has been reviewed.
Planned Activities:	• Design (Preparing and finalizing drawings, specifications, and other documents describing thework to allow construction of the project • Construction (Construction of the project up to final payment as defined in the constructionsubcontract, construction administration by the design team • Project Management, Laboratory Services, and Government Furnished Equipment (Project management; independent testing/inspection, commissioning, and other third-party services; technical oversight during design and construction; IT and other laboratory provided services; procurement and installation of Government Furnished Equipment
Significant Changes from original plan:	Design completion changed from FY 2021 to FY 2022 and Project completion changed from FY 2021 to FY 2023 due to a delay in the start of design.

Minor Construction Projects ($K)

Facilities & Infrastructure Operations & Maintenance	
Project Name:	Research and Innovation Laboratory (RAIL)
Project Location/Site:	NREL South Table Mountain Campus:
Type: Total Estimated Cost: Construction Design: Project Start: Design Complete: Construction Complete:	Minor Construction (Direct funded) $24,910 $ 1,650 FY 2020 FY 2022 FY 2023
Project Description:	This project provides flexible laboratory space for highly integrated, interdisciplinary research open to support active collaboration across disciplines with enhanced types of ventilation required to keep researchers safe and to enable conducting diverse experiments compatibly and safely in proximity with each other. Design of the laboratories will enable adapting quickly to new research opportunities with state-of-the-art capabilities to attract and collaborate with industry to move knowledge and knowhow from proof-of-principal experiments to co-development and initial experimentation at a scale that catalyzes commercial investment. In addition to typical building and site improvements, the project scope accommodates lab equipment fit out, design, procurement and installation for major lab equipment items which requires infrastructure modifications, site improvements and features that will support external collaboration activities, access roadway improvements, and pedestrian scale improvements including walkways, hardscaping and ramps to enhance ADA accessibility. The project will employ a design-build contract estimated to take nearly 30 months to complete from design through beneficial occupancy. Estimated facility size is approximately 15,000 square feet. Useful segments: • Design FY 2021 $1,350 • Construction FY 2022 $18,560
Prior Year Accomplishments	• Selected and awarded a contract to Mortenson Construction • NEPA for design and construction has been completed • Preliminary design has been completed • Construction started August 2021 • Ongoing construction (Construction of the project up to final payment as defined in the construction subcontract; construction oversight by NREL)
Planned Activities:	• Project Management, Laboratory Services, and Government Furnished Equipment (Project management; independent testing/inspection, commissioning, and other third-party services; technical oversight during design and construction; IT and other laboratory provided services; procurement and installation of Government Furnished Equipment) • Complete construction
Significant Changes from original plan:	A $400K budget and scope increase was approved in FY 2021 that directly supports the decarbonization of the NREL STM campus. The change in budget and scope incorporates microgrid infrastructure capabilities, an Emergency Branch Backup Inverter, and provides a service upgrade to enable renewable technology power sources for the RAIL, in lieu of diesel generation, for back-up power. A $5M budget and scope increase was approved in FY 2022 that accommodates lab equipment fit out, design, procurement and installation for major lab equipment items which requires infrastructure modifications, site improvements and features that will support external collaboration activities, access roadway improvements, and pedestrian scale improvements including walkways, hardscaping and ramps to enhance ADA accessibility.

Minor Construction Projects ($K)

Facilities & Infrastructure Operations & Maintenance	
Project Name:	34.5kV Grid Infrastructure
Location/Site:	NREL Flatirons Campus
Type:	Minor Construction (Direct funded)
Total Estimated Cost:	$8,000
Construction Design:	$1,600
Project Description:	This project includes an expansion to the substation, 34.5kV transformers, switchgear, and underground cable Installation. The 34.5kV is required to support next generation wind turbines and the second Controllable Grid Interface (CGI) connectivity bus expected to be completed in FY21. Useful segments: • Design FY 2021 $1,600 • Construction FY 2022 – FY 2023 $6,400
Prior Year Accomplishments:	• The PMP has been approved by the IPT. • The NEPA for design has been reviewed. • The proposal for design services is under review.
Planned Activities:	• Design (Preparing and finalizing drawings, specifications, and other documents describing the work to allow construction of the project) • Construction (Construction of the project up to final payment as defined in the construction subcontract, construction administration by the design team) • Project Management, Laboratory Services (project management, independent testing/inspection, commissioning, and other third-party services, technical oversight during design and construction)
Significant Changes from original plan:	N/A

Minor Construction Projects ($K)

Facilities & Infrastructure **Facilities Management**	
Project Name:	ESIF HPC Datacenter - 7.5-Megawatt Upgrade
Location/Site:	NREL STM Campus
Type:	Minor Construction (Direct funded)
Total Estimated Cost:	$6,000
Construction Design:	$430
Project Description:	The upgrade to the ESIF Datacenter will include: • Populating the existing transformer pads, main distribution panels and sub distribution panels to increase the datacenter electrical capacity from 5KVA (4 MW usable) to 7.5KVA (6 MW usable) • Add ERW (datacenter cooling water) distribution piping in the ESIF HPC Datacenter mechanical room (B215). Add pumps, heat exchangers, cooling towers, and building control system to increase the datacenter cooling capacity to match the new electrical capacity. • Completing electrical and mechanical designs to increase HPC datacenter capacity.
Prior Year Accomplishments:	• Cost Estimates
Planned Activities:	• RFP • Award Contract
Significant Changes from original plan:	Starting later than expected

Minor Construction Projects ($K)

Facilities & Infrastructure Operations & Maintenance	
Project Name:	Waste Handling Facility
Location/Site:	NREL STM Campus
Type:	Minor Construction (Direct funded)
Total Estimated Cost:	$9,350
Construction Design:	$1,000
Project Description:	The lab proposes to construct an 8,000 sq. ft. facility to store, stage, and process hazardous wastes to support R&D and operational activities. Additional space and facility attributes are required to effectively and efficiently manage hazardous wastes and support the lab's mission. The facility would: 1) allocate space for materials, supplies, and equipment, 2) allow for forklift access, 3) incorporate a transport truck dock, 4) provide separate processing and storage areas to allow for continued acceptance of wastes while others are being processed for offsite shipment, 5) co-locate a portion of the lab's hazardous materials preparedness and response activities (such as spill control materials, chemical response team equipment, SCBA bottle refilling), 6) provide a small office area for waste management administrative activities, 7) provide locker room and shower facilities for worker health and safety, 8) centralize industrial hygiene equipment calibration and respiratory fit testing. The current 1,000 sq. ft. Waste Handling Facility is not adequately sized to meet NREL's current or reasonably foreseeable level of activities. The current size and configuration require waste acceptance to be paused while stored items are packaged and processed for offsite shipment. The lack of sufficient storage and adequate aisle space requires just-in-time procurement of containers and supplies which leads to inefficiencies in removal of wastes from R&D labs. NREL has encountered significant growth throughout the last 8 years with a corresponding increase in research staff and laboratory space generating a variety of hazardous waste streams. To optimize packaging, transportation, and cost-effective disposal, working floorspace which can accommodate physical segregation of cubic yard containers and drums up to 55-gallons in size is necessary to support expanding laboratory R&D operations. Useful segments: • Design FY 2022 $1,000 • Construction FY 2023 – FY 2024 $8,350
Prior Year Accomplishments:	N/A
Planned Activities:	• Design (Preparing and finalizing drawings, specifications, and other documents describing the work to allow construction of the project) • Construction (Construction of the project up to final payment as defined in the construction subcontract; construction oversight by NREL) • Project Management, Laboratory Services, and Government Furnished Equipment (Project management; independent testing/inspection, commissioning, and other third-party services; technical oversight during design and construction; IT and other laboratory provided services; procurement and installation of Government Furnished Equipment)
Significant Changes from original plan:	N/A

Minor Construction Projects ($K)

Facilities & Infrastructure Operations & Maintenance	
Project Name: Location/Site:	Flatirons Campus Infrastructure Upgrade NREL Flatirons Campus
Type: Total Estimated Cost: Construction Design:	Minor Construction (Direct funded) $5,000 $800
Project Description:	To support the new facilities and site research infrastructure, additional site infrastructure is needed at the Flatirons Campus to support the ARIES facilities and research investments, improvements and upgrades to the existing roadways, parking lots, storm drainage collection and storage systems, natural gas supply system, electrical distribution systems, metering (electrical, water, and wastewater), sidewalks and ADA pathways, as well as water and fire distribution system repairs and enhancements. Useful Segments: • Design FY 2023 $800 • Construction FY 2023 – FY 2024 $4,200
Prior Year Accomplishments:	N/A
Planned Activities:	• Design (Preparing and finalizing drawings, specifications, and other documents describing the work to allow construction of the project) • Construction (Construction of the project up to final payment as defined in the construction subcontract; construction oversight by NREL) • Project Management, Laboratory Services, and Government Furnished Equipment (Project management; independent testing/inspection, commissioning, and other third-party services; technical oversight during design and construction; IT and other laboratory provided services; procurement and installation of Government Furnished Equipment)
Significant Changes from original plan:	N/A

Minor Construction Projects ($K)

Facilities & Infrastructure Operations & Maintenance	
Project Name:	
Location/Site:	NREL South Table Mountain Campus
Type:	Minor Construction (Direct funded)
Total Estimated Cost:	$15,000
Construction Design:	$1,500
Project Start	FY 2023
Design Complete	FY 2024
Construction Complete	FY 2026
Project Description:	STM Central Plant upgrades to maximize chilled water and heating water plant capacity at the FTLB and SERF and extend underground utilities and roads to support EMAPS. STM Central Plant do not have capacity to accommodate EMAPS and future buildings. Design-bid-build. Useful Segments: • Design FY 2023 $1,500 • Construction FY 2024 – FY 2025 $13,500
Prior Year Accomplishments:	N/A
Planned Activities:	• RFP • Award of Contract • Design (Preparing and finalizing drawings, specifications, and other documents describing the work to allow construction of the project) • Construction (Construction of the project up to final payment as defined in the construction subcontract; construction oversight by NREL) • Project Management, Laboratory Services, and Government Furnished Equipment (Project management; independent testing/inspection, commissioning, and other third-party services; technical oversight during design and construction; IT and other laboratory provided services; procurement and installation of Government Furnished Equipment)
Significant Changes from original plan:	N/A

Minor Construction Projects ($K)

Facilities & Infrastructure Operations & Maintenance	
Project Name:	Flatirons Campus Utility Distribution Duct Work
Location/Site:	NREL Flatirons Campus
Type:	Minor Construction (Direct funded)
Total Estimated Cost:	$19,500
Construction Design:	$1,500
Project Start	FY 2023
Design Complete	FY 2023
Construction Complete	FY 2029
Project Description:	Design and construct for four (4) separate segments of the Flatirons Campus Utility Distribution Duct Network in FY 2023 - FY 2028. Useful Segments: • Design FY 2023 $1,500 • Construction Segment 1 FY 2025 $4,500 • Construction Segment 2 FY 2026 $4,500 • Construction Segment 3 FY 2027 $4,500 • Construction Segment 4 FY 2028 $4,500
Prior Year Accomplishments:	N/A
Planned Activities:	• Project scope definition • PMP preparation and approval • Design • Equipment procurement • Construction • Equipment Installation and Commissioning • Project management
Significant Changes from original plan:	N/A

Minor Construction Projects ($K)

Facilities & Infrastructure Operations & Maintenance	
Project Name:	Decarbonization - Distributed Energy Grid East STM Campus (*formerly STM Thermal Energy Conversion*)
Project Location/Site:	NREL STM Campus
Type:	Minor Construction (Direct-funded)
Total Estimated Cost:	$19,500
Construction Design:	$3,000
Project Start:	FY 2023
Design Complete:	FY 2023
Construction Complete:	FY 2025
Project Description:	As NREL expands its facilities at the STM Campuses, it should take advantage of the opportunity to develop distributed renewable energy districts, leveraging NREL's own research expertise on the subject. Alternative thermal energy sources such as ground-source heat pumps, air- source heat pumps, other electric HVAC technologies, energy storage, and hydrogen fuel cells that reduce emissions will be evaluated for their potential to support buildings that serve simultaneously as research projects and operational assets. This is a shift in the operational behavior and performance from being only consumptive to a Grid-interactive Efficient Building (GEB) with dynamic capability modes of demand management and islanding. Implementing an autonomous (islanded) distributed energy district on an NREL campus is a long-term goal that requires a phased approach to manage risks associated with disconnecting from the electrical grid. At the STM Campus, which is capacity and export constrained, a distributed energy district would investigate behind-the-meter design and control strategies to minimize utility energy costs and maximize flexibility within interconnection constraints. Estimate includes assessment of technologies, project costs and capital installation and infrastructure costs. Technology solutions and processes achieved will additionally benefit DOE program offices for replicable applications.
Prior Year Accomplishments:	Initial analysis has been conducted for the STM Campus. NREL researchers are currently finalizing the scope of an assessment for the eastern expansion of the STM Campus to determine the most efficient options for a distributed energy district given NREL's programmatic and infrastructure needs.
Planned Activities:	• Project scope definition • PMP preparation and approval • Project management • Design • Equipment procurement • Construction • Equipment Installation and Commissioning • Case study for technology interoperability
Significant Changes from original plan:	N/A

Minor Construction Projects ($K)

Facilities & Infrastructure Operations & Maintenance	
Project Name: Project Location/Site:	Decarbonization - Electric Heating for All New Buildings NREL STM Campus, NREL Flatirons Campus
Type: Total Estimated Cost: Construction Design: Project Start: Design Complete: Construction Complete:	Minor Construction (Direct funded) $6,000 $1,200 FY 2023 FY 2023 FY 2025
Project Description:	New facilities will be designed to use all electric heating (e.g. ambient loop central plant, ground source heat pumps) and/or to use low grade waste heat (95-110 °F) from the HPC on the STM Campus or process loads wherever possible. Ongoing effort. NREL has been able to share globally its design and process to construct the net-zero Research Support Facility and the LEED Platinum Energy Systems Integration Facility (ESIF) which houses the most energy efficient data center in the world. New facilities using innovative technologies, design processes and structures to reach goals of all electric heating could be similarly shared to highlight the pathway to be carbon-neutral facilities.
Prior Year Accomplishments:	N/A
Planned Activities:	• Project scope definition • PMP preparation and approval • Project Management • Design • Equipment procurement • Construction • Equipment Installation and Commissioning • Case studies to highlight processes, deployment, and operational parameters
Significant Changes from original plan:	N/A

21-EE-001, Energy Materials and Processing at Scale, TEC
Project is for Design and Construction

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

Summary: The FY 2023 Budget Request proposes to fund $60,000,000 (of the Total Estimated Cost (TEC)) toward the first segment of the final design and construction phase after the Critical Decision 2/3 Project Baseline Design/Build approach the Energy Materials and Processing at Scale project. The first segment would fund the final design, initial sitework, and foundation. The current, preliminary Total Estimated Cost (TEC) range is $130,000,000 to $160,000,000 and the preliminary Total Project Cost (TPC) range is $135,000,000 to $165,000,000 per preliminary conceptual Architect/Engineering support estimates. The TEC and TPC estimates are consistent with the DOE Cost Estimating Guide 413.3-21A. The DOE 413.3B Critical Decision 0 (CD-0) approval was obtained on 12/9/19. The preliminary estimate for CD-1, Approve Alternative Selection and Cost Range, is anticipated in the first quarter of FY 2023. This project is pre-CD-2; therefore, schedule estimates are preliminary and subject to change. The FPD for this project is Amy Read (certified level 1 with a pending Certification for Level 2) of the Golden Field Office.

Significant Changes:
The estimated dates for Concept Design completion and CD-1 have slipped two quarters due to the efforts required to integrate the Cooperative Construction Contracting Approach (CCCA) task order agreement procurement strategy with the EMAPS project.

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 2021	1Q FY2020	2Q FY2022	3Q FY2022	3Q FY2023	4Q FY2023	3Q FY2023	NA	2QFY2025
FY 2022	1Q FY2020	2Q FY2022	3Q FY2022	3Q FY2023	4Q FY2023	3Q FY2023	NA	2Q FY2025
FY 2022	1Q FY2020	4Q FY2022	1Q FY2023	4Q FY2023	1Q FY2024	4Q FY2023	NA	3Q FY2025

Note: preconceptual timeline to provide a rough order of magnitude for milestones

CD-0 – Approve Mission Need for a construction project with a conceptual scope and cost range
Conceptual Design Complete – Actual date the conceptual design was completed (if applicable)
CD-1 – Approve Alternative Selection and Cost Range
CD-2 – Approve Performance Baseline
Final Design Complete – Estimated/Actual date the project design will be/was complete (d)
CD-3 – Approve Start of Construction
D&D Complete – Completion of D&D work
CD-4 – Approve Start of Operations or Project Closeout

Project Cost History

(Dollars in Thousands)							
Fiscal Year	**TEC, Design**	**TEC, Construction**	**TEC, Total**	**OPC, Except D&D**	**OPC, D&D**	**OPC, Total**	**TPC**
FY 2021	12,000	148,000	160,000	5,000	0	5,000	165,000
FY 2022	12,000	147,000	159,000	6,000	0	6,000	165,000
FY 2023	12,000	148,000	160,000	5,000	0	5,000	165,000

Note: preconceptual amounts to provide an initial rough order of magnitude, assuming a research facility at the high end of 110,000 to 125,000 square feet.

2. Project Scope and Justification

Scope

As advanced energy generation technologies including photovoltaics, wind, and batteries approach terawatt scale, end-of-life and supply chain management becomes increasingly important. The challenge requires much more than end-of-life recycling for complex components, devices, and systems deployed at large scales. Design is required for maximum economic useful life, reuse, refurbishment, repair, remanufacturing, and then recycling, all of which require multi-disciplinary research and scalable research facilities. These technologies may also utilize new recyclable polymers and composites as their scalability and durability are established. To advance this critical need to address end-of-life considerations for energy-related technologies, a multi-disciplinary research capability in process integration that draws on bench scale innovations from multiple institutions and transforms them into integrated and scalable "hybrid technology processes" is needed to ready Department of Energy innovations for commercial development. The Financial Schedule provides an initial rough order of magnitude, assuming the high end of the rough order magnitude cost estimate with a 110,000-125,000 square foot research facility.

Justification

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. The TEC and TPC estimates used in this document are the high end of the Rough Order of Magnitude (ROM) cost range developed. The estimate was based on a new facility which conservatively bounds the potential alternatives. An Analysis of Alternatives (AoA) to include a justification of the alternative to be selected was conducted prior to CD-1 approval and endorsed by the Acting Assistant Secretary of Office of Energy Efficiency and Renewable Energy to proceed with conceptual planning.

With decarbonization efforts, as well as many energy technologies, it is becoming clear that the United States needs to increase efficiencies for energy-relevant and energy-intensive materials and processes incorporating other more traditional attributes such as high performance, affordability and reliability into new energy technologies at the start rather than dealing with future legacies. There are now major opportunities at the interfaces of biology, chemistry and materials science and engineering to develop hybrid processes to couple abiotic (e.g., chemical, catalytic, electrochemical) and biological (e.g., enzymatic or organism-based) processes for chemical synthesis, polymer deconstruction and carbon dioxide reduction to useful products and materials.

Addressing the full lifecycle of our materials, products, and energy economy is important for the U.S. to maintain global economic competitiveness. This project allows DOE to lead innovation at the interfaces of biology, physics, chemistry and materials science and engineering to develop hybrid processes to couple abiotic and biological processes for synthesis, polymer deconstruction, and carbon dioxide reduction to useful products and materials.

Key Performance Parameters (KPPs)

The Key Performance Parameters (KPPs) are preliminary and derived from a pre-CD-1 draft Analysis of Alternatives (AoA) report that is not yet finalized and not yet approved. KPPs may change as the project continues through CD-1. At CD-2 approval, the KPPs will be baselined. The Threshold KPPs represent the minimum acceptable performance that the project must achieve, are high-level screening criteria that must be met to satisfy the mission need and determine viability or non-viability. The Objective KPPs represent the desired project performance. Since we are at the draft AoA stage, Threshold and Objective KPP descriptions are the same. Achievement of the Threshold KPPs will be a prerequisite for approval of CD-4, Project Completion.

Performance Measure	Threshold	Objective
1 – Electrons to Molecules	Laboratory facilities to allow research disciplines to achieve capability to produce multi-disciplinary capabilities that integrate electricity-driven processes with both biotic and abiotic processes that enable net zero fuels and deep decarbonization of transportation and industrial sectors. Key elements include novel electrochemistry, H2 production, CO2 conversion, rapid membrane electrode assembly, multi-scale hybrid processing (e.g., electrochemical/bio) from g to kg scale.	Multi-disciplinary capabilities that integrate electricity-driven processes with both biotic and abiotic processes that enable net zero fuels and deep decarbonization of transportation and industrial sectors. Key elements include novel electrochemistry, H2 production, CO2 conversion, rapid membrane electrode assembly, multi-scale hybrid processing (e.g., electrochemical/bio) from g to kg scale.
2 – Green Process Integration	Laboratory facilities to allow research disciplines to achieve capability to produce multi-disciplinary research capabilities for process innovation and integration to create scalable processes including hybrid concepts that accelerate sustainable manufacturing. Key elements included: synthesis and scalable processing of complex and hybrid (e.g., organic/inorganic perovskites) materials, components, and multifunctional structures for photovoltaics, electrochemical systems (membrane electrode assemblies, battery electrodes, separation membranes, catalysts), photonics, and buildings.	Multi-disciplinary research capabilities for process innovation and integration to create scalable processes including hybrid concepts that accelerate sustainable manufacturing. Key elements included: synthesis and scalable processing of complex and hybrid (e.g., organic/inorganic perovskites) materials, components, and multifunctional structures for photovoltaics, electrochemical systems (membrane electrode assemblies, battery electrodes, separation membranes, catalysts), photonics, and buildings.
3 – Advanced Electrification	Laboratory facilities to allow research disciplines to achieve capability to produce next-generation batteries and power electronics that leapfrog state-of-the-art to achieve low- cost, safety, long-life goals while being inherently scalable, manufacturable, and free of critical materials to enable	Next-generation batteries and power electronics that leapfrog state-of-the-art to achieve low- cost, safety, long-life goals while being inherently scalable, manufacturable, and free of critical materials to enable integration of electrified mobility (e.g., fast EV charging), buildings, grid, and renewable energy

	integration of electrified mobility (e.g., fast EV charging), buildings, grid, and renewable energy generation. Key elements include advanced materials and devices, thermal management, beyond Li-ion battery chemistries, prototype development, characterization, and manufacturing	generation. Key elements include advanced materials and devices, thermal management, beyond Li-ion battery chemistries, prototype development, characterization, and manufacturing.
4 – Advanced Bio and Chemical Processing	Laboratory facilities to allow research disciplines to achieve capability to develop robust scalable bio and chemical processes that are scalable and demonstrate use of novel systems that apply advanced bioprocessing technologies to produce biofuels, bio-based chemicals, and value added bioproducts from renewable sources. This includes cost effective bio-based chemicals and polymer composites.	Develop robust scalable bio and chemical processes that are scalable and demonstrate use of novel systems that apply advanced bioprocessing technologies to produce biofuels, bio-based chemicals, and value added bioproducts from renewable sources. This includes cost effective bio-based chemicals and polymer composites.
5 – Pilot-Scale Process Integration and Scale-up	High Bay Laboratory facilities to allow research disciplines to achieve Integrated, modular, pilot-scale capabilities that provide interchangeable configurations for g-kg per day production equipment for intermediate chemicals, polymers, and composites as well as energy device fabrication and electricity-driven process scale-up capabilities.	Integrated, modular, pilot-scale capabilities that provide interchangeable configurations for g-kg per day production equipment for intermediate chemicals, polymers, and composites as well as energy device fabrication and electricity-driven process scale-up capabilities.

3. Financial Schedule

(Dollars in Thousands)

	Budget Authority (Appropriations)	Obligations	Costs
Total Estimated Cost (TEC)			
Design			
FY 2021	4,000	0	0
FY 2022	8,000	0	4,730
FY 2023	0	12,000	7,270
Total Design	12,000	12,000	12,000
Construction			
FY 2021	0	0	0
FY 2022	0	0	0
FY 2023	60,000	60,000	26,370
FY 2024	57,000	57,000	82,330
FY 2025	31,000	31,000	39,300

	Budget Authority (Appropriations)	Obligations	Costs
Total Construction	148,000	148,000	148,000
Total Estimated Costs (TEC)			
FY 2021	4,000	0	0
FY 2022	8,000	0	4,730
FY 2023	60,000	72,000	33,640
FY 2024	57,000	57,000	82,330
FY 2025	31,000	31,000	39,300
Total TEC	**160,000**	**160,000**	**160,000**
Other Project Costs (OPC)			
FY 2021	2,000	1,500	750
FY 2022	0	500	1,250
FY 2023	0	0	0
FY 2024	0	0	0
FY 2025	3,000	3,000	3,000
Total OPC	**5,000**	**5,000**	**5,000**
Total Project Costs (TPC)			
FY 2021	6,000	1,500	750
FY 2022	8,000	500	5,980
FY 2023	60,000	72,000	33,640
FY 2024	57,000	57,000	82,330
FY 2025	34,000	34,000	42,300
Grand Total	**165,000**	**165,000**	**165,000**

Note: preconceptual amounts to provide an initial rough order of magnitude, assuming a research facility at the high end of 110,000 to 125,000 square feet.

4. Details of Project Cost Estimate

(Budget Authority in Thousands of Dollars)

	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
Total Estimated Cost (TEC)			
Design			
Design	10,000	10,000	N/A
Contingency	2,000	2,000	N/A
Total, Design	12,000	12,000	N/A
Construction			
Site Work	1,250	1,250	N/A
Equipment	15,300	15,300	N/A

	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
Construction	97,450	97,450	N/A
Other, as needed	4,700	4,700	N/A
Contingency	29,300	29,300	N/A
Total, Construction	148,000	148,000	N/A
Other TEC (if any)			
Cold Startup	0	0	N/A
Contingency	0	0	N/A
Total, Other TEC	0	0	N/A
Total Estimated Cost	**160,000**	**160,000**	N/A
Contingency, TEC	*31,300*	*31,300*	N/A
Other Project Cost (OPC)			
OPC except D&D			
R&D	0	0	N/A
Conceptual Planning	1,000	1,000	N/A
Conceptual Design	2,000	2,000	N/A
Other OPC Costs	2,000	2,000	N/A
Contingency	0	0	N/A
Total, OPC	**5,000**	**5,000**	N/A
Contingency, OPC	*0*	*0*	N/A
Total Project Cost	**165,000**	**165,000**	N/A
Total Contingency (TEC+OPC)	**31,300**	**31,300**	N/A

Note: preconceptual amounts to provide an initial rough order of magnitude, assuming a research facility at the high end of 110,000 to 125,000 square feet.

5. Schedule of Appropriations Requests

(Dollars in Thousands)

Request Year	Type	FY 2021	FY 2022	FY 2023	FY 2024	FY 2025	Total
FY 2022	TEC	0	8,000	0	151,000	0	159,000
	OPC	6,000	0	0	0	0	6,000
	TPC	6,000	8,000	0	151,000	0	165,000
FY 2023	TEC	4,000	8,000	60,000	57,000	31,000	160,000
	OPC	2,000	0	0	0	3,000	5,000
	TPC	6,000	8,000	60,000	57,000	34,000	165,000

Note: preconceptual amounts to provide an initial rough order of magnitude, assuming a research facility at the high end of 110,000 to 125,000 square feet. FY 2022 was the first-year funding is requested. In FY 2021, Congress appropriated $6,000 for OPC.

6. Related Operations and Maintenance Funding Requirements

Start of Operation or Beneficial Occupancy (fiscal quarter or date)	3QFY2025
Expected Useful Life (number of years)	50
Expected Future Start of D&D of this capital asset (fiscal quarter)	1QFY2055

Related Funding Requirements
(Budget Authority in Millions of Dollars)

	Annual Costs		Life Cycle Costs	
	Previous Total Estimate	Current Total Estimate	Previous Total Estimate	Current Total Estimate
Operations and Maintenance	5.4	5.4	270	270

Note: preconceptual amounts to provide an initial rough order of magnitude, assuming a research facility at the high end of 110,000 to 125,000 square feet.

7. D&D Information

If the preferred alternative is a new Federal facility, then this new facility will not replace existing facilities.

8. Acquisition Approach

An Acquisition Approach/Plan will be developed post CD-1 approval in accordance with DOE O 413.3B.

23-TBD, South Table Mountain (STM) Carbon Free District Heating/Cooling
Project is for Design and Construction

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

Summary: The FY 2023 Request includes $32,500,000 to support full design and the first segment of the construction phase (of the Total Project Cost (TPC)) for the STM Carbon Free District Heating/Cooling project, which includes core and shell elements of the facility. The current, preliminary Total Estimated Cost (TEC) estimate is $62,000,000 and the TPC estimate is $65,000,000. The TEC and TPC estimates are consistent with the DOE Cost Estimating Guide 413.3-21A. The DOE 413.3B Critical Decision 0 (CD-0) approval is planned for the third quarter FY 2023. The preliminary estimate for CD-1, Approve Alternative Selection and Cost Range, is anticipated in the fourth quarter of FY 2023. This project is pre-CD-2; therefore, schedule estimates are preliminary and subject to change.

Significant Changes: This project is a new start for FY 2023.

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 2023	3QFY2023	3QFY2023	4QFY2023	3QFY2024	4QFY2024	3QFY2024	NA	3QFY2026

Note: preconceptual timeline to provide a rough order of magnitude for milestones

CD-0 – Approve Mission Need for a construction project with a conceptual scope and cost range
Conceptual Design Complete – Actual date the conceptual design was completed (if applicable)
CD-1 – Approve Alternative Selection and Cost Range
CD-2 – Approve Performance Baseline
Final Design Complete – Estimated/Actual date the project design will be/was complete (d)
CD-3 – Approve Start of Construction
D&D Complete – Completion of D&D work
CD-4 – Approve Start of Operations or Project Closeout

Project Cost History

(Dollars in Thousands)

Fiscal Year	TEC, Design	TEC, Construction	TEC, Total	OPC, Except D&D	OPC, D&D	OPC, Total	TPC
FY 2023	5,000	57,000	62,000	3,000	0	3,000	65,000

Note: preconceptual amounts to provide an initial rough order of magnitude estimate, assuming a heating/cooling facility of 7,500 square feet.

10. Project Scope and Justification

Scope

Aligning with Executive Order 14008, *Tackling the Climate at Home and Abroad*, NREL's strategic approach to decarbonizing the laboratory's footprint will require the elimination of greenhouse gas (GHG) emissions from all campus facilities' energy use. NREL's STM Central Plant is at capacity and many of the chillers and boilers are reaching end of service life. Addressing these two very significant challenges is crucial to NREL's implementation strategy that must deliver infrastructure support to all mission critical facilities. The STM Campus has nine major facilities connected to the campus central plant. The central plant provides hot and chilled water for heating, cooling and research needs in these facilities. NREL intends to migrate these facilities to a carbon-free district heating and cooling system. The estimated cost includes technology assessments, project development and capital infrastructure.

Multiple regional partners (government agencies, universities, and commercial campuses) have central heating and cooling systems as well as achieving aggressive carbon reduction goals. Using NREL developed tools and in partnership with research teams such as the Building Technologies and Science Center (BTSC), NREL will determine a replicable approach and a climate specific technology assessment for designing and constructing a carbon- free district heating and cooling system. Construction of this plant will decrease Scope 1 greenhouse gas emissions by 1,397 MTOCO2e, providing a reduction of more than 75% in our Scope 1 greenhouse gas emissions for the campus operational footprint. This will make NREL a resource for these types of upgrades with other organizations. Further analysis will investigate delivery and equipment options, implementation phasing, and funding sources.

Justification

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*. The TEC and TPC estimates used in this document are the high end of the Rough Order of Magnitude (ROM) cost range developed. The estimate was based on a new facility, which conservatively bounds the potential alternatives. An Analysis of Alternatives (AoA) to include a justification of the alternative to be selected will be conducted prior to CD-1 approval.

Key Performance Parameters (KPPs) Performance parameters will be developed prior to CD-2 approval.

11. Financial Schedule

(Dollars in Thousands)

	Budget Authority (Appropriations)	Obligations	Costs
Total Estimated Cost (TEC)			
Design			
FY 2023	5,000	5,000	1,000
FY 2024	0	0	4,000
Design Total	5,000	5,000	5,000
Construction			
FY 2023	26,500	26,500	500
FY 2024	30,500	30,500	1,500
FY 2025	0	0	35,000
FY 2026	0	0	20,000
Construction Total	57,000	57,000	57,000
Total Estimated Costs (TEC)			
FY 2023	31,500	31,500	1,500
FY 2024	30,500	30,500	5,500
FY 2025	0	0	35,000
FY 2026	0	0	20,000
Total TEC	**62,000**	**62,000**	**62,000**

	Budget Authority (Appropriations)	Obligations	Costs
Other Project Costs			
FY 2023	1,000	1,000	1,000
FY 2024	2,000	2,000	1,000
FY 2025	0	0	500
FY 2026	0	0	500
Total OPC	**3,000**	**3,000**	**3,000**
Total Project Costs (TPC)			
FY 2023	32,500	32,500	2,500
FY 2024	32,500	32,500	6,500
FY 2025	0	0	35,500
FY 2026	0	0	20,500
Grand Total	**65,000**	**65,000**	**65,000**

Note: preconceptual amounts to provide an initial rough order of magnitude.

12. Details of Project Cost Estimate

(Budget Authority in Thousands of Dollars)

		Current Total Estimate	Previous Total Estimate	Original Validated Baseline
Total Estimated Cost (TEC)				
Design				
	Design	4,500		
	Contingency	500		
	Total, Design	5,000		
Construction				
	Site Work	1,000		
	Equipment	25,000		
	Construction	25,000		
	Other, as needed	1,000		
	Contingency	5,000		
	Total, Construction	57,000		
Other TEC (if any)				
	Cold Startup			
	Contingency			
	Total, Other TEC	0		
Total Estimated Cost		62,000		
Contingency, TEC		5,500		
Other Project Cost (OPC)				
OPC except D&D				
	R&D			

		Current Total Estimate	Previous Total Estimate	Original Validated Baseline
	Conceptual Planning	1,000		
	Conceptual Design			
	Other OPC Costs	2,000		
	Contingency			
Total, OPC		3,000		
Contingency, OPC		0		
Total Project Cost		**65,000**		
Total Contingency (TEC+OPC)		***5,500***		

Note: preconceptual amounts to provide an initial rough order of magnitude.

13. Schedule of Appropriations Requests

(Dollars in Thousands)

Request Year	Type	Prior Years	FY 2023	FY 2024	FY 2025	FY 2026	FY 2027	Outyears	Total
FY 2023	TEC	0	31,500	30,500	0	0	0		62,000
	OPC	0	1,000	2,000	0	0	0		3,000
	TPC	0	32,500	32,500	0	0	0	0	65,000

Note: preconceptual amounts to provide an initial rough order of magnitude.

14. Related Operations and Maintenance Funding Requirements

Start of Operation or Beneficial Occupancy (fiscal quarter or date)	3QFY2026
Expected Useful Life (number of years)	30
Expected Future Start of D&D of this capital asset (fiscal quarter)	1QFY2056

Related Funding Requirements
(Budget Authority in Millions of Dollars)

	Annual Costs		Life Cycle Costs	
	Previous Total Estimate	Current Total Estimate	Previous Total Estimate	Current Total Estimate
Operations and Maintenance	0	2.130	0	106.365

Note: preconceptual amounts to provide an initial rough order of magnitude.

15. D&D Information

The preference of a new facility will replace the existing central plant, which is at the end of its useful life and lacks sufficient capacity. It should be noted that a large part of the justification for a new central plant is to minimize disruptions to campus operations and research that would occur with upgrading the existing facilities.

16. Acquisition Approach

An Acquisition Approach/Plan will be developed post CD-1 approval in accordance with DOE O 413.3B.

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 and increase the NREL facilities and infrastructure resilience to climate risks. 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 2021 Actual Cost	FY 2021 Planned Cost	FY 2022 Planned Cost	FY 2023 Planned Cost
National Renewable Energy Laboratory	16,760	16,605	18,550	19,400
Total, Direct-Funded Maintenance and Repair	**16,760**	**16,605**	**18,550**	**19,400**

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

	FY 2021 Actual Cost	FY 2022 Planned Cost	FY 2023 Planned Cost
National Renewable Energy Laboratory	0	0	0
Total, Indirect-Funded Maintenance and Repair	**0**	**0**	**0**

Report on FY 2021 Expenditures for Maintenance and Repair

This report responds to explanatory 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 2021 to the amount planned for FY 2021, including Congressionally-directed changes.

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

	FY 2021 Actual Cost	FY 2021 Planned Cost
National Renewable Energy Laboratory	16,760	16,605
Total, Maintenance and Repair	**16,760**	**16,605**

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

	FY 2021 Enacted	FY 2022 Annualized CR[1]	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted
Protective Forces	3,215	3,215	3,600	+385
Physical Security Systems	815	815	925	+110
Information Security	515	515	575	+60
Cybersecurity	7,200	7,200	9,200	+2,000
Personnel Security	215	215	240	+25
Material Control and Accountability	0	0	0	0
Program Management	820	820	720	-100
Security Investigations	170	170	190	+20
Transportation Security	0	0	0	0
Construction	0	0	0	0
Total, Safeguards and Security	**12,950**	**12,950**	**15,450**	**+2,500**

[1] The FY 2022 Annualized CR amounts reflect the P.L. xxx-yyy continuing resolution level annualized to a full year. These amounts are shown only at the congressional control level and above, below that level, a dash (-) is shown.

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

	FY 2021 Enacted	FY 2022 Annualized CR	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted
Basic	0	0	0	0
Applied	1,248,215	676,784	1,046,682	-201,533
Development	684,112	1,378,725	2,106,555	+1,422,443
Subtotal, R&D	1,932,327	2,055,509	3,153,237	+1,220,910
Equipment	20,262	20,262	38,775	+18,513
Construction	73,421	73,421	151,650	+78,229
Total, R&D	**2,026,010**	**2,149,192**	**3,343,662**	**+1,317,652**

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

	FY 2021 Enacted	FY 2022 Annualized CR	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted
Vehicles Technologies				
SBIR	10,768	11,734	16,142	+5,374
STTR	1,514	1,650	2,270	+756
Bioenergy Technologies				
SBIR	7,128	8,131	10,630	+3,502
STTR	1,002	1,143	1,495	+493
Hydrogen and Fuel Cell Technologies				
SBIR	4,936	4,776	5,374	+438
STTR	536	672	756	+220
Solar Energy				
SBIR	8,025	7,387	14,237	+6,212
STTR	1,128	1,039	2,002	+874
Wind Energy				
SBIR	4,007	2,837	7,488	+3,481
STTR	355	399	1,053	+698
Water Power				
SBIR	9,742	4,627	5,860	-3,882
STTR	619	651	824	+205
Geothermal Technologies				
SBIR	3,344	3,146	6,107	+2,763
STTR	470	442	859	+389
Advanced Manufacturing				
SBIR	11,232	11,238	15,745	+4,513
STTR	2,920	1,580	2,214	-706
Building Technologies				
SBIR	11,150	5,830	7,999	-3,151
STTR	1,596	820	1,125	-471
Total, SBIR	70,332	59,706	89,582	+19,250
Total, STTR	10,140	8,396	12,598	+2,458

DEPARTMENT OF ENERGY
Funding by Site Detail
Energy Efficiency and Renewable Energy FY 2023
(Dollars in Thousands)

	FY 2021 Enacted Requested Total	FY 2022 Annualized CR Requested Total	FY 2023 Request Detail Requested Total
Ames Laboratory			
Vehicle Technologies	300	300	300
Hydrogen and Fuel Cells Technologies	9,100	200	200
Sustainable Transportation	9,400	500	500
Advanced Manufacturing	25,397	0	0
Energy Efficiency	25,397	0	0
Total Ames Laboratory	**34,797**	**500**	**500**
Argonne National Laboratory			
Vehicle Technologies	45,640	48,355	44,500
Bioenergy Technologies	12,800	12,635	12,500
Hydrogen and Fuel Cells Technologies	7,412	6,800	7,300
Sustainable Transportation	65,852	67,790	64,300
Solar Energy Technologies	2,025	2,025	2,800
Wind Energy Technologies	2,318	2,405	6,640
Water Power Technologies	1,000	2,091	5,973
Renewable Power	5,343	6,521	15,413
Advanced Manufacturing	6,206	1,300	1,500
Building Technologies	2,282	1,550	1,897
Energy Efficiency	8,488	2,850	3,397
Strategic Programs	800	200	1,500
Corporate Support	800	200	1,500
Total Argonne National Laboratory	**80,483**	**77,361**	**84,610**
Brookhaven National Laboratory			
Vehicle Technologies	2,900	4,675	4,000
Hydrogen and Fuel Cells Technologies	1,000	200	200
Sustainable Transportation	3,900	4,875	4,200
Solar Energy Technologies	1,267	1,267	1,745
Geothermal Technologies	50	25	0
Renewable Power	1,317	1,292	1,745
Building Technologies	700	213	213
Energy Efficiency	700	213	213
Total Brookhaven National Laboratory	**5,917**	**6,380**	**6,158**
Golden Field Office			
Vehicle Technologies	0	5,000	0
Bioenergy Technologies	87,000	93,000	180,000
Hydrogen and Fuel Cells Technologies	60,691	63,500	90,600
Sustainable Transportation	147,691	161,500	270,600
Wind Energy Technologies	34,472	28,159	130,889
Water Power Technologies	53,050	39,650	77,792
Geothermal Technologies	64,240	78,725	170,000
Renewable Power	151,762	146,534	378,681
Advanced Manufacturing	80,275	283,846	475,000
Building Technologies	19,223	34,198	57,600
Federal Energy Management Program (EERE)	13,000	20,000	0
Weatherization Assistance Program (EERE)	0	24,800	0
Training and Technical Assistance (EERE)	2,075	1,900	0
State Energy Program Grants (EERE)	2,150	1,000	0
Weatherization and Intergovernmental Programs	4,225	27,700	0
Energy Efficiency	116,723	365,744	532,600
Program Direction - Energy Efficiency and Renewable Energy	24,516	22,712	36,250
Corporate Support	24,516	22,712	36,250
Total Golden Field Office	**440,692**	**696,490**	**1,218,131**

DEPARTMENT OF ENERGY

Funding by Site Detail

Energy Efficiency and Renewable Energy FY 2023

(Dollars in Thousands)

	FY 2021 Enacted Requested Total	FY 2022 Annualized CR Requested Total	FY 2023 Request Detail Requested Total
Idaho National Laboratory			
Vehicle Technologies	9,825	11,460	11,000
Bioenergy Technologies	15,900	15,900	15,000
Hydrogen and Fuel Cells Technologies	4,350	7,600	8,100
Sustainable Transportation	30,075	34,960	34,100
Solar Energy Technologies	80,534	80,534	131,190
Wind Energy Technologies	1,534	1,170	4,394
Water Power Technologies	1,570	4,355	10,232
Geothermal Technologies	100	71	0
Renewable Power	83,738	86,130	145,816
Advanced Manufacturing	3,939	0	0
Building Technologies	0	815	0
Federal Energy Management Program (EERE)	442	600	0
Energy Efficiency	4,381	1,415	0
Total Idaho National Laboratory	**118,194**	**122,505**	**179,916**
Lawrence Berkeley National Laboratory			
Vehicle Technologies	16,970	20,480	19,900
Bioenergy Technologies	11,000	11,000	8,500
Hydrogen and Fuel Cells Technologies	6,844	4,600	4,800
Sustainable Transportation	34,814	36,080	33,200
Solar Energy Technologies	134,623	134,623	303,450
Wind Energy Technologies	1,515	2,918	4,340
Geothermal Technologies	1,950	3,550	0
Renewable Power	138,088	141,091	307,790
Advanced Manufacturing	7,656	24,800	32,000
Building Technologies	37,041	37,788	36,859
Federal Energy Management Program (EERE)	4,000	2,000	0
Weatherization Assistance Program (EERE)	24,800	0	0
Training and Technical Assistance (EERE)	75	200	0
State Energy Program Grants (EERE)	475	800	0
Weatherization and Intergovernmental Programs	25,350	1,000	0
Energy Efficiency	74,047	65,588	68,859
Strategic Programs	1,300	0	1,000
Corporate Support	1,300	0	1,000
Total Lawrence Berkeley National Laboratory	**248,249**	**242,759**	**410,849**
Lawrence Livermore National Laboratory			
Vehicle Technologies	4,416	2,325	2,790
Bioenergy Technologies	1,650	1,650	1,250
Hydrogen and Fuel Cells Technologies	1,091	2,000	2,000
Sustainable Transportation	7,157	5,975	6,040
Solar Energy Technologies	31,848	31,848	43,970
Wind Energy Technologies	1,040	1,746	2,979
Geothermal Technologies	350	0	0
Renewable Power	33,238	33,594	46,949
Advanced Manufacturing	7,716	5,000	10,000
Building Technologies	128	178	178
Energy Efficiency	7,844	5,178	10,178
Strategic Programs	0	300	300
Corporate Support	0	300	300
Total Lawrence Livermore National Laboratory	**48,239**	**45,047**	**63,467**

DEPARTMENT OF ENERGY
Funding by Site Detail
Energy Efficiency and Renewable Energy FY 2023
(Dollars in Thousands)

	FY 2021 Enacted Requested Total	FY 2022 Annualized CR Requested Total	FY 2023 Request Detail Requested Total
Los Alamos National Laboratory			
Bioenergy Technologies	6,800	6,800	6,000
Hydrogen and Fuel Cells Technologies	4,940	4,500	5,000
Sustainable Transportation	11,740	11,300	11,000
Solar Energy Technologies	21,686	21,686	40,350
Wind Energy Technologies	365	440	1,046
Geothermal Technologies	250	12	0
Renewable Power	22,301	22,138	41,396
Total Los Alamos National Laboratory	**34,041**	**33,438**	**52,396**
National Energy Technology Lab			
Vehicle Technologies	170,560	145,000	362,421
Bioenergy Technologies	800	800	750
Hydrogen and Fuel Cells Technologies	4,000	16,100	16,100
Sustainable Transportation	175,360	161,900	379,271
Geothermal Technologies	30,553	0	25,000
Renewable Power	30,553	0	25,000
Building Technologies	14,295	3,548	4,790
Energy Efficiency	14,295	3,548	4,790
Program Direction - Energy Efficiency and Renewable Energy	10,928	11,472	22,874
Strategic Programs	1,500	0	0
Corporate Support	12,428	11,472	22,874
Total National Energy Technology Lab	**232,636**	**176,920**	**431,935**
National Renewable Energy Laboratory			
Vehicle Technologies	34,550	38,460	44,525
Bioenergy Technologies	63,600	63,000	42,500
Hydrogen and Fuel Cells Technologies	15,236	18,500	21,500
Sustainable Transportation	113,386	119,960	108,525
Renewable Energy Grid Integration	0	0	10,000
Wind Energy Technologies	36,164	38,420	103,590
Water Power Technologies	18,606	17,850	21,633
Geothermal Technologies	1,416	12,985	3,000
Renewable Power	56,186	69,255	138,223
Advanced Manufacturing	10,707	4,500	5,500
Building Technologies	33,120	27,510	26,000
Federal Energy Management Program (EERE)	9,000	8,150	0
Weatherization Assistance Program (EERE)	1,000	0	0
Training and Technical Assistance (EERE)	1,800	1,000	0
State Energy Program Grants (EERE)	475	1,200	0
Weatherization and Intergovernmental Programs	3,275	2,200	0
Energy Efficiency	56,102	42,360	31,500
Strategic Programs	5,500	2,000	6,385
Facilities and Infrastructure - NREL	130,000	130,000	210,100
21-EE-001, Energy Materials Processing at Scale (EMAPS)	0	0	60,000
23-TBD, South Table Mountain (STM) Carbon Free District Heating/Cooling	0	0	31,500
Facilities and Infrastructure	130,000	130,000	301,600
Corporate Support	135,500	132,000	307,985
Total National Renewable Energy Laboratory	**361,174**	**363,575**	**586,233**
Oak Ridge Institute for Science & Education			
Vehicle Technologies	350	350	600
Bioenergy Technologies	650	850	850
Hydrogen and Fuel Cells Technologies	1,000	900	1,000
Sustainable Transportation	2,000	2,100	2,450
Solar Energy Technologies	1,151	1,151	1,590

DEPARTMENT OF ENERGY
Funding by Site Detail
Energy Efficiency and Renewable Energy FY 2023
(Dollars in Thousands)

	FY 2021 Enacted Requested Total	FY 2022 Annualized CR Requested Total	FY 2023 Request Detail Requested Total
Geothermal Technologies	630	0	0
Renewable Power	1,781	1,151	1,590
Advanced Manufacturing	6,375	5,560	4,500
Building Technologies	2,300	1,825	2,500
Federal Energy Management Program (EERE)	599	200	0
Training and Technical Assistance (EERE)	100	400	0
State Energy Program Grants (EERE)	965	1,000	0
Weatherization and Intergovernmental Programs	1,065	1,400	0
Energy Efficiency	10,339	8,985	7,000
Strategic Programs	0	300	300
Corporate Support	0	300	300
Total Oak Ridge Institute for Science & Education	**14,120**	**12,536**	**11,340**
Oak Ridge National Laboratory			
Vehicle Technologies	33,970	37,600	29,310
Bioenergy Technologies	11,900	11,300	9,250
Hydrogen and Fuel Cells Technologies	3,584	3,200	3,600
Sustainable Transportation	49,454	52,100	42,160
Solar Energy Technologies	652	652	900
Wind Energy Technologies	1,954	2,509	5,597
Water Power Technologies	8,258	8,498	8,631
Geothermal Technologies	0	1,000	0
Renewable Power	10,864	12,659	15,128
Advanced Manufacturing	40,329	29,800	25,000
Building Technologies	18,848	37,906	19,000
Federal Energy Management Program (EERE)	4,000	2,000	0
Weatherization Assistance Program (EERE)	825	1,000	0
Training and Technical Assistance (EERE)	400	1,000	0
State Energy Program Grants (EERE)	49	100	0
Weatherization and Intergovernmental Programs	1,274	2,100	0
Energy Efficiency	64,451	71,806	44,000
Total Oak Ridge National Laboratory	**124,769**	**136,565**	**101,288**
Pacific Northwest National Laboratory			
Vehicle Technologies	16,314	29,260	18,665
Bioenergy Technologies	17,800	17,800	16,000
Hydrogen and Fuel Cells Technologies	6,855	5,800	6,500
Sustainable Transportation	40,969	52,860	41,165
Solar Energy Technologies	5,347	5,347	7,380
Wind Energy Technologies	6,107	5,913	17,493
Water Power Technologies	14,186	19,692	15,911
Geothermal Technologies	700	0	0
Renewable Power	26,340	30,952	40,784
Advanced Manufacturing	1,779	0	0
Building Technologies	23,406	35,670	35,600
Federal Energy Management Program (EERE)	4,157	2,050	0
State Energy Program Grants (EERE)	0	100	0
Weatherization and Intergovernmental Programs	0	100	0
Energy Efficiency	29,342	37,820	35,600
Strategic Programs	350	300	2,000
Corporate Support	350	300	2,000
Total Pacific Northwest National Laboratory	**97,001**	**121,932**	**119,549**
Sandia National Laboratories			
Vehicle Technologies	10,556	4,800	4,820
Bioenergy Technologies	7,900	7,900	7,000
Hydrogen and Fuel Cells Technologies	10,986	6,500	7,300

DEPARTMENT OF ENERGY
Funding by Site Detail
Energy Efficiency and Renewable Energy FY 2023
(Dollars in Thousands)

	FY 2021 Enacted Requested Total	FY 2022 Annualized CR Requested Total	FY 2023 Request Detail Requested Total
Sustainable Transportation	29,442	19,200	19,120
Wind Energy Technologies	10,097	11,051	28,922
Water Power Technologies	8,796	7,565	7,583
Geothermal Technologies	650	3,000	0
Renewable Power	19,543	21,616	36,505
Building Technologies	618	293	168
Energy Efficiency	618	293	168
Strategic Programs	250	0	0
Corporate Support	250	0	0
Total Sandia National Laboratories	**49,853**	**41,109**	**55,793**
Sandia Site Office			
Advanced Manufacturing	2,075	0	0
Energy Efficiency	2,075	0	0
Total Sandia Site Office	**2,075**	**0**	**0**
Savannah River National Laboratory			
Vehicle Technologies	390	500	400
Hydrogen and Fuel Cells Technologies	1,065	200	200
Sustainable Transportation	1,455	700	600
Total Savannah River National Laboratory	**1,455**	**700**	**600**
SLAC National Accelerator Laboratory			
Vehicle Technologies	4,050	4,350	6,000
Bioenergy Technologies	365	365	350
Hydrogen and Fuel Cells Technologies	0	300	500
Sustainable Transportation	4,415	5,015	6,850
Solar Energy Technologies	867	867	1,200
Renewable Power	867	867	1,200
Advanced Manufacturing	0	1,500	1,500
Building Technologies	640	0	0
Energy Efficiency	640	1,500	1,500
Total SLAC National Accelerator Laboratory	**5,922**	**7,382**	**9,550**
Washington Headquarters			
Vehicle Technologies	49,209	47,085	53,500
Bioenergy Technologies	16,835	12,000	40,050
Hydrogen and Fuel Cells Technologies	11,846	9,100	11,100
Sustainable Transportation	77,890	68,185	104,650
Renewable Energy Grid Integration	0	0	47,730
Wind Energy Technologies	14,434	15,269	39,500
Water Power Technologies	44,534	50,299	42,745
Geothermal Technologies	5,111	6,632	4,000
Renewable Power	64,079	72,200	133,975
Advanced Manufacturing	203,546	39,694	27,500
Building Technologies	137,399	108,506	207,195
Federal Energy Management Program (EERE)	4,802	5,000	0
Weatherization Assistance Program (EERE)	0	825	0
Training and Technical Assistance (EERE)	550	500	0
State Energy Program Grants (EERE)	2,386	2,300	0
Weatherization and Intergovernmental Programs	2,936	3,625	0
Energy Efficiency	348,683	156,825	234,695
Program Direction - Energy Efficiency and Renewable Energy	129,556	130,816	165,350
Strategic Programs	4,800	11,400	47,900
Corporate Support	134,356	142,216	213,250
Total Washington Headquarters	**625,008**	**439,426**	**686,570**

DEPARTMENT OF ENERGY

Funding by Site Detail

Energy Efficiency and Renewable Energy FY 2023

(Dollars in Thousands)

	FY 2021 Enacted Requested Total	FY 2022 Annualized CR Requested Total	FY 2023 Request Detail Requested Total
Grants			
Weatherization Assistance Program (EERE)	283,375	283,375	0
State Energy Program Grants (EERE)	56,000	56,000	0
Weatherization and Intergovernmental Programs	339,375	339,375	0
Energy Efficiency	339,375	339,375	0
Total Grants	**339,375**	**339,375**	**0**
Total Funding by Site - Energy Efficiency and Renewable Energy	**2,864,000**	**2,864,000**	**4,018,885**

Electricity

Electricity

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 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, $297,386,000, to remain available until expended: Provided, That of such amount, $17,586,000 shall be available until September 30, 2024, for program direction.

[For an additional amount for "Electricity", $8,100,000,000, to remain available until expended: *Provided*, That of the amount provided under this heading in this Act, $5,000,000,000 shall be for grants under section 40101 of division D of this Act: *Provided further*, That of the funds in the preceding proviso, $1,000,000,000, to remain available until expended, shall be made available for fiscal year 2022, $1,000,000,000, to remain available until expended, shall be made available for fiscal year 2023, $1,000,000,000, to remain available until expended, shall be made available for fiscal year 2024, $1,000,000,000, to remain available until expended, shall be made available for fiscal year 2025, and $1,000,000,000, to remain available until expended, shall be made available for fiscal year 2026: *Provided further*, That of the amount provided under this heading in this Act, $50,000,000 shall be to carry out the Transmission Facilitation Program, including for any administrative expenses of carrying out the program, as authorized in section 40106(d)(3) of division D of this Act: *Provided further*, That of the funds in the preceding proviso, $10,000,000, to remain available until expended, shall be made available for fiscal year 2022, $10,000,000, to remain available until expended, shall be made available for fiscal year 2023, $10,000,000, to remain available until expended, shall be made available for fiscal year 2024, $10,000,000, to remain available until expended, shall be made available for fiscal year 2025, and $10,000,000, to remain available until expended, shall be made available for fiscal year 2026: *Provided further*, That of the amount provided under this heading in this Act and in addition to amounts otherwise made available for this purpose, $3,000,000,000, to remain available until expended, shall be to carry out activities under the Smart Grid Investment Matching Grant Program, as authorized in section 1306 of the Energy Independence and Security Act of 2007 (42 U.S.C. 17386), as amended by section 40107 of division D of this Act: *Provided further*, That of the funds in the preceding proviso, $600,000,000, to remain available until expended, shall be made available for fiscal year 2022, $600,000,000, to remain available until expended, shall be made available for fiscal year 2023, $600,000,000, to remain available until expended, shall be made available for fiscal year 2024, $600,000,000, to remain available until expended, shall be made available for fiscal year 2025, and $600,000,000, to remain available until expended, shall be made available for fiscal year 2026: *Provided further*, That of the amount provided under this heading in this Act, $50,000,000 shall be to carry out an advanced energy security program to secure energy networks, as authorized under section 40125(d) of division D of this Act: *Provided further*, That not later than 90 days after the date of enactment of this Act, the Secretary of Energy shall submit to the House and Senate Committees on Appropriations and the Senate Committee on Energy and Natural Resources and the House Committee on Energy and Commerce a detailed spend plan for fiscal year 2022: *Provided further*, That for each fiscal year through 2026, as part of the annual budget submission of the President under section 1105(a) of title 31, United States Code, the Secretary of Energy shall submit a detailed spend plan for that fiscal year: *Provided further*, That up to three percent of the amounts made available under this heading in this Act in each of fiscal years 2022 through 2026 shall be for program direction: *Provided further*, That such amount is designated by the Congress as being for an emergency requirement pursuant to section 4112(a) of H. Con. Res. 71 (115th Congress), the concurrent resolution on the budget for fiscal year 2018, and to section 251(b) of the Balanced Budget and Emergency Deficit Control Act of 1985.**]** *(Infrastructure Investment and Jobs Act)*

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
- Public Law 116-260, Division Z, "Energy Act of 2020"
- Public Law 117-58, Division D, "Infrastructure Investment and Jobs Act," 2021

Electricity
($K)

FY 2021 Enacted	FY 2021 Enacted (Comparable)[a]	FY 2022 Enacted Annualized CR[b]	FY 2022 CR (Comparable)[a]	FY 2023 Request
211,720	201,720	211,720	201,720	297,386

Overview

The Office of Electricity (OE) leads the Department's efforts in developing new technologies to strengthen, transform, and improve electricity delivery infrastructure so consumers have access to resilient, secure, and clean sources of electricity. OE provides solutions to technical, market, institutional, and operational failures that go beyond any one utility's ability to solve.[c] To accomplish this critical mission, OE engages stakeholders throughout the sector on a variety of innovative technology solutions to modernize the electric grid. OE works to ensure that our Nation's electricity delivery system can accommodate all the changes at generation and load sides of the grid and ensure reliable, resilient, and secure operations of the decarbonized electric grid.

A dramatic structural transformation of the electricity delivery system is needed to ensure reliability is maintained in light of the rapid integration of renewable generation and customer-based technologies, including the electrification of transportation and building infrastructure. The future grid will be a more dynamic and structurally complex system, with bidirectional power flows. Managing this transition will require significant reengineering, involving advancements in grid technology and system architectures.

Proactive, coordinated, and innovative steps are needed to lay the foundation for economic growth, workforce development, and the creation of good-paying jobs and to ensure benefits accrue to marginalized and overburdened communities while addressing 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 offshore) 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

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[a] The FY 2023 Budget Request to Congress proposes to split the Electricity appropriation account into two accounts: Electricity and Grid Deployment Office (GDO). To allow an apples-to-apples comparison with the FY 2023 request, the comparable amounts for Electricity in FY 2021 and FY 2022 exclude all funding ($7,000,000) from the Transmission Permitting and Technical Assistance program and $3,000,000 from Program Direction funding, equivalent to what would have been in GDO had the proposed structure been in place in FY 2021 and FY 2022.

[b] FY 2022 amounts shown reflect the P.L. 117–87 continuing resolution level through March 11, 2022, annualized to a full year.

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

- Efficiency—low losses in electricity delivery and more optimal use of system assets
- Energy Justice— investing in research and development that addresses energy resilience in disadvantaged and energy-burdened communities

Within the Request, OE funds:

- Research, Development and Demonstration (RD&D)—pursuing research and demonstrations for technologies to improve grid reliability, resilience, efficiency, flexibility, and functionality
- Power Grid 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
- Data Platforms and advanced control and communications designs—pursuing national-scale sensor, data, and secure communication architecture platforms to mitigate risk and improve the economic efficiency of grid operations such as improved asset management
- Cyber Resilience—designing next-generation systems that are built from inception to automatically detect, reject, and withstand cyber incidents, regardless of the threat to the electricity delivery system
- Coordination with the Power Marketing Administrations to develop relevant RD&D solutions

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

- Grid flexibility through Megawatt-Scale Grid Storage—pursuing megawatt-scale storage capable of supporting voltage and frequency regulation, ramping, and energy management for bulk and distribution power systems
- Improved Observability and Deep Learning via Sensing Technology Utilization—driving integration of high-fidelity sensing technology for predictive and correlation modeling for electricity and interdependencies with oil and natural gas (ONG) systems
- Expanding Data Development, Visualization, and Analytics for Transmission Systems and Advanced Grid Architectures—leading research to better understand the issues surrounding the current and future electric power grid and developing robust model-based solutions that result in new software and analytical toolsets for operators and planners
- North American Energy Resilience Model—using the integrated North American Energy Resilience Model (NAERM), developed from 2019–2021 in partnership with the national laboratories and relevant stakeholders, to aid in energy planning, transmission planning, and contingency analyses to drive infrastructure investment in the North American energy system
- Building in Cybersecurity—accelerating and expanding cybersecurity and secure communications for electricity infrastructure and mitigating vulnerabilities
- Integrated Grid Planning to Ensure Coherence—formulating coherent grid investment strategies that apply advanced technologies for meeting reliability, resilience, decarbonization, efficiency, equity, and flexibility objectives through the advancement of integrated planning practices in concert with the electric industry

OE's FY 2023 Budget Request will extend the impact of our research, development, and demonstration (RD&D) funding by leveraging creative funding mechanisms—such as prizes, competitions, and programs targeted to small businesses. The goal is to enable the commercialization of climate change and clean energy innovations that will stimulate job creation, expand other public impact outcomes, and yield a more geographically diverse and impactful research portfolio.

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 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 along with other OE R&D efforts that will also complement ESGC goals.

Grid Modernization Initiative and Grid Modernization Laboratory Consortium: The Grid Modernization Initiative (GMI) is 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 GMI 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 has been multiple Grid Modernization Lab Calls, which reflected comprehensive grid research across 14 national laboratories and coordinated through the Grid Modernization Laboratory Consortium (GMLC).[a]

Highlights and Major Changes in the FY 2023 Budget Request

Transmission Reliability and Resilience (TRR) ($37,300,000; -$10,920,000) is focused on ensuring the reliability and resilience of the U.S. electric grid through R&D on measurement and control of the electricity system, including mitigation of widescale, cascading blackouts. TRR is also assessing evolving system needs, identifying pathways to achieve an equitable transition to decarbonization and electrification, and risk assessment to address challenges across integrated energy systems. Funding decreases due to the FY 2021 completion of funding for NAERM Phase II development, as well as for fully funded FY 2021 congressionally directed projects for sensors and analytics technologies, a composite utility pole assessment, and the Grid Research Integration and Demo Center. These funding decreases in FY 2023 offset growth in other TRR activities. NAERM operations and maintenance are funded in the Energy Delivery Grid Operations Technology (EDGOT) program in FY 2023.

Energy Delivery Grid Operations Technology (EDGOT) ($39,000,000; +$39,000,000) starting in FY 2022, will support operations, further development, and maintenance for NAERM. EDGOT develops national-scale planning models for energy and interdependent infrastructure and real-time situational awareness capabilities that rely on large-scale networked communication and data infrastructures across multiple utility boundaries. NAERM will help us transition from the current reactive state-of-practice to a new energy planning, investment, and operations paradigm that is capable of proactively informing infrastructure investment strategies. The EDGOT technology portfolio will enable assessment of risks and uncertainty, evaluation and identification of effective mitigation strategies, and support of more informed infrastructure planning and investment decisions by both public and private sectors, thereby enhancing U.S. energy and economic security.

Resilient Distribution Systems (RDS) ($50,000,000; $0) develops transformative technologies, tools, and techniques to enable industry to modernize the distribution system, supports transformation of the electric grid through the growing convergence of transmission and distribution portions of the electricity delivery system, and develops solutions that enable all consumers to participate in the clean energy economy. RD&D addresses equity in both the social and economic participation in the energy system and improves energy resilience in disadvantaged and energy-burdened communities. The FY 2023 Request supports a competitive award process to harness emerging sources of energy for balance, reliability, and control such as EVs, connected homes and buildings, increasing distributed solar, and energy storage. Activities include research in microgrids, transactive controls, distribution management systems, and resilience tools, as well as working with States, regional planners, and the electric industry to advance integrated planning approaches to ensure the formulation and implementation of coherent grid strategies to enable grid modernization.

Cyber Resilient and Secure Utility Communications Networks (SecureNet) ($20,00,000; +$20,000,000) was called Cyber R&D in the FY 2022 Request to Congress. SecureNet addresses R&D for energy sector cybersecurity associated with electricity delivery systems and will focus on developing security-by-design solutions based on data and physics to address vulnerabilities of the grid and critical operational data processing, management, and communications systems that could expose the electricity system to cyber threats. SecureNet will pursue coordinated engagement with DOE's other cyber-related activities, including in CESER and the Office of Intelligence and Counterintelligence. An important part of the SecureNet portfolio will be academic R&D for technology-focused activities that, in combination with industry guidance, result in impactful real-world solutions while helping train and develop the next generation of cybersecurity specialists.

Energy Storage ($81,000,000; +$1,000,000) is designed to develop new and advanced technologies that will ensure the stability, reliability, and resilience of electricity infrastructure. The Request supports a new emerging technology FOA focused on ultra-low-cost chemistries, a new Grid Storage Launchpad (GSL) fellowship program, and continued development of the Rapid Operational Validation Initiative. The GSL construction project, which will accelerate materials development,

[a] https://www.energy.gov/grid-modernization-initiative

testing, and independent evaluation of battery materials and battery systems for grid applications, is fully funded in FY 2022 through the completion of construction and commissioning of the facility, and no funding is requested in FY 2023, offsetting increases in Energy Storage R&D.

Transformer Resilience and Advanced Components (TRAC) ($22,500,000; +$15,000,000) develops innovations for grid hardware that carries, controls, and converts electricity, helping achieve decarbonization goals, ensure reliability and resilience of electric infrastructure, adapt the electricity delivery system to the evolution of the electric power grid, and provide the foundation to invigorate domestic transformer manufacturing and grid-related supply chains. TRAC develops hardware solutions in coordination with TRR and RDS. The FY 2023 Request supports the testing and field validation of Grid Enhancing Technologies (GETs), such as dynamic line rating and power flow controls, to accelerate deployment for optimal transmission asset utilization and to facilitate renewable energy and carbon-neutral technology system integration. GETs have been shown to improve the energy transfer capabilities of existing transmission paths and are able to be deployed more quickly than building new lines at costs significantly below traditional upgrades. TRAC will also address critical research needs for solid-state power substations (SSPS) with an emphasis on advanced materials, embedded intelligence for equipment monitoring, and validation of prototype converter building blocks.

Applied Grid Transformation Solutions (AGTS) ($30,000,000; +$30,000,000) is a new program in FY 2023 to address the pressing need for rapidly validating and deploying new systems by integrating technology suites in controlled pilot environments to drive new technology adoption. Applied integrated pilots are needed to validate how new technologies for transmission and distribution will achieve community, state, and national objectives. AGTS will initiate 3–4 integrated pilots to show how new technologies can help achieve stakeholder objectives. For each applied demonstration area, AGTS will consult stakeholders to ensure that the project scope and outputs will be immediately useful to targeted decisionmakers.

Defense Critical Electric Infrastructure (DCEI) Energy Mission Assurance ($0; -$1,000,000) was established in FY 2021 to identify, evaluate, prioritize, and assist in developing executable strategies to ensure that critical national defense and security missions have reliable access to power as energy supply disruptions threaten the civilian grid due to intensifying cybersecurity threats as well as other hazards. In the FY 2022 Request, DOE proposed to integrate the functions of the DCEI Energy Mission Assurance program into CESER's suite of activities partnering with, supporting, and sharing information with the electric utility industry to enhance energy resilience through its energy assurance planning efforts. No FY 2023 funding is requested in OE for DCEI Energy Mission Assurance.

Transmission Permitting and Technical Assistance activities are transferred to the Grid Deployment Office in the FY 2023 Request.

FY 2021 Key Accomplishments

Energy Storage Efficiency: The Energy Storage program demonstrated a kW-scale prototype stack of aqueous soluble organic flow battery technology operating at 225 mA/cm^2, a 50 percent improvement over the FY 2020 target and capable of meeting a $200/kWh cost target for a 1MW/4MWh system.

Microgrids: The Resilient Distribution Systems program completed microgrid simulation testing of integrated software capabilities for resilient distribution design and restoration control on a distribution utility feeder circuit and developed a methodology to quantify the resilience value under extreme weather, cyber, and physical events.

Distributed Energy Resource Technologies: The Resilient Distribution System program successfully developed cost-effective technologies to increase the utilization of clean distributed energy resources (DERs) demonstrating the feasibility of using microgrid building blocks (MBB) as fundamental units for microgrids to reduce costs and project implementation time, focusing on integration of power conversion and microgrid communication and control as a standard, modular unit and developing the Beyond Distributed Energy Resource Management System (DERMS) software platform to provide automated scheduling of DERs to offset costs associated with peak loads. The DERMS platform successfully demonstrated the integration of over 300 DERs with two utility partners for peak load reduction and load shaping for real-time energy price arbitrage.

Small Business Projects for Enhanced Grid Operations: Two Phase I Small Business Innovation Research (SBIR) projects were successfully completed under the Transformer Resilience and Advanced Components program. Terves developed a prototype low-mass magnesium-based conductor for use in transmission infrastructure, which promises a low-cost, high-strength alternative that will reduce system losses, improve system resilience, and decrease costs. Achillea Research developed a scalable method to optimize Flexible AC Transmission System controller placement, enhancing power flows across the entire grid to increase system efficiency and reducing customer rates, enabling an affordable scenario under deep renewable penetration.

Flexible Transformer Energization: In November 2021, GE and Cooperative Energy announced the energization of the world's first flexible transformer that adapts to a range of voltage ratios and impedance levels. Flexible transformers significantly reduce the manufacturing cost and time needed for today's custom-made transformers. By allowing damaged transformers to be replaced more quickly, flexible transformers will be an important tool in increasing the grid's resilience to extreme weather events or cyber incidents. This field demonstration markets the final phase of a multi-year project originally awarded in 2018 through an OE FOA on flexible and modular large power transformers.

North American Energy Resiliency Model (NAERM): OE developed the NAERM platform, a first-of-a-kind advanced modeling and analysis tool focusing on the Nation's energy infrastructure and interdependent systems. OE continues to demonstrate its capabilities internally and externally to other Federal agencies and stakeholders.

Wildfire Mitigation: In April 2021, OE sponsored 4 Wildfire Mitigation webinars attended by 1,196 participants. The webinars were designed to enable the rapid transfer or deployment of mature laboratory capabilities. As a result of these webinars and industry interest, DOE announced $2.25 million in awards to develop and deploy technologies to address the growing and severe threat of wildfires to the electric grid. The webinar presentations and transcripts are available at https://www.energy.gov/oe/wildfire-mitigation-webinar-series.

Transmission Innovation: In March 2021, OE hosted a Transmission Innovation Symposium focused on modernizing the U.S. power grid. The symposium featured presentations and panel discussions about 5 DOE-commissioned white papers on transmission R&D priorities, featuring the technologies required to address current and future challenges facing transmission infrastructure. The white papers guided a dialogue focused on preparing the industry for the transmission system of the future and are available at https://www.energy.gov/oe/transmission-innovation-symposium.

Energy Storage Grand Challenge Roadmap: In December 2020, DOE released the Energy Storage Grand Challenge Roadmap, the Department's first comprehensive energy storage strategy.[a] The Roadmap's approach includes accelerating the transition of technologies from the lab to the marketplace, focusing on ways to competitively manufacture technologies at scale in the United States, and ensuring secure supply chains to enable domestic manufacturing. The Roadmap includes an aggressive but achievable goal: to develop and domestically manufacture energy storage technologies that can meet all U.S. market demands by 2030.

Energy Storage for Social Equity: OE launched the Energy Storage for Social Equity Initiative to assist up to 15 underserved and frontline communities in leveraging energy storage to increase resilience and lower energy burdens, helping to deliver affordable electricity to disadvantaged communities.

Long Duration Storage Energy Earthshot: In July 2021, DOE announced the Long Duration Storage Energy Earthshot. The initiative establishes a target to reduce the cost of grid-scale energy storage by 90 percent within a decade for systems that deliver 10+ hour durations. Developing the technology and manufacturing to reach the Long Duration Storage Shot cost targets will establish a new, U.S.-based manufacturing industry for storage products. In September 2021, in conjunction with World Energy Storage Day, DOE held a series of events to engage communities, industry, and other stakeholders, including a Long Duration Storage Shot Summit.

[a] https://www.energy.gov/energy-storage-grand-challenge/downloads/energy-storage-grand-challenge-roadmap

Electricity
Funding by Congressional Control ($K)

	FY 2021 Enacted	FY 2021 Enacted (Comparable)[a]	FY 2022 Enacted Annualized CR[b]	FY 2022 CR (Comparable)[ab]	FY 2023 Request	FY 2023 Request vs FY 2021 Comp. ($)	FY 2023 Request vs FY 2021 Comp. (%)
Grid Controls and Communications							
Transmission Reliability and Resilience	48,220	48,220	48,220	48,220	37,300	-10,920	-22.6%
Energy Delivery Grid Operations Technology	0	0	0	0	39,000	+39,000	N/A
Resilient Distribution Systems	50,000	50,000	50,000	50,000	50,000	0	0.0%
Cyber Resilient and Secure Utility Communications Networks	0	0	0	0	20,000	+20,000	N/A
Total, Grid Controls and Communications	98,220	98,220	98,220	98,220	146,300	+48,080	+49.0%
Grid Hardware, Components, and Systems							
Energy Storage							
Research	57,000	57,000	57,000	57,000	81,000	+24,000	+42.1%
Construction: 20-OE-100 Grid Storage Launchpad	23,000	23,000	23,000	23,000	0	-23,000	-100.0%
Total, Energy Storage	80,000	80,000	80,000	80,000	81,000	+1,000	+1.3%
Transformer Resilience and Advanced Components	7,500	7,500	7,500	7,500	22,500	+15,000	+200.0%
Applied Grid Transformation Solutions	0	0	0	0	30,000	+30,000	N/A
Total, Grid Hardware, Components, and Systems	87,500	87,500	87,500	87,500	133,500	+46,000	+52.6%
DCEI Energy Mission Assurance	1,000	1,000	1,000	1,000	0	-1,000	-100.0%
Transmission Permitting and Technical Assistance	7,000	0[a]	7,000	0[a]	0	0	0.0%
Program Direction	18,000	15,000[a]	18,000	15,000[a]	17,586	+2,586	+17.2%
Total, Electricity	**211,720**	**201,720**[a]	**211,720**	**201,720**[a]	**297,386**	**+95,666**	**+47.7%**

[a] The FY 2023 Budget Request to Congress proposes to split the Electricity appropriation account into two accounts: Electricity and GDO. To allow an apples-to-apples comparison with the FY 2023 request, the comparable amounts for Electricity in FY 2021 and FY 2022 exclude all funding ($7,000,000) from the Transmission Permitting and Technical Assistance program and $3,000,000 from Program Direction funding, equivalent to what would have been in GDO had the proposed structure been in place in FY 2021 and FY 2022.

[b] FY 2022 amounts shown reflect the P.L. 117–95 continuing resolution level annualized to a full year. These amounts are shown only at the "congressional control" level and above; below that level, a dash (–) is shown.

	FY 2021 Enacted	FY 2021 Enacted (Comparable)[a]	FY 2022 Enacted Annualized CR[b]	FY 2022 CR (Comparable)[ab]	FY 2023 Request	FY 2023 Request vs FY 2021 Comp. ($)	FY 2023 Request vs FY 2021 Comp. (%)
Federal Full Time Equivalent Employees (FTEs)	**63**	**56**	**–**	**–**	**63**	**+7**	**+12.5%**
Additional FE FTEs at NETL supporting OE[a]	11	10	–	–	10	0	0.0%
Total OE-funded FTEs	74	66	–	–	73	+5	+10.6%

SBIR/STTR:
FY 2021 Enacted: SBIR/STTR: $4,646
FY 2023 Request: SBIR/STTR: $6,151

Comparability Matrices

The tables below show the funding allocation between OE and GDO in FY 2021 through FY 2023 under the prior and the proposed budget structures.

FY 2021 Enacted Appropriation Comparability Matrix
($K)

	FY 2023 Proposed Budget Structure				
		Grid Deployment Office			
	Electricity	Grid Technical Assistance	Program Direction	Total, GDO	**Total**
FY 2022 and Prior Budget Structure					
Transmission Permitting & Technical Assistance	0	7,000	0	7,000	**7,000**
Program Direction	15,000	0	3,000	3,000	**18,000**
Other on-going OE programs	186,720	0	0	0	**186,720**
Total	**201,720**	**7,000**	**3,000**	**10,000**	**211,720**

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

FY 2022 Annualized CR Comparability Matrix
($K)

	FY 2023 Proposed Budget Structure				Total
	Electricity	Grid Deployment Office			
		Grid Technical Assistance	Program Direction	Total, GDO	
FY 2022 and Prior Budget Structure					
Transmission Permitting & Technical Assistance	0	7,000	0	7,000	**7,000**
Program Direction	15,000	0	3,000	3,000	**18,000**
Other on-going OE programs	186,720	0	0	0	**186,720**
Total	**201,720**	**7,000**	**3,000**	**10,000**	**211,720**

FY 2023 Request to Congress Comparability Matrix
($K)

	FY 2023 Proposed Budget Structure							Total
	Electricity	Grid Deployment Office						
		Grid Planning & Develop-ment	Grid Technical Assistance	Wholesale Electricity Market TA & Grants	Interregional & Offshore Transmission Planning	Program Direction	Total, GDO	
FY 2022 and Prior Budget Structure								
Transmission Permitting & Technical Assistance	0	16,200	29,500	0	0	0	45,700	**45,700**
Program Direction	17,586	0	0	0	0	5,521	5,521	**23,107**
Other on-going OE programs	279,800	0	0	0	0	0	0	**279,800**
New GDO programs in FY 2023	0	0	0	19,000	20,000	0	39,000	**39,000**
Total	**297,386**	**16,200**	**29,500**	**19,000**	**20,000**	**5,521**	**90,221**	**387,607**

Bipartisan Infrastructure Law and Programmatic Realignment
OE was appropriated funds through the Bipartisan Infrastructure Law (BIL) (P.L. 117-58). BIL activities appropriated in the Electricity account will be implemented by the Grid Deployment Office (GDO) as part of the Department's efforts to best execute the BIL mission. In FY 2023, the following BIL programs appropriated to OE will be executed by GDO:

- Preventing Outages and Enhancing the Resilience of the Electric Grid (Section 40101)
- Transmission Facilitation Fund (Section 40106)
- Deployment of Technologies to Enhance Grid Flexibility (Section 40107)

In addition, GDO will continue to execute the Advanced Energy Security Program to Secure Energy Networks, Modeling and Assessing Energy Infrastructure Risk (Section 40125(d)) program, which was appropriated funds under OE in FY 2022 only.

DOE created new offices for the Under Secretary for Infrastructure and realigned some existing offices and components to better execute the BIL appropriation and the overall DOE mission. For OE, activities under the Transmission Permitting and Technical Assistance program, as well as a corresponding portion of the Program Direction program, were realigned under the newly formed GDO, which reports to the Under Secretary for Infrastructure. The remaining OE programs report to the Under Secretary for Science and Innovation and will continue to fulfill their current roles and responsibilities.

Future Years Energy Program
($k)

	FY 2023 Request	FY 2024	FY 2025	FY 2026	FY 2027
Electricity	297,386	304,000	311,000	318,000	325,000

Outyear Priorities and Assumptions

In the FY 2012 Consolidated Appropriations Act (P.L. 112-74), Congress directed the Department to include a future-years energy program (FYEP) in subsequent requests that reflects the proposed appropriations for five years. This FYEP shows outyear funding for each account for FY 2024 - FY 2027. The outyear funding levels use the growth rates from and match the outyear account totals published in the FY 2023 President's Budget for both the 050 and non-050 accounts. Actual future budget request levels will be determined as part of the annual budget process.

OE priorities in the outyears include the following:

- Continued development of long duration energy storage technologies consistent with the 2030 Long Duration Storage Shot goal of $0.05/kwh Levelized Cost of Storage for 10+ hour systems
- Continued development of materials, components, and systems that enable advanced grid capabilities through Grid Enhancing Technologies, HVDC, modular and flexible large power transformers, etc.

Transmission Reliability and Resilience

Overview

The Transmission Reliability and Resilience (TRR) program provides the electric sector with the necessary tools and analyses to achieve decarbonization, reliability, resilience, and energy justice by assessing risks, informing decisions, and improving power system planning and performance including mitigating the risks of large-scale blackouts and adapting to evolving system needs.

TRR focuses on:

- Ensuring the reliability and resilience of the U.S. electric grid through research and development (R&D) concentrated on measurement and control of the electricity system
- Developing and validating models to assess evolving system needs and identify pathways for achieving an equitable energy transition towards decarbonization and electrification
- Mitigating 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.

Transmission Reliability and Renewable Integration (TRRI) is developing transmission system tools and data analytics to inform planning and operational decisions that maintain and improve system reliability while accelerating the integration of renewable energy for the electricity industry. Advances in data analytics ensure utilities are getting the full value from new and existing sensors and enable inference of complex underlying dynamics and diagnosis of system behavior and abnormalities, while providing situational awareness for operators to make informed and equitable decisions. TRRI is developing tools that help system operators understand and adapt to changes in supply and load, including expanded growth in clean generation, decarbonization, access to distributed energy resources, and increased electrification. TRRI is modernizing transmission system tools through human factor and cognitive science research for system operations to allow for more timely mitigation of reliability events, such as blackouts, and allow for the development of training simulators for operator workforce development. TRRI R&D will enable determining the state of the power system with the greater speed, accuracy, and precision that are 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.

Advanced Grid Modeling (AGM) supports building the capacity and capability within the electric sector to analyze the electricity delivery system using Big Data, advanced mathematical theory, and high-performance computing to assess the current state of the grid, mitigate reliability risks, and understand future needs to facilitate decarbonization and energy justice, and to ensure the reliability and resilience of the electric grid. AGM aims to lead the research activities in better understanding the issues surrounding the current and future electric power grid and developing robust model-based solutions that result in new software, analytical toolsets for operators and planners. Successful research in this area will enable grid operators and planners to optimize their decision-making, giving the electric industry sophisticated tools to dramatically improve electric delivery system efficiency, reliability, resilience, and security.

Protective relaying is required at all levels of the electric grid with the purpose of quickly identifying and isolating faults such that the remaining system will continue to operate under normal conditions. This prevents or reduces damage to equipment and potential injury to utility personnel and the public. Originally developed as a last line of defense, protective relaying is becoming more integrated with normal operations of the grid such as stabilizing voltage and frequency. Protective relaying complexity varies by function and vendor and, with many senior technicians and engineers retiring, the burden on the remaining workforce is increasing. The Protective Relaying subprogram will address ongoing issues in the industry, such as misoperations of relays, while advancing state-of-the-art technology that will function in an evolving environment that includes bi-directional power flow, a need for faster response times, and enhanced detection methods. The subprogram will also develop guidelines, best practices, and toolsets to support workforce development of relaying professionals across the Nation.

Building and maintaining effective public-private partnerships is a key strategy for the TRR program. In achieving its vision, TRR also fosters strategic, university-based power system research. Partnerships with universities focus on developing state of the art tools and analytic methods, while simultaneously providing important opportunities for the next generation of scientists and researchers in power systems. Such partnerships facilitate innovations in R&D and enable industry (and ultimately consumers) to capitalize on the outcomes. TRRI, for example, will continue work to develop research datasets and data platforms that reduce utility burden from data requests and facilitate tool development with real data. This will set the groundwork for catalyzing artificial intelligence and machine learning in the transmission system. Advancing analytics to be capable of fully capturing and understanding new system dynamics from the integration of renewable energy, inverter-based technologies, and advanced transmission control schemes (such as dynamic line rating and transmission topology control) will further develop the electricity system as a resource.

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 2023 Budget Request
The TRR program continuously investigates ways to make the present and future grid resilient, reliable, efficient, and secure. In FY 2023, TRR's will concentrate on:

- Developing high-fidelity sensing technologies and analytics that manage uncertainty associated with data and decision support capabilities
- Advancing the application of cognitive science and human factors to identify and develop tools needed for decision making and training
- Advancing protective relaying methods to improve the functional integrity and effectiveness at preventing and mitigating power outages
- Researching the impact of changes in the grid with a concentration on transmission planning to accommodate large deployment of renewables to facilitate decarbonization
- Identifying and mitigating risk across the integrated energy system
- Increasing collaboration between OE and other public and private entities
- Increasing the level of understanding and industry awareness related to energy justice
- Continuing the partnership with the National Science Foundation (NSF) on the Algorithms for Modern Power Systems (AMPS) program
- Managing and understanding the impact of changes in the grid amid increasing complexity and accelerated grid technology development.
- Developing integrated risk-based, measurement-model approaches to improve detection, mitigation, and recovery/ restoration from system failure, weather events and man-made attacks to the electric power system, and plan to enable the operation of degraded or damaged electricity systems while sustaining critical functionality

Technology, tools, and applications developed under TRR will be evaluated for security risks including cybersecurity. Testing and evaluations will be conducted to ensure that security is built-in and new security risks are not being introduced into the electric sector.

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

Centers[a]
The Request includes planned DOE support for a new university-based Engineering Research Center (ERC), which would be jointly funded by 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 2021 Enacted	FY 2022 Enacted Annualized CR[a]	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
Transmission Reliability and Resilience					
Transmission Reliability and Renewable Integration	3,586	–	10,500	+6,914	+192.8%
Advanced Modeling Grid Research	17,810	–	21,800	+3,990	+22.4%
Protective Relaying	0	–	5,000	+5,000	N/A
North American Energy Resilience Model	19,905	–	0	-19,905	-100.0%
Transmission Sensors	419	–	0	-419	-100.0%
Sensors and Analytic Technologies	1,000	–	0	-1,000	-100.0%
Composite Utility Pole Assessment	500	–	0	-500	-100.0%
Grid Research Integration & Demonstration Center	5,000	–	0	-5,000	-100.0%
Total, Transmission Reliability and Resilience	**48,220**	**48,220**	**37,300**	**-10,920**	**-22.6%**

SBIR/STTR:

- FY 2021 Enacted: SBIR/STTR: $1,527
- FY 2023 Request: SBIR/STTR: $1,155

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

	FY 2023 Request vs FY 2021 Enacted
• Transmission Reliability and Renewable Integration: The increase supports modernization of transmission system tools through human factor and cognitive science research for system operations to allow for more timely mitigation of reliability events, such as blackouts, and allow for the development of training simulators for operator workforce development.	+6,914
• Advanced Modeling Grid Research: The increase supports R&D to increase the net power flowing through transmission lines, develop analytical methods to manage impact of uncertainty associated with increase in the deployment of renewables on the bulk power system, and increase the level of understanding and industry awareness related to energy justice.	+3,990

[a] FY 2022 amounts shown reflect the P.L. 117–95 continuing resolution (CR) level annualized to a full year. These amounts are shown only at the “congressional control” level and above; below that level, a dash (–) is shown.

	FY 2023 Request vs FY 2021 Enacted
• Protective Relaying: This subprogram addresses ongoing issues in the industry, such as misoperations of relays, while advancing state-of-the-art technology that will function in an evolving environment that includes bi-directional power flow, a need for faster response times, and enhanced detection methods. The increase also supports development of guidelines, best practices, and toolsets to support workforce development of relaying professionals across the Nation. Related activities were supported in AGM in FY 2021.	+5,000
• North American Energy Resilience Model: The FY 2021 appropriation included support to complete phase 2 NAERM development. NAERM transitions to a transmission planning tool under the EDGOT program in FY 2023.	-19,905
• Transmission Sensors: Funding supporting both transmission and distribution sensors is consolidated under the Resilient Distribution Systems program in FY 2023.	-419
• Sensors and Analytics Technologies: Planned activities for this Congressionally directed activity are completed with funding provided in FY 2021.	-1,000
• Composite Utility Pole Assessment: Planned activities for this Congressionally directed activity are completed with funding provided in FY 2021.	-500
• Grid Research Integration and Demonstration Center: Planned activities for this Congressionally directed activity are completed with funding provided in FY 2021.	-5,000
Total, Transmission Reliability and Resilience	**-10,920**

Transmission Reliability and Resilience

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Transmission Reliability and Resilience $48,220,000	**$37,300,000**	**-$10,920,000**
Transmission Reliability and Renewable Integration $3,586,000	*$10,500,000*	*+$6,914,000*
• Continue technical support for the North American SynchroPhaser Initiative (NASPI) to conduct information sharing and joint problem solving among utilities, vendors, universities, and the Federal Government	• Continue technical support for NASPI to conduct competitions, information sharing and joint problem solving among utilities, vendors, universities, and the Federal Government	• Initiate a Prize program for AI/ML tool development utilizing open transmission system data sets, facilitated by industry partnerships with DOE, to catalyze independent academic research and equitable workforce development

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
	• Develop and demonstrate management tools for Grid Enhancing Technologies like Dynamic Line Rating and Power Flow Control to facilitate integration of renewable energy and better utilize existing transmission infrastructure • Support operating strategies, dynamic load modeling, contingency analysis, and control approaches that recognize and incorporate the control capabilities offered by, and attributes of, wind and solar generation • Develop transmission system data modernization of for wide area situational awareness, to prevent cascading power outages, through prizes, data set creation, and AI/ML research. • Advance cognitive science and human factors research to catalyze development and adoption of new tools for workforce training and development, control room application improvements, and robust decision making	• Improve load modeling to support transmission planning studies that include distributed energy resources and the development of standards articulating grid-friendly behavior • Advance contingency analysis and improve simulations of dynamic behavior related to inverter-based resources • Develop advanced operating strategies and control approaches that allow greater utilization of existing lines to support renewable integration
Advanced Modeling Grid Research $17,810,000	*$21,800,000*	*+$3,990,000*
• Initiate assessment of research needs for a new university-based engineering research center related to electric power systems in coordination with NSF • Continue exploring the mathematical and computational research to manage uncertainty, associated with data, modeling, and model validation • Continue development, co-funded with NSF's AMPS program, of next-generation mathematical and statistical algorithms to improve the security, reliability, and resilience of the electric power system	• Continue mathematical and computational research to manage uncertainty, associated with data, modeling, and model validation • Continue development, co-funded with NSF's AMPS program, of next-generation mathematical and statistical algorithms to improve the security, reliability, and resilience of the electric power system • Continue exploring alternative methods for transmission planning to increase the amount of energy delivered using existing rights of way	• Identify and mitigate grid risks to accommodate increasing levels of renewables to facilitate decarbonization while ensuring grid reliability, resilience, security, and efficiency • Increase the level of understanding and industry awareness related to energy justice while exploring mitigation through R&D

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
• 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 exploring the impact of changes in the grid with a concentration on transmission planning to accommodate large deployment of renewables to facilitate decarbonization • Increase the level of understanding and industry awareness related to energy justice while exploring mitigation through R&D • Identify and mitigate grid risk to accommodate increasing levels of renewables to facilitate decarbonization while ensuring grid reliability, resiliency, security, and efficiency	
Protective Relaying $0	*$5,000,000*	*+$5,000,000*
	• Develop mitigations that reduce misoperations at both transmission and distribution levels • Develop solutions to distinguish between momentary and permanent faults for reclosers at the distribution level • Develop cybersecurity solutions for protective relaying at both the transmission and distribution levels • Continue research on adaptive relay settings that address bi-directional power flow • Address best practices and toolsets that will support the protective relaying workforce in an evolving grid environment	• Advancing state-of-the-art protective relaying technology that will function in an evolving environment that includes bi-directional power flow, a need for faster response times, and enhanced detection methods • Related activities were supported in AGM in FY 2021
Transmission Sensors $419,000	*$0*	*-$419,000*
• Continue support for existing sensor activities		• Funding supporting both transmission and distribution sensors is consolidated under the Resilient Distribution Systems program in FY 2023

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Sensors and Analytics Technologies $1,000,000	*$0*	*-$1,000,000*
• Sensors and data analytics work, in alignment with sensor's roadmap was performed at NREL and ORNL		• Planned activities for this Congressionally directed activity are completed with funding provided in FY 2021
Composite Utility Pole Assessment $500,000	*$0*	*-$500,000*
• Field testing of utility poles constructed of composite materials to determine the benefit to overall grid infrastructure resilience from environmental factors was completed at ORNL		• Planned activities for this Congressionally directed activity are completed with funding provided in FY 2021
Grid Research Integration and Demonstration Center (GRID-C) $5,000,000	*$0*	*-$5,000,000*
• Multiple laboratory activities were completed at ORNL's GRID-C facility • Work supported energy and electrification research, enabling study of dynamic interactions across buildings, vehicles, manufacturing, and the utility sectors		• Planned activities for this Congressionally directed activity are completed with funding provided in FY 2021

Energy Delivery Grid Operations Technology

Overview
The Nation's energy resilience strategy would benefit from advancements in national-scale energy planning and situational awareness capabilities to better characterize risk and uncertainty across multiple utility and infrastructure boundaries. Built around rigorous and quantitative assessment, sensing, prediction, and deep learning, the Energy Delivery Grid Operations Technology (EDGOT) program enhances the analytical capability needed to ensure reliable and resilient energy delivery, and provides the architecture and process for identifying a range of scalable mitigation solutions to changing climate conditions and other emerging threats.

The core of the EDGOT portfolio is the North American Energy Resilience Model (NAERM). NAERM development was funded under the Transmission Reliability and Resilience program in FY 2019–2021. NAERM is a hybrid data/model platform for the quantitative assessment of the significant interdependencies that have evolved within the energy sector and that could affect reliability. NAERM allows for the simulation of impacts to the energy system from natural and manmade events and through collaborative partnerships, strategic insights will be accessible to utilities and other Federal agencies. NAERM will provide for enhanced planning and analysis capabilities that can be leveraged to facilitate grid investments that address disproportionate health, environmental, economic, and climate impacts on disadvantaged communities; and increase the reliability and resilience of the energy infrastructure, inform national security investments, and enhance decision making under DOE's authorities to respond to grid security emergencies.

EDGOT's tools will support several private and public efforts:

- Utilizing a systems perspective to compare and collectively plan for impacts across organizational, geographic, sector, and jurisdictional boundaries.
- Targeting collaboration on mitigations with the Department's Power Marketing Administrations (PMAs) and other energy infrastructure owners and operators to effectively address multi-regional-scale natural threats and national security concerns.
- Supporting and advising on better utilization of optical power ground wire (OPGW) to support grid timing and synchronization, and potentially enabling rural broadband expansion.

The EDGOT portfolio leverages previous national laboratory efforts to fully understand the resilience risks associated with the regionally diversified North American electric system and associated infrastructure systems. National laboratories, including Argonne, Idaho, Lawrence Livermore, Los Alamos, National Renewable Energy, Oak Ridge, Pacific Northwest, Sandia, and Savannah River, have a long history of developing system-wide modeling and analysis tools, as well as transformational sensing and communications technology.

Impacts of FY 2022 Appropriations
Due to the level of funding provided and direction under the FY 2022 Energy and Water Development and Related Agencies Appropriations Act, NAERM operational aspects in FY 2022 are limited to maintenance support and all development work is deferred.

Highlights of the FY 2023 Budget Request
Predicting the impact of a specific event on energy system operations, restoration, and recovery is vexing due to the scale of the North American energy system—crossing organizational, geographic, sector, and jurisdictional boundaries—and the underlying physics of energy transport. Our current ability to analyze extreme events in this context is limited due to the lack of key information and capabilities:

- Unclassified details regarding potential threats
- Data and predictions on resulting impacts
- Tools and expertise to characterize and analyze the relationships between electricity and associated infrastructures, such as natural gas, communications, transportation, carbon management, and water
- Scripting interfaces to allow users to quickly build co-simulations and planning models
- Data availability to support infrastructure grid planning across seams, including transmission and distribution as well as grid-edge devices such as customer-owned distributed energy resources (DERs) and electric vehicles (EVs)

The FY 2023 Request focuses on developing and enhancing the portfolio of tools to help address these limitations and to transition the underlying capabilities to a robust, secure operational state:

- Incorporating the best available information on threat characteristics and their evolution over time
- Integrating the Situational Awareness Network (SAN) and the availability of real-time data feeds into the NAERM platform
- Formalizing procedures and establish partnerships for sharing data with utilities and independent system operators (ISOs)
- Hardening and integrating research innovations in advanced analytics to rapidly identify system vulnerabilities and enhance decision support for system analysis
- Initiating development of complex multi-infrastructure contingency analyses providing snapshots of the national resilience posture
- Enhancing infrastructure models and facilitating their integration into the NAERM architectural framework
- Expanding NAERM's operational capability in protecting and supporting the increase in data sources and access to the NAERM
- Collaborating with PMAs on implementation and validation of mitigation approaches
- Engaging with industry experts to get a better understanding of issues and practices on a regional basis to ensure that threat and consequence models are realistic and representative of actual system responses
- Supporting short- and long-term planning activities necessary to achieve a significant and early decarbonization of the power sector while meeting increasing electrical loads and bridging extreme events on a pathway to a net-zero carbon economy
    - These activities could include analysis of interstate transmission corridors, intraday flexibility within the grid, dispatchability of zero-carbon generation and associated supply chain and carbon management interdependencies, and optimal siting and expanded use of DERs such as energy storage, transportation electrification, and transformative resilience-by-design system solutions

Technology, tools, and applications developed under the EDGOT program will be evaluated for security risks including cybersecurity. Testing and evaluations will be conducted to ensure that security is built in.

Energy Delivery Grid Operations Technology
Funding ($K)

	FY 2021 Enacted	FY 2022 Enacted Annualized CR[a]	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
Energy Delivery Grid Operations Technology					
North American Energy Resilience Model (NAERM)					
NAERM Operations	0	—	14,000	+14,000	N/A
NAERM Upgrades	0	—	20,000	+20,000	N/A
Total, NAERM	0	—	34,000	+34,000	N/A
Synchronization, Timing, and Sensors	0	—	5,000	+5,000	N/A
Total, Energy Delivery Grid Operations Technology	**0**	**0**	**39,000**	**+39,000**	**N/A**

Energy Delivery Grid Operations Technology
Explanation of Major Changes ($K)

	FY 2023 Request vs FY 2021 Enacted
• NAERM:	
• NAERM Operations: Supports operations and maintenance of existing data infrastructure, models, communications network, and software platform	+14,000
• NAERM Upgrades: Supports the development and incorporation of enhanced planning model capabilities into the NAERM platform	+20,000
• Synchronization, Timing, and Sensors: Development continues for communications flexibility in providing synchronization environments and the potential coverage area and sensor sites for Advanced Sensor Technology Systems (ASTS) will be assessed while development continues for sensor technology from data received	+5,000
Total, Energy Delivery Grid Operations Technology	**+39,000**

[a] FY 2022 amounts shown reflect the P.L. 117–95 continuing resolution (CR) level annualized to a full year. These amounts are shown only at the “congressional control” level and above; below that level, a dash (–) is shown.

Energy Delivery Grid Operations Technology

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Energy Delivery Grid Operations Technology $0	**$39,000,000**	**+$39,000,000**
NAERM Operations $0	*$14,000,000*	*+$14,000,000*
	• NAERM begins expected operations in FY 2023	• Development costs for NAERM in FY 2021 were funded in the Transmission Reliability and Resilience program
NAERM Upgrades $0	*$20,000,000*	*+$20,000,000*
	• Create transmission/distribution planning tool • Create DER network planning tool • Expand climate change natural threat modeling to include climate change awareness impact to the grid	• Development costs for NAERM in FY 2021 were funded in the Transmission Reliability and Resilience program
Synchronization, Timing, and Sensors $0	*$5,000,000*	*+$5,000,000*
	• Build CAST to operational readiness to support the Federal assets with precision synchronization and timing to include national labs infrastructure, PMAs, and NAERM • Maintain and integrate SAN into the NAERM platform for the detection of anomalies across the U.S. grid landscape	• Development costs for CAST in FY 2021 were funded within the DarkNet project in the Office of Cybersecurity, Energy Security, and Emergency Response

Resilient Distribution Systems

Overview

Resilient, reliable, and affordable electricity is a cornerstone for equitable economic growth and job creation, a critical platform to address climate change, and a foundation for communities to grow and attract new businesses and meet energy demands. 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. However, that same distribution system is facing dramatic changes—increased electrification, decarbonization of the electricity supply, and continued energy efficiency and conservation. The growing convergence of the entire electricity delivery system requires new architectural, control, and operational approaches. While these changes provide new benefits and new opportunities, they also present significant operational challenges. As the electricity distribution system continues to evolve and its complexity increases, new technologies are needed that enable changes to the way the electric grid is planned and operated. For utilities to maintain reliable and resilient operations, they require tools and capabilities to enhance observability, control, and dynamic protection across all distribution system assets.

The Resilient Distribution Systems (RDS) program focuses on addressing challenges facing the electric power grid by developing transformative technologies, tools, and techniques to enable industry to modernize the distribution portion of the electric delivery system. RDS pursues strategic investments in innovative technologies and practices that improve reliability, increase resilience, support vehicle electrification, integrate clean distributed energy resources (DER), and provide consumers with more choices for managing their energy consumption. The program builds upon grid modernization efforts including the Grid Modernization Laboratory Consortium (GMLC).

Microgrid research & development (R&D) focuses on developing and validating new technologies and methods to improve grid reliability and resilience under both normal and disruptive conditions, while enabling DER integration, enhancing consumer participation and choice, and driving grid technology innovation. Microgrid investments have successfully enhanced reliability, resilience, and efficiency, particularly at the community level, and continue to be an RDS focus area.

New approaches and technologies will also be investigated, including Dynamic Controls R&D to enhance the Nation's electric distribution grid to harness flexibility across all distribution assets. This includes expanded sensor research to increase situational awareness at the distribution level, which provides the ability to withstand and recover from disruptions caused by extreme weather events and man-made events, as well as supporting normal operations. In addition, Dynamic Controls will explore the local, regional, and structural implications of transportation electrification.

Results from the RDS research in Microgrids and Dynamic Controls will enable industry to strengthen the reliability and resilience of electrical infrastructure and support the ongoing evolution of the electric grid in a manner that supports a just transition to a decarbonized economy.

The integrated planning component of the program will develop methods, tools, and guidelines through collaborative efforts with the electric utility industry, including regulators and consumer advocates, that enable the formulation of staged strategies for transitioning to an advanced, decarbonized, and resilient electric grid. These strategies will address technological and institutional issues associated with the implementation of advanced grid capabilities by the industry. They will also include the advancement of integrated planning practices to ensure the formulation of coherent grid investment strategies that apply advanced technologies for meeting reliability, resilience, decarbonization, efficiency, equity, and flexibility objectives.

Highlights of the FY 2023 Budget Request

Microgrid activities in FY 2023 support R&D in several areas:

- Development of microgrid building blocks (MBBs) as fundamental units for microgrids to reduce the cost and time for microgrid deployment will continue. In FY 2023, this development, led by multiple national laboratories and universities, will complete the design and prototype of MBB hardware and software that integrates the power conversion, switching, communication, and microgrid controller functions into one single unit. The resultant MBB prototype will feature functions for a wide range of microgrids, and provide modular and standard interfaces to generation, load, control facilities, and the utility system. Modeling and simulation to validate the MBB prototype performance design and performance is planned to be complete in FY 2024, followed by field demonstrations. The low-cost standard approach for MBBs is key to achieving affordability for widespread equitable deployment of microgrids.

- Developing modeling and simulation capabilities for optimal system design and operations of networked microgrids continues. Networking two or more microgrids that share loads and complementary power resources can increase their combined resilience during power outages, while lowering capital and operational costs for normal operations. Work in FY 2023 will examine various control schemes for mixes of generation assets, and include, but not be limited to, decentralized load control, centralized voltage control, and adaptive controls, to support a range of resiliency and decarbonization operations at U.S. ports.
- Another activity in networked microgrids will focus on enabling dynamic formation of microgrid boundaries for optimized operations under both normal and emergency conditions. This DynaGrid approach, built on the Resilient Operations of Networked Microgrids (RONM) activity that was completed in FY 2022, will lay the foundation for a future grid that is composed of dynamically formed microgrids in a repetitive pattern (a fractal grid). Key tasks in FY 2023, led by multiple national laboratories, include developing realistic use cases and developing and evaluating algorithms for optimization-based dynamic reconfiguration on the use cases. Evaluation will be done in lab environments in FY 2023 to assess the effect on equity, energy justice, and outcomes for different groups of customers, followed by field validation testing and demonstration planned in FY 2024. Dynamic microgrids through this activity are expected to accommodate larger-scale integration of DERs and electrification envisioned for the future grid.
- The Net-Zero Microgrids (NZMs) activity will implement its technology roadmap developed in FY 2022. The roadmap defines cross-cutting research needed to support the accelerated removal of carbon-emitting generation from microgrids. FY 2023 tasks include modeling and simulation of a microgrid design with a small modular reactor (SMR) integrated as part of its generation mix to investigate power system engineering issues involving microgrid operations and its integrated operations with the grid to provide grid services. A net-zero techno-economic analysis platform to model and evaluate NZMs will be developed. The platform will be applied for infrastructure electrification, with the first application centering on microgrid fast charging station designs for electric vehicles.
- 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. Protection research for secondary networks involving DERs and microgrids also continues. In FY 2023, this work will complete development of a potential replacement technique for reverse power relaying protection for secondary network. Currently, heavy reliance on reverse power flow for protection poses a fundamental challenge to placing DERs in secondary systems. The research outcome will be applicable for future meshed distribution systems, networked microgrids, and transmission protection.

Dynamic Controls R&D activities will support priorities on grid resiliency and dynamically sourced grid support services to transform 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 will see continued simulation, development, and demonstration. A new effort in this area will explore data efficiency, maximizing the utilization of high volumes of data while minimizing computing and communications resources. Blockchain and other digital-ledger technology 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 Data Science: R&D activities will develop highly resilient distribution designs capable of accommodating evolving electricity supply and adapting to extreme events and disruptions. Data flow across ownership boundaries creates the need for new data integrity methods, data sharing agreements, and coordination frameworks. The effort will also extend the linkage between secure distributed compute environments and their associated impacts on data transport architectures within the utility environment.
- Transport Electrification: Increasing the intensity of the linkage between the electric and transportation sectors creates interdependencies that can have both positive and negative effects. Dynamic Controls will launch two efforts examining vehicle electrification. A Sector Coupling Analysis will look at structural and architectural aspects, seeking to establish a converged perspective on reliability, sustainability, and resilience across both transportation and electricity. In parallel, control and coordination approaches that address vehicle grid integration issues through both nodal and network solution paths, encompassing all grid and DER assets and their incentive mechanisms.

Sensors: R&D activities will support the development and integration of high-fidelity, fast-acting sensor technologies and advanced data analytics into the power grid. The program will also revolutionize the use of these technologies in electricity operations and delivery—from transmission to distribution to end-use load (including behind-the-meter DER)—for improved diagnostics and prediction of system variables and assets during normal and extreme-event conditions. Advances in sensing on the distribution system will facilitate better two-way power flow across the transmission and distribution system. It will also enable better understanding and tracking of energy equity and enable the development of more effective strategies to address energy justice. Developing tools for sensor management and data analytics enable utilities to better forecast and react to changes in generation from DERs and load to maintain reliability and reduce costs. This could include advanced contingency analysis and improved simulations of dynamic behavior, such as those related to inverter-based resources in the distribution system. Distribution system visibility is behind the visibility of the transmission level, and reducing this asymmetry is important for the full participation of distribution in markets and system planning. Distribution sensors, and their associated tools and analytics, provide the foundation for enhanced observability, predictability, and flexibility—from advanced distribution management systems to microgrid controllers to distributed controls.

RDS is working closely with industry stakeholders, including regulators, utilities, states, and communities, through the integrated planning component of the program to address both technological and institutional issues and develop strategies to enable a just transition to a modern electricity delivery system. This aspect of the program is focused on the formulation and implementation of coherent strategies for deploying needed functional and structural features of the electric grid through the application of grid architecture and the advancement of integrated grid planning practices. Efforts include:

- Working collaboratively with various associations (NARUC, NASEO, NRECA, APPA, NGA, and NCSL) through formal arrangements to engage their respective stakeholders to:
  - Advance methods for incorporating resilience, decarbonization, and energy justice into utility planning practices;
  - Undertake demonstration projects that apply renewable and advanced grid technologies within underserved communities;
  - Address interjurisdictional oversight issues related to grid and market operations that cross transmission, distribution, and behind-the-meter domains; and
  - Institute practical grid modernization strategies, including the provision of training to inform state officials of best practices.
- Developing an architecture for the distribution system that can accommodate many forms of distributed (inverter-based) energy resources, ownership models, and market structures, and ensuring an effective transfer of know-how to the industry.
- Producing "Voluntary Model Pathways" (per Section 8008 of the Energy Act of 2020) in concert with the industry to identify technological and institutional barriers to the attainment of a resilient, decarbonized, and equitable electricity delivery system, and developing transitional, coordinated strategies for addressing them.
- A demonstrated multi-objective decision framework incorporating decarbonization, resilience, flexibility, and energy justice with traditional planning objectives that can then guide the formulation of holistic and equitable grid modernization strategies and technology investment plans by regulators, utilities, and planners at the regional system level.
- A set of practical design guidelines that address operational coordination requirements to enable evolving industry, business, and market structures at the grid edge (such as community microgrids, virtual power plants, and electric vehicle infrastructure) to interface with the electric grid, as well as share services across the transmission and distribution system domains.

Technology, tools, and applications developed under RDS will be evaluated for security risks including cybersecurity. Testing and evaluations will be conducted to ensure that security is built-in and new security risks are not being introduced into the electric sector.

OE coordinates with the Office of Energy Efficiency and Renewable Energy (EERE) 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 supporting urban, rural, and underserved communities, as well as islanded and remote grids.

In FY 2022, RDS and EERE will also jointly fund competitively selected projects to engage with regional and local partners, especially in underserved communities, to develop and demonstrate innovative technologies (including distributed solar, energy storage, EVs, and other DERs) and planning practices to enhance community resilience to physical hazards and to support decarbonization goals.

Resilient Distribution Systems
Funding ($K)

	FY 2021 Enacted	FY 2022 Enacted Annualized CR[a]	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
Resilient Distribution Systems					
Microgrids	9,800	–	14,000	+4,200	+42.9%
Dynamic Controls & Communications	12,218	–	20,000	+7,782	+63.7%
Sensors	3,800	–	7,000	+3,200	+84.2%
Electricity Delivery Systems	9,182	–	9,000	-182	-2.0%
Demonstration Sensors	5,000	–	0	-5,000	-100.0%
COMMANDER National Testbed Laboratory	10,000	–	0	-10,000	-100.0%
Total, Resilient Distribution Systems	**50,000**	**50,000**	**50,000**	**0**	**0.0%**

SBIR/STTR:
- FY 2021 Enacted: SBIR/STTR: $1,265
- FY 2023 Request: SBIR/STTR: $1,315

Resilient Distribution Systems
Explanation of Major Changes ($K)

	FY 2023 Request vs FY 2021 Enacted
• Microgrids: The increase supports microgrid building block development, advancing the design and production of the prototype unit. It also supports the multi-laboratory DynaGrid approach with development of use cases to assess the effect on equity, energy justice, and outcomes for different groups of customers.	+4,200
• Dynamic Controls & Communications: The increase supports a sector coupling analysis looking at structural and architectural aspects as well as control and coordination approaches addressing vehicle grid integration issues through both nodal and network solution paths encompassing all grid and DER assets and their incentive mechanisms. The increase also supports research related to data flow across ownership boundaries, such as the need for new data integrity methods, data sharing agreements, and coordination frameworks.	+7,782
• Sensors: The increase supports the development and integration of high-fidelity, fast-acting sensor technologies and advanced data analytics into the electricity delivery system.	+3,200

[a] FY 2022 amounts shown reflect the P.L. 117–95 continuing resolution level annualized to a full year. These amounts are shown only at the "congressional control" level and above; below that level, a dash (–) is shown.

	FY 2023 Request vs FY 2021 Enacted
• Electricity Delivery Systems: Work continues as planned with a slight reduction of effort in activities with States	-182
• Demonstration Sensors: Planned activities for this Congressionally directed activity are completed with funding provided in FY 2021.	-5,000
• COMMANDER National Testbed Laboratory: Planned activities for this Congressionally directed activity are completed with funding provided in FY 2021.	-10,000
Total, Resilient Distribution Systems	**0**

Resilient Distribution Systems

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Resilient Distribution Systems $50,000,000	**$50,000,000**	**$0**
Microgrids $9,800,000	*$14,000,000*	*+$4,200,000*
• 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	• Conduct R&D on the DynaGrid concept to enable dynamic formation of microgrid boundaries for optimized operations of networked microgrids, building on the RONM capabilities developed for static-boundary applications • Develop modeling and simulation capabilities for optimal system design and operations of networked microgrids for decarbonization and resilience of critical infrastructure with a focus of the use case on ports • Complete the design and prototype of MBB hardware and software that integrates the power conversion, switching, communication, and microgrid controller functions into one single unit • Develop modeling and simulation of a small-modular-reactor-integrated microgrid design to examine power system engineering issues and operational challenges for providing grid services	• Increase support of the multi-lab MBB development to advance the design and produce the prototype unit • Increase support of the multi-lab DynaGrid approach with development of use cases to assess the effect on equity, energy justice, and outcomes for different groups of customers • Support implementation of the technology roadmap for the Net-Zero Microgrids (NZMs) activity, including development of modeling/ simulation capabilities and a techno-economic analysis platform

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
• 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 analytics • Conduct funding opportunity on highly resilient adaptive networks leveraging analysis and laboratory activities accomplished in FY 2020	• Develop a net-zero techno-economic analysis platform and apply it to evaluate microgrid fast charging station designs for electric vehicles • Develop protection schemes for microgrids (singular and networked) with high penetration of inverter-based resources and for secondary networks with DERs and microgrids • Complete development of a potential replacement technique for reverse power relaying protection of secondary network	
Dynamic Controls & Communications $12,218,000	*$20,000,000*	*+$7,782,000*
• Initiate the development of a comprehensive communications planning toolkit • Demonstrate the feasibility and benefits of resilience services utilizing Dynamic Control Source	• Develop data efficient operations approach with increased reliance on combinations of distributed control and incentivization of flexible DER for reliability and resilience • Develop FERC Order 2222 implementation paths that emphasize transmission and distribution coordination and increased storage utilization • Develop a broad framework for data sharing across ownership and responsibility boundaries that assures data security, integrity, and privacy while ensuring operational objectives of all stakeholders are attained • Extend Sector Coupling Analysis of the Transport and Electricity Sectors including structural and architectural aspects, seeking to establish a converged perspective on reliability, sustainability, and resilience across both transportation and electricity	• Increase support for the deployment mission through enhanced emphasis on implementation strategies • Expand data science approaches in the rapidly expanding grid-edge, collaborative control frontier, strengthening coordination capabilities and enabling decarbonized and resilient systems • Anticipate the substantial impact of transportation electrification through increased research on interdependency, adaptation of distribution systems, and coordination of optimizations across new and legacy participants in the electric system

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
	• Develop control and coordination approaches that address vehicle grid integration issues through nodal and network solution paths, encompassing all grid and DER assets and their incentive mechanisms. • Develop digital ledger technology use cases that further enable DER integration and data integrity in distributed control and distributed compute environments	
Sensors $3,800,000	*$7,000,000*	*+$3,200,000*
• Operation, maintenance, and expansion of the SAN	• Develop approaches and tools that will accurately detect, characterize, and forecast DER behavior and its impacts on distribution systems • Develop new analytical algorithms that utilize real-time sensor data from transmission and distribution systems to diagnose asset health and predict imminent failures • Demonstrate grid models and tools that optimize sensor placement in terms of monitoring effectiveness and cost • Fund a prize program for AI/ML tool development utilizing open distribution system data sets, to catalyze independent academic research into equity and integration of DERs	• Develop and integrate high-fidelity, fast-acting sensor technologies and advanced data analytics into the electricity delivery system
Electricity Delivery Systems $9,182,000	*$9,000,000*	*-$182,000*
• Establish formal relationships with NARUC, NASEO, NGA, NCSL, NRECA, and APPA to address institutional barriers related to advancing grid capabilities	• Develop formal methods for incorporating resilience, energy justice, and decarbonization, as well as for balancing priorities among multiple objectives, into integrated planning processes	• Work continues as planned with a slight reduction of effort in activities with States

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
• Establish a Steering Committee (EAC, FERC, and national laboratories) to begin the process to develop pathways for addressing barriers to grid transformation	• Develop architecture-based guidelines to enable the formulation of frameworks to support the coordination of distributed energy resources within grid and market operations across the transmission, distribution, and behind-the-meter domains • Develop draft architecture specifications for a distribution grid, including structural views (physical and cyber) that can accommodate all forms of DERs, ownership models, and market structures • Establish and use formal working groups with NARUC, NASEO, NRECA, and APPA to vet and disseminate advanced planning practices and guidelines for operational coordination, as well as to provide technical assistance in these areas	
Demonstration Sensors $5,000,000	*$0*	*-$5,000,000*
• Utilize sensor data and data analytics from distribution utilities that have deployed advanced metering infrastructure to improve electrical system performance		• Planned activities for this Congressionally directed activity are completed with funding provided in FY 2021
COMMANDER National Testbed Laboratory $10,000,000	*$0*	*-$10,000,000*
• Multiple lab activities were conducted at ORNL • Activities included testing new technologies, examining the use of microgrids, and developing new analytics that will unlock the power of the smart grid data to improve operations		• Planned activities for this Congressionally directed activity are completed with funding provided in FY 2021

Cyber Resilient and Secure Utility Communications Networks[a]

Overview

The increasingly sophisticated cybersecurity exploit capabilities of our adversaries, coupled with increased reliance on the data communications and cyber-physical control of our Nation's energy systems, have made it extremely challenging for the energy sector to stay ahead of a quickly evolving risk landscape. The Department has prioritized investment in secure communications and cybersecurity to identify solutions to reduce risk for the energy sector.

The Cyber Resilient and Secure Utility Communications Networks (SecureNet) program develops solutions to strengthen electricity infrastructure against cyber-related threats and to mitigate vulnerabilities through support of game-changing R&D. The program focuses on enhancing the inherent 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 electricity delivery system. SecureNet ensures a security-by-design approach based on data and physics to address vulnerabilities of the grid and critical operational data, communications, and control systems that expose the electricity system to cyber threats.

The SecureNet program is designing next-generation cyber and grid-communications systems that are built from inception to automatically detect, reject, and withstand cyber incidents, regardless of the threat. The evolving electric grid—with its rapidly growing number of cyber-enabled, highly-distributed components—is increasingly reliant on data communications and cyber-physical control for reliable operation. This requires new approaches to prevent or mitigate the impact of potential cyber-related risks. To accomplish this goal, the increasing focus is on data and physics to redesign the current grid cyber, data, communications, and control architecture that exposes the electricity system to cyber threats. Proactive assessment of technology, design modifications, or operational considerations early in the R&D process will position the grid solutions to more effectively and economically mitigate physical consequences from a cyber-attack. This ensures that all relevant OE R&D activities have an embedded security-by-design philosophy that directly complements ongoing OE research to understand, characterize, and model the electricity system.

Complementing its strategic R&D approach, SecureNet also pursues coordinated engagement with the Department's cyber-related operational activities, including that of the Office of Cybersecurity, Energy Security, and Emergency Response (CESER) and the Office of Intelligence and Counterintelligence. Through these partnerships, the SecureNet program will develop unmatched scientific and technical expertise in support of the Department's national security mission; strengthen public-private sector outreach, information sharing, training, and technical assistance; and enhance emergency preparedness, response, and recovery of U.S. infrastructure from all threats and hazards.

Highlights of the FY 2023 Budget Request

The FY 2023 Budget request provides support to research and develop advanced solutions that focus on a security-by-design approach based on data and physics to address vulnerabilities of the grid and critical operational data acquisition, processing, communications, and control systems that are specific to the electricity delivery system, both transmission and distribution. It also addresses OE's responsibility for catalyzing energy sector cybersecurity associated with electricity delivery systems, providing an opportunity to strengthen the relationship with other OE research for accelerated results. CESER retains lead responsibility for crosscutting cybersecurity issues that span beyond electricity delivery systems, as well as for coordinating energy sector cybersecurity activities across the Department.

The SecureNet program will develop technical solutions enabling accelerated and expanded efforts to strengthen electricity infrastructure against cyber threats while mitigating vulnerabilities. Working closely with the energy sector and our government partners, the request focuses on accelerating game-changing R&D to mitigate cyber incidents in today's systems and to develop next-generation resilient electricity delivery systems. The resilient electricity delivery systems (including synergistic communications networks) will be designed, installed, operated, and maintained to survive a cyber incident while sustaining critical functions. For instance, research could accelerate development of technical solutions based on artificial intelligence (AI) techniques for critical electricity delivery infrastructure, such as machine learning using data generated by the underlying physical process of electricity delivery as well as data generated by the cyber-systems that

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[a] The Cyber Resilient and Secure Utility Communications Network program was called Cybersecurity Research and Development in the FY 2022 Request to Congress.

control that physical process, to provide for an automatic response to cyber-attack. Such AI techniques could allow for electricity delivery systems or components to automatically adapt operations and survive a cyber-attack that would otherwise disrupt energy delivery. This effort may leverage advancements in grid modeling and data analytics from other OE programs, such as Transmission Reliability and Resilience, Resilient Distribution Systems, and Energy Delivery Grid Operations Technology.

The request continues to support 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 SecureNet 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.

SecureNet will support R&D activities through the Grid Modernization Laboratory Consortium (GMLC).

Cyber Resilient and Secure Utility Communications Networks (SecureNet)
Funding ($K)

	FY 2021 Enacted	FY 2022 Enacted Annualized CR[a]	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
Cyber Resilient and Secure Utility Communications Networks (SecureNet)					
University Research	0	–	2,000	+2,000	N/A
Industry Research	0	–	10,000	+10,000	N/A
Cyber Assessments and Technology	0	–	8,000	+8,000	N/A
Total, Cyber Resilient and Secure Utility Communications Networks (SecureNet)	**0**	**0**	**20,000**	**+20,000**	**N/A**

SBIR/STTR:
- FY 2021 Enacted: SBIR/STTR: $0
- FY 2023 Request: SBIR/STTR: $412

Cyber Resilient and Secure Utility Communications Networks (SecureNet)
Explanation of Major Changes ($K)

	FY 2023 Request vs FY 2021 Enacted
• University Research: Supports cyber research partnerships with universities on electricity delivery system technologies (such as energy storage and microgrids) and related NSF partnerships	+2,000
• Industry Research: Improves cybersecurity practice and technology development related to the electricity delivery system, with particular focus on cyber-enabled, highly distributed components	+10,000
• Cyber Assessments and Technology: Conducts cyber maturity reviews and assessment of existing OE research, development and demonstration programs	+8,000
Total, Cyber Resilient and Secure Utility Communications Networks (SecureNet)	**+20,000**

[a] FY 2022 amounts shown reflect the P.L. 117–95 continuing resolution (CR) level annualized to a full year. These amounts are shown only at the "congressional control" level and above; below that level, a dash (–) is shown.

Cyber Resilient and Secure Utility Communications Networks (SecureNet)

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Cyber Resilient and Secure Utility Communications Networks (SecureNet) $0	**$20,000,000**	**+$20,000,000**
University Research $0	*$2,000,000*	*+$2,000,000*
	• Create cyber research partnerships with universities on electricity delivery system technologies (such as energy storage and microgrids) and support related NSF partnerships	• FY 2022 is the first year of funding for this program
Industry Research $0	*$10,000,000*	*+$10,000,000*
	• Improve cybersecurity practice and technology development related to the electricity delivery system, with particular focus on cyber-enabled, highly distributed components	• FY 2022 is the first year of funding for this program
Cyber Assessments and Integrity $0	*$8,000,000*	*+$8,000,000*
	• Conduct cyber maturity reviews and assessment of existing OE research, development and demonstration programs	• FY 2022 is the first year of funding for this program

Energy Storage

Overview

The Energy Storage program leads a national effort to ensure a more flexible, resilient, and equitable North American power grid through increased deployment of bi-directional electrical energy storage. Executive Order 14008 establishes a goal to reach 100% carbon pollution-free electricity by 2035 and a net-zero emissions economy by no later than 2050. Maintaining grid reliability and resource adequacy with increased levels of variable renewable energy technologies will require cost-effective methods of storing and discharging energy. Energy storage is the key 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. Executive Order 14008 created the Justice40 Initiative, a plan to deliver 40% of the overall benefits of climate investments to disadvantaged communities. Energy storage provides new tools to improve grid resiliency in underserved communities and, when paired with renewable generation or offsetting the use of fossil-based resources, can help alleviate environmental issues in these communities.

Compared to the U.S. electric grid's installed electricity generation summer capacity of just over 1 terawatt (TW) (1,000 GW), the grid has roughly 23 GW of energy storage, of which 22 GW is provided by large pumped storage hydropower (PSH) energy storage plants and the remainder provided mostly by lithium-ion batteries. Achieving grid and full economy-wide decarbonization could require 300–1,000 GW or more of new storage power capacity, along with thousands of terawatt-hours (TWh) in storage energy duration. While existing storage technologies have the potential for significant growth, they face certain limitations. Underlying materials costs will limit the ability of lithium batteries to cost-effectively provide long-duration storage, and there are not enough PSH sites to achieve the hundreds of gigawatts required for daily and seasonal energy supply and demand imbalances. Ongoing research, development, demonstration, and deployment (RDD&D) efforts are focused on increasing storage durations, reducing technology costs, and deploying next generation energy storage solutions around the country. Further research is also needed 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 not only greater understanding of technical and economic benefits energy storage can provide to utilities and grid operators, but also the role storage plays in providing equitable power for consumers and communities and the impact of long-duration storage on deep decarbonization of the power sector.

The Energy Storage program is designed to foster new and advanced energy storage technologies that will ensure a reliable and resilient electricity infrastructure, equitably delivered to all stakeholders. The R&D program focuses on:

- Cost-Competitive and Long-Duration 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 manganese dioxide, and lead-based 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, in line with the Long Duration Storage Shot, enabling widespread deployment of longer-duration storage solutions and supporting increased domestic manufacturing.
  - Supporting a competitive funding opportunity announcement (FOA) to target innovative, longer-duration energy storage technologies that have require preliminary early-stage validation. The FOA will provide a pathway for demonstration and deployment of new flow or other innovative battery chemistries that can ultimately achieve the Long Duration Energy Storage EarthShot target of 5¢/kWh on a levelized cost basis.
  - Initiating a new Fellowship program for the Grid Storage Launchpad (GSL) to leverage the new capabilities being developed at the upcoming GSL facility.
- Validated Reliability and Safety
  - Developing a scientifically derived knowledge base to improve the understanding and predictability of energy storage systems and components under realistic grid use cases, inspiring 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 for an Equitable Regulatory and Social Environment
  - 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.

    - Quantifying the environmental and social impacts storage impacts to decarbonizing the power sector and enabling consistent and reliable power to underserved communities.
    - 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 testing advanced control systems to optimize fleets of diverse energy storage systems to supply existing and emerging grid services.
    - Developing new analytical tools that help quantify the societal and environmental impacts that storage provides to communities with poor electrical reliability.
    - Additional funding support new cohort of communities and projects in recently launched Energy Storage for Social Equity Technical Assistance Program, designed to provide a range of defined, community-centered energy storage analyses including valuation, grid services, system resilience, and equity to measure the relationship between storage investments and community benefit outcomes.
- Storage Grid and Field Validation
    - Develop the Rapid Operational Validation Initiative (ROVI), a cross-cutting analytical framework that can support faster validation and industry acceptance of new storage technologies. ROVI aims to provide at least a 15-year technology life and performance prediction using 1-year or less of data.

Highlights of FY 2023 Budget Request
Grid energy storage is one of the key components for the development of a flexible and resilient electric grid infrastructure. The Request continues support for the program's core R&D agenda including materials research on the next generation of long-duration energy storage technologies, development of new materials and devices 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 request also continues the program's outreach and support to the energy storage industry through workshops with public utility commissions (PUCs), educational programs and materials for code officials and first responders, and technical conferences for industry.

The research 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 storage technologies with an emphasis on longer-duration (8–12 hour) technologies such as flow batteries and new systems based on advanced sodium and zinc chemistries).
- Materials research is aimed at improving the operational lifetime and performance of the chemistries and all critical cell components and moving these technologies toward practical prototypes that can potentially achieve cost-competitive long-range cost targets of 5¢ per kWh levelized cost of storage (LCOS), consistent with the recently announced Long Duration Energy Storage Earthshot.
- Targeted R&D efforts for low-cost, earth-abundant systems (e.g., sodium, zinc manganese dioxide, and lead-based systems) that are coordinated in national programs that engage a cross-section of national laboratories, universities, and industry partners to meet ultimate performance objectives.

In FY 2023, materials and device R&D efforts will progress to validation of novel storage technologies that can cost-effectively provide longer discharge durations (10+ hours continuously), and storage systems that may enable seasonal shifting of electrical energy usage.

The Request also supports a competitive funding opportunity announcement (FOA) that targets innovative, longer-duration energy storage technologies that have require preliminary early-stage validation. The FOA will provide a pathway for demonstration and deployment of new flow or other innovative battery chemistries that can ultimately achieve the Long Duration Energy Storage EarthShot target of 5¢/kWh on a levelized cost basis. This FOA would leverage prior work performed within the OE storage program and the recent EERE-AMO Redox Flow Battery Manufacturing call, and directly supports both the Energy Storage Grand Challenge (ESGC) and the Long Duration Energy Storage Earthshot. This FOA will prepare technologies for scaled demonstrations that would be subsequently supported by the Energy Storage

Demonstration Projects and the Long Duration Demonstration Initiatives created by 42 USC § 17232 (c) and (d), respectively.[a]

Power electronics and power conversion systems can represent up to 30% of an installed storage system's cost. The program's leadership in advanced power electronics will continue with anticipated improvements in new wide-bandgap materials for power electronics and advanced dielectric materials for high voltage capacitors. 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 supporting industry-led effort to establish 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, and providing fundamental research information for use by standards development organizations such as the Institute of Electrical and Electronics Engineers (IEEE), National Fire Protection Association (NFPA), and UL. The Program will continue to engage with national and international safety organizations to understand the root cause of known failures and facilitate uniformity of safety codes and standards. Establishing a validated and referenceable database of energy storage degradation and expected lifetimes, in collaboration with industry, will continue to be a significant program priority as new storage technologies are introduced into the marketplace. The Grid Storage Launchpad will make critical testing and validation capabilities (up to 100kW) available to industry and academia aimed at long-term and accelerated testing methodologies to determine the expected lifetime of storage technologies when operated under grid duty cycles.

Uncertainty on the economic performance of energy storage technologies continues to impede 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 of open-source analytic tools for the North American electric utility industry to ensure availability of tools required for greater adoption of flexible energy storage assets. In addition to quantifying the economic benefits of storage technologies, these new models must also capture the societal and environmental benefits storage can provide to consumers through improved power quality and environmental mitigation. The impact of improving electrical reliability in underserved communities and improvements in air-quality through reduction of fossil generation are examples of benefits that are not currently captured in analytical models but are critical to achieve social equity. Developmental tools that accurately capture the complete economic and societal value proposition for storage in both well-defined markets and non-market conditions will continue to be a priority. 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.

Real-world validation of storage tools and models 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 reliability and equity 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. The program's support of energy storage installations to enhance resilience will continue through joint projects with local and rural utilities responsible for supplying electricity to critical infrastructures. The data and experience from these projects will be used to support 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.

Insufficient operational performance data will be a distinct barrier to wide commercial deployments of new storage technologies. Nascent technologies do not have a long-term operational track record, and traditional calendar-life-based validation methods today will not allow sufficient time to develop, validate and install the various energy storage systems required to meet the Administration's 2035 goals for the Nation. The Rapid Operational Validation Initiative (ROVI) aims to provide at least a 15-year technology life and performance prediction using 1-year or less of data. ROVI is envisioned as a

[a] https://www.law.cornell.edu/uscode/text/42/17232

cross-cutting analytical framework that can support faster validation of storage technologies currently being developed. ROVI will use a combination of physical characterization and performance data, data generated from physics-based models and digital twins, and deployment data. The FY 2023 request includes support for the ROVI framework and its initial development for 1–2 emerging electrochemistries.

The FY 2023 Request continues support for the recently launched Energy Storage for Social Equity Technical Assistance and Pilot Program.[a] Communities across the country face significant energy challenges but may not fully understand how energy storage can be a solution. This program is designed to provide a range of defined, community-centered energy storage analyses including valuation, grid services, system resilience, and equity to measure the relationship between storage investments and community benefit outcomes. The program offers assessments on energy storage feasibility, design, application, operations, and maintenance in support of disadvantaged communities.

Support for 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, was fully funded through the completion of construction by FY 2022 appropriations. Beneficial occupancy is planned for late 2023, and start of operations (CD-4) in 2025. GSL will:

- Focus on materials development and prototype battery systems (up to 100 kW, rather than megawatt-scale systems integration and testing), to identify and solve issues before moving to larger-scale systems
- Standardize grid performance testing across the spectrum of battery materials, battery systems, inverters, auxiliary power, and battery management systems under grid use-case conditions
- Provide an objective national resource to report battery testing performance under grid conditions
- Integrate and coordinate researchers from universities and national labs together to rapidly solve crosscutting science and technology challenges
- 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
- Conduct realistic testing of design options in a laboratory environment

The GSL mission directly supports the ESGC crosscut, the Long Duration Energy Storage Earthshot, and the Rapid Operational Validation Initiative. Project Engineering and Design (PED) funds were used in FY 2020 and FY 2021 to complete the DOE O 413.3B requirements leading up to Critical Decision (CD)–2/3. FY 2021 funding was used to initiate a design-build acquisition strategy in which design and construction services are secured together, including start of construction. The FY 2022 appropriation supports final construction and commissioning of the GSL facility. CD-4 (to approve start of operations) is planned in the last quarter of FY 2025 (including schedule contingency for risk mitigation).

The request includes support to initiate a new GSL Fellowship program. The GSL facility includes space for early-stage entities or early-career innovators to utilize the testing and validation capabilities for storage development. In 2023, this program will be developed and begin initial recruitment. Selections by late 2023 will provide awardees sufficient time to relocate to the GSL in parallel with the anticipated beneficial occupancy date.

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

Energy Storage Grand Challenge: ESGC is a crosscutting effort managed by DOE's Research and Technology Investment Committee (RTIC) and co-chaired by OE and the Office Energy Efficiency and Renewable Energy (EERE). ESGC coordinates R&D across DOE, including complementary R&D investments beyond the applied energy offices, to advance energy storage and technologies that provide similar capabilities. OE's Energy Storage program's request supports grid-related ESGC objectives and other OE R&D efforts are also complementary to ESGC goals. 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 the Energy Storage Grand Challenge, an integrated, comprehensive DOE-wide strategy. The ESGC is deploying 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

[a] https://www.pnnl.gov/projects/energy-storage-social-equity/technical-assistance-program

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.

Energy Storage
Funding ($K)

	FY 2021 Enacted	FY 2022 Enacted Annualized CR[a]	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
Energy Storage					
Research					
Cost-Competitive and Long-Duration Energy Storage	19,500	–	35,000	+15,500	+79.5%
Validated Reliability and Safety	14,700	–	16,200	+1,500	+10.2%
Energy Storage Analytics for an Equitable Regulatory and Social Environment	7,500	–	12,400	+4,900	+65.3%
Grid and Field Validation	10,300	–	17,400	+7,100	+68.9%
Resilience Projects	5,000	–	0	-5,000	-100.0%
Total, Research	57,000	57,000	81,000	+24,000	+42.1%
Construction	23,000	23,000[b]	0	-23,000	-100.0%
Total, Energy Storage	**80,000**	**80,000**	**81,000**	**+1,000**	**+1.3%**

SBIR/STTR:
- FY 2021 Enacted: SBIR/STTR: $1,606
- FY 2023 Request: SBIR/STTR: $2,639

Energy Storage
Explanation of Major Changes ($K)

	FY 2023 Request vs FY 2021 Enacted
Research	
• Cost-Competitive and Long-Duration Energy Storage: Initiate new emerging technology FOA focused on ultra-low-cost chemistries and consistent with goals of the Long Duration Energy Storage Earthshot. Initiate new GSL fellowship program.	+15,500
• Validated Reliability and Safety: Expanded training and technical assistance for fire and safety officials.	+1,500

[a] FY 2022 amounts shown reflect the P.L. 117–95 continuing resolution (CR) level annualized to a full year. These amounts are shown only at the "congressional control" level and above; below that level, a dash (–) is shown.
[b] The FY 2022 appropriation provided $47,000,000 for GSL, which represents full funding through the completion of construction.

	FY 2023 Request vs FY 2021 Enacted
• Energy Storage Analytics for an Equitable Regulatory and Social Environment: Additional funding support new cohort of communities and projects in recently launched Energy Storage for Social Equity Technical Assistance Program.	+4,900
• Grid and Field Validation: Development of the Rapid Operational Validation Initiative, to incorporate data and models for 1–2 chemistries or storage technology types.	+7,100
• Resilience Projects: Planned activities for this Congressionally directed activity are completed with funding provided in FY 2021	-5,000
Total, Research	**+24,000**
Construction	
• The FY 2022 appropriation provided $47,000,000 to complete construction funding for the Grid Storage Launchpad (GSL).	-23,000
Total, Energy Storage	**+1,000**

Energy Storage

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Research $57,000,000	**$81,000,000**	**+$24,000,000**
Cost-Competitive and Long-Duration Energy Storage $19,500,000	*$35,000,000*	*+$15,500,000*
• 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	• Initiate new emerging technology FOA focused on ultra-low-cost chemistries and consistent with goals of the Long Duration Energy Storage Earthshot. Multi-year consortium targeting progress toward the 5¢/kWh levelized cost of storage (LCOS) goal with intermediate targets of 30¢/kWh, 20¢/kWh, etc. • Continue focused development programs on other earth-abundant materials systems (sodium, zinc, sulfur, etc.) with potential to meet 2030 LCOS target	• New $15 million emerging technology FOA focused on ultra-low-cost chemistries and consistent with goals of the Long Duration Energy Storage Earthshot. Multi-year consortium targeting progress toward the 5¢/kWh levelized cost of storage (LCOS) goal with intermediate targets of 30¢/kWh, 20¢/kWh, etc. • Initiate new GSL fellowship program

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
• 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 • Expand R&D efforts on lead-acid batteries as potential grid scale energy storage solutions	• Demonstrate prototype pack architectures with capacities greater than 5 kWh based on 300 Ah zinc-manganese dioxide batteries and projected cell level costs below $50 per kWh when produced in volume • Initiate new GSL fellowship program • Migrate new power electronics and power converter topologies from R&D to scalable prototype formats and demonstrate efficient coupling between batteries and power electronics	
Validated Reliability and Safety $14,700,000	*$16,200,000*	*+$1,500,000*
• 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	• Expand training and technical assistance to fire officials and safety code officials for energy storage best practices. • Continue development and validation of novel control strategies and architectures with industry for distributed control of energy storage 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 grid scale storage system reliability metrics with industry for use at GSL	• Expand training and technical assistance to fire and safety officials
Equitable Regulatory and Social Environment $7,500,000	*$12,400,000*	*+$4,900,000*
• Disseminate open-source software tools and validated analytical models for optimal sizing, location, and operation of grid scale energy storage	• Continues support for execution of projects selected under FY 2022 FOA • Continues engagement with PUC's and States developing energy storage policy and integrated resource planning	• Additional funding supports a new cohort of communities and projects in the recently launched Energy Storage for Social Equity Technical Assistance Program

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
	• Continues Energy Storage for Social Equity Technical Assistance Program	
Grid Deployment and Field Validations $10,300,000	*$17,400,000*	*+$7,100,000*
• 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	• Continues development of higher fidelity software tools and analytical models for the optimal value, sizing based on storage location • Adds additional functionality to tools to quantify environmental (e.g., greenhouse gas reductions) and social benefits storage provides • Development of the Rapid Operational Validation Initiative (ROVI), to incorporate data and models for 1–2 additional chemistries or storage technology types	• Incorporate data and models for 1–2 additional chemistries or storage technology types to populate ROVI
Construction $23,000,000	**$0**	**-$23,000,000**
• Complete funding for construction and commissioning of the Grid Storage Launchpad facility		• No funding is required in FY 2023; full funding for the remainder of construction is provided in FY 2022

Construction Projects Summary ($K)

	Total Project Cost (TPC)	Prior Years	FY 2021 Enacted	FY 2022 Enacted	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted	Future Years
20-OE-100 Grid Storage Launchpad							
Total Estimated Cost (TEC)	75,000	5,000	23,000	47,000	0	-23,000	0
Other Project Costs (OPC)	2,000[a]	1,000[a]	0	0	1,000[a]	+1,000	0
TPC	77,000	6,000	23,000	47,000	1,000	-22,000	0

[a] OPC is funded through laboratory overhead.

Transformer Resilience and Advanced Components

Overview

The Transformer Resilience and Advanced Components (TRAC) program develops innovations for grid hardware to carry, control, and convert electricity. These technologies help the electric grid achieve decarbonization goals, ensure reliability and resilience of electric infrastructure, and adapt the electricity delivery system to the evolution of the electric power grid. TRAC addresses the unique challenges facing transformers, critical components, and other grid hardware technologies responsible for delivering electricity from where it is available to where it is needed. As the electric power system evolves, legacy grid components will need to overcome historic performance limits. Research in advanced power electronics, materials, and sensors will provide the enhancements in next-generation grid hardware required to accommodate the rapidly changing power system. Program activities will ultimately address the need for real and reactive power flow control, facilitate the integration of grid-scale energy storage and new centralized and distributed energy resources (DERs), develop new system components, and increase system efficiency, stability, and resilience.

Decarbonization of the electric grid will require modernization of the transmission and distribution (T&D) systems and application of new components to support the changing mix and characteristics and types of electricity generation. In addition, T&D equipment such as transformers, power lines, and substation equipment are often exposed to the elements and are vulnerable to adverse conditions, which are occurring increasingly often. To support the transition to a decarbonized grid and enhance the security, reliability, and resilience of the electric power system, the next generation of these grid hardware technologies will need to support the requirements of an evolving grid and be built to withstand and rapidly recover from the impact of extreme terrestrial or space weather events, electrical disturbances, equipment failures, accidents, 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 modularity, and sharing in emergency situations as highlighted in the 2021 National Academies Report, *The Future of Electric Power in the United States*.[a]

TRAC focuses on innovative designs, materials research, exploratory concepts (such as a high-voltage direct current (HVDC) 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; many existing components cannot support evolving grid demands, while the age of existing grid assets degrades their ability to withstand physical stresses and may result in higher failure rates that could lead to widespread outages and long restoration times. For example, a large power transformer (LPT) failure could disrupt power to a half million homes and take over 12 months to procure, transport, and install a replacement. A significant percentage of grid infrastructure assets are reaching or past replacement age, and results of the TRAC program will help lay the foundation for the grid of the future by catalyzing advances in the underlying physical infrastructure. TRAC supports projects that spur innovative LPT designs that are more flexible and adaptable, increasing the resilience of the Nation's power grid, and providing the foundation to reinvigorate domestic LPT manufacturing.

Highlights of the FY 2023 Budget Request

To enable the Administration's decarbonization goals, TRAC will accelerate work to address the unique challenges facing LPTs and other critical components, such as advanced conductors and cables, power flow controllers, high voltage direct current (HVDC) equipment, and related grid hardware. The FY 2023 budget request supports testing and field validation of Grid Enhancing Technologies (GETs) by conducting a full scale, multi-faceted field exercise fostering public–private partnerships to accelerate the deployment of GETs for optimal transmission asset utilization and facilitate renewable energy and carbon neutral technology system integration. GETs, such as dynamic line rating and power flow controls, have been shown to improve the energy transfer capabilities of existing transmission paths and are able to be deployed more quickly than building new lines at costs significantly below traditional upgrades.

The FY 2023 budget request also supports the development of characterization methods and tools to evaluate reliability, transient stability, and economics of large-scale direct current (DC) architectures in alternating current (AC) grids. HVDC systems can be an important technology to integrate renewables to load centers in the existing AC transmission systems in

[a] https://nap.nationalacademies.org/catalog/25968/the-future-of-electric-power-in-the-united-states

United States. Some studies have shown that HVDC systems can improve the transient stability, reliability, and economics of operating grids.

TRAC will also continue to address critical research needs for solid-state power substations (SSPS) with an emphasis on advanced materials, embedded intelligence for equipment monitoring, validation of prototype converter building blocks, and medium voltage converter building block development.[a] 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 DERs and energy storage for enhanced resilience. Additionally, efforts will be pursued to expand on the current consortium of academics, vendors, national laboratories, other government agencies, and utilities to guide advancement of the SSPS vision.

Technology, tools, and applications developed under TRAC will be evaluated for security risks including cybersecurity, electromagnetic pulses, and geomagnetic disturbances. Testing and evaluations will be conducted to ensure that security is built-in and new security risks are not being introduced into the electric sector.

TRAC will also expand activities in technology solutions that can provide continued grid reliability under an increased frequency of extreme weather events. Such solutions include fire-resistant distribution infrastructure and improved cost and performance of undergrounded power lines to improve, or harden, the current infrastructure.

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

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

Transformer Resilience and Advanced Components
Funding ($K)

	FY 2021 Enacted	FY 2022 Enacted Annualized CR[a]	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
Transformer Resilience and Advanced Components					
Market and System Impact Analysis	520	–	5,000	+4,480	+861.5%
Component Design and Development	6,670	–	14,500	+7,830	+117.4%
Applied Material R&D	310	–	3,000	+2,690	+867.7%
Total, TRAC	**7,500**	**7,500**	**22,500**	**+15,000**	**+200.0%**

SBIR/STTR:
- FY 2021 Enacted: SBIR/STTR: $247
- FY 2023 Request: SBIR/STTR: $557

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

	FY 2023 Request vs FY 2021 Enacted
• Market and System Impact Analysis: methods and tools to evaluate reliability, transient stability, and economics of large-scale DC architectures	+4,480
• Component Design and Development: increased development of critical power conversion and control technologies; full scale testing and field validation of Grid Enhancing Technologies (GETs)	+7,830
• Applied Materials R&D: advanced materials, embedded intelligence for equipment monitoring, validation of prototype converter building blocks, and medium voltage converter building block development	+2,690
Total, TRAC	**+15,000**

[a] FY 2022 amounts shown reflect the P.L. 117–95 continuing resolution (CR) level annualized to a full year. These amounts are shown only at the "congressional control" level and above; below that level, a dash (–) is shown.

Transformer Resilience and Advanced Components

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Transformer Resilience and Advanced Components $7,500,000	**$22,500,000**	**+$15,000,000**
Market and System Impact Analysis $520,000	*$5,000,000*	*+$4,480,000*
• Establish modeling and testing capabilities to evaluate the performance and interoperability of SSPS building blocks	• Develop the Smart Universal Power Electronics Regulators (SUPER) library, the SSPS controller for the consumer end node and validate the use case • Develop characterization methods and tools to evaluate reliability, transient stability, and economics of large-scale DC architectures in AC grids	• Increased efforts to develop the Smart Universal Power Electronics Regulators (SUPER) library, and characterization methods and tools for large-scale DC architectures
Component Design and Development $6,670,000	*$14,500,000*	*+$7,830,000*
• Continue applied research on converter components • Establish a consortium of diverse stakeholders around the SSPS vision to help guide technology development and maturation	• Develop reliable medium voltage power stages with advanced features for SSPS • Develop advanced medium voltage to high voltage semiconductor modules • Develop advanced gate driver technologies to support advanced semiconductor switches • Develop high voltage auxiliary power supply stages • Develop subsystems to support EMI mitigation and thermal limitations • Develop advanced features for diagnostics and prognostics of future grid interfaces • Test and validate Grid Enhancing Technologies (GETs) by conducting a full scale, multi-faceted field exercise	• Increased development of critical power conversion and control technologies, including medium voltage power stages with advanced features for SSPS, advanced medium voltage to high voltage semiconductor modules, advanced gate driver technologies, high voltage auxiliary power supply stages, subsystems to support EMI mitigation and thermal limitations, and advanced features for diagnostics and prognostics of future grid interfaces • New field testing and validation of GETs

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Applied Material R&D $310,000	*$3,000,000*	*+$2,690,000*
• Applied materials research with an emphasis on packaging and embedded intelligence	• Develop magnetics and passives to advance basic insulation level (BIL) and high frequency requirements for power electronic systems and future grid infrastructure • Develop high voltage and high current interconnects to support the integration of subsystems for large scale power electronic systems • Research to address critical needs in packaging for the high voltage, high current, and high temperature environments associated power electronic systems, transmission, distribution • Address insulation issues associated with transmission, sub-transmission, and distribution voltage grid systems • Fund a prize program to demonstrate Power Electronic Systems (PES) developed using recycled/refurbished parts	• Increased efforts to develop advanced materials, embedded intelligence for equipment monitoring, validation of prototype converter building blocks, and medium voltage converter building block development

Applied Grid Transformation Solutions

Overview

A dramatic transformation of the electric power sector is needed to reach 100% carbon pollution-free electricity by 2035 and net-zero emissions by 2050.[a] This change must take the existing complexity of the system into account through solutions that crosscut nationally across technological innovations, regulatory layers, and a safety- and reliability-focused industry that requires high confidence to consider new solutions. Technologies such as energy storage, electricity delivery hardware, power electronics, grid modeling software, and protection systems each have the potential to provide value to the system when considered in isolation. However, to achieve the drastic system transformation that customers and evolving threats will require to keep the grid reliable and clean, these systems must be developed for integrability, validated, and rapidly incorporated into an increasingly complex existing system in order to meet this evolving need.

The Applied Grid Transformation Solutions (AGTS) program will address the pressing need for rapidly validating and deploying new systems by integrating technology suites in pilot environments to drive new technology adoption. Applied, integrated pilots are needed to validate how new technologies for transmission and distribution will achieve community, state, and national objectives. Today, the benefits of new grid technologies are difficult to extrapolate when tested in isolation, and difficult to quantify when measuring some benefits like resilience or equity. Risk-averse utilities need the ability to quantify and validate benefits before deploying new technologies.

AGTS will integrate technology suites in pilot environments to complete specialized development and broadcast benefits across stakeholders to accelerate adoption. AGTS will optimize technology portfolio operations, reduce technical risk in deployment, directly connect performance results to stakeholder use cases, and build on previous Grid Modernization Laboratory Consortium (GMLC) device and integrated system projects.

AGTS results will enable decisionmakers to drive new technology adoption. The hardware-in-the-loop results will connect to the needs of decisionmakers such as planners, operators, manufacturers, investors, regulators, and ratepayers. After demonstration, AGTS will encapsulate results to enable decisionmakers to evaluate new T&D approaches alongside legacy solutions. The results can also help technology vendors address emerging market opportunities.

Through integrated pilots, AGTS will enable the availability a validated suite of technology solutions to planners and decision-makers. By working with stakeholders to understand the needs and rapidly evolving demands of the grid, and showing how integrated pilot technologies meet that evolution, the power sector will be better positioned to meet the aggressive goals, address the customer demands, and protect against extreme conditions of the future system.

Highlights of the FY 2023 Budget Request

AGTS is a new program in FY 2023 that will initiate 2–3 integrated pilots to show how new technologies can help achieve stakeholder objectives. For each applied demonstration area, AGTS will consult stakeholders ensure that the project scope and outputs will be immediately useful to targeted decisionmakers. AGTS will identify the most suitable test bed to conduct the demonstration, and then select a suite of technologies that can be used to achieve the desired functionality. These technologies could include:

- High voltage direct current (HVDC)
- Modular large power transformers (LPTs)
- Dynamic line rating and dynamic transformer rating
- Power flow controllers (PFCs)
- Sensors and visibility
- Topology control algorithms
- Energy storage
- Power electronics

These technologies will be integrated onto the test bed and operated to validate the operational capabilities of the new technologies. AGTS will connect hardware-in-the-loop demonstration results to the informational needs of decisionmakers

[a] https://www.whitehouse.gov/briefing-room/presidential-actions/2021/01/27/executive-order-on-tackling-the-climate-crisis-at-home-and-abroad/

(planners, operators, manufacturers, investors, regulators, ratepayers) and explore benefits such as cost, ratepayer impact, emissions, access, and enhanced reliability. Coordinating with stakeholders to quantify and disseminate the measured benefits is essential to a successful demonstration, as is understanding the alignment of benefits and incentives as it relates to these new technologies. At the conclusion of the project, decisionmakers should have sufficient information to evaluate new T&D approaches alongside legacy solutions. Project results can also inform manufacturers of these new technologies in addressing new or emerging market opportunities.

In 2023, AGTS will:

- Scope and solicit an initial cohort of potential projects, potentially through a phased down-select process.
- Develop test beds and initiate 2–3 pilots to validate operational capabilities of advanced grid technologies.
- Conduct stakeholder-focused Grid Transformation Summits to show how new technologies enable community, state, and regional goals.
- Provide technical assistance through modeling, analysis, and use case validation by leveraging existing AGR&D and GMI tools and utilizing pilot projects to test stakeholder-focused hardware-in-the-loop use cases.

AGTS will include coordination with the GMLC on shared technology development objectives.

Applied Grid Transformation Solutions
Funding ($K)

	FY 2021 Enacted	FY 2022 Enacted Annualized CR[a]	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
Applied Grid Transformation Solutions					
Scoping, Design, and Stakeholder Collaboration	0	–	10,000	+10,000	N/A
Demonstrations	0	–	20,000	+20,000	N/A
Total, AGTS	**0**	**0**	**30,000**	**+30,000**	**N/A**

SBIR/STTR:
- FY 2021 Enacted: SBIR/STTR: $0
- FY 2023 Request: SBIR/STTR: $73

Applied Grid Transformation Solutions
Explanation of Major Changes ($K)

	FY 2023 Request vs FY 2021 Enacted
• Scoping, Design, and Stakeholder Collaboration: Conduct stakeholder-focused Grid Transformation Summits and provide technical assistance through modeling, analysis, and validation by leveraging existing OE R&D and GMI tools, and utilizing pilot projects to test stakeholder-focused hardware-in-the-loop use cases	+10,000
• Demonstrations: Develop test beds; solicit and initiate 2–3 pilots to validate operational capabilities of advanced grid technologies.	+20,000
Total, AGTS	**+30,000**

[a] FY 2022 amounts shown reflect the P.L. 117–95 continuing resolution (CR) level annualized to a full year. These amounts are shown only at the “congressional control” level and above; below that level, a dash (–) is shown.

Applied Grid Transformation Solutions

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Applied Grid Transformation Solutions $0	**$30,000,000**	**+$30,000,000**
Scoping, Design, and Stakeholder Collaboration $0	*$10,000,000*	*+$10,000,000*
	• Conduct stakeholder-focused Grid Transformation Summits • Technical assistance through modeling, analysis, and use case validation	• This is a new activity in FY 2023
Demonstrations $0	*$20,000,000*	*+$20,000,000*
	• Develop test beds • Initiate 2–3 demonstrations	• This is a new activity in FY 2023

Defense Critical Electric Infrastructure Energy Mission Assurance

Overview

The Defense Critical Electric Infrastructure (DCEI) Energy Mission Assurance program was established in FY 2021 to identify, evaluate, prioritize, and assist in developing executable strategies to ensure that critical national defense and security missions have reliable access to power as energy supply disruptions threaten the civilian grid due to intensifying cybersecurity threats and other hazards. This effort directly supports Secretary of Energy's authority to designate Critical Defense Facilities (CDFs) and identify their associated DCEI under Sec. 215A of the Federal Power Act (FPA) as amended by the Fixing America's Surface Transportation (FAST) Act in 2015. This effort complements additional DOE authorities including emergency grid orders under Sec. 202(c) of the FPA, the protection of critical infrastructure in the energy sector under Presidential Policy Directive 21, improving critical infrastructure cybersecurity under Executive Order 13636, strengthening the cybersecurity of Federal networks and critical infrastructure under Executive Order 13800, and other Departmental authorities and capabilities.

In FY 2022, DOE proposed a realignment of activities, and as part of that realignment, the functions of the DCEI Energy Mission Assurance program were moved to the Office of Cybersecurity, Energy Security, and Emergency Response (CESER) to be integrated with CESER's suite of activities partnering with, supporting, and sharing information with the electric utility industry to enhance energy resilience through its energy assurance planning efforts.

Highlights of the FY 2023 Budget Request

No funding is requested in OE in FY 2023 for DCEI Energy Mission Assurance.

DCEI Energy Mission Assurance
Funding ($K)

	FY 2021 Enacted	FY 2022 Enacted Annualized CR[a]	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
DCEI Energy Mission Assurance	**1,000**	**1,000**	**0**	**-1,000**	**-100.0%**

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

	FY 2023 Request vs FY 2021 Enacted
• Responsibility for the activities formerly funded in the DCEI Energy Mission Assurance program has been transferred to CESER	-1,000

DCEI Energy Mission Assurance

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
DCEI Energy Mission Assurance $1,000,000	**$0**	**-$1,000,000**
• Develop electric power resiliency requirements and metrics for essential critical infrastructure nodes • Develop electric power resiliency strategies and evaluation methodologies for Critical Defense Facilities • Identify and select at least one site for execution of a suite of site-specific strategies	• Responsibility for the activities formerly funded in the DCEI Energy Mission Assurance program has been transferred to CESER	• No funding is requested in OE in FY 2023 for DCEI Energy Mission Assurance

[a] FY 2022 amounts shown reflect the P.L. 117–95 continuing resolution (CR) level annualized to a full year. These amounts are shown only at the "congressional control" level and above; below that level, a dash (–) is shown.

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 regarding 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 analyses 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.

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

Highlights of the FY 2023 Budget Request

The FY 2023 Program Direction Request reflects a small increase in the Headquarters staffing pay due to planned staffing levels that support OE's proposed growing portfolio of activities in OE's programs. The increases also address within grade promotions and step increases in some program areas. With the heightened attention and priority of OE's mission to accelerate the transformation of our Nation's power grid, proper staffing levels are crucial to expeditiously meet our goals and objectives. This Request allows for staffing that the programs to address skill gaps and succession planning.

Program Direction
Funding ($K)

	FY 2021 Enacted	FY 2021 Enacted (Comparable)[a]	FY 2022 Enacted Annualized CR[b]	FY 2022 CR (Comparable)[ab]	FY 2023 Request	FY 2023 Request vs FY 2021 Comp. ($)	FY 2023 Request vs FY 2021 Comp. (%)
Program Direction Summary							
Washington Headquarters							
Salaries and Benefits	9,873	7,913	–	–	10,182	+2,269	+28.7%
Travel	300	250	–	–	310	+60	+24.0%
Support Services	1,440	1,077	–	–	1,098	+21	+1.9%
Other Related Expenses	2,965	2,668	–	–	2,861	+193	+7.2%
Total, Washington Headquarters	**14,578**	**11,908**	–	–	**14,451**	**+2,543**	**+21.4%**
National Energy Technology Laboratory							
Salaries and Benefits	1,700	1,468	–	–	1,511	+43	+2.9%
Travel	130	100	–	–	45	-55	-55%
Support Services	371	320	–	–	324	+4	+1.3%
Other Related Expenses	1,221	1,204	–	–	1,255	+51	+4.2%
Total, National Energy Technology Laboratory	**3,422**	**3,092**	–	–	**3,135**	**+43**	**+1.4%**
Total Program Direction							
Salaries and Benefits	11,573	9,381	–	–	11,693	+2,312	+24.6%
Travel	430	350	–	–	355	+5	+1.4%
Support Services	1,811	1,397	–	–	1,422	+25	+1.8%
Other Related Expenses	4,186	3,872	–	–	4,116	+244	+6.3%
Total, Program Direction	**18,000**	**15,000**	**18,000**	**15,000**	**17,586**	**+2,586**	**+17.2%**

[a] The FY 2023 Budget Request to Congress proposes to split the Electricity appropriation account into two accounts: Electricity and Grid Deployment Office. To allow an apples-to-apples comparison with the FY 2023 Request, the comparable amounts for FY 2021 and FY 2022 exclude a portion of Program Direction funding equivalent to what would have been in the Grid Deployment Office had the proposed structure been in place in FY 2021 and FY 2022.

[b] FY 2022 amounts shown reflect the P.L. 117–95 continuing resolution (CR) level annualized to a full year. These amounts are shown only at the "congressional control" level and above; below that level, a dash (–) is shown.

	FY 2021 Enacted	FY 2021 Enacted (Comparable)[a]	FY 2022 Enacted Annualized CR[b]	FY 2022 CR (Comparable)[ab]	FY 2023 Request	FY 2023 Request vs FY 2021 Comp. ($)	FY 2023 Request vs FY 2021 Comp. (%)
Federal FTEs	**63**	**56**	–	–	**63**	**+7**	**+12.5%**
Additional FE FTEs at NETL supporting OE[a]	11	10	–	–	10	0	0.0%
Total OE-funded FTEs	74	66	–	–	73	+7	+10.6%
Support Services and Other Related Expenses							
Support Services							
Technical Support	964	744	–	–	757	+13	+1.7%
Management Support	847	653	–	–	665	+12	+1.8%
Total, Support Services	**1,811**	**1,397**	–	–	**1,422**	**+25**	**+1.8%**
Other Related Expenses							
Other Services	1,250	1,234	–	–	1,451	+217	+17.6%
EITS Desktop Services	392	330	–	–	593	+263	+79.7%
WCF	2,544	2,308	–	–	2,072	-236	-10.2%
Total, Other Related Expenses	**4,186**	**3,872**	–	–	**4,116**	**+244**	**+6.3%**

Program Direction

Activities and Explanation of Changes

FY 2021 Enacted (Comparable)	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Program Direction $15,000,000	**$17,586,000**	**+$2,586,000**
Salaries and Benefits $9,381,000	*$11,693,000*	*+$2,312,000*
• Salaries and Benefits support 66 FTEs at HQ and NETL that provide executive management, programmatic oversight, and analysis for the effective implementation of the OE program	• Salaries and Benefits support 73 FTEs at HQ and NETL that provide executive management, programmatic oversight, and analysis for the effective implementation of the OE program	• Supports 7 additional FTEs and the 2023 Federal pay increase

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

FY 2021 Enacted (Comparable)	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
• An additional 4 OE FTEs at HQ are reimbursed by FEMA through an interagency agreement for place-based long-term recovery and power system resilience planning	• An additional 4 OE FTEs at HQ are reimbursed by FEMA through an interagency agreement for place-based long-term recovery and power system resilience planning	
Travel $350,000	*$355,000*	*+$5,000*
• Travel includes transportation, subsistence, and incidental expenses that allow OE to effectively facilitate its mission	• Travel includes transportation, subsistence, and incidental expenses that allow OE to effectively facilitate its mission	• Increase due to the rising cost of air fares, baggage fees, and per diem
Support Services $1,397,000	*$1,422,000*	*+$25,000*
• 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	• 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	• Increase in support services to support NAERM, Cyber R&D, and increasing IT Governance requirements
Other Related Expenses $3,872,000	*$4,116,000*	*+$244,000*
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	• 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	• Other Related Expenses increases due to additional IT equipment, cellular services, and other IT related expenses with offsetting WCF decreases for transit subsidies and supply store purchases

Electricity

Research and Development ($K)[a]

	FY 2021 Enacted	FY 2022 Enacted Annualized CR[b]	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
Basic	14,146	–	15,185	+1,039	+7.3%
Applied	56,453	–	86,119	+29,666	+52.5%
Development	75,587	–	84,588	+9,001	+11.9%
Total, R&D	146,186	–	185,892	+39,706	+27.2%
R&D-related construction	25,137	–	0	-25,137	-100.0%
Total, R&D and related facilities	171,323	–	185,892	+14,569	+8.5%

Electricity

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

	FY 2021 Enacted Transfer	FY 2022 Annualized CR Projected Transfer	FY 2023 Request Projected Transfer	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
Transmission Reliability and Resilience	1,527	–	1,155	-372	-24.4%
Resilient Distribution Systems	1,265	–	1,315	+50	+4.0%
Cyber Resilient and Secure Utility Communication Networks	0	–	412	+412	N/A
Energy Storage	1,607	–	2,639	+1,032	+64.2%
Transformer Resilience and Advanced Components	247	–	557	+310	+125.5%
Applied Grid Transformation Solutions	0	–	73	+73	N/A
Total, SBIR/STTR	4,646	–	6,151	+1,505	+32.4%

[a] R&D reporting includes a proportional share of program direction funding in addition to direct R&D funding.
[b] FY 2022 amounts shown reflect the P.L. 117–95 continuing resolution (CR) level annualized to a full year. These amounts are shown only at the "congressional control" level and above; below that level, a dash (–) is shown.

DEPARTMENT OF ENERGY
Funding by Site Detail
Electricity FY 2023
(Dollars in Thousands)

	FY 2021 Enacted Requested Total	FY 2022 Annualized CR Requested Total	FY 2023 Request Detail Requested Total
Argonne National Laboratory			
Transmission Reliability and Resilience	3,972	0	3,250
Energy Delivery Grid Operations Technology	0	0	1,300
Resilient Distribution Systems	1,328	0	1,300
Cyber Resilient & Secure Utility Communication Network (SecureNet)	0	0	500
Grid Controls and Communications	5,300	0	6,350
Energy Storage R&D	100	0	100
Energy Storage	100	0	100
Grid Hardware, Components, and Systems	100	0	100
DCEI Energy Mission Assurance	500	500	0
Transmission Permitting and Technical Assistance	250	0	0
Total Argonne National Laboratory	**6,150**	**500**	**6,450**
Brookhaven National Laboratory			
Transmission Reliability and Resilience	900	0	1,000
Grid Controls and Communications	900	0	1,000
Total Brookhaven National Laboratory	**900**	**0**	**1,000**
Consolidated Service Center - Tennessee			
Transmission Reliability and Resilience	15	0	0
Grid Controls and Communications	15	0	0
Total Consolidated Service Center - Tennessee	**15**	**0**	**0**
Idaho National Laboratory			
Transmission Reliability and Resilience	3,266	0	5,350
Energy Delivery Grid Operations Technology	0	0	700
Resilient Distribution Systems	1,460	0	1,300
Cyber Resilient & Secure Utility Communication Network (SecureNet)	0	0	1,000
Grid Controls and Communications	4,726	0	8,350
Energy Storage R&D	50	0	100
Energy Storage	50	0	100
Transformer Resilience and Advanced Components	190	0	500
Grid Hardware, Components, and Systems	240	0	600
Total Idaho National Laboratory	**4,966**	**0**	**8,950**
Idaho Operations Office			
Transmission Reliability and Resilience	5	0	0
Grid Controls and Communications	5	0	0
Total Idaho Operations Office	**5**	**0**	**0**
Lawrence Berkeley National Laboratory			
Transmission Reliability and Resilience	1,657	0	3,050
Resilient Distribution Systems	1,263	0	1,300
Grid Controls and Communications	2,920	0	4,350
Transmission Permitting and Technical Assistance	250	0	0
Total Lawrence Berkeley National Laboratory	**3,170**	**0**	**4,350**
Lawrence Livermore National Laboratory			
Transmission Reliability and Resilience	6,319	0	2,650
Energy Delivery Grid Operations Technology	0	0	8,000
Resilient Distribution Systems	996	0	900

DEPARTMENT OF ENERGY
Funding by Site Detail
Electricity FY 2023
(Dollars in Thousands)

	FY 2021 Enacted Requested Total	FY 2022 Annualized CR Requested Total	FY 2023 Request Detail Requested Total
Grid Controls and Communications	7,315	0	11,550
Total Lawrence Livermore National Laboratory	**7,315**	**0**	**11,550**
Los Alamos National Laboratory			
Transmission Reliability and Resilience	3,926	0	3,250
Energy Delivery Grid Operations Technology	0	0	4,500
Resilient Distribution Systems	1,281	0	1,300
Grid Controls and Communications	5,207	0	9,050
Total Los Alamos National Laboratory	**5,207**	**0**	**9,050**
National Energy Technology Lab			
Transmission Reliability and Resilience	250	0	2,000
Energy Delivery Grid Operations Technology	0	0	500
Cyber Resilient & Secure Utility Communication Network (SecureNet)	0	0	1,900
Grid Controls and Communications	250	0	4,400
Program Direction - Electricity	1,469	2,610	1,435
Total National Energy Technology Lab	**1,719**	**2,610**	**5,835**
National Renewable Energy Laboratory			
Transmission Reliability and Resilience	4,615	0	1,600
Energy Delivery Grid Operations Technology	0	0	1,000
Resilient Distribution Systems	5,350	0	5,300
Cyber Resilient & Secure Utility Communication Network (SecureNet)	0	0	3,000
Grid Controls and Communications	9,965	0	10,900
Energy Storage R&D	208	0	100
Energy Storage	208	0	100
Transformer Resilience and Advanced Components	0	0	1,000
Grid Hardware, Components, and Systems	208	0	1,100
Transmission Permitting and Technical Assistance	3,725	0	0
Total National Renewable Energy Laboratory	**13,898**	**0**	**12,000**
Oak Ridge National Laboratory			
Transmission Reliability and Resilience	9,208	0	2,350
Energy Delivery Grid Operations Technology	0	0	10,000
Resilient Distribution Systems	13,587	0	12,900
Grid Controls and Communications	22,795	0	25,250
Energy Storage R&D	2,815	0	3,600
Energy Storage	2,815	0	3,600
Transformer Resilience and Advanced Components	6,000	0	16,000
Grid Hardware, Components, and Systems	8,815	0	19,600
Total Oak Ridge National Laboratory	**31,610**	**0**	**44,850**
Pacific Northwest National Laboratory			
Transmission Reliability and Resilience	10,103	0	6,850
Energy Delivery Grid Operations Technology	0	0	9,500
Resilient Distribution Systems	17,016	0	16,500
Cyber Resilient & Secure Utility Communication Network (SecureNet)	0	0	2,000
Grid Controls and Communications	27,119	0	34,850
Energy Storage R&D	19,400	0	23,800
20-OE-100 Grid Storage Launchpad	22,968	23,000	0
Construction - Energy Storage	22,968	23,000	0
Energy Storage	42,368	23,000	23,800
Transformer Resilience and Advanced Components	140	0	1,000
Grid Hardware, Components, and Systems	42,508	23,000	24,800

DEPARTMENT OF ENERGY
Funding by Site Detail
Electricity FY 2023
(Dollars in Thousands)

	FY 2021 Enacted Requested Total	FY 2022 Annualized CR Requested Total	FY 2023 Request Detail Requested Total
Transmission Permitting and Technical Assistance	280	0	0
Total Pacific Northwest National Laboratory	**69,907**	**23,000**	**59,650**
Sandia National Laboratories			
Transmission Reliability and Resilience	2,186	0	2,550
Energy Delivery Grid Operations Technology	0	0	3,000
Resilient Distribution Systems	3,176	0	3,100
Cyber Resilient & Secure Utility Communication Network (SecureNet)	0	0	1,100
Grid Controls and Communications	5,362	0	9,750
Energy Storage R&D	32,458	0	33,000
Energy Storage	32,458	0	33,000
Transformer Resilience and Advanced Components	365	0	1,000
Grid Hardware, Components, and Systems	32,823	0	34,000
Transmission Permitting and Technical Assistance	290	0	0
Total Sandia National Laboratories	**38,475**	**0**	**43,750**
SLAC National Accelerator Laboratory			
Transmission Reliability and Resilience	260	0	0
Resilient Distribution Systems	55	0	0
Grid Controls and Communications	315	0	0
Total SLAC National Accelerator Laboratory	**315**	**0**	**0**
Undesignated Lab/Plant/Installation			
Energy Delivery Grid Operations Technology	0	0	20
Grid Controls and Communications	0	0	20
Total Undesignated Lab/Plant/Installation	**0**	**0**	**20**
Washington Headquarters			
Transmission Reliability and Resilience	3	288	245
Energy Delivery Grid Operations Technology	0	0	300
Resilient Distribution Systems	1,186	1,474	1,500
Grid Controls and Communications	1,189	1,762	2,045
Energy Storage R&D	200	287	600
Energy Storage	200	287	600
Transformer Resilience and Advanced Components	225	228	200
Grid Hardware, Components, and Systems	425	515	800
Transmission Permitting and Technical Assistance	764	1,082	0
Program Direction - Electricity	13,931	15,390	13,608
Total Washington Headquarters	**16,309**	**18,749**	**16,453**
Western Area Power Administration Office			
Transmission Reliability and Resilience	15	0	0
Grid Controls and Communications	15	0	0
Total Western Area Power Administration Office	**15**	**0**	**0**
Grants			
Transmission Reliability and Resilience	1,494	1,494	3,155
Energy Delivery Grid Operations Technology	0	0	180
Resilient Distribution Systems	3,002	2,714	4,300
Cyber Resilient & Secure Utility Communication Network (SecureNet)	0	0	10,230
Grid Controls and Communications	4,496	4,208	17,865
Energy Storage R&D	1,751	809	19,575
20-OE-100 Grid Storage Launchpad	32	0	0

DEPARTMENT OF ENERGY
Funding by Site Detail
Electricity FY 2023
(Dollars in Thousands)

	FY 2021 Enacted Requested Total	FY 2022 Annualized CR Requested Total	FY 2023 Request Detail Requested Total
Construction - Energy Storage	32	0	0
Energy Storage	1,783	809	19,575
Transformer Resilience and Advanced Components	197	194	2,060
Applied Grid Transformation Solutions	0	0	15,000
Grid Hardware, Components, and Systems	1,980	1,003	36,635
Transmission Permitting and Technical Assistance	1,313	3,100	0
Program Direction - Electricity	2,600	0	2,543
Total Grants	**10,389**	**8,311**	**57,043**
Undesignated LPI			
Transmission Reliability and Resilience	26	46,438	0
Resilient Distribution Systems	300	45,812	300
Cyber Resilient & Secure Utility Communication Network (SecureNet)	0	0	270
Grid Controls and Communications	326	92,250	570
Energy Storage R&D	18	55,904	125
Energy Storage	18	55,904	125
Transformer Resilience and Advanced Components	383	7,078	740
Applied Grid Transformation Solutions	0	0	15,000
Grid Hardware, Components, and Systems	401	62,982	15,865
DCEI Energy Mission Assurance	500	500	0
Transmission Permitting and Technical Assistance	128	2,818	0
Total Undesignated LPI	**1,355**	**158,550**	**16,435**
Total Funding by Site - Electricity	**211,720**	**211,720**	**297,386**

Nuclear Energy

Nuclear Energy

Nuclear Energy
($K)

FY 2021 Enacted[1,2]	FY 2022 Annualized CR[3]	FY 2023 Request
1,507,600	1,507,600	1,675,060

Overview

Nuclear energy is a key element of the President's plan to put the United States (U.S.) on a path to net-zero emissions by 2050. America's nuclear energy sector provides approximately 55 percent of the nation's annual clean electricity production and generates about 20 percent of U.S. electricity from a fleet of 93 operating units in 28 states. America's nuclear energy sector also plays key national security and global strategic roles for the U.S., including nuclear nonproliferation.

The U.S. pioneered the development and peaceful use of nuclear power to produce around-the-clock, emission-free baseload electricity generation as well as the development of the civilian nuclear fuel cycle. The Office of Nuclear Energy (NE) is now leading the effort to move new and innovative advanced reactors, small modular reactors, and microreactors from the conceptual and development stages into the commercial energy sector. NE executes its mission through investments in early-stage research and development efforts with the national laboratories, U.S. universities, and industry technical organizations, as well as through partnerships with the U.S. industry and commercial stakeholders to develop and demonstrate advanced reactor technologies and designs.

The FY 2023 Request helps to advance U.S. leadership in critical technologies, invest in our workforce, and upgrade America's research infrastructure. U.S. leadership in new nuclear technologies is critical to both our future economic competitiveness and our national security.

The Office of Nuclear Energy (NE) focuses on three major mission area: the nation's existing nuclear fleet, the development of advanced nuclear reactor concepts, and fuel cycle technologies. Investments in these areas leverage the tremendous innovation capacity of the United States' National Laboratories, universities, and advanced reactor developers to transform America's power sector. NE is also responsible for ensuring the secure operational availability of the Idaho National Laboratory (INL) as a national asset supporting a broad range of civilian and national security research.

The NE FY 2023 Request will extend the impact of our RD&D (Research, Development, & Demonstration) funding by leveraging creative funding mechanisms - such as prizes, competitions, technical assistance, and programs targeted to small businesses. The goal is to enable the commercialization of climate change and clean energy innovations that will activate job creation, expand other public impact outcomes, and yield a more geographically diverse and impactful research portfolio.

[1] Funding does not reflect the transfer of SBIR/STTR to the Office of Science.
[2] Funding does not reflect the mandatory transfer of $91.0M from Naval Reactors for operation of the Advanced Test Reactor.
[3] Funding does not reflect the mandatory transfer of $91.0M from Naval Reactors for operation of the Advanced Test Reactor.

Highlights and Major Changes in the FY 2023 Budget Request

Supporting the President's commitment to put America on a path to achieve net-zero emissions no later than 2050 by investing in resilience, clean energy innovation and U.S. competitiveness, the NE budget request provides a $167.5M increase (+11%) above the FY 2021 appropriation. These investments will leverage the tremendous innovation capacity of the National Laboratories, universities, and advanced reactor developers to transform America's power sector.

- A new element, **Directed R&D and University Programs**, requests $161.0M to consolidate and focus support to universities and small businesses in areas relevant to NE's mission. Most of this support will be awarded through competitive opportunities for researchers, students, faculty, and small businesses. Additionally, the program will continue to provide fuel services and support maintenance and safety upgrades of fuel fabrication equipment and facilities for U.S. university research reactors. This program also seeks to ensure that access to these opportunities and benefits are equitably provided, specifically seeking ways to include communities that have historically faced limits in access to such capabilities, such as students and faculty at Minority Serving Institutions (MSIs). These efforts will include initiating a competitively awarded, consortium-led project to establish an advanced research reactor at a U.S. university, potentially along with additional, complementary research infrastructure at additional locations.
- **High-Assay, Low Enriched Uranium (HALEU) Availability**, requests $95M to make available small quantities of HALEU from limited DOE uranium inventories and HALEU production in the short term and will work with the private sector in its design and establishment of commercial U.S. HALEU production capability in the long term.
- The **Advanced Reactor Demonstration Program** is requesting $230.2M to focus Departmental and non-federal resources on supporting the development of advanced reactors that have the potential for near and mid-term demonstration and commercial deployment and addressing challenges hindering their deployment. In the FY 2022 Bipartisan Infrastructure Law (BIL) (Infrastructure Investment and Jobs Act, P.L. 117-58, November 15, 2021, multi-year funding for the advanced reactor demonstration elements of this program was provided under the new Office of Clean Energy Demonstrations (OCED) and as such no FY 2023 funding is requested within NE.
- $53M is requested to support the implementation of a consent-based siting process for an **interim storage** facility to address the near-term requirements for storage of commercial used fuel. These funds are included within the Integrated Waste Management System subprogram within the Fuel Cycle R&D program.
- Acknowledging the tremendous recent advances that have been made in microreactor research and development, the **Transformational Challenge Reactor** effort is ended in FY 2023. The associated crosscutting research, particularly in areas such as advanced manufacturing, are integrated into the base NE R&D programs.
- Within its **Infrastructure Program**, NE is requesting $326M for INL Facilities Operations and Maintenance (IFM) subprogram. The request will focus on maintaining mission critical facilities to support technical advancements in existing nuclear fleet, reactors, and nuclear fuel cycle. It will also focus on investing in the Advanced Test Reactor (ATR) Complex and the Materials and Fuels Complex to improve reliability and modernize capabilities in support of nuclear energy R&D objectives. Additionally, within the Construction subprogram, NE is requesting $7.3M to complete the Sample Preparation Laboratory (SPL) at INL, which will provide world-class capability to conduct post-irradiation examinations at micro/nano scale of existing and advanced nuclear fuels and materials.

Nuclear Energy
Funding by Congressional Control ($K)

	FY 2021 Enacted[1,2]	FY 2022 Annualized CR[1,3]	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
Directed R&D and University Programs					
Directed Research and Development	0	0	137,029	+137,029	+100%
University Nuclear Leadership Program	0	0	6,500	+6,500	+100%
University Fuel Services	0	0	17,500	+17,500	+100%
Directed R&D and University Programs	**0**	**0**	**161,029**	**+161,029**	**+100%**
Integrated University Program	**5,000**	**5,000**	**0**	**+0**	**+0%**
STEP Research & Development (R&D)	**5,000**	**5,000**	**0**	**+0**	**+0%**
Reactor Concepts Research, Development & Demonstration (RD&D)					
Advanced SMR RD&D	115,000	115,000	40,000	-75,000	-65%
Light Water Reactor Sustainability	47,000	47,000	45,000	-2,000	-4%
Advanced Reactor Technologies	46,000	46,000	50,000	+4,000	+9%
Reactor Concepts RD&D	**208,000**	**208,000**	**135,000**	**-73,000**	**-35%**
Fuel Cycle Research and Development					
Mining, Conversion and Transportation	2,000	2,000	1,500	-500	-25%
Civil Nuclear Enrichment	40,000	40,000	0	-40,000	-100%
Materials Recovery and Waste Form Development	25,000	25,000	38,000	+13,000	+52%
Accident Tolerant Fuels	105,800	105,800	113,900	+8,100	+8%
TRISO and Graphite Qualification	36,000	36,000	27,000	-9,000	-25%
Fuel Cycle Core R&D	20,000	20,000	46,500	+26,500	+133%
High Assay Low Enriched Uranium Availability	0	0	95,000	+95,000	+100%
Used Nuclear Fuel Disposition R&D	62,500	62,500	46,875	-15,625	-25%
Integrated Waste Management System	18,000	18,000	53,000	+35,000	+194%
Fuel Cycle R&D	**309,300**	**309,300**	**421,775**	**+112,475**	**+36%**

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[2] Funding does not reflect the mandatory transfer of $91.0M from Naval Reactors for operation of the Advanced Test Reactor.
[3] Funding does not reflect the mandatory transfer of $91.0M from Naval Reactors for operation of the Advanced Test Reactor.

	FY 2021 Enacted[1,2]	FY 2022 Annualized CR[1,3]	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
Nuclear Energy Enabling Technologies					
Crosscutting Technology Development	28,000	28,000	35,250	+7,250	+26%
Joint Modeling and Simulation Program	35,000	35,000	28,327	-6,673	-19%
Nuclear Science User Facilities	30,000	30,000	39,160	+9,160	+31%
Transformational Challenge Reactor	29,869	29,869	0	-29,869	-100%
Nuclear Energy Enabling Technologies	**122,869**	**122,869**	**102,737**	**-20,132**	**-16%**
Advanced Reactor Demonstration Program					
National Reactor Innovation Center	30,000	30,000	75,000	+45,000	+150%
Demonstration 1	80,000	80,000	0	-80,000	-100%
Demonstration 2	80,000	80,000	0	-80,000	-100%
Risk Reduction for Future Demonstrations	40,000	40,000	140,238	+100,238	+251%
Regulatory Development	15,000	15,000	10,250	-4,750	-32%
Advanced Reactor Safeguards	5,000	5,000	4,750	-250	-5%
Subtotal, Advanced Reactors Demonstration Program	**250,000**	**250,000**	**230,238**	**-19,762**	**-8%**
Versatile Test Reactor Project					
Other Project Costs	43,000	43,000	45,000	+2,000	+5%
21-E-200, Versatile Test Reactor	2,000	2,000	0	-2,000	-100%
Versatile Test Reactor Project	**45,000**	**45,000**	**45,000**	**+0**	**+0%**
Infrastructure					
INL Facilities Operations & Maintenance	280,000	280,000	326,924	+46,924	+17%
ORNL Infrastructure Facilities O&M	20,000	20,000	0	-20,000	-100%
Research Reactor Infrastructure	11,500	11,500	0	-11,500	-100%
Construction					
16-E-200, Sample Preparation Laboratory	26,000	26,000	7,300	-18,700	-72%
Subtotal, Infrastructure	**337,500**	**337,500**	**334,224**	**-3,276**	**-1%**

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[2] Funding does not reflect the mandatory transfer of $91.0M from Naval Reactors for operation of the Advanced Test Reactor.

[3] Funding does not reflect the mandatory transfer of $91.0M from Naval Reactors for operation of the Advanced Test Reactor.

	FY 2021 Enacted[1,2]	FY 2022 Annualized CR[1,3]	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
Idaho Sitewide Safeguards and Security	**149,800**	**149,800**	**156,600**	**+6,800**	**+5%**
International Nuclear Energy Cooperation	**0**	**0**	**3,000**	**+3,000**	**+100%**
Program Direction	**75,131**	**75,131**	**85,457**	**+10,326**	**+14%**
Total, Nuclear Energy R&D	**1,507,600**	**1,507,600**	**1,675,060**	**+167,460**	**+11%**
Federal FTEs	256	283	356	+100	+39%

SBIR/STTR:

- FY 2021 Transferred: SBIR $16,564; STTR $2,329
- FY 2022 Projected: SBIR $25,636; STTR $3,605
- FY 2023 Request: SBIR $22,513; STTR $3,166

Future Year Energy Program

($K)					
	FY 2023 Request	**FY 2024**	**FY 2025**	**FY 2026**	**FY 2027**
Nuclear Energy (Non 050)	1,518,460	1,553,000	1,589,000	1,625,000	1,663,000
Nuclear Energy (050) S&S	156,600	161,000	164,000	168,000	172,000

Outyear Priorities and Assumptions

In the FY 2012 Consolidated Appropriations Act (P.L. 112-74), Congress directed the Department to include a future-years energy program (FYEP) in subsequent requests that reflects the proposed appropriations for five years. This FYEP shows outyear funding for each account for FY 2024 - FY 2027. The outyear funding levels use the growth rates from and match the outyear account totals published in the FY 2023 President's Budget for both the 050 and non-050 accounts. Actual future budget request levels will be determined as part of the annual budget process.

Nuclear Energy priorities in the outyears include the following:

- Supporting the five Risk Reduction for Future Demonstration awards and the National Reactor Innovation Center under the Advanced Reactor Demonstration Program.

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[2] Funding does not reflect the mandatory transfer of $91.0M from Naval Reactors for operation of the Advanced Test Reactor.
[3] Funding does not reflect the mandatory transfer of $91.0M from Naval Reactors for operation of the Advanced Test Reactor.

- Providing limited quantities of HALEU for NE research and demonstration requirements.
- Providing for the secure availability of the Idaho National Laboratory for NE, DOE and other U.S. government requirements.
- Expanding access to university based nuclear energy science and engineering opportunities.

Bipartisan Infrastructure Law (BIL) Investments

NE was appropriated funds through the Bipartisan Infrastructure Law (BIL) (P.L. 117-58). Not all BIL activities will be managed by the organization to which funds were appropriated. Activities that will be managed by other organizations are discussed below.

($K)

Nuclear Energy	FY 2022 BIL Appropriation	FY 2023 BIL Appropriation	Managing Organization
Civil Nuclear Credit Program	1,200,000	1,200,000	GDO
Total, Nuclear Energy	**1,200,000**	**1,200,000**	

- **Civil Nuclear Credit Program:** The goal of this investment is to help preserve the existing U.S. reactor fleet and save thousands of high-paying jobs across the country. Under the new program, owners or operators of commercial U.S. reactors can apply for certification to bid on credits to support their continued operations. An application must demonstrate the reactor is projected to close for economic reasons and that closure will lead to a rise in air pollutants and carbon emissions. The program is available for plants that are certified as safe to continue operations and prioritizes plants that use domestically produced fuel. Although funds were appropriated to NE, the Grid Deployment Office (GDO) will continue to execute the Civil Nuclear Credit Program in FY 2023.

Directed R&D and University Programs

Overview

The Office of Nuclear Energy (NE) Directed Research & Development (R&D) and University Programs is a new program that consolidates and focuses support to universities and small businesses in areas relevant to NE's mission. This program will fund university research, infrastructure, workforce development, and commercialization efforts for nuclear energy. Most of this support will be awarded through competitive opportunities for researchers, students, faculty, and small businesses. Additionally, the program will continue to provide fuel services and support maintenance and safety upgrades of fuel fabrication equipment and facilities for U.S. university research reactors. This program also seeks to ensure that access to these opportunities and benefits are equitably provided, specifically seeking ways to include communities that have historically faced limits in access to such capabilities, such as students and faculty at minority-serving institutions (MSI). These efforts will include initiating competitively awarded, consortium-led activities to establish one or more advanced research reactor(s) and related capabilities at U.S. universities.

Highlights of the FY 2023 Budget Request

The Directed R&D and University Programs will be implemented by consolidating the following programs: Small Business Innovation Research and Small Business Technology Transfer Program (SBIR/STTR), the Technology Commercialization Fund (TCF) program, the Nuclear Energy University Program (NEUP), the University Nuclear Leadership Program (UNLP), and University Fuel Services (UFS). SBIR/STTR, TCF, and NEUP were previously funded through allocated charges from other NE research, development, and demonstration programs. UNLP, formerly the Integrated University Program (IUP) and UFS, formerly Research Reactor Infrastructure (RRI), were funded as separate line items.

The Directed R&D subprogram will encompass the program's competitive awarded opportunities including SBIR/STTR, TCF, and competitively awarded, university-led R&D and infrastructure (NEUP).

The reorganization of these efforts into a new program in FY 2023 provides a more flexible, streamlined, and transparent approach for NE to support universities, small businesses, and researchers moving nuclear energy technology forward. The Advanced Reactor Infrastructure element under the Directed Research and Development subprogram initiates competitively awarded, consortium-led efforts to establish one or more advanced research reactor(s) and related capabilities at U.S. universities. These activities will help U.S. universities (1) develop a workforce with hands-on experience with commercially relevant advanced reactor concepts, reflective of those being deployed by industry; (2) offer research capabilities that address emerging technical challenges; and (3) ensure that access to the opportunities and benefits of these facilities are equitably provided, specifically seeking ways to include communities that have historically faced limits in access to such capabilities.

Directed R&D and University Programs
Funding ($K) (Non-Comparable)

	FY 2021 Enacted	FY 2022 Annualized CR	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
Directed R&D and University Programs					
Directed Research and Development	0	0	137,029	+137,029	+100%
University Nuclear Leadership Program	0	0	6,500	+6,500	+100%
University Fuel Services	0	0	17,500	+17,500	+100%
Total, Directed R&D and University Programs	**0**	**0**	**161,029**	**+161,029**	**+100%**

Directed R&D and University Programs
Funding ($K) (Comparable)

	FY 2021 Enacted	FY 2022 Enacted	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
Directed R&D and University Programs					
Directed Research and Development	90,417[1]	100,000[2]	137,029	+46,612	+51.6%
University Nuclear Leadership Program	5,000	6,000	6,500	+1,500	+30.0%
University Fuel Services	11,500	15,000	17,500	+6,000	+52.2%
Total, University Programs and Directed Research	**106,917**	**121,000**	**161,029**	**+54,112**	**+50.6%**

SBIR/STTR:

- FY 2021 Transferred: SBIR $16,093; STTR $2,800
- FY 2022 Enacted: SBIR $25,636; STTR $3,605[3]
- FY 2023 Request: SBIR $22,513; STTR $3,166

[1] Funding for SBIR/STTR transferred to the Office of Science from NE R&D programs (STEP R&D, Reactor Concepts RD&D, Fuel Cycle Research and Development, Nuclear Energy Enabling Technologies, and Advanced Reactors Demonstration Program).
[2] FY 2022 funding for Directed Research and Development reflects actual appropriated amount for "NEUP, SBIR/STTR, and TCF".
[3] FY 2022 Funding for SBIR and STTR reflects estimates based on actual FY 2022 enacted appropriations.

Directed R&D and University Programs
Proposed Budget Structure Changes

The reorganization of these efforts into a new program in FY 2023 provides a more consistent approach for NE to support universities, small businesses, and researchers moving nuclear energy technology forward.

	Directed R&D and University Programs			
	Directed Research & Development	**University Nuclear Leadership Program**	**University Fuel Services**	**Total**
FY 2022 Enacted Budget Structure				
Integrated University Program		6,500		6,500
Infrastructure				
Research Reactor Infrastructure			17,500	17,500
NEUP, SBIR/STTR, and TCF	137,029			137,029
Total, Directed R&D and University Programs	**137,029**	**6,500**	**17,500**	**161,029**

Directed R&D and University Programs
Explanation of Major Changes ($K)

	FY 2023 Request vs FY 2021 Enacted
Directed Research & Development:	
The increase from $0 to $137,029,000 reflects consolidation of funding for:	
• Small Business Innovation Research and Small Business Technology Transfer	**+25,679**
• Technology Commercialization Fund	**+6,692**
• University-Led Research and Development	**+59,658**
• University Infrastructure	**+45,000**
University Nuclear Leadership Program: Of the increase from $0 to $6,500,000, $5,000,000 reflects the transfer of scholarships and fellowships previously funded under the Integrated University Program; the additional increase supports $1,000,000 for a scholarship opportunity targeting 2-year applied technical degree programs focused on nuclear energy-related topics, with priority funding set-aside specifically to support Historically Black Colleges and Universities (HBCUs), MSIs, and institutions in disadvantaged communities; and $500,000 for the OMNI internship program that will help build careers for talented cybersecurity and information technology professionals who are often from disadvantaged communities.	**+6,500**
University Fuel Services: Of the increase from $0 to $17,500,000, $11,000,000 reflects the transfer of fuel services previously funded under Research Reactor Infrastructure. An additional $5,000,000 ensures a maximum number of orders for fresh TRIGA fuel elements per year can be purchased to minimize overall cost. An additional increase of $1,500,000 reflects support to the North Carolina State University Pulstar reactor, including new fuel assembly boxes and end fittings, neutronic and thermal-hydraulic modeling of a fuel package, safety analysis, licensing support and fuel design and engineering studies.	**+17,500**
Total, University Programs and Directed Research	**+161,029**

Directed Research & Development

Description

The Directed Research and Development subprogram includes competitive awarded opportunities for small businesses and universities. Establishing a single program funding line provides more flexibility to NE's competitive award process; streamlines program execution; and provide enhanced transparency for small businesses, universities, and other stakeholders.

The principal focus areas for FY 2023 include four elements: (1) Small Business Innovation Research and Small Business Technology Transfer (SBIR/STTR); (2) Technology Commercialization Fund (TCF); (3) University-led Research and Development; and (4) University Infrastructure.

1. **SBIR/STTR** – NE supports small business through the Department's SBIR/STTR program. The SBIR/STTR reauthorizing language (Reauthorization Act of 2011 (P.L. 112-81, 125 STAT 1822)) directs the Department to spend not less than 3.2 percent of its extramural research and development (R&D) budget for SBIR and not less than 0.45 percent of its extramural R&D budget for STTR. NE's contribution supports scope relevant to NE's R&D mission, for example technologies for improvements of existing reactors, advanced reactors, and fuel cycle systems.
2. **TCF** – NE supports the transfer of promising nuclear energy technologies developed at the Department's national laboratories to the nuclear industry for commercialization through TCF. The TCF was established under 42 U.S. Code § 16391, which directed the Secretary to "establish an Energy Technology Commercialization Fund, using 0.9 percent of the amount made available to the Department for applied energy research, development, demonstration, and commercial application for each fiscal year based on future planned activities and the amount of the appropriations for the fiscal year, to be used to provide matching funds with private partners to promote promising energy technologies for commercial purposes."
3. **University-led Research and Development** – NE supports the U.S. university community with competitive research and development through yearly competitive solicitations. The program's goal is to support outstanding, cutting-edge, and innovative research at U.S. universities, including minority-serving institutions (MSIs) and historically black colleges and universities (HBCUs), in the areas of nuclear energy science, technology and social impacts including Health Physics, Nuclear Materials Science, Radiochemistry, Applied Nuclear Physics, and intergenerational knowledge transfer through the following funding opportunities:
    a. **Consolidated Innovative Nuclear Research (CINR):** NE plans to continue to utilize the CINR funding opportunity to align nuclear energy research being conducted at U.S. colleges and universities with DOE's mission and goals, focusing on the needs and priorities of key NE programs including fuel cycle, reactor concepts, and mission supporting research. This opportunity will also include Integrated Research Projects (IRPs), which are multi-disciplinary and multi-institutional projects that address near-term, specific needs, problems, or capability gaps, including workforce development, related to nuclear energy. IRPs are intended to integrate several disciplinary skills to present solutions to complex systems design problems that cannot be addressed by a less comprehensive team.
    b. **Distinguished Early Career Program (DECP):** NE plans to continue to utilize its most prestigious opportunity for faculty members, DECP. This program will focus on faculty conducting transformative research, education, and leadership aligned with the Office of Nuclear Energy's mission. It will provide stable support to enable awardees to develop careers in nuclear energy relevant areas, not only as outstanding researchers but also as educators demonstrating commitment to teaching, learning, and dissemination of knowledge. This opportunity will support the development of faculty members to advance their research focus while training the next generation of nuclear energy professionals. DECP aims to recognize distinguished researchers at the pivotal initial stage of their careers and to support high-impact contributions to nuclear energy research, innovation, discovery, leadership, and dissemination of knowledge.

4. **University Infrastructure** – NE supports the infrastructure needed at universities to conduct cutting edge research and to educate and train the next generation nuclear workforce. It has been organized into the following elements:
   - **a. Advanced Reactor Infrastructure**: This element initiates competitively awarded, consortium-led efforts to establish one or more advanced research reactor(s) and related capabilities at U.S. universities. These activities will help U.S. universities (1) develop a workforce with hands-on experience with commercially relevant advanced reactor concepts, reflective of those being deployed by industry; (2) offer research capabilities that address emerging technical challenges; and (3) ensure that access to the opportunities and benefits of these facilities are equitably provided, specifically seeking ways to include communities that have historically faced limits in access to such capabilities. These activities are expected to be led by one or more diverse consortia with appropriate expertise to ensure that the new capabilities will support these goals. This scope may include one or more research reactors and complementary infrastructure projects at different locations. A goal is to maximize the research and educational value and the broad accessibility of these resources in support of the administration's Justice40 Initiative.
   - **b. Scientific Infrastructure Support:** This element provides competitively-awarded improvements to existing university infrastructure in the areas of general scientific infrastructure and reactor upgrades through NE's Scientific Infrastructure Support funding opportunity. General scientific infrastructure is focused on equipment, instrumentation, and associated non-reactor upgrades that significantly improve or expand research, instruction, and training capabilities. Reactor upgrades are focused on upgrades and improvements to existing nuclear research and training reactors. It includes purchase and maintenance of equipment to enhance the safety, security, performance, control, or operational reliability of the research reactor.

Directed Research & Development

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
SBIR/STTR $0	**$25,679,000**	**+$25,679,000**
• In FY 2021, NE provided $18,893,000 for SBIR/STTR through allocated charges to other R&D programs. Awards were made in areas such as advanced technologies for nuclear energy and used fuel.	• Support competitively awarded nuclear science and engineering small business and technology awards focusing in the areas of advanced technologies for nuclear energy and used fuel.	• The increase is due to increased Nuclear Energy research and development funding.
Technology Commercialization Fund $0	**$6,692,000**	**+$6,692,000**
• In FY 2021, NE provided $7,516,000 for the TCF through allocated charges to other R&D programs. Awards were made in areas such as advanced technologies for nuclear energy and used fuel.	• Supports competitive laboratory funding opportunity designed to help commercialize promising nuclear energy related technologies developed at the national laboratories.	• No significant change.
University Led Research & Development $0	**$59,658,000**	**+$59,658,000**
• In FY 2021, NE provided $58,259,000 for university led R&D through allocated charges to other R&D programs. Awards were made for research in areas such as fuel cycle, reactor concepts, and mission supporting research.	• Supports competitively awarded, university-led nuclear energy R&D that focus on the priorities of NE programs, including fuel cycle, reactor concepts, and mission supporting research. • Supports early career awards focused on faculty conducting transformative research, education, and leadership aligned with the NE mission.	• The increase is due to increased Nuclear Energy research and development funding.
University Infrastructure $0	**$45,000,000**	**+$45,000,000**
• In FY 2021, NE provided $5,749,000 for university infrastructure through allocated charges to other R&D programs. Awards supported general scientific infrastructure and reactor upgrades at U.S. universities.	• General scientific infrastructure and reactor upgrades are supported through the Scientific Infrastructure Support for Consolidated Innovative Nuclear Research funding opportunity. • Initiates competitively awarded, consortium-led activities to establish one or more advanced research reactor(s) and related capabilities at one or more U.S. universities.	• The increase is to initiate a competitively awarded, consortium-led project to establish an advanced research reactor at a U.S. university and provide competitively awarded general scientific and reactor upgrade support to U.S. universities.

University Nuclear Leadership Program

Description

The University Nuclear Leadership Program (UNLP) provides scholarships and fellowship to two and four-year college students and supports other internship programs that support disadvantaged communities.

The Office of Nuclear Energy (NE) UNLP subprogram supports the next generation of the nuclear energy workforce. The subprogram provides important educational support to bolster scientific discovery and innovation in nuclear science and engineering (NS&E) at U.S. universities and colleges.

The subprogram in intended to attract qualified students to nuclear energy professions by providing single-year undergraduate scholarships and multi-year graduate fellowships. Scholarships are awarded for undergraduate study at two- and four-year institutions leading to a major or minor degree or certificate and fellowships are awarded for graduate level work leading to a masters or doctoral degree in the fields or disciplines of NS&E relevant to the NE mission. NS&E disciplines of interest include nuclear engineering, mechanical engineering, electrical engineering, chemistry, health physics, nuclear materials science, radiochemistry, applied nuclear physics, nuclear policy, radiation protection technology, nuclear power technology, nuclear maintenance technology, and nuclear engineering technology.

NE has awarded more than $55 million for 929 nuclear energy-related scholarships and fellowships at 75 universities and colleges—including 11 minority-serving institutions (MSI) and two Historically Black Colleges and Universities (HBCU)—in 32 states since the program was initiated in 2009 under the Integrated University Program. Currently, scholarships are offered at $10,000 for one year to students attending four-year institutions and $5,000 to students attending two-year trade schools and community colleges. The maximum award for a fellowship is $52,000 per year for three years, with an additional one-time $5,000 allotment to fund a minimum 10-week internship at a Department of Energy (DOE) national laboratory or other designated facility.

All scholarship and fellowship awards are competitively awarded to students attending U.S. institutions of higher education offering NS&E educational programs, including MSIs and HBCUs. Emphasis is placed on increasing the involvement of HBCUs/MSIs, resulting in direct and meaningful investments in the areas of clean energy training and workforce development in support of the administration's Justice40 Initiative.

OMNI Internships

A new focus area is the OMNI Internships, a DOE Office of the Chief Information Officer-led effort to help build careers for talented cybersecurity and information technology professionals to strengthen the security of the Department, the national laboratories, and the nuclear industry.

University Nuclear Leadership Program
Funding ($K)

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
University Nuclear Leadership Program $0	**$6,500,000**	**+$6,500,000**
• In FY 2021 NE provided $5,000,000 under the Integrated University Program. • Support nuclear science and engineering study and research by fully funding approximately 30 or more multi-year student fellowships and 45 or more single-year scholarships in the nuclear energy field of study.	• Support nuclear science and engineering study and research by fully funding approximately 30 or more multi-year student fellowships and 45 or more single-year scholarships in the nuclear energy field of study. • Support a new scholarship program opportunity that targets two-year applied technical degree programs focused on nuclear energy-related topics, all with an increased emphasis on capacity-building and education at HBCUs, MSIs, and institutions in disadvantaged communities. This opportunity will focus on workforce development for nuclear relevant technician training, including nuclear operations, mechanical maintenance, electrical maintenance, chemistry, health physics and other nuclear energy-related topics. • Bolster outreach efforts focused on increasing HBCU/MSI involvement to include website resources, conference promotion, and university visits. • Support an OMNI internship program that will help build careers for talented cybersecurity and information technology professionals to strengthen the security of the Department, the national laboratories, and the nuclear industry.	• The increase reflects fully funding single-year scholarships and multi-year fellowships and maintaining or increasing the number of such awards via the UNLP and initiating a new scholarship opportunity that targets two-year applied technical degree programs focused on nuclear energy related topics, all with an increased emphasis on capacity-building and education at HBCUs, MSIs, and institutions in disadvantaged communities. The increase includes support for an OMNI internship program geared toward cybersecurity and information technologies professionals primarily from disadvantaged communities.

University Fuel Services

Description

University Fuel Services (UFS) provides fuel services for U.S. university research reactors. These activities were previously funded within the Research Reactor Infrastructure (RRI) subprogram.

UFS provides fresh reactor fuel to, and removes used fuel from, 25 operating university research reactors to support their continued operation. This provides continued research and training reactor capability to U.S. universities to ensure their continued ability to support U.S. nuclear energy initiatives in the areas of research, development, and educational opportunities.

The continued operation of U.S. university research reactors directly supports the successful execution of the nuclear energy research mission and plays an important role in developing future scientists and engineers in the U.S. These research reactors provide irreplaceable training, education and research support to hundreds of students annually, and many hosting universities expand access to these reactors through partnerships with minority serving institutions in underserved or disadvantaged communities, including innovative online opportunities providing direct access to reactor operating data. RRI support ensures continued reactor operations that directly expand diversity of Science, Technology, Engineering and Math (STEM) opportunities. This subprogram sustains unique capabilities for research and development and educational opportunities supporting U.S. energy initiatives. Used nuclear fuel shipments support U.S. and Department of Energy non-proliferation and national security objectives.

UFS provides project management, technical support, quality engineering and inspection, and nuclear material support to 25 research reactors located at 24 U.S. universities. Major program deliverables include procuring new plate fuel elements and shipping them to select universities; transporting used fuels from U.S. universities to a DOE site; procuring High Assay Low Enriched Uranium (HALEU) and shipping it to the Training, Research, Isotopes, General Atomics (TRIGA) Fuel Fabrication Facility (TFFF) in Romans, France, for fabrication of TRIGA fuel and procuring new TRIGA fuel elements from the TFFF; and reusing lightly-irradiated TRIGA fuel currently in inventory at Idaho National Laboratory (INL) by retrieving, inspecting and shipping it to universities with the most urgent need.

Major equipment and safety process upgrades to the TFFF, required by French safety authority, were completed and commercial production started in FY 2022, resulting in the initial procurement of 55 TRIGA fuel elements. In FY 2023, UFS will provide $7.3 million for the second procurement of TRIGA fresh fuel elements, to meet the increased fresh fuel requests from the 12 TRIGA research reactors located at U.S. universities, and to take advantage of the significant fuel cost discount provided to the Department if full orders are placed annually. UFS will also continue to ship used plate and TRIGA reactor fuel elements from supported universities to DOE used fuel receipt facilities. The Department will continue its policy, initiated in FY 2017, of reusing lightly-irradiated TRIGA fuel in the DOE inventory and will evaluate additional alternative sources.

The existing North Carolina State University Pulstar reactor fuel is reaching end of life. It is estimated that a new fuel core and fuel boxes will be needed by the end of FY 2025 for this reactor to remain operational. FY 2023 funding will be used to initiate design and fabrication activities.

University Fuel Services
Funding ($K)

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
University Fuel Services $0	**$17,500,000**	**+$17,500,000**
• In FY 2021 NE provided $11,500,000 under the Research Reactor Infrastructure program. • Procured 40 and delivered 33 plate fuel elements required annually by MURR and MIT as determined by need and fuel availability. • Established the contract for the procurement of TRIGA fuel elements from the TRIGA Fuel Fabrication Facility (TFFF) in Romans, France upon resumption of operations. Due to COVID, there were delays in completing upgrades to the TFFF, gathering documentation from vendors to support the French regulator review, and significant increased time for the French regulator to complete their review. Therefore, fuel procurement will start in early FY 2022. • Procured and shipped HALEU metal to the TFFF in Romans, France, to support procurement of TRIGA fuel elements, and ship fuel elements to TRIGA reactor facilities as determined by need and fuel availability. • Completed 4 used fuel shipments to SRS and the INL, pending resolution of moratorium on such shipments to the INL. • Continued RRI project management, quality assurance, nuclear material accountability, and transportation cask maintenance.	• Procure 40 and deliver between 33 and 36 plate fuel elements required annually by MURR and MIT as determined by need and fuel availability. • As needed, ship up to two cask loads of lightly-irradiated 8.5 wt% standard TRIGA fuel elements from the Irradiated Fuel Storage Facility at INL to select U.S. university research reactor facilities. • Procure up to 90 TRIGA fuel elements annually after the first year from TFFF. As needed, procure and ship HALEU metal to the TFFF in Romans, France, to support procurement of TRIGA fuel elements, and ship fuel elements to TRIGA reactor facilities as determined by need and fuel availability. • Complete up to 5 used fuel shipments to SRS and the INL, pending resolution of moratorium on such shipments to the INL. • Initiate fuel design and engineering studies; modeling, design and licensing of a shipment package, and procurement of fuel assembly boxes and end fittings for the North Carolina State University (NCSU) Pulstar reactor. • Continue UFS project management, quality assurance, nuclear material accountability, and transportation cask maintenance.	• Reflects additional TRIGA fresh fuel orders to ensure a maximum number of fuel elements per year can be purchased, resulting in the lowest average price per element to obtain the 668 fuel elements identified as the lifetime required fuel supply for the 12 U.S. university TRIGA research reactors within 10 years. • The existing NCSU Pulstar reactor fuel is reaching end of life. It is estimated that a new fuel core and fuel boxes will be needed by the end of FY 2025 to remain operational. FY 2023 funding will be used to initiate design and fabrication activities. Additional funding will be required in FY 2024 and FY 2025 to procure the required fuel.

Integrated University Program

Overview

The Office of Nuclear Energy (NE) Integrated University Program (IUP) supports the next generation of the nuclear energy workforce. The program provides important educational support to bolster scientific discovery and innovation in nuclear science and engineering (NS&E) programs at U.S. universities and colleges. This program is now requested under Directed R&D and University Program with new name of University Nuclear Leadership Program.

Integrated University Program
Funding ($K)

	FY 2021 Enacted	FY 2022 Annualized CR	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
Integrated University Program					
Integrated University Program	5,000	5,000	0	-5,000	-100%
Total, Integrated University Program	**5,000**	**5,000**	**0**	**-5,000**	**-100%**

Integrated University Program
Explanation of Major Changes ($K)

	FY 2023 Request vs FY 2021 Enacted
Integrated University Program:	
The decrease reflects funding requested under Directed R&D and University Program for the University Nuclear Leadership Program.	-5,000
Total, Integrated University Program	**-5,000**

Integrated University Program

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Integrated University Program $5,000,000	**$0**	**-$5,000,000**
• Support nuclear science and engineering study and research by fully funding approximately 30 or more multi-year student fellowships and 45 or more single-year scholarships in the nuclear energy field of study. • Support a new scholarship program opportunity that targets two-year applied technical degree programs focused on nuclear energy-related topics, all with an increased emphasis on capacity-building and education at HBCUs, MSIs, and institutions in disadvantaged communities. This opportunity will focus on workforce development for nuclear relevant technician training, including nuclear operations, mechanical maintenance, electrical maintenance, chemistry, health physics and other nuclear energy-related topics. • Bolster outreach efforts focused on increasing HBCU/MSI involvement to include website resources, conference promotion, and university visits.	• Funding is now requested under Directed R&D and University Programs for the University Nuclear Leadership Program.	• This funding is now requested under Directed R&D and University Programs for the University Nuclear Leadership Program.

Reactor Concepts Research, Development, and Demonstration

Overview

The Reactor Concepts Research, Development, and Demonstration (RD&D) program supports conducting RD&D on existing and advanced reactor designs and technologies to enable industry to address technical and regulatory challenges associated with maintaining the existing fleet of nuclear reactors, promoting the development of a robust pipeline of advanced reactor designs and technologies and associated supply chains, and progressing these advanced reactor designs and technologies towards demonstration when deemed appropriate. Program activities are focused on addressing technical, economic, safety, and security enhancement challenges associated with the existing commercial light water reactor fleet and advanced reactor technologies, covering large, small, and micro-sized designs and an array of reactor types including fast reactors using liquid metal coolants and high temperature reactors using gas or molten salt coolants.

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

- improving affordability of nuclear energy technologies;
- enhancing safety and reducing technical and regulatory risk;
- minimizing proliferation risks of nuclear materials; and
- improving the economic outlook for the United States (U.S.) nuclear industry.

Reactor Concepts RD&D is key to enabling the industry to reverse the downward market trajectory of our nation's nuclear energy sector by regaining a technological and market leadership role. Through cost-shared RD&D activities, related technical assistance, and cross-cutting innovative research and development (R&D), the Department will enable industry to accelerate the timeline for commercialization of new, advanced, and more economic reactor technologies that will help revive and expand the domestic nuclear industry while advancing America's leadership role in the global nuclear sector and meeting our nation's clean energy goals.

The Reactor Concepts RD&D program continues to support RD&D efforts focused on small modular reactors (SMR) in FY 2023. The Advanced SMR RD&D subprogram supports cost-shared RD&D activities for the purpose of accelerating the development of U.S. SMR technologies for domestic and international markets, including countries that have expressed interest in near-term SMR deployment. In FY 2023, the program will support funding awards to U.S. recipients to encourage domestic SMR technology development and to produce results that are widely applicable across the spectrum of emerging reactor concepts.

The Light Water Reactor Sustainability (LWRS) subprogram conducts research in support of light water reactor (LWR) technologies so that LWR-based commercial nuclear power plants can continue to provide safe, clean, and reliable energy. The goal is to enable industry to enhance the efficient and economic performance of current nuclear power plants while enabling their extended operation. The primary focus of the subprogram is on cost-shared, private-public partnerships to help industry resolve its highest priority and highest uncertainty technical issues where U.S. government partnership is appropriate. Examples of such partnerships are the R&D on methods of control room and plant modernization to address aging and obsolescence of existing analog instrumentation and controls to improve plant efficiency and increasing revenue opportunities through the demonstration of non-electric applications such as hydrogen production.

The Advanced Reactor Technologies (ART) subprogram conducts targeted R&D on advanced reactor technologies, including molten salt reactors, fast reactors, high temperature gas-cooled reactors, and microreactors. The subprogram also supports work on cross-cutting R&D that can be applied to multiple advanced reactor concepts, including non-light water reactor SMRs. This subprogram focuses on efforts in the following areas: fundamental technologies and design methods for advanced reactors, interactions of diverse reactor coolants with materials and components, advanced energy conversion, analysis of reactor response to severe accidents, research to enhance safety and reduce regulatory risk, experimental validation of models, advanced materials development and codification, and continued international collaborations. Funding will also support competitively awarded projects to assist the progression of emerging advanced reactor designs and technologies.

Highlights of the FY 2023 Budget Request

The Advanced SMR RD&D subprogram will successfully finalize support for the NuScale SMR First-of-a-Kind Nuclear Demonstration Readiness Project, which supports development of a U.S. SMR technology for deployment in domestic and international markets. Domestic SMR demonstration activities are not funded.

The Reactor Concepts RD&D program will continue to conduct RD&D activities to address technical, cost, safety, and security enhancement challenges associated with the existing commercial light water reactor fleet and advanced reactor technologies.

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

	FY 2021 Enacted	FY 2022 Annualized CR	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
Reactor Concepts Research, Development and Demonstration					
Advanced Small Modular Reactor RD&D	115,000	115,000	40,000	-75,000	-65%
Light Water Reactor Sustainability	47,000	47,000	45,000	-2,000	-4%
Advanced Reactor Technologies	46,000	46,000	50,000	+4,000	+9%
Total, Reactor Concepts Research, Development and Demonstration	**208,000**	**208,000**	**135,000**	**-73,000**	**-35%**

SBIR/STTR:

- FY 2021 Enacted: SBIR $2,814; STTR $490
- FY 2022 Annualized CR: SBIR $2,814; STTR $490
- FY 2023 Request: Funding provided in the Directed R&D and Universities Program line.

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

	FY 2023 Request vs FY 2021 Enacted
Advanced Small Modular Reactor RD&D: The decrease from $115,000,000 to $40,000,000 successfully finalizes support for the development of a U.S. SMR technology for deployment in domestic and international markets. Domestic SMR demonstration activities are not funded.	**-75,000**
Light Water Reactor Sustainability: The decrease from $47,000,000 to $45,000,000 reflects $2,000,000 partially associated with funding for Small Business Innovation Research (SBIR), Small Business Technology Transfer (STTR), Technology Commercialization Fund (TCF), and Nuclear Energy University Program (NEUP) awards being consolidated within the new Directed R&D and University Programs line.	**-2,000**
Advanced Reactor Technologies: The increase from $46,000,000 to $50,000,000 reflects a greater emphasis on essential research and development activities to address high priority technical challenges and reduce the technical risks associated with advanced reactor technologies and systems.	**+4,000**
Total, Reactor Concepts Research, Development & Demonstration	**-73,000**

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

Description

The Advanced Small Modular Reactor (SMR) Research, Development and Demonstration (RD&D) subprogram supports enabling industry to reverse the downward market trajectory of our nation's nuclear energy sector, reestablishing U.S. leadership in the nuclear technology development arena, and meeting our nation's climate change and clean energy goals. A range of significant technological challenges remain in developing advanced SMR designs. The Department intends to leverage its appropriate federal role and notable expertise to facilitate industry's development of advanced SMR designs that have the potential to provide safe, clean, and affordable energy generation options.

The Advanced SMR RD&D subprogram will support RD&D to assist in maturing concepts toward commercial readiness. Results are generally intended to be widely applicable and adopted by domestic nuclear reactor vendors for the purpose of accelerating the development of their technologies. In so doing, the Advanced SMR RD&D subprogram will help address the climate crisis and achieve 100% carbon-free electricity by 2035. Funding will support ongoing awards, including the final year of funding for the NuScale First-of-a-Kind Demonstration Readiness Project, and will leverage ongoing and planned R&D activities supported by the related Advanced Reactor Technologies subprogram.

The subprogram will support industry awards that have high potential to accelerate the development of more mature SMR designs.

Advanced Small Modular Reactor RD&D

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Advanced Small Modular Reactor RD&D		
$115,000,000	**$40,000,000**	**-$75,000,000**
• Supported targeted research and development (R&D) to further advance small modular reactors (SMR). • Awarded one project under the Industry Funding Opportunity Announcement (Industry FOA) to complete a study on the effort required to repurpose a southern Ohio site for deployment of an SMR. The award also included the development of an Early Site Permit (ESP) template that has broad applicability to many advanced SMR technologies. • Provided funding to support the NuScale SMR design development project that was originally selected competitively. • Supported the reduction of first-mover's risk to deploy an advanced SMR by cost-sharing site-specific characterization, licensing, and planning efforts needed to demonstrate a NuScale SMR.	• Supports successful finalization of a cost-shared industry partnership award that has high potential to accelerate the development of both emerging and more mature SMR designs.	• The decrease finalizes support for the development of a U.S. SMR technology for deployment in domestic and international markets. Domestic SMR demonstration activities are not funded.

Reactor Concepts Research, Development and Demonstration
Light Water Reactor Sustainability

Description

The Light Water Reactor Sustainability (LWRS) subprogram conducts research and development (R&D) on technologies and other solutions that can improve economics, sustain safety, and maintain the technical reliability of the current domestic fleet of commercial nuclear power plants.

With the initial success of the lead plants' Subsequent License Renewal submittals in FY 2018, the focus for sustaining the existing fleet has shifted from enabling industry's effort to extend their operational licenses to conducting R&D to address technical questions that affect the industry's economic challenges leading to premature shutdowns. LWRS will continue to collaborate with nuclear power plant owner-operators, vendors, suppliers, industry support organizations, other research organizations, and the Nuclear Regulatory Commission (NRC) to closely coordinate research that both supports industry needs and maximizes taxpayer benefit.

Currently, the LWRS subprogram consists of the following primary technical areas of R&D:

- Plant Modernization: R&D to address nuclear power plant economic viability in current and future energy markets by increasing efficiency through the implementation of digital technologies. The R&D products will enable modernization of plant systems and processes across the industry by enabling a shift from a labor centric to a technology-centric business model platform that supports improved performance at a lower cost.
- Flexible Plant Operations and Generation: R&D to establish the technical feasibility and economic potential of dispatching thermal and electrical energy to diversify and increase revenue of light water reactors in the U.S. The R&D products, including hydrogen production demonstration activities, will allow the existing fleet of nuclear reactors to readily respond to rapid changes in electricity supply due to the widespread adoption of variable renewable energy resources and demonstrate the ability to repurpose nuclear power reactors into flexible energy sources for low-carbon industrial commodity production.
- Risk-Informed Systems Analysis: R&D to support decision-making related to the economics, reliability, and safety of the existing fleet by providing analysis solutions for integrated plant systems. In addition, the R&D products in this area will be used to optimize plant economic performance and safety by incorporating the impacts of physical aging and degradation processes.
- Physical Security Research: R&D that will validate methods and tools which can be used to implement an updated, cost-effective physical security regime. The R&D products are expected to enable companies across the industry to reduce excessive conservatisms in security modeling, leverage automation as force multipliers, optimize security postures, and develop additional means to risk-inform approaches to evaluate security changes.
- Materials Research: R&D to develop the scientific basis for understanding and predicting long-term environmental degradation behavior of materials in nuclear power plants. The R&D products will be used to define operational limits and aging mitigation approaches for materials in nuclear power plant systems, structures and components (SSC) subject to long-term operating conditions, providing key input to both regulators and industry.

In FY 2023, the LWRS subprogram continues to leverage cost-shared, private-public partnerships and our national laboratory system to conduct R&D to resolve industry's highest priority and highest uncertainty challenges where U.S. government partnership is appropriate. These high priority areas include providing science and technology-based solutions to improve the current business model and associated practices of the current fleet and develop the scientific bases for managing the aging of SSCs to allow existing nuclear power plants to continue to operate safely and cost-effectively.

Light Water Reactor Sustainability

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Light Water Reactor Sustainability **$47,000,000**	**$45,000,000**	**-$2,000,000**
• Materials Research – Completed environmental fatigue assessment of stainless steel and dissimilar metal weldments under relevant light water reactor conditions. Continued development of a predictive model for cable degradation. • Risk-Informed Systems Analysis – Completed human-reliability analysis to credit Diverse and Flexible Coping Strategies (FLEX) in accident management and perform risk-informed analysis of a passive-cooling design. Developed the strategy to extend the implementation of fire Probabilistic Risk Assessment (PRA) tools for the existing fleet. • Plant Modernization – Completed development of asset risk models that will be applicable to a variety of existing reactor designs and will be made widely available to the industry to enable adoption of predictive maintenance strategies to replace time-based maintenance activities of plant equipment. Conducted targeted research and development (R&D) on technologies that can enable online monitoring of plant equipment to replace labor-based approaches to equipment condition assessment at commercial nuclear power plants to reduce operating costs and improve equipment availability and reliability. • Flexible Plant Operations and Generation – Working with other applied energy offices, competitively selected one industry-led project	• Materials Research - Implement the reactor pressure vessel predictive embrittlement model through American Society for Testing and Materials (ASTM) and American Society of Mechanical Engineers (ASME) for code acceptance and wide industry use. Publish a methodological guideline on concrete degradation for industry and accompany with the public release of Microstructure Oriented Scientific Analysis of Irradiated Concrete (MOSAIC) for industry use. • Risk-Informed Systems Analysis – Enhance the algorithm used to optimize the reactor core reload process and enable crediting Terry Turbines for extended operation, which will expand the mitigation options available to operators under both normal and emergency conditions. • Plant Modernization - Complete development of the Integrated Operations for Nuclear business operating model and demonstrate its use with an operating nuclear power plant which will allow utilities to shift their operations from a labor centric to a technology centric business model. Produce an Artificial Intelligence/Machine Learning methodology to achieve a fully automated risk-informed predictive maintenance strategy. • Flexible Plant Operation and Generation - Develop the methods and licensing approach for thermal extraction, thermal energy storage, and	The decrease from $47,000,000 to $45,000,000 reflects $2,000,000 partially associated with funding for Small Business Innovation Research (SBIR), Small Business Technology Transfer (STTR), Technology Commercialization Fund (TCF), and Nuclear Energy University Program (NEUP) awards being consolidated within the new Directed R&D and University Programs line.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
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. • Physical Security – Developed the technical basis for potential future, industry-funded pilots of remote operated weaponry, increasing the operating fleet's security posture and allowing for the first implementation of automated weapons at an operating commercial nuclear power plant.	distribution. Engineer and simulate operations and control systems for direct use of heat generated from the existing light water reactor fleet. Develop architectural and engineering models, and investor-grade reports to detail the opportunities for providing clean thermal and electrical energy for industrial applications (e.g., hydrogen, ammonia, metals, chemicals, and fuels production). • Physical Security - Deliver guidance to industry on the use and implementation of dynamic risk analysis tools to support dynamic physical security risk assessments, reducing utility security cost burdens and improving market competitiveness.	

Reactor Concepts Research, Development and Demonstration
Advanced Reactor Technologies

Description

The Advanced Reactor Technologies (ART) subprogram conducts essential research and development (R&D) activities to reduce technical risks associated with advanced reactor technologies and systems. The subprogram R&D scope reflects input from advanced reactor stakeholders with a goal of enabling industry to mature and ultimately demonstrate advanced reactor technologies by the 2030s. Innovative advanced reactor concepts have the potential to offer significant benefits versus existing technologies, including possible lower costs, enhanced safety and security, greater resource utilization, and simpler operating regimes. Such advantages could allow nuclear energy to increase its contributions to domestic clean and resilient energy sources and to support the growth of high-paying U.S. jobs. The ART subprogram conducts R&D that can help reduce long-term technical barriers for multiple reactor technology concepts with a focus on innovative technologies. This subprogram will address the full range of high-value R&D to enable advancement of innovative technologies that benefit multiple advanced reactor concepts, including microreactor designs, and stimulation of new ideas for transformational future concepts.

ART R&D efforts support innovative reactor concepts, including high temperature gas-cooled reactors (HTGR), fast reactors, and molten salt reactors (MSR) using liquid salt coolants and/or fuels. The ART subprogram focuses on industry-informed R&D priorities that could provide widely-applicable benefits across many different advanced reactor concepts including: fundamental technologies and design methods for advanced reactors; interactions of advanced reactor coolants with materials and components; advanced systems and components that can operate in extreme high temperature environments; research to enhance safety; advanced materials development and codification; cross-cutting areas of support in advanced energy conversion technologies; and research to support microreactors for remote and micro-grid commercial applications. The ART subprogram conducts R&D to mature emergent advanced reactor technologies to enhance the likelihood of future demonstration and commercialization of these technologies. The ART subprogram continues support for international collaborations on advanced materials, advanced reactor operations, and safety that will promote the development of advanced reactors in the United States (U.S.) and support deployment of U.S. technologies in the global marketplace.

Industry-led, innovative cost-shared R&D activities are supported through competitively selected industry awards to reduce technical and regulatory risks associated with advanced reactor designs. Specifically, in FY2021, DOE announced the selection of three awards to support the development of designs that could have significant impact on the energy market in the mid-2030s or later. The three concepts selected for award were:

- Development of a conceptual design of a seismically isolated advanced sodium-cooled reactor facility - Advanced Reactor Concepts, LLC;
- Development of a fast modular reactor conceptual design with verifications of key metrics in fuel, safety, and operational performance - General Atomics; and
- Maturing the Modular Integrated Gas-Cooled High Temperature Reactor (MIGHTR) concept from a pre-conceptual stage to a conceptual stage - Massachusetts Institute of Technology (MIT).

FY2023 activities for the ART subprogram will focus on essential research to address the highest priority challenges facing advanced reactor technologies and continued support for innovation through cost-shared partnerships with industry.

Advanced Reactor Technologies

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Advanced Reactor Technologies $46,000,000	**$50,000,000**	**+$4,000,000**
• Fast Reactor Technologies – Maintained Mechanisms Engineering Test Loop (METL) facility operational readiness to support industry-identified fast reactor component experiments. Qualified historical fast reactor data sets targeted by U.S. vendors using the Nuclear Regulatory Commission (NRC)-approved Quality Assurance (QA) methodology. Qualified Grade 91 sodium in support of NRC licensing by fast reactor developers. • Gas Reactor Technologies – Performed experimental validation of normal operation and transient conditions and support modeling and simulation using the water-based reactor cavity cooling system at the Natural Convection Shutdown Heat Removal Test Facility (NSTF) at the Argonne National Laboratory (ANL). Continued American Society of Mechanical Engineers (ASME) code qualification of Alloy 617 and resolved issues necessary to achieve endorsement by the NRC. • Molten Salt Reactor Technologies – Developed chemical monitoring requirements, methods, and instrumentation. Continued development of a modeling framework for salt characterization. Continued to collect and analyze fundamental data to understand fission product behavior in salt-fueled systems. • Microreactor Technologies – Performed nonnuclear testing and validation of high priority components. Continued code case	• Fast Reactor Technologies – Perform additional testing of the Thermal Hydraulic Experiment Test Article (THETA) in METL to generate data for fast reactor design and safety code validation and commission the gripper test article to demonstrate key aspects of an under-sodium fuel handling machinery. Perform model development and experimental validation activities to support development and licensing activities for fast reactors. • Gas Reactor Technologies – Perform additional experimental validation of normal operation and transient conditions and support modeling and simulation activities using the water-based reactor cavity cooling system at the NSTF at ANL. Support long term testing to characterize creep behaviors of high temperature alloys. • Molten Salt Reactor (MSR) Technologies – Maintain and expand the molten salt thermal properties database to aid in the design and licensing of MSRs. Investigate salt/graphite interactions and conduct corrosion tests at high temperatures to demonstrate the performance of materials under prototypic MSR conditions. • Microreactor Technologies – Continue qualification and testing of high temperature moderator materials that have the broadest potential application for microreactor applications. Begin nonnuclear integrated testing and validation of microreactor systems and operational regimes. Complete installation of the Microreactor Applications, Research,	• The increase reflects a greater emphasis on essential research to address the highest priority industry identified challenges associated with advanced reactor technologies and systems, including a ramp-up in testing at the METL facility, increased research to reduce the technical risks associated with MSRs, increased activities to support completing installation of MARVEL, increased support for materials development, and increased efforts for experimentally validating advanced reactor modeling and simulation capabilities.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
development for Grade 91 steel as an improved structural material for microreactors. • Cross-Cutting Technologies – Continued cross-cutting research and development for advanced reactor designs. Continued work on printed circuit heat exchangers, intermediate heat exchanger alloys and Brayton cycle plant analysis codes. • Industry Awards – Selected U.S. based teams to receive funding through the Advanced Reactor Concepts (ARC)–20 program. Finalized the work-scopes and milestones to be supported through the ARC-20 program and initiated execution of project activities.	Validation and Evaluation (MARVEL) test platform (nuclear microreactor test platform to demonstrate the integration of commercial end-user applications). • Industry Awards (ARC-20) – Support execution of the three ARC-20 projects per established project plans and using current and prior year carryover funds. Specific project activities include: ○ For the Advanced Reactor Concepts, LLC award: Conduct further pre-application engagement with the NRC and complete conceptual design report. ○ For the General Atomics award: Conduct further pre-application engagement with the NRC, complete report documenting analysis of reactor passive safety, and initiate irradiation testing of fuel in INL's Advanced Test Reactor (ATR). ○ For the MIT award: Complete the design of the reactor building to include consideration of radiation shielding, equipment support, safety and seismic response.	

Fuel Cycle Research and Development

Overview

The Fuel Cycle Research and Development (FCR&D) program conducts applied research and development (R&D) on advanced fuel cycle technologies that have the potential to accelerate progress on managing and disposing of the nation's spent fuel and high-level waste, improve resource utilization and energy generation, reduce waste generation, and limit proliferation risk. Advancements in fuel cycle technologies support the enhanced availability, economics, and security of nuclear-generated electricity in the United States (U.S.), further enhancing U.S. energy independence and economic competitiveness. The FCR&D program also contributes to the Department's policies and programs for ensuring a reliable and economic nuclear fuel supply.

The FCR&D program participates in world-class R&D and employs internationally renowned technical experts. FCR&D subprograms leverage their technical expertise by participating in international collaborations through bilateral and multilateral technical agreements. The program also participates in projects sponsored by the International Atomic Energy Agency and the Organization for Economic Co-operation and Development/Nuclear Energy Agency which provides further leverage in key technical areas.

The program supports R&D and evaluation of spent fuel and high-level waste disposition pathways, covering storage, transportation, and disposal technologies. The program also supports R&D on multiple advanced fuel technologies that hold promise for reduced risks and improved economics or are an important element in the development of the next generation of reactor designs; exploring the feasibility of reprocessing highly enriched uranium to produce high-assay, low-enriched uranium (HALEU); and providing fuel to support demonstration of advanced reactor technologies. These activities provide valuable information that will inform industry's decisions on the commercialization and deployment of advanced reactors, including micro reactors.

Highlights of the FY 2023 Budget Request

Continue the HALEU Availability subprogram to support civilian domestic demonstration and commercial use. This subprogram will work to make available small quantities of HALEU from limited DOE uranium inventories and HALEU production in the short term and will work with the private sector in its design and build out of commercial U.S. HALEU production capability in the long term.

Within the Accident Tolerant Fuel subprogram, the Request includes increased irradiation testing and examination at the national laboratories and in commercial reactors as industry nears its objective to install the first reload quantities of accident tolerant fuel in pilot plants by the mid-2020s and qualify the fuel for use at higher burnup levels. This irradiation testing and examination involves accident tolerant fuel concepts and fuel previously irradiated to higher burnup levels. Testing and examination will take place at the Idaho National Laboratory and Oak Ridge National Laboratory and be guided by the examination test plan being coordinated with industry and the U.S. Nuclear Regulatory Commission. The plan calls for more tests and examinations than experienced to date in the commissioning tests.

Within the Fuel Cycle Core R&D subprogram, a new metallic fuel qualification effort is initiated, building upon recent R&D on accelerated testing and qualification of new fuels to support advanced reactor developers. To ensure a robust pipeline of advanced in-core and fuel cladding materials, research activities are included to discover and develop innovative alloys and composites. The innovative process control activities will continue to support advanced reactor fuel preparation and treatment capabilities using molten salt technologies at national laboratories.

The Integrated Waste Management System (IWMS) subprogram includes working collaboratively with the public, communities, stakeholders, and governments at the Tribal, state, and local levels to lay the groundwork for effective implementation of consolidated interim storage for the nation's nuclear waste. In FY 2021, funding for related activities was appropriated within the Interim Storage and Nuclear Waste Fund Oversight program (Nuclear Waste Disposal account).

Fuel Cycle Research and Development
Funding ($K)

	FY 2021 Enacted	FY 2022 Annualized CR	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
Fuel Cycle Research and Development					
Material Recovery and Waste Form Development	25,000	25,000	38,000	+13,000	+52%
Mining, Conversion, and Transportation	2,000	2,000	1,500	-500	-25%
Civil Nuclear Enrichment	40,000	0	0	-40,000	-100%
Accident Tolerant Fuels	105,800	105,800	113,900	+8,100	+8%
TRISO Fuel and Graphite Qualification	36,000	36,000	27,000	-9,000	-25%
Fuel Cycle Core R&D	20,000	20,000	46,500	+26,500	+133%
High-Assay, Low-Enriched Uranium Availability	0	0	95,000	+95,000	+100%
Used Nuclear Fuel Disposition R&D	62,500	62,500	46,875	-15,625	-25%
Integrated Waste Management System	18,000	18,000	53,000	+35,000	+194%
Total, Fuel Cycle Research and Development	**309,300**	**309,300**	**421,775**	**+112,475**	**+36%**

SBIR/STTR:
- FY 2021 Enacted: SBIR $7,034; STTR $1,224
- FY 2022 Annualized CR: SBIR $7,034; STTR $1,224
- FY 2023 Request: Funding provided in the Directed R&D and Universities Program line.

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

	FY 2023 Request vs FY 2021 Enacted
Material Recovery and Waste Form Development: Funding increase from $25,000,000 to $38,000,000 reflects increased staffing needs and facility operation costs associated with accelerating Experimental Breeder Reactor-II (EBR-II) activities from 7 days/week, 12 hours/day to 7 days/week, 24 hours/day.	**+13,000**
Mining, Conversion, and Transportation Funding decrease from $2,000,000 to $1,500,000 reflects that funding for Small Business Innovation Research (SBIR), Small Business Technology Transfer (STTR), Technology Commercialization Fund (TCF), and Nuclear Energy University Program (NEUP) awards being consolidated within the new Directed R&D and University Programs line.	**-500**
Civil Nuclear Enrichment Funding decrease from $40,000,000 to $0 reflects that FY 2021 was the final year of funding for this initiative. Completion of the HALEU Enrichment Demonstration and one year of limited operation to produce HALEU will be included under the HALEU Availability subprogram.	**-40,000**
Accident Tolerant Fuels: Funding increase from $105,800,000 to $113,900,000 reflects increased irradiation testing and examination at the national laboratories and in commercial reactors as industry nears its near-term objective to install the first reload quantities of accident tolerant fuel in pilot plants and qualify the fuel for use at higher burnup levels.	**+8,100**
TRISO Fuel and Graphite Qualification Funding decrease from $36,000,000 to $27,000,000 reflects associated funding for SBIR, STTR, TCF, and NEUP awards being consolidated within the new Directed R&D and University Programs line and the TRISO fuel qualification program ramping down as it nears completion and high-cost activities such as irradiation experiments have been completed.	**-9,000**
Fuel Cycle Core R&D: Funding increase from $20,000,000 to $46,500,000 reflects the initiation of a metallic fuel qualification program that supports advanced reactor developers using metallic fuel and continuing advances in accelerated fuel qualification for advanced reactor fuel. The increase reflects the initiation of a process control program to accelerate the fuel preparation and treatment using molten salt technologies as well as investment in nuclear materials and molten salt fuels development capabilities at the national laboratories that necessary for molten salt reactor development.	**+26,500**

	FY 2023 Request vs FY 2021 Enacted
High-Assay, Low-Enriched Uranium Availability Funding increase from $0 to $95,000,000 for the HALEU availability program to make available small quantities of HALEU from limited DOE uranium inventories and HALEU production in the short term and support the private sector in its design and build out of commercial U.S. HALEU production capability in the long term.	**+95,000**
Used Nuclear Fuels Disposition R&D Funding decrease from $62,500,000 to $46,875,000 reflects associated funding for SBIR, STTR, TCF, and NEUP awards being consolidated within the new Directed R&D and University Programs line.	**-15,625**
Integrated Waste Management System Funding increase from $18,000,000 to $53,000,000 reflects a ramp up of activities to support effective implementation of consolidated interim storage for the nation's nuclear waste, including support for working collaboratively with the public, communities, stakeholders, and governments at the Tribal, state, and local levels. The funding increase also reflects funding for Interim Storage activities that were previously appropriated within the Interim Storage and Nuclear Waste Fund Oversight program (Nuclear Waste Disposal account), in the amount of $20,000,000 in FY 2021. The FY 2023 request for Interim Storage activities is instead included as part of the Office of Nuclear Energy's IWMS subprogram within Fuel Cycle R&D.	**+35,000**
Total, Fuel Cycle R&D	**+112,475**

Fuel Cycle Research and Development
Material Recovery and Waste Form Development

Description

The Material Recovery and Waste Form Development (MRWFD) subprogram conducts applied research and development (R&D) on advanced fuel recycle technologies that have the potential to improve resource utilization and energy generation, reduce waste generation, and limit proliferation risk. The subprogram focuses on developing advanced fuel cycle technologies and addressing fundamental materials separation and recovery challenges that present significant degrees of technical risks and financial uncertainties.

MRWFD provides unique nuclear chemistry expertise and technical capabilities in separation technologies to a broad range of applications by seeking a fundamental understanding of various chemical challenges related to civil nuclear applications. MRWFD stewards the capabilities and knowledge relied upon by policy makers to make informed decisions regarding nuclear fuel cycle options. Such decisions in turn rely on the development of efficient and economical separation methods that can accept the used nuclear fuel containing actinides and fission products to recycle selected actinides, recover valuable by-products, and deliver waste streams that are suitable for disposal. For example, MRWFD supports molten salt chemistry research to support advanced nuclear technologies using molten salts as electrolytes, fuel solvent and coolants. MRWFD funds research on integrated advanced technologies encompassing R&D on off gas capture, and waste form development. The subprogram employs a science-based approach to foster innovative and transformational technology solutions to achieve this objective. Specifically, MRWFD subprogram will continue to:

- Exploit principles of coordination chemistry to simplify actinide separations;
- Understand and manage radiation effects on materials and processes;
- Develop advanced salt waste forms to efficiently immobilize fission products;
- Design robust materials for separation of gas-phase species; and apply physical phenomena and gradients to intensify separations.

MRWFD subprogram also supports the development and demonstration of different recycling technologies to make available small quantities of high-assay low enriched uranium (HALEU) materials for advanced reactor fuel-fabrication R&D needs. HALEU can be recovered from feedstock that contains highly-enriched uranium (HEU) by using the molten salt and hybrid ZIRCEX processes. Specifically, the subprogram supports the accelerated treatment of irradiated Experimental Breeder Reactor-II (EBR-II) fuel to produce HALEU materials for fast spectrum advanced reactor fuels R&D needs. The accelerated EBR-II fuel activity will also support fulfilling a supplemental agreement between DOE and the State of Idaho to complete treatment of all sodium bonded EBR-II driver fuel by December 2028. In anticipation of expanding the runtime in FY 2024 from 7 days a week, 12 hours a day to 7 days a week, 24 hours a day, the EBR-II activities will continue in FY 2023 for training of qualified workers for hot cell and facility operations. The subprogram continues to evaluate the feasibility of recycling federally owned HEU fuels for HALEU production using a ¼-scale ZIRCEX pilot facility at the Idaho National Laboratory. In FY 2023, the hybrid ZIRCEX activity will continue demonstrating the feasibility of aluminum extraction using unirradiated fuel from the Advanced Test Reactor (ATR) and establish a back-end polishing process which is also capable of cleansing HALEU materials obtained from the EBR-II fuels treatment.

Material Recovery and Waste Form Development
Funding

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Material Recovery and Waste Form Development **$25,000,000**	**$38,000,000**	**+$13,000,000**
• Continued the acceleration of Experimental Breeder Reactor-II (EBR-II) used fuel treatment. • Continued Joint Fuel Cycle Study (JFCS) for its 10th and final year of collaboration with South Korea. • Continued hybrid ZIRCEX process focusing on cold pilot plant studies. • Supported fundamental aqueous and molten salt separation chemistries to address chemical challenges related to civil nuclear energy applications. • Explored next generation fuel cycle technologies targeting high-value used fuels.	• Develop innovative fuel recycling technologies targeting high-value used fuels. • Support fundamental aqueous and molten salt separation chemistries to address challenges related to civil nuclear energy applications. • Determine efficiency of advanced complexants for simplified uranium recovery. • Develop advanced salt waste form and off-gas technologies. • Continue the accelerated EBR-II fuel treatment to fully fund an anticipated expansion of fuel treatment operations starting in FY 2024.Complete processing demonstration of unirradiated Aluminum-clad fuel in the material recovery pilot plant.	• The increase reflects the increased staffing and facilities costs associated with the anticipated expansion of EBR-II fuel treatment facility operation from 7 days a week, 12 hours a day to 7 days a week, 24 hours a day in FY 2024.

Fuel Cycle Research and Development
Mining, Conversion, and Transportation

Description

This subprogram supports, cost-shared research and development (R&D) that enables technological advances in uranium mining, conversion, and transportation capabilities in the United States as well as the conducting evaluations and assessments related to these areas. This subprogram supports activities related to the front end of the nuclear fuel cycle and supply chain.

Mining sites are often located in underserved communities and locations with limited water resources. Improvements to mining technology spurred by R&D may enable local economic opportunities and include environmental justice equities while reducing the amount of water used during uranium production.

In FY 2023, this subprogram will continue to fund cost-shared R&D for uranium mining and processing technologies that reduce water usage and/or improve extraction efficiency and resource utilization for uranium production.

Mining, Conversion, and Transportation
Funding

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Mining, Conversion, and Transportation $2,000,000	**$1,500,000**	**-$500**
• Supported research and Development (R&D) for uranium mining and processing technologies that reduce water usage and/or improve extraction efficiency and resource utilization for uranium production.	• Continue R&D for uranium mining and processing technologies that reduce water usage and/or improve extraction efficiency and resource utilization for uranium production.	• The decrease reflects funding for Small Business Innovation Research (SBIR), Small Business Technology Transfer (STTR), Technology Commercialization Fund (TCF), and Nuclear Energy University Program (NEUP) awards being consolidated within the new Directed R&D and University Programs line.

Fuel Cycle Research and Development
Civil Nuclear Enrichment

Description

This subprogram executed a three-year, limited scope, demonstration of a U.S. origin, enrichment technology for producing high-assay, low enriched uranium (HALEU). FY 2021 was the final year of funding for this initiative.

Civil Nuclear Enrichment
Funding

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Civil Nuclear Enrichment $40,000,000	**$0**	**-$40,000**
• Completed cascade design work, install support equipment such as the inventory withdrawal station, restore the Piketon, OH facility for handling classified material/information, install centrifuge machinery, condition the system for operation, calibrate operations and operate a lead cascade of centrifuges. • Continued regulatory support related to demonstrating the production of high-assay, low-enriched uranium.	• FY 2021 was the final year of funding for this initiative.	• FY 2021 was the final year of funding for this initiative.

Fuel Cycle Research and Development
Accident Tolerant Fuels

Description

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

Following the accident at Fukushima, Advanced Fuels initiated a program in collaboration with fuel suppliers, national laboratories, and universities to explore advanced LWR fuel with enhanced accident tolerance to benefit existing U.S. commercial nuclear power reactors. After five years of feasibility studies and assessments of potential fuel concepts, the program identified promising concepts that have the potential to significantly enhance accident tolerance.

The U.S. fuel suppliers are developing accident tolerant fuel concepts that the owner/operators of commercial U.S. reactors believe will provide substantial performance improvements during accidents and under normal operations. The greatest improvements will come with using the robust nature of the accident tolerant fuel to enable the fuel to operate for a longer period of time in the reactor. This would allow reactors to operate for a longer time between refueling outages. Many reactors would be able to increase their cycle lengths from 18 to 24 months and less fuel would be needed to generate the same amount of electricity resulting in substantially reduced spent nuclear fuel storage and disposal requirements.

This subprogram supports the industry's objective to install the first reload quantities of accident tolerant fuel in pilot plants by the mid-2020s and qualify the fuel for use at higher burnup levels. In FY 2023 this will involve cost-shared testing and examination of fuel and cladding material performance to generate data that can be used by industry partners to support their NRC licensing efforts, research and development of pilot fuel pellet and cladding manufacturing equipment, analysis and redesign of fuel fabrication processes, and revising fuel performance codes and methods.

This subprogram is using the experimental and analytical capabilities only found at the Department of Energy (DOE) National laboratories to provide the U.S. nuclear industry with the data needed to qualify the accident tolerant fuel concepts, including for use at higher burn up levels and to demonstrate the performance of the fuel to take advantage of the safety and economic benefits that come with these more robust fuel designs. In FY 2023, this includes continuing the modifications at Idaho National Laboratory to expand its experimental capabilities. This involves: (1) the design, fabrication, and testing of experimental capsules to house irradiated fuel samples to simulate loss of coolant accident conditions in the transient test reactor (TREAT) and (2) the design and installation of a new test loop in the Advanced Test Reactor (ATR) to provide experimental capabilities lost when the Halden test reactor in Norway shutdown. These capabilities are boiling water reactor conditions, highly-instrumented test trains, ramp testing, and dry out testing. Also, in FY 2023, the partnership with industry to implement the test plans needed to develop the data needed to qualify the Accident Tolerant Fuel concepts for higher burn up will continue.

Accident Tolerant Fuels
Funding

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Accident Tolerant Fuels $105,800,000	**$113,900,000**	**+$8,100,000**
• Continued irradiations of fuel rodlets in the central water loop of the Advanced Test Reactor (ATR). • In the Transient Reactor Test Facility (TREAT), performed reactivity insertion accident tests on irradiated fuel in static water capsules. • Continued investment in fuel development capabilities at the Department of Energy (DOE) National laboratories that are critical for accident tolerant fuel development. • Continued to advance the accident tolerant fuel concepts under development by the three fuel vendor teams under cooperative agreements with the Department.	• Continue irradiations of fuel rodlets in the central water loop of the ATR. Initiate advanced instrumented tests to expand data generation for real time fuel performance under irradiation. • Continue in partnership with industry to support the Fuel Performance and Testing Technical Experts Group for burn up extension. This includes examination of high burn up fuel rods, furnace testing, re-irradiation of test samples in ATR, and loss of coolant tests in TREAT. • Conduct advanced LWR fuel technology research on ceramic fuel and cladding concepts. This includes fabrication technology development, separate effects irradiation tests in HFIR and ATR, and advanced characterization of properties and irradiation performance. • Continue to advance the accident tolerant fuel concepts under development by the three fuel vendor teams under cooperative agreements with the Department. This involves cost-shared testing and examination of fuel and cladding material performance, research and development of pilot fuel pellet and cladding manufacturing equipment, analysis and redesign of fuel fabrication processes, and revising fuel performance codes and methods.	• The increase reflects acceleration of irradiation testing and examination at the national laboratories and in commercial reactors as we near industry's objective to install the first reload quantities of accident tolerant fuel in pilot plants by the mid-2020s and qualify the fuel for use at higher burnup levels.

Description

The Tristructural-isotropic (TRISO)-coated particle fuel and graphite subprogram includes activities for fuel and material irradiation, post-irradiation examination (PIE) and safety testing, fuel performance modeling, and fission product transport and source term research.

TRISO particle fuel development and qualification activities support prismatic and pebble-bed high temperature fuel designs. Since the onset of the TRISO Fuel Program in 2002, the program has focused on qualification of the fuel design for high temperature gas reactor concepts; however, TRISO fuel also has applications for other reactor concepts such as molten salt-cooled high temperature reactors. Irradiation, safety testing, and PIE of TRISO fuel will provide data for fuel development and qualification in support of industry efforts to eventually establish a domestic commercial TRISO fuel fabrication capability.

The graphite development and qualification efforts provide data to support the use of graphite in high temperature reactor environments. Since historical grades of graphite used in previous high temperature reactors are no longer available, graphite development includes efforts to characterize and irradiate new grades of graphite. These efforts provide non-irradiated and irradiated properties so that the thermomechanical design of the structural graphite in advanced high temperature reactors can be validated. The irradiation experiments span the proposed temperature and dose envelope for a prismatic high temperature gas reactor and is also applicable to pebble-bed and possibly molten salt-cooled high temperature reactors.

TRISO Fuel and Graphite Qualification
Funding

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
TRISO Fuel and Graphite Qualification $36,000,000	**$27,000,000**	**-$9,000,000**
• Continued post irradiation examination (PIE) of the AGR-3/4 TRISO fuel experiment. • Continued safety testing of TRISO fuel in elevated temperatures. • Commissioned the air and moisture ingress furnace to understand TRISO fuel performance in a transient scenario resulting in air or moisture ingress. • Began high dose graphite experiment irradiation in Idaho National Laboratory (INL)'s ATR. • Continued characterization and PIE of graphite specimens. • Continued to pursue addition of graphite to the American Society of Mechanical Engineers (ASME) code for use in high temperature reactors.	• Perform further PIE of the AGR-3/4 and AGR-5/6/7 TRISO fuel experiments to characterize fission product inventory and fuel performance in response to varying reactor fluence and temperature to support industry TRISO fuel qualification efforts. • Perform additional safety testing of TRISO fuel to characterize performance in elevated temperatures and fission product transport. • Begin testing of TRISO fuel in the air and moisture ingress furnace to understand performance in a transient scenario. • Further irradiate high dose graphite experiment in INL's ATR to subject graphite to doses that more closely reflect what would be experienced in pebble bed type reactors. • Perform additional characterization and PIE of graphite specimens to provide qualification data of various grades of graphite for use in high temperature reactors. • Enhance the American Society of Mechanical Engineers (ASME) code to extend the use of graphite in high temperature reactors.	• The decrease from $36,000,000 to $27,000,000 reflects associated funding for Small Business Innovation Research (SBIR), Small Business Technology Transfer (STTR), Technology Commercialization Fund (TCF), and Nuclear Energy University Program (NEUP) awards being consolidated within the new Directed R&D and University Programs line. • The decrease also reflects the fact that the TRISO fuel qualification program is ramping down as it nears completion and high-cost activities such as irradiation experiments have been completed.

Fuel Cycle Research and Development
Fuel Cycle Core R&D

Description

This subprogram supports research activities that advance the knowledge base for nuclear fuel cycles and provide transformative changes to accelerate development of civil nuclear technologies, including consideration of fuel cycle impacts from the potential deployment of advanced reactor technologies. It also includes activities in Materials Protection, Accounting and Control Technologies (MPACT), Systems Analysis and Integration (SAI), Innovative Nuclear Materials (INM), Innovative Process Control Capabilities (IPCC) and advanced reactor fuels research and development (R&D).

MPACT develops innovative technologies, analysis tools and advanced integration methods to enable U.S. domestic nuclear materials management and safeguards for emerging nuclear fuel cycles. It also includes assessing vulnerabilities in current nuclear systems while minimizing proliferation risks. Addressing U.S. energy security needs requires innovative approaches to material control and accounting to ensure that nuclear material is not misused, diverted, or stolen.

SAI activities include strategic planning and analysis, and integrated evaluation of program activities. It provides the critical capability needed to analyze complex fuel cycle system options, assess overall performance under various scenarios, and improve understanding of the interdependencies between various subsystems and associated technologies.

INM activities focus on longer-term materials discovery and development for advanced nuclear energy systems applications. It seeks to develop new tools, techniques, and capabilities at national laboratories. The goal is to accelerate the pace of new materials discovery, building on recent advances in artificial intelligence, machine learning, theory, modeling, and computing, and advanced characterizations. For example, innovative approaches are needed to develop advanced metallic alloys and composite materials that are optimized to meet new reactor performance targets within the reactor core and fuel cladding. It also includes recycling of zircaloy cladding material, which is the second largest mass in used fuel assemblies. Developing recovery process with sufficient Zr purity to permit re-use will reduce the waste quantity as well as enhance resource utilization. Similar recycling approaches will be developed for other high value nuclear materials.

IPCC activities include the development of-innovative fuel cycle process control technologies to enhance process controllability and to enable predictive modeling capability in advanced nuclear separation systems. A significant fraction of the space in a nuclear fuel recycling plant is occupied by large tanks—used for surge capacity or system redundancy. Implementing advanced process control and modeling technologies into the recycling plant design will reduce the size of such tanks, or even eliminate the need for this tank space. This in turn would directly reduce the cost of plant construction. The activity also supports fuel development and capabilities using advanced processing control technologies in molten salt recycling at the national laboratories.

Advanced reactor fuels activities include continued advances in accelerated fuel qualification activities to support advanced reactor development. Conventional fuel qualification takes more than 20 years and costs hundreds of millions of dollars. Recent advances in modeling, examination and analysis techniques, irradiation testing techniques, and even artificial intelligence and machine learning can significantly reduce the time and expense of fuel qualification. In FY 2023 we propose to build upon the advanced irradiation testing techniques recently developed at the national labs. Those techniques are the Fission Accelerated Steady-State Testing (FAST) approach at INL and MiniFuel separate effects testing at ORNL. Both techniques allow for much shorter irradiation times to gather meaningful data on fuel performance. Also, in FY 2023 we propose to initiate a metallic fuel qualification program that supports advanced reactor developers using metallic fuel. Many advanced reactor developers are proposing metallic fuel for their reactors. Metallic fuel is a mature and may become a key strategic U.S. developed and owned technology. This program would establish a reference fuel performance baseline using legacy data and analyses, improve performance modeling capability in the BISON fuel performance code, and prepare for transient experiments in Transient Reactor Test Facility (TREAT) on legacy Experimental Breeder Reactor-II (EBR-II) reactor fuel.

Fuel Cycle Core Research & Development
Funding

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Fuel Cycle R&D $20,000,000	**$46,500,000**	**+$26,500,000**
• Continued the development of innovative technologies, analysis tools, and advanced integration methods for aqueous and molten salt separation process controls and nuclear materials management and other limited fuel cycle research and development activities. • Developed innovative on-line process monitoring capabilities for advanced reactors fuel recycling. • Developed advanced solvent extractants and complexation agents to improve the separation processes controllability. • Developed and maintained leading-edge analysis capabilities to ensure world-class analysis of complete nuclear energy systems. • Performed scenario analysis studies of fuel cycle facilities for promising advanced reactor technologies. • Supported advanced reactor developers with innovative fuel irradiation experiments that accelerate the qualification of fuel for their reactor concepts. • Collaborated with Japan on transient testing of advanced fuel concepts.	• Continue developing innovative technologies, analysis tools, and advanced integration methods for material control and accounting applications. • Continue innovative on-line process monitoring capabilities for advanced reactors fuel recycling. • Demonstrate high resolution microcalorimeter measurements at INL • Deploy an acoustic system to monitor uranium and plutonium mass values in aqueous processing. • Continue to conduct performance assessments and economic and market analyses of promising advanced nuclear energy systems and their role in achieving a net-zero economy by 2050. • Continue accelerated irradiation experiments using the ATR and HFIR using Fission -Accelerated Steady-State Testing (FAST) and Mini-fuel Testing, respectively. Continue U.S./Japan joint transient testing of advanced reactor fuel concepts in TREAT. • Initiate a metallic fuel qualification program that supports advanced reactor developers using metallic fuel. This includes establishing a reference fuel baseline, improving performance modeling capability, and preparing for future transient experiments. • Initiate molten salt recycling for salt fuels development capabilities at the national laboratories. • Support new and recycled materials development for fuel cladding, coating and in-core materials.	• The increase reflects the initiation of a metallic fuel qualification program that supports advanced reactor developers using metallic fuel and continuing advances in accelerated fuel qualification for advanced reactor fuel. • The increase reflects the initiation of an innovative process control program to accelerate the fuel preparation and treatment using molten salt technologies. • The increase reflects investment in innovative nuclear materials and molten salt fuels development capabilities at the national laboratories that are critical for advanced fuel cycle development.

Fuel Cycle Research and Development
High Assay, Low-Enriched Uranium Availability

Description

Advanced reactors are being developed for flexible baseload power generation, providing U.S. leadership in nuclear technology, enabling new markets for export, and reducing greenhouse gas emissions. Many of these reactors are expected to require high-assay, low-enriched uranium (HALEU) fuel. HALEU is uranium with the fissionable isotope U-235 enriched to between greater than 5 and less than 20 percent. Current commercial light water reactors use uranium enriched to up to 5 percent U-235. There are no commercial suppliers of HALEU in the U.S. and advanced reactor developers will need small quantities of HALEU in the near term to support the qualification of their fuel and larger quantities for the first demonstration reactors. Much larger quantities of HALEU would be needed when advanced reactors requiring HALEU fuel are commercialized. The Energy Policy Act of 2020 authorized DOE to begin working to address HALEU availability issues.[1]

This subprogram will work to make available small quantities of HALEU from limited DOE uranium inventories and leverage the HALEU enrichment demonstration capability in the short term, in coordination with the National Nuclear Security Administration (NNSA), and work with the private sector in its building out of commercial U.S. HALEU production and supply chain capability for the long term.

In FY 2022, the Department received many responses to its request regarding the establishment of a HALEU consortium, technical and regulatory barriers to licensing fuel cycle facilities, cost-sharing approaches or contracting vehicles, transportation capabilities, conversion capabilities, market-related barriers, financing. Human resources, and/or other topics. Responses to the RFI are informing the Department's planning for FY 2023 and beyond. In FY 2022, DOE will develop a cost recovery process in preparation for the supplying of HALEU to members of a consortium for commercial use in future years.

In FY 2023, subprogram activities include initiating the recovery and down-blending of limited excess quantities of DOE uranium inventories to HALEU for DOE's use in research, development, and demonstration programs. In coordination with NNSA, NE will recover and downblend highly-enriched uranium from existing inventories located at the Savannah River Site and NNSA will identify and repurpose unused or scrap material at Y-12 under their Convert subprogram. This is anticipated to be a three-year effort which will reduce the costs to store, process and dispose of this material under current plans. Under this NE subprogram, NE will initiate activities to support the production of 2.0-2.4 MT HALEU from existing HEU uranyl nitrate solution at Savannah River and prepare it for shipping and conversion to oxide. NNSA's Convert subprogram will produce an additional ~2.2 MT of HALEU.

In FY 2022, DOE will transition the HALEU enrichment activities in Piketon, Ohio to a new competitively awarded, cost-share program to complete the HALEU Enrichment Demonstration and operate the 16-centrifuge cascade to produce a limited quantity of HALEU for one year. Future options to continue the operation of the cascade beyond FY 2023 are subject to the annual budget process. In FY 2023, the private sector partner awarded the contract will staff and operate the enrichment facility to produce a limited quantity of HALEU for DOE's use in research, development, and demonstration programs. The facility may contribute to the long-term commercialization of HALEU supply by private industry beyond FY 2023.

DOE will also initiate efforts to address critical near-term supporting elements of the HALEU availability program: (1) developing and executing a strategy to address the National Environmental Policy Act requirements, (2) explore with industry the processes that would be needed to convert HALEU to the various fuel forms needed to fuel their advanced reactors, and (3) working with industry on HALEU transportation needs including criticality benchmark data needed to reduce conservatism in package designs and cost-shared competitive awards to support package development.

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[1] The Energy Act of 2020 authorized a HALEU availability program, which authorized the Department perform activities regarding developing criticality benchmark data, supporting design and licensing of transportation packages, considering options for acquiring or providing HALEU to advanced reactor developers, surveying stakeholders, and establishing a HALEU consortium. The Act also directs DOE to be prepared to supply HALEU to commercial industry by January 1, 2026 and requires DOE to develop an associated cost recovery process.

High-Assay, Low-Enriched Uranium Availability
Funding

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
HALEU for R&D $0	**$95,000,000**	**+$95,000,000**
• Funding was not provided in FY 2021.	• Initiate the recovery and down-blending of limited excess quantities of DOE uranium inventories to HALEU. In coordination with NNSA, NE will recover and downblend highly-enriched uranium from existing inventories located at the Savannah River Site and NNSA will identify and repurpose unused or scrap material at Y-12 under their Convert subprogram. • Continue activities under a new competitively awarded cost share program to operate the 16-centrifuge cascade in Piketon to produce a limited quantity of HALEU for research, development, and demonstration use for one year, with the option to extend in future years. The private sector partner awarded the contract will operate the facility and produce HALEU for DOE's use. • Initiate efforts to address critical near-term supporting elements of the HALEU availability program: : (1) develop and execute a strategy to address the National Environmental Policy Act requirements, (2) explore with industry the processes that would be needed to convert HALEU to the various fuel forms needed to fuel their advanced reactors, and (3) work with industry on HALEU transportation needs including criticality benchmark data needed to reduce conservatism in package designs and research and development.	• Initiate a HALEU availability program as authorized by the Energy Act of 2020 in order to make available small quantities of HALEU from limited DOE Uranium inventories and HALEU production in the short term and support the private sector in its design and build out of commercial U.S. HALEU production capability in the long term.

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

Description

The Used Nuclear Fuel Disposition Research and Development (R&D) subprogram conducts scientific research and technology development to enable long term storage, transportation, and disposal of spent nuclear fuel and wastes. The primary focus of this subprogram supports the development of disposition-path-neutral waste management systems and options in the context of the current inventory of spent nuclear fuel and waste.

Research and Development

Full-Scale Storage Cask Demonstration – Although the nuclear power industry has used dry storage for many years, this storage option has been for low-burnup fuel; therefore, there is limited data available on the degradation of more contemporary high-burnup fuels. To address this data gap, the Department of Energy (DOE), the Nuclear Regulatory Commission (NRC), and nuclear industry are cooperating to investigate extended storage of high-burnup fuels (≥ 45 GWd/MTHM). DOE, in cooperation with the NRC and industry, is conducting a full-scale demonstration of storage for high-burnup fuel that will be beneficial by: 1) benchmarking the predictive models and empirical conclusions developed from short-term laboratory testing, and 2) building confidence in the ability to predict the performance of these systems over extended time periods.

Storage and Transportation R&D – In addition to the Full-Scale Storage Cask project, DOE will continue to support other lab testing, field studies, and modeling R&D related to the storage and transport of high-burnup fuel to include: testing of cladding response with hydride reorientation and embrittlement; the effects of atmospheric corrosion on storage welds; measuring the embrittlement of elastomer seals; determining thermomechanical degradation of bolts, welds, seals and poisons; analyzing thermal profiles of stored fuels; determining the stress profiles of fuels and casks; evaluating cask drying processes; laboratory post-irradiation examination and testing of the fuel from the cask demonstration project at the North Anna Generating Station in Mineral, Virginia; and the development of sensors for internal and external cask monitoring. R&D will focus on contributing to the technical knowledge to support long-term storage and eventual transportation of high-burn-up fuels. As the DOE continues to make progress on the accident tolerant fuels, research will be done to ensure that data are gathered on the new/modified cladding and fuel materials to ensure that they can be stored and transported in the future. Current work also indicates that burnup rates for accident tolerant fuels could go up to 75 to 80 GWD/MTU for which very little if any data exists, so additional R&D will be done to address this gap.

Disposal R&D – Activities continue to further the understanding of long-term performance of disposal systems in three main geologic rock types: clay/shale, salt, and crystalline rock. These activities include collaborations with international partners to leverage and integrate applicable R&D being conducted by other countries into the U.S. disposal R&D portfolio. Also, evaluations will continue to determine the feasibility of directly disposing existing single (storage only) and dual-purpose (storage and transportation) used-fuel canisters in a mined repository. Evaluate the disposal performance characteristics of new accident tolerant fuels and high-level radioactive waste glass compositions. Support a pilot program to increase participation of underrepresented groups in research activities related to management and disposal of radioactive wastes.

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

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Used Nuclear Fuel Disposition Research & Development $62,500,000	**$46,875,000**	**-$15,625,000**
• Completed non-destructive testing and continue destructive testing of fuel rods that were pulled from a commercial power station to establish the performance baseline of the stored used fuel. • Characterized external loadings on fuel rods during normal conditions of transport. • Developed an understanding of material degradation phenomena in safety components associated with long term storage and transportation systems. This work will support licensing applications for extended dry storage and subsequent retrieval and transport of high burnup used nuclear fuel. • Evaluated integration and implementation methodologies of process-level models with performance assessment tools relating to argillite and crystalline media disposal. Integrate developed modeling tools with analysis software for uncertainty quantification and sensitivity analysis. • Continued science and engineering technical basis for the disposal of heat generating waste in salt. • Continued research and development (R&D) activities associated with exploring potential disposal options for various waste and spent nuclear fuel forms, including collaboration with international partners to leverage R&D being conducted in various geologic media. • Issued evaluation of the technical feasibility of direct disposal of dual-purpose canisters to	• Continue ongoing disposal R&D. • Evaluate the storage, transportation, and disposal performance characteristics of new accident tolerant fuels and high-level radioactive waste glass compositions. • Support pilot program to increase participation of underrepresented groups in research activities related to management and disposal of radioactive wastes. • Consistent with the results of an Independent Technical Review continue evaluations to determine the feasibility of directly disposing existing single (storage only) and dual-purpose (storage and transportation) used-fuel canisters in a mined repository. • Continue destructive testing on sibling rods. • Work with SONGS to install instrumentation on typical canisters used by the nuclear power plant industry. • Continue work to clear hot cells and prepare for acceptance of new accident tolerant fuels.	• The decrease reflects funds for NE's Directed R&D and University Programs being requested outside of the UNFD program's budget.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
potentially eliminate the need for repackaging these canisters for disposal. • Prepare to begin testing and evaluation of the storage, transportation and disposal performance characteristics of the new accident tolerant fuels.		

Fuel Cycle Research and Development
Integrated Waste Management System

Description

The Nuclear Waste Policy Act of 1982 (NWPA) assigns the Department of Energy the responsibility for disposition of U.S. spent nuclear fuel (SNF) and high-level radioactive waste (HLW), and the Department remains committed to fulfilling the Federal Government's legal obligations to properly manage and dispose of that material. The Integrated Waste Management System (IWMS) subprogram supports efforts to develop and implement a Federal interim storage program that uses a consent-based approach to siting as part of an overarching waste management system, as well as storage, transportation, and system development and analysis activities. The activities of this subprogram include developing a consent-based siting process, preparing for large-scale transportation of spent nuclear fuel, and working with communities, stakeholders, and governmental entities including in the more than 30 states where SNF and HLW is currently stored.

The IWMS subprogram's FY 2023 Budget Request funds critical, foundational planning and development actions required to lay the groundwork for effective implementation of consolidated interim storage of the nation's nuclear waste. As part of its efforts, the Department will work collaboratively with the public, communities, stakeholders, and governments at the Tribal, state, and local levels. The Department will develop a consent-based approach to siting, engaging with potential host communities. These activities include:

- Initiate $10,000,0000 of early-phase grant funding for interested groups, communities, states, or Tribes to explore consent-based siting and interim storage, support mutual learning, and reduce barriers to participation in the consent-based siting process;
- Build public participation into the consent-based siting process, allowing opportunities for the public and stakeholders to engage with the Department;
- Develop communication plans, materials, and strategies to support strong public engagement and meaningful information sharing capabilities;
- Develop a waste management system that incorporates social equity and environmental justice;
- Conduct technical activities to develop facility design concept information to share and support interactions with stakeholders to better inform the consent-based siting process;
- Evaluate the costs and benefits of interim storage facility approaches;
- Analyze regulatory considerations applicable to interim storage facility design options and siting process;
- Analyze and update critical data needed to identify quantities of and collect detailed information on relevant nuclear waste inventories to inform options analyses and transportation planning;
- Continue funding engagement with State and Tribal partners to cooperatively plan for large-scale SNF transportation, including approaches to emergency response training and safety inspections;
- Begin acquisition of transportation casks for SNF, which may require moderate lead times to update cask certificates of compliance and initiate commercial fabrication capacity; and
- Begin planning for a full-scale package performance test of a rail-sized SNF cask to aid in building public trust and confidence in the safety of SNF transport.

As part of the subprogram, storage facility design and operations options are explored and evaluated. These activities include investigating methods to mitigate the possibility of stress corrosion cracking and advanced manufacturing techniques for spent fuel containers. Evaluations of storage system design alternatives conducted in this subprogram inform an understanding that will help guide future approaches as well as the development of system interface requirements. The IWMS subprogram’s work to implement SNF storage facilities and transport SNF complements and builds on the Used Nuclear Fuel Disposition R&D subprogram’s work to conduct research on SNF and HLW disposal options, high-burnup fuel storage, and impacts to fuel rods during transport.

Preparations for large-scale transportation of SNF and HLW includes development of purpose-built railcar equipment, design of a safety and security monitoring system for rail shipments, assessment of transportation infrastructure and transport options at nuclear power plant sites, employment of state-of-the-science data and software tools to support decision-making and communications, thorough analysis of transportation system operational elements and dependencies, active engagement with State and Tribal government representatives through the Department's National Transportation Stakeholders Forum and associated working groups, and coordination with appropriate Federal agencies on safety and security considerations. These efforts build on successes and lessons learned from previous DOE radioactive materials transportation programs and campaigns as identified through knowledge management activities.

Waste management system analysis capabilities will be maintained and enhanced as part of the IWMS subprogram. These analytical tools and database systems provide the ability to model various system architectures and configurations including options involving interim storage of SNF. Using these models and analytical tools, different system scenarios can be evaluated and the effect of varying input assumptions can be examined, including interim storage facility receipt rate and capacities. Other analytical tools provide the capability to explore SNF storage, transport, and disposal considerations. In FY 2023, work will focus on incorporating output from detailed system analysis tools into a prototype user-friendly siting analysis tool to assist interested communities in interactive exploration of consolidated interim storage.

Integrated Waste Management System
Funding

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Integrated Waste Management System $18,000,000	**$53,000,000**	**+$35,000,000**
• Investigated possible storage approaches and solutions using advanced analytical methods and techniques. • Continued development of computational systems analysis tools to support facility design analyses and transportation operational planning. • Issued an updated report on evaluations of transportation infrastructure at nuclear power plant sites. • Maintained spent nuclear fuel inventory data and system analysis modeling tools by incorporating enhancements into software. • Supported development of a prototype web-based application to streamline future collection, processing, and analysis of spent nuclear fuel data from U.S. nuclear power plants. • Continued testing and demonstration of the Atlas railcar consist. • Received approval for the Fortis railcar design and began procurement for a prototype Fortis railcar.	• Continue early-phase funding to interested groups, communities, States, or Tribes exploring the consent-based siting process and interim storage. • Develop a prototype siting analysis tool to assist interested communities in exploring interim storage. • Finalize the railcar safety inspection protocol developed in coordination with States and Tribes. • Update DOE's proposed Section 180(c) Policy to provide emergency response training funds and technical assistance to States and Tribes. • Conduct demonstration run and delivery of one Atlas 12-axle cask-carrying railcar, two buffer railcars, and one REV. • Provide one complete rail consist approved by the Association of American Railroads (AAR) and achieve ready to transport in accordance with AAR Standard S-2043. • Complete fabrication of one Fortis 8-axle cask-carrying railcar prototype and begin railcar performance testing. • Conduct integrated system analyses of interim storage options, factoring in early feedback from consent-based siting activities. • Develop an updated reference concept for a generic Federal Consolidated Interim Storage Facility (CISF). • Commence work on conceptual design options of interest for Federal CISFs to inform consent-based siting efforts.	• Funding increase reflects a ramp-up in activities to develop a consent-based process for siting interim storage facilities and identify one or more sites for an interim storage facility based on that process. • Funding increase reflects $10,000,000 of dedicated funding for communities and Tribes to participate in the consent-based siting process. • Funding increase reflects additional SNF transportation planning activities, including work to begin acquiring SNF transportation casks, and preparations for full-scale accident testing of a rail-sized transport cask. • Funding increase also reflects funding for interim storage activities that were previously appropriated within the Interim Storage and Nuclear Waste Fund Oversight program (Nuclear Waste Disposal account), in the amount of $20,000,000 in FY 2021. The FY 2023 request for Interim Storage activities is instead included as part of the Office of Nuclear Energy's IWMS subprogram within Fuel Cycle R&D.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
	• Continue and expand upon existing planning, analysis, and outreach work for large-scale SNF transportation.	

Nuclear Energy Enabling Technologies

Overview

The Nuclear Energy Enabling Technologies (NEET) program conducts research and development (R&D) and makes strategic investments in research capabilities to develop innovative and crosscutting nuclear energy technologies to resolve nuclear technology development issues. The Crosscutting Technology Development (CTD) subprogram focuses on innovative research that directly supports the existing fleet of nuclear reactors and enables the development of advanced reactors and fuel cycle technologies, including topical areas such as advanced sensors and instrumentation; nuclear cybersecurity; innovative materials and manufacturing technologies; and integrated energy systems. Also, NEET invests in modeling and simulation tools for existing and advanced reactors and fuel system technologies. The program also provides industry, universities, and national laboratories with access to unique nuclear energy research capabilities through the Nuclear Science User Facilities (NSUF) subprogram. Collectively, NEET-sponsored activities support the Department's priorities to combat the climate crisis, create clean energy jobs with the free and fair chance to join a union and bargain collectively, and promote equity and environmental justice by delivering innovative clean energy and advanced manufacturing technologies for nuclear energy systems. NEET also makes these technology advancements accessible to the U.S. industry through the Gateway for Accelerated Innovation in Nuclear (GAIN) initiative and private-public partnerships.

Highlights of the FY 2023 Budget Request

Within CTD, the Advanced Materials and Manufacturing Technologies (AMMT) subprogram will continue to accelerate the development, qualification, and demonstration of innovative materials and manufacturing technologies to enable reliable and economical technologies for nuclear energy production. AMMT will work with a broad range of stakeholders to develop new materials and manufacturing technologies, establish a comprehensive framework for rapid qualification, and perform technology demonstrations.

The Nuclear Science User Facilities subprogram includes, within its request, funding for the High Performance Computing (HPC) nuclear energy computation system that provides scientific computing capabilities to NE's R&D programs, universities, industry, national laboratories, and federal agencies to support their research and development efforts.

Nuclear Energy Enabling Technologies
Funding ($K)

	FY 2021 Enacted	FY 2022 Annualized CR	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
Nuclear Energy Enabling Technologies					
Crosscutting Technology Development	28,000	28,000	35,250	+7,250	+26%
Joint Modeling and Simulation Program	35,000	35,000	28,327	-6,673	-19%
Nuclear Science User Facilities	30,000	30,000	39,160	+9,160	+31%
Transformational Challenge Reactor	29,869	29,869	0	-29,869	-100%
Total, Nuclear Energy Enabling Technologies	**122,869**	**122,869**	**102,737**	**-20,132**	**-16%**

SBIR/STTR:

- FY 2021 Enacted: SBIR $3,758; STTR $654
- FY 2022 Annualized CR: SBIR $3,758; STTR $654
- FY 2023 Request: Funding provided in the Directed R&D and Universities Program line.

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

	FY 2023 Request vs FY 2021 Enacted
Crosscutting Technology Development: The increase from $28,000,000 to $35,250,000 reflects support for the Advanced Materials and Manufacturing Technologies (AMMT) activity, which consolidates efforts from the Nuclear Materials Discovery and Qualification initiative, the crosscutting research previously conducted under the Transformational Challenge Reactor subprogram, and the Advanced Methods for Manufacturing area. This increase also provides support for the Integrated Energy Systems activity and additional support for research and development (R&D) in the areas of advanced sensors and instrumentation and cybersecurity.	**+7,250**
Joint Modeling and Simulation: The decrease from $35,000,000 to $28,327,000 reflects $8,592,500 in associated funding for Small Business Innovation Research (SBIR), Small Business Technology Transfer (STTR), Technology Commercialization Fund (TCF), and Nuclear Energy University Program (NEUP) awards being consolidated within the new Directed R&D and University Programs line, and additional funding in the amount of $1,919,500 to support industry needs for modeling fuel fragmentation, relocation, and dispersion at higher burnup.	**-6,673**
Nuclear Science User Facilities: The increase from $30,000,000 to $39,160,000 reflects additional support for industry, universities, and national laboratories access to unique nuclear energy research facilities and continued support for NE's High Performance Computing capability.	**+9,160**
Transformational Challenge Reactor: The decrease from $29,869,000 to $0 reflects the subprogram's transition to an R&D effort to be managed under the Crosscutting Technology Development (CTD) subprogram with other relevant R&D.	**-29,869**
Total, Nuclear Energy Enabling Technologies	**-20,132**

Crosscutting Technology Development

Description

The Crosscutting Technology Development (CTD) subprogram develops innovative solutions to crosscutting nuclear energy technology challenges. The CTD subprogram focuses on foundational research on transformative technologies to maintain the current fleet of nuclear reactors and support the development of advanced reactors and fuels. CTD research and development (R&D) projects include industry, universities, and national laboratory collaborations and it is closely coordinated with the Office of Nuclear Energy's other R&D programs to ensure that developed technologies and capabilities are part of an integrated investment strategy aimed at improving reliability and economics of U.S. nuclear technologies.

Activities within this subprogram include:

- developing new capabilities needed for domestic nuclear energy R&D, with focus on gaps to commercial deployment of advanced reactors;
- conducting high-risk research that could overcome current technological limitations;
- developing enabling technologies that have applicability across multiple technical areas; and
- conducting leading-edge R&D to improve the economics, quality, security, and efficiency of nuclear technologies.

The principal focus areas for FY 2023 include advanced sensors and instrumentation, nuclear cybersecurity research, advanced materials and manufacturing technologies, and integrated energy systems as follows:

- Advanced Sensors and Instrumentation supports R&D of unique sensor and instrumentation technologies that provides enhanced monitoring and control capabilities to the existing reactor fleet, adapts novel sensor types for advanced reactor development and demonstration, and provides expanded capability to fuel cycle and advanced materials development;
- Nuclear Cybersecurity Research develops technologies and methods to address cyber threats to the U.S. nuclear power infrastructure, in coordination with the Department's Cybersecurity, Energy Security, and Emergency Response office, and supports secure implementation of advanced technologies such as wireless control and remote or autonomous operations;
- Advanced Materials and Manufacturing Technologies supports the development of technology-based solutions for advanced materials and manufacturing technologies for use in the deployment of advanced nuclear reactors and sustainment of the existing fleet. This consolidated focus area integrates the cutting-edge research formerly pursued through the Advanced Methods for Manufacturing topic area, the Nuclear Materials Discovery and Qualification Initiative, and the crosscutting research previously performed under the Transformational Challenge Reactor subprogram; and
- Integrated Energy Systems supports the expansion of nuclear energy's role beyond supplying electricity to the grid, such that nuclear energy can also support various industrial, transportation, and energy storage applications, both electrical and thermal. The successful integration of energy systems will allow the electric grid to continue to rely on the economic benefits, reliability, and emissions-free electricity from nuclear energy while offering additional economic benefits from using high-grade process heat and providing flexible energy dispatch. Integrated nuclear systems will allow clean, affordable nuclear energy to decarbonize industrial, chemical, and transportation applications currently relying on other energy sources.

Crosscutting Technology Development

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Change FY 2023 Request vs FY 2021 Enacted
Crosscutting Technology Development **$28,000,000**	**$35,250,000**	**+$7,250,000**
• Advanced Sensors and Instrumentation (ASI): ○ Completed a successful first-of-a-kind demonstration of optical-fiber based Distributed Temperature Sensing (DTS) in a nuclear fuel test. DTS provides mapping of temperature profiles instead of single point measurements, expanding the capabilities of current fuel cycle testing and support development of data-intensive algorithms for optimized control of advanced reactors. ○ Performed test of real-time, in-core neutron flux monitoring sensors at high temperature (up to 800 C) towards the qualification of temperature compensation techniques to inform advanced reactor design. ○ Procured a prototype system to demonstrate instrumentation of irradiated fuel elements by remote handled re-manufacturing, aiding in characterization of high burn-up fuel and acceleration of novel fuel form development for the existing fleet and advanced reactors. • Cybersecurity: ○ Developed a unified process formally integrating nuclear and cybersecurity risk analysis methods and initiated a demonstration of the technique at a U.S. nuclear power plant. ○ Expanded programmatic efforts to support cybersecurity by design in advanced reactors, by initiating the documentation of postulated attack surfaces and advanced reactor architectures. These will be used to prioritize	• Conduct research on Advanced Sensors and Instrumentation to address future capabilities needed for advanced reactor demonstrations, fuel cycle and materials testing, and modernization of the existing fleet. Program activities will include development of temperature compensated neutron flux sensors, radiation drift compensated thermocouples, linear variable differential transformer (LVDTs), acoustic-based structural health monitoring, and process control algorithm and instrumentation integration in nuclear digital twin (NDT) platforms. • Continue the development of cybersecurity standards and reference architectures for wireless communication and autonomous control and zero-trust implementation. Pursue additional real-world pilot opportunities for the application of cyber-informed engineering and advanced risk management techniques for advanced reactors under development. • Continue the Advanced Materials and Manufacturing Technologies (AMMT) program to accelerate materials and manufacturing technologies development to support the existing reactor fleet as well as the deployment of advanced reactors. Program activities will include improvement and optimization of existing materials with minor chemistry modifications to improve use for advanced reactors; development of technical basis for regulatory approval of additively-manufactured 316 SS; initiation of ASME	• The increase reflects support for the Integrated Energy Systems subprogram and the Advanced Materials and Manufacturing Technologies (AMMT) subprogram, initiated in FY 2021, which consolidates efforts from the Nuclear Materials Discovery and Qualification initiative, the crosscutting research previously conducted under the Transformational Challenge Reactor subprogram, and the Advanced Methods for Manufacturing area. • This increase provides support for R&D in the areas of advanced sensors and instrumentation and cybersecurity. For advanced sensors and instrumentation, funding supports expediting sensor development towards commercialization, providing sensors to be available for upcoming advanced reactor demonstrations, and investigating integration of advanced instrumentation and control algorithms into nuclear digital twin (NDT) platforms. In the cybersecurity area, this funding supports advanced reactor control systems design, such as development of zero trust architectures, secure wireless architectures, and methods for applying consequence-driven, cyber-informed engineering techniques. • The request reflects associated funding for Small Business Innovation Research (SBIR), Small Business Technology Transfer (STTR), Technology Commercialization Fund (TCF), and Nuclear

FY 2021 Enacted	FY 2023 Request	Explanation of Change FY 2023 Request vs FY 2021 Enacted
additional R&D needs, particularly in cyber-informed engineering, risk-informed cybersecurity management, wireless communications and autonomous control. ○ Supported international standards development for nuclear power plant cybersecurity. • Advanced Materials and Manufacturing Technologies (AMMT): ○ Initiated the consolidation of materials and manufacturing technologies performed within different programs to improve the efficiency of the similar efforts. ○ Competitively solicited and awarded a project to improve manufacturing techniques on oxide dispersion strengthened (ODS) ferritic alloys. ○ Initiated research on the positive effects of advanced manufacturing techniques to improve use of critical minerals for nuclear energy applications. • Integrated Energy Systems: ○ Released enhanced, open-source modules for the Framework for Optimization of Resources and Economics (FORCE) suite of tools used for optimizing flexible energy dispatch, and the economic benefits of integrated energy systems comprised of multiple energy sectors with several electricity generation types. ○ Completed the design and installation of a laboratory-scale thermal distribution system for testing the control and dynamic behavior of heat exchangers and control valves for advanced light water reactor technologies involving multiple thermal outputs.	Code case development for additively-manufactured 316 SS for elevated temperatures; and identification of specific reactor components with industry that could take advantage of new AM technologies. • Develop Integrated Energy Systems techno-economic assessments; thermal storage and distribution, dynamic controls, and site integration technology for using clean nuclear heat and electricity from advanced reactors to decarbonize distributed industrial applications. These applications may include refining and biorefining; hydrogen and synthetic fuels production; chemicals, minerals, metals, and biomass processing; material recycling; combined heat and power; and dedicated reliable power for data centers.	Energy University Program (NEUP) awards being consolidated within the new Directed R&D and University Programs Line.

Joint Modeling and Simulation

Description

The Joint Modeling and Simulation subprogram, as implemented through the Office of Nuclear Energy's Nuclear Energy Advanced Modeling and Simulation (NEAMS) program, develops and deploys a set of predictive modeling and simulation tools to support and, in some cases, enable improved operation of the current fleet and the development and deployment of advanced reactors. NEAMS engages scientists and engineers in developing state-of-the-art, multi-scale models of physics and chemistry that drive advanced computational methods for simulations of advanced nuclear energy systems. NEAMS empowers researchers and designers to gain fundamental insights that are unattainable through experiment alone and inform experiment selection and design to minimize cost of research and development. Advanced modeling and simulation capabilities also support the Office of Nuclear Energy (NE) program priorities, such as the development of fuels with enhanced accident tolerance.

The NEAMS program has developed a set of analytic modeling and simulation tools that is flexible and able to accommodate different reactor types and designs. Through an enhanced programmatic framework, NEAMS tools support NE's mission priority areas: continued operation of the existing fleet of U.S. nuclear reactors; enable deployment of advanced nuclear reactors; develop advanced nuclear fuel cycles; and maintain U.S. leadership in nuclear energy technology.

For the existing fleet, NEAMS tools address core performance optimization issues and accelerate development of fuels with enhanced accident tolerance to help assure the long-term availability and market competitiveness of nuclear energy. The Bison fuel performance code, and the lower-length scale work that underpins it, helps to provide fundamental insight into how nuclear fuel behaves under normal and extreme reactor conditions, as well as higher fuel "burnup." When coupled with experimental work performed under the Fuel Cycle Research & Development program, this has the potential to accelerate the design and licensing of new fuel forms that can improve or extend the operation of existing reactors.

For advanced reactor technologies, NEAMS tools help industry accelerate advanced reactor development and meet otherwise cost-prohibitive data needs and will support Nuclear Regulatory Commission (NRC) efforts to address its confirmatory analysis needs. While many existing industry codes are designed for specific reactor designs, primarily light-water reactors, NEAMS has developed and continues to add capabilities to a suite of tools for reactor physics, thermal hydraulics, fuel performance, materials, chemistry, and system modeling that are intentionally flexible to accommodate the range of reactor designs currently being considered by industry. Several of these tools are being used, adopted, and modified by industry and NRC to meet their needs, and NEAMS incorporates feedback and inputs from these stakeholders to ensure proper focus on relevant capabilities.

For fuel cycle technologies, continued modeling and simulation tool development provide capabilities that can support future used nuclear fuel research and development, including development of strategies to burn less fuel, and high-fidelity analysis and prediction of fuel and cladding performance through the storage cycle.

Joint Modeling and Simulation

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Change FY 2023 Request vs FY 2021 Enacted
Joint Modeling and Simulation $35,000,000	**$28,327,000**	**-$6,673,000**
• Enabled and accelerated industry's advanced reactor deployment efforts through advanced multiscale and multi-physics modeling and simulation approaches. ○ Demonstrated fast reactor multi-physics modeling capability for core radial expansion as an important reactivity feedback mechanism taking structural and irradiation impacts into consideration. ○ Fully incorporated and updated existing tristructural-isotropic (TRISO) fuel models into fuels modeling capability and perform validation against historical Advanced Gas Reactor tests. ○ Simulated key molten salt properties and validate them with selected measured data. • Performed initial validation of advanced modeling tools consistent with Nuclear Regulatory Commission-specified priorities for specific validation experiments and reactor types. • Completed development and validation of fuel performance and cladding models for Accident Tolerant Fuels (ATF). Updated verification and validation plan with experimental data. • Transitioned the VERA Users Group to a self-sustaining model for funding the development and maintenance of the VERA software. • Continued and updated quality assurance (QA) assessments and documentation to meet stakeholder requirements, such as Nuclear QA-1 research level.	• Enable and accelerate industry's advanced reactor deployment efforts through advanced multiscale and multi-physics modeling and simulation approaches. ○ Develop fully coupled, full-core simulation of entire microreactor to demonstrate self-regulation and load-following, during transient scenarios. ○ Conduct graphite structural analysis and behavior for gas-cooled reactors during steady-state and transient conditions including swelling and oxidization as well as multiscale structural materials modeling for metallic structures including piping, heat exchangers, and reactor vessel. ○ Develop and assemble molten salt reactor modeling capability and data sufficient to support the development of a mechanistic source term to support data safety and licensing. • Implement and demonstrate use of mechanistic tools to assess high-burnup fuel pulverization and burst potential for Light Water Reactor fuels to support licensing process associated with extending fuel burnup limits. • Maintain software tools with strong software quality assurance such that the tools can be used by industry and research institutions in research, design, and ultimately commercial deployment.	• The decrease reflects $8,592,500 associated funding for Small Business Innovation Research (SBIR), Small Business Technology Transfer (STTR), Technology Commercialization Fund (TCF), and Nuclear Energy University Program (NEUP) awards being consolidated within the new Directed R&D and University Programs line, and additional funding in the amount of $1,919,500 to support industry needs for modeling fuel fragmentation, relocation, and dispersion at higher burnup.

Nuclear Science User Facilities

Description

The Nuclear Science User Facilities (NSUF) subprogram is the Nation's designated program to gain access to user facilities for nuclear energy research. As a consortium of partner facilities, the NSUF connects a broad range of nuclear research capabilities, expert mentors, and experimenters. The NSUF represents a "prototype laboratory for the future," promoting the use of unique nuclear research facilities located at multiple sites across the Nation and encouraging active university, industry, and laboratory collaboration in relevant nuclear science research. The NSUF, through competitive solicitations, provides a mechanism for research organizations to collaborate, conduct experiments and post-experiment analysis, and utilize high performance computing at facilities not normally accessible to these organizations. On an annual basis, researchers propose projects to be conducted at these unique facilities, with timelines ranging from a few months to several years. When projects are awarded, the NSUF subprogram pays for experiment support and laboratory services at the partner user facilities. In this manner, researchers benefit from the introduction to new techniques, equipment, and personnel. In FY 2021, the NSUF program supported 136 researchers from 23 different States through awards and 766 researchers across 26 States and eight other countries through access to high performance computing capabilities. Moving forward, emphasis will be placed on increasing the involvement of Historically Black Colleges and Universities, Minority Serving Institutions, and institutions in underserved communities, resulting in direct and meaningful investments through project selection and NSUF partnership agreements in support of the Administration's Justice40 Initiative.

The principal focus areas in NSUF for FY 2023 includes irradiation and post-irradiation examination of fuels and materials, high performance computing, and maintenance of the Nuclear Fuels and Materials Library as follows:

- The NSUF program competitively supports all pertinent irradiation and post-irradiation examination activities by providing researchers with access to unique nuclear research facilities. Support includes access to research reactors, hot cells, beam-line capabilities, irradiation capabilities, and irradiation experiment design and fabrication support, expert support, and community outreach.
- High Performance Computing (HPC) supports INL scientific computing capabilities to enable advanced modeling and simulation. These resources support a wide range of research activities, including performance of materials in harsh environments (such as the effects of irradiation and high temperatures), performance of existing light water and advanced nuclear reactors, and multiscale multi-physics analysis of nuclear fuel performance. HPC capabilities are available to industry, universities, national laboratories, and federal agencies to support research and development. Three HPC supercomputers are currently in operation at the Idaho National Laboratory: Sawtooth, Hoodoo and Lemhi.
- The Nuclear Fuels and Materials Library (NFML) supports the maintenance of a collection of specialized information and material specimens from past and ongoing irradiation test campaigns, real-world components retrieved from decommissioned power reactors, and donations from other sources. Everything in NFML is available to the nuclear research community, either through a peer-reviewed proposal process or through direct programmatic request.

Nuclear Science User Facilities

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Change FY 2023 Request vs FY 2021 Enacted
Nuclear Science User Facilities		
$30,000,000	**$39,160,000**	**+$9,160,000**
• Competitively solicited and awarded four new fully-funded facility access awards. • Awarded 29 new fully-funded Rapid Turnaround Experiment awards through one competitive proposal process. • Optimized the capabilities available through partnerships with universities, industry, and national laboratories to offer unparalleled research opportunities in a highly cost-effective manner by leveraging capabilities and investments at partner institutions. • Enhanced the research tools provided to the Nuclear Science User Facilities (NSUF) user community. These online tools include the Nuclear Energy Infrastructure Database, the Nuclear Fuels and Materials Library, and Combined Materials Experiment Toolkit which, in concert, provide access to information on scientific equipment, previously irradiated materials, irradiation dose predictions and subject matter experts. • Invested in select domestic scientific infrastructure capabilities to support the advancement of applied research and development (R&D) in support of the Office of Nuclear Energy (NE) mission. • Conducted a workshop on the current capability gaps in performing materials research on irradiated materials.	• Competitively solicit and award new fully-funded facility access awards. • Award more than 100 Rapid Turnaround Experiment projects through three competitive proposal periods. • Continue NSUF partnership agreements with universities, industry, and national laboratories to support ongoing irradiation experiments ranging from neutron, gamma and ion irradiation to post-irradiation examination and incorporate new irradiation capabilities as needs are identified. • Enhance the Nuclear Fuels and Materials Library through the addition of irradiated fuels and materials. • Operate three supercomputers totaling more than 120,000 processor cores and 7 Petaflops of computational performance. Support more than 800 users by providing training, user support, and code optimization. Ensure effective cybersecurity and user access controls.	• The increase reflects support for High Performance Computing activities and additional access for industry, universities, and national laboratories to unique nuclear energy research facilities and a restoration of three Rapid Turnaround Experiment award cycles. • Additionally, the NSUF FY 2023 request reflects not having to provide funding for Small Business Innovation Research (SBIR), Small Business Technology Transfer (STTR), Technology Commercialization Fund (TCF), and Nuclear Energy University Program (NEUP) awards, which is being consolidated within the new Directed R&D and University Programs line.

Transformational Challenge Reactor

Description
The Transformational Challenge Reactor (TCR) subprogram provided a revolutionary platform to help demonstrate the ability to reduce the deployment costs and timelines for nuclear energy systems and enhanced the development of breakthrough technologies that provided the ability to manufacture small/micro advanced reactor components using additive manufacturing techniques. A central goal of the TCR subprogram was to demonstrate the ability to exploit advanced manufacturing techniques and digital predictive analysis capabilities to deliver a new approach to nuclear design and qualification for advanced reactor technologies. TCR combined advanced manufacturing with materials and computational sciences to predict optimal performance of components to enable faster innovation and certification.

Highlights of the FY 2023 Budget Request
No funding is requested in the FY 2023 Budget for the Transformational Challenge Reactor subprogram. In FY 2023, crosscutting research initiated under the TCR subprogram will continue under the Crosscutting Technology Development subprogram to consolidate all relevant technologies under one program.

Transformational Challenge Reactor

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Change FY 2022 Request vs FY 2021 Enacted
Transformational Challenge Reactor $29,869,000	**$0**	**-$29,869,000**
• Demonstrated application of Artificial Intelligence (AI) to perform multi-physics optimization of additively manufactured component and provided benchmark test data to verify the framework. • Demonstrated predictive capability of the Digital Platform to assess nuclear component quality with Software Quality Assurance. • Performed irradiation testing of additively manufactured structures with embedded sensors and collected in situ data. • Published handbook of properties for additively manufactured ceramic and metal materials including neutron irradiation data.	• No funding is requested to continue this program in FY 2023. Crosscutting research will continue under the Crosscutting Technology Development (CTD) subprogram.	• No funding is requested to continue this program in FY 2023.

Advanced Reactor Demonstration Program

Overview
The Advanced Reactor Demonstration Program (ARDP) focuses Departmental and non-federal resources on supporting the development of advanced reactors that have the potential for near and mid-term demonstration and commercial deployment and addressing challenges hindering their deployment.

In the FY 2020 Further Consolidated Appropriations Act, Congress established ARDP to demonstrate multiple advanced reactor designs. In the Bipartisan Infrastructure Law (Infrastructure Investment and Jobs Act, P.L. 117-58), multi-year funding for the reactor demonstration elements of this program was provided under the new Office of Clean Energy Demonstrations (OCED). The ARDP research and development elements leading to demonstration remain with Nuclear Energy and include these four major elements:

- National Reactor Innovation Center (NRIC) – Supports testing, demonstration, and performance assessment to accelerate deployment of advanced reactors through development of advanced nuclear energy technologies by utilizing the unique DOE national laboratory facilities and capabilities;
- Risk Reduction for Future Demonstrations – Supports f cost-shared (up to 80% government, not less than 20% industry) partnerships with U.S.-based teams to address technical, operational, and regulatory challenges to enable development of a diverse set of advanced nuclear reactor designs for future demonstration;
- Regulatory Development – Coordinates activities with the Nuclear Regulatory Commission (NRC) and U.S. industry to address and resolve key regulatory framework and licensing technical issues that directly impact the "critical path" to advanced reactor demonstration and deployment; and
- Advanced Reactor Safeguards – Evaluates safeguards and security issues that are unique to advanced reactors to help reduce roadblocks by solving regulatory challenges, reducing safeguards and security costs, and utilizing the latest technologies and approaches for plant monitoring and protection.

In FY 2023, the Department focuses on the execution of the Risk Reduction projects selected in FY 2021. For the Risk Reduction projects, funding supports five domestic advanced reactor development partners in resolving technical, operational, and regulatory challenges to enable future demonstration of their concepts. Efforts initiated under the NRIC, Regulatory Development, and Advanced Reactor Safeguards subprograms continue in FY 2023.

The ongoing ARDP demonstration projects, funded in OCED, and the risk reduction projects are working to overcome barriers to future demonstrations and have the potential to create substantial numbers of new short and long-term domestic jobs. For example, in the early stages of design development and licensing, the reactor demonstration vendors are adding many technical and professional employees to address design, engineering, testing, procurement, and licensing requirements. The construction phase is expected to result in hundreds of short-term construction jobs, many of which are expected to be union filled. The eventual operation of these reactors will require the creation of additional long-term operations, maintenance, and security positions with the utility owners. Overall, the deployment and operation of these reactors are expected to have significant positive, long-term economic impacts on the communities in which they are operated.

Highlights of the FY 2023 Budget Request
The primary focus of the FY 2023 request is supporting ongoing activities under the Risk Reduction projects selected in FY 2021, and the NRIC, Regulatory Development, and Advanced Reactor Safeguards subprogram areas.

Funding for the two advanced reactor demonstrations previously included in this budget are now funded, per the Bipartisan Infrastructure Law (BIL), within the Office of Clean Energy Demonstrations.

Advanced Reactor Demonstration Program
Funding ($K)

	FY 2021 Enacted	FY 2022 Annualized CR	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
Advanced Reactor Demonstration Program					
National Reactor Innovation Center	30,000	30,000	75,000	+45,000	+150%
Demonstration 1	80,000	80,000	0	-80,000	-100%
Demonstration 2	80,000	80,000	0	-80,000	-100%
Risk Reduction for Future Demonstrations	40,000	40,000	140,238	+100,238	+251%
Regulatory Development	15,000	15,000	10,250	-4,750	-32%
Advanced Reactor Safeguards	5,000	5,000	4,750	-250	-5%
Total, Advanced Reactor Demonstration Program	**250,000**	**250,000**	**230,238**	**-19,762**	**-8%**

SBIR/STTR:

- FY 2021 Enacted: SBIR $2,332; STTR $406
- FY 2022 Annualized CR: SBIR $2,332; STTR $406
- FY 2023 Request: Funding provided in the Direct R&D and Universities Program line.

Advanced Reactor Demonstration Program
Explanation of Major Changes ($K)

	FY 2023 Request vs FY 2021 Enacted
National Reactor Innovation Center: The increase from $30,000,000 to $75,000,000 reflects a transition from design to refurbishment/construction activities to support the establishment of demonstration test beds as well as the transition from the development to demonstration phase of the Advanced Construction Technologies (ACT) Initiative.	**+45,000**
Demonstration 1: The decrease from $80,000,000 to $0 reflects multi-year funding provided by the Bipartisan Infrastructure Law (BIL) for the advanced reactor demonstrations provided under the Office of Clean Energy Demonstrations.	**-80,000**
Demonstration 2: The decrease from $80,000,000 to $0 reflects multi-year funding provided by BIL for the advanced reactor demonstrations provided under the Office of Clean Energy Demonstrations.	**-80,000**
Risk Reduction for Future Demonstration: The increase from $40,000,000 to $140,238,000 reflects a ramp up in activities to maintain the project schedules and increased funding required to fully fund the third budget year of the projects.	**+100,238**
Regulatory Development: The decrease from $15,000,000 to $10,250,000 reflects associated funding for Small Business Innovation Research (SBIR), Small Business Technology Transfer (STTR), Technology Commercialization Fund (TCF), and Nuclear Energy University Program (NEUP) awards being consolidated within the new Directed R&D and University Programs line.	**-4,750**
Advanced Reactor Safeguards: The decrease from $5,000,000 to $4,750,000 reflects $250,000 associated funding for SBIR, STTR, TCF, and NEUP awards being consolidated within the new Directed R&D and University Programs line.	**-250**
Total, Advanced Reactor Demonstration Program	**-19,762**

National Reactor Innovation Center

Description

The National Reactor Innovation Center (NRIC) mission is to enable and accelerate the testing and demonstration of advanced reactors by utilizing the unique capabilities of U.S. national laboratories. NRIC provides private sector technology developers with access to the strategic infrastructure and assets of the national laboratories to enable physical validation of advanced nuclear reactor concepts, resolve technical uncertainties, and generate data relevant to safety, resilience, security, and functionality of advanced nuclear reactor concepts. NRIC works closely with R&D programs within the Office of Nuclear Energy to avoid duplication. NRIC does not conduct R&D; it facilitates information sharing and connectivity necessary to enable the demonstration of selected nuclear reactor designs.

The NRIC subprogram activities include interactions with reactor developers who are considering options for demonstrating their reactor technologies as well as investigation and development of national laboratory capabilities for hosting advanced reactor demonstrations. Subprogram activities also include completing design and pre-construction activities and supporting construction/refurbishment activities to enable the development of infrastructure for the testing and demonstration of multiple advanced reactor concepts. While NRIC is led by the Idaho National Laboratory (INL) with significant activities at the INL Site, resources at other national laboratories and potential nuclear reactor demonstration sites will play an important role in achieving NRIC's objectives.

NRIC is expected to help accelerate technology readiness from proof of concept through proof of operations. Key support to be provided by NRIC includes:

- Facilitating industry access to key resources, such as materials needed for nuclear reactor fuel, facilities for fabrication of fuel for demonstrations, test reactors such as the Advanced Test Reactor and Transient Reactor Test Facility at the INL and High Flux Isotope Reactor at the Oak Ridge National Laboratory, characterization capabilities such as INL's Irradiated Materials Characterization Laboratory, and access to advanced modeling and simulation codes and high performance computers through the INL Collaborative Computing Center;
- Providing access to national laboratory experts to support technology development;
- Developing complementary technologies, in conjunction with relevant Nuclear Energy R&D programs, such as application of digital engineering philosophies and development and proof of concept of advanced construction technologies, to reduce the cost and schedule risks associated with the deployment of advanced reactors;
- Assisting with National Environmental Policy Act (NEPA) evaluations, Nuclear Regulatory Commission (NRC) licensing, and DOE authorization related to nuclear facility operations;
- Developing a resource network of sites, facilities, and capabilities suitable for performing key R&D, experiments, tests, or fabrications, and for hosting advanced reactor demonstrations; and
- Identifying and facilitating resolution of experimental capability gaps which are vital to advanced reactor development and demonstration.

National Reactor Innovation Center

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Change FY 2023 Request vs FY 2021 Enacted
National Reactor Innovation Center $30,000,000	**$75,000,000**	**+$45,000,000**
• Initiated siting and regulatory preparation for advanced reactors and identified siting strategies that are scalable and incorporate environmental justice principles. • Established a formal agreement with the NRC to facilitate the sharing of technical expertise and knowledge on advanced nuclear reactor technologies and nuclear energy innovation, including reactor concept demonstrations. • Continued activities to reduce the regulatory risks and costs associated with advanced reactor demonstration, including development of a plant parameter envelope approach for advanced reactors. • Commenced design activities to inform future decisions about the implementation of demonstration test beds and ensured that project management best practices were applied to these activities. • Procured equipment and designed laboratory spaces to close vital experimental gaps. • Issued an award to support design, development, and testing of advanced construction technologies that may reduce the cost and schedule risk associated with construction of advanced reactors.	• Continue support for establishment of the Molten Salt Thermophysical Examination Capability (MSTEC) at INL to close a vital experimental gap for molten salt reactors (MSRs). • Complete Phase I of the ACT Initiative to enable development of advanced construction technologies that may reduce the cost and schedule risks associated with advanced reactor construction. • Initiate Phase II of the ACT Initiative to support proof of concept of advanced construction technologies. • Further engage with key stakeholders such as the NRC, advanced reactor developers, and potential end-users. • Continue evaluating capabilities and gaps and working with R&D programs to facilitate coordinated actions to address critical needs. • Complete construction of the Demonstration and Operation of Microreactor Experiments (DOME) test bed to enable development and demonstration of microreactor technologies. • Complete design of a Safeguards Category I test bed to support development and demonstration of experimental reactors utilizing Category I materials for operation. • Provide support to advanced reactor developers to enable successful execution of development and demonstration activities.	• The increase reflects a transition from design to refurbishment/construction activities to support the establishment of advanced reactor test beds as well as the transition from the development to demonstration phase of the ACT Initiative

FY 2021 Enacted	FY 2023 Request	Explanation of Change FY 2023 Request vs FY 2021 Enacted
	• Help make available infrastructure, materials, and expertise to support advanced reactor demonstration.	

Demonstration 1

Description

This subprogram focused efforts on the execution of one of two cost-shared projects for the eventual construction of an advanced reactor demonstration.
In FY 2020, DOE announced an award to X-energy to design, license, construct, and start up an advanced nuclear reactor that can be operational within seven years. The award is a cost-shared partnership that will deliver a first-of-a-kind advanced reactor to be licensed for commercial operations. X-energy will cover at least 50 percent the costs of this program.

The Bipartisan Infrastructure Law provides multi-year funding for the X-energy demonstration under the Office of Clean Energy Demonstrations. As such, no FY 2023 funding is requested for this effort within Nuclear Energy.

Demonstration 1

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Change FY 2023 Request vs FY 2021 Enacted
Demonstration 1 $80,000,000	**$0**	**-80,000,000**
• DOE completed award negotiations and formalized cooperative agreements with X-energy. • X-energy completed and submitted several early-stage project deliverables to DOE for milestones consistent with their project applications in areas such as: o Establishing project management structure and execution planning. o Development of licensing application documents and conducting pre-application engagement with the regulator. o Reactor systems design development. o Procurement planning. o Fuel fabrication facility design and licensing document development per 10 CFR Part 70. o Site selection and characterization activities. • Continued to execute project scope for both Demonstration projects per established project plans using current and prior year carryover funds.	• No funding is requested for the X-energy advanced reactor demonstration within Nuclear Energy.	• The decrease reflects the transfer of the X-energy advanced reactor demonstration to the Office of Clean Energy Demonstrations.

Demonstration 2

Description

This subprogram focused efforts on the execution of one of two cost-shared projects for the eventual construction of advanced reactor demonstrations. In FY 2020, DOE announced an award to TerraPower LLC to design, license, construct, and start up an advanced nuclear reactor that can be operational within seven years. The award is a cost-shared partnership that will deliver a first-of-a-kind advanced reactor to be licensed for commercial operations. TerraPower will cover at least 50 percent the costs of this program.

The Bipartisan Infrastructure Law provided multi-year funding for the TerraPower demonstration under the Office of Clean Energy Demonstrations. As such, no FY 2023 funding is requested for this effort within Nuclear Energy.

Demonstration 2

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Change FY 2023 Request vs FY 2021 Enacted
Demonstration 1 $80,000,000	**$0**	**-$80,000,000**
• TerraPower completed and submitted mid-stage project deliverables to DOE for project milestones consistent with their project applications in areas such as: o Establishing project management structure and execution planning. o Development of licensing application documents and conducting pre-application engagement with the regulator. o Reactor systems design development. o Procurement planning. o Fuel fabrication facility design and licensing document development per 10 CFR Part 70. o Site selection and characterization activities. • Continue to execute project scope for both Demonstration projects per established project plans using current and prior year carryover funds.	• No funding is requested for the TerraPower advanced reactor demonstration within Nuclear Energy.	• The decrease reflects the transfer of the TerraPower advanced reactor demonstration to the Office of Clean Energy Demonstrations

Risk Reduction for Future Demonstrations

Description

The Risk Reduction for Future Demonstrations subprogram supports advanced reactor concepts with the potential for future demonstration through cost-shared (up to 80% government, not less than 20% industry) competitively awarded (through a financial assistance solicitation) projects that are designed to maximize the utility of the results across the nuclear energy industry. The projects are aimed at reducing risk and technical uncertainty for a broad range of advanced reactor designs. Project activities may include R&D to address technical challenges associated with development of technologies and methods to improve the timelines for advanced reactor deployments, the cost and schedule for delivery of nuclear products, services, and capabilities supporting these nuclear technologies, design and engineering processes, and resolution of certification challenges potentially impeding the introduction of these technologies into the marketplace. This subprogram coordinates closely with the Reactor Concepts Research, Development & Demonstration program and other relevant programs to avoid duplication, leverage existing expertise, and maximize synergies.

In FY 2021, DOE announced the selection of five projects to aid advanced reactor developers in resolving technical, operational, and regulatory challenges to enable potential future demonstration of a diverse set of advanced reactor designs. The Risk Reduction projects support the development of safe and affordable advanced reactor technologies that can be licensed and deployed over the next 10 to 13 years. Industry partners will provide at least 20 percent in matching funds for their cost share of the program.

The five projects are:

- Kairos Power, LLC (Alameda, CA) will work to design, construct, and operate its Hermes reduced-scale test reactor. Hermes is intended to lead to the development of Kairos Power's commercial-scale fluoride salt-cooled high temperature reactor (FHR), a novel advanced nuclear reactor technology that leverages TRI-structural ISOtropic particle fuel (TRISO) fuel in pebble form combined with a low-pressure fluoride salt coolant;
- Westinghouse Electric Company, LLC (Cranberry Township, PA) will advance the design of a heat pipe-cooled microreactor;
- BWXT Advanced Technologies, LLC (Lynchburg, VA) will mature a commercially viable transportable microreactor conceptual design focused on using TRISO fuel particles to achieve higher uranium loading and an improved core design using a silicon carbide (SiC) matrix;
- Holtec Government Services, LLC (Camden, NJ) will focus on early-stage design, engineering, and licensing activities to accelerate the development of its light water-cooled small modular reactor (SMR); and
- Southern Company Services Inc. (Birmingham, AL) will lead a project to design, construct, and operate the Molten Chloride Reactor Experiment (MCRE), a critical nuclear test bed supporting molten salt reactor systems and components demonstrations.

FY 2023 activities focus on continuing design activities; supporting further interactions with the NRC on high impact regulatory related topics; conducting activities to resolve technical, operational and regulatory challenges; and developing and executing plans for establishing infrastructure and support capabilities to enable execution of the Risk Reduction projects and future commercialization activities.

Risk Reduction for Future Demonstrations

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Change FY 2023 Request vs FY 2021 Enacted
Risk Reduction for Future Demonstrations **$40,000,000**	**$140,238,000**	**+$100,238,000**
• Finalized Risk Reduction project selections through a competitive merit review process. • Finalized scope and milestones for Risk Reduction projects. • Initiated execution of project activities.	• Support execution of the Risk Reduction projects per established project plans and using current and prior year carryover funds. Specific project activities include: ○ For the Kairos project: Conduct activities to support the design, licensing, construction, and operation of an FHR test reactor. ○ For the Westinghouse project: Scale-up and enhance heat pipe manufacturing operations to enable design, procurement, and manufacturing of a microreactor demonstration unit. ○ For the BWXT project: Complete fabrication of TRISO fuel specimens to support irradiation testing in INL's Advanced Test Reactor (ATR). ○ For the Holtec project: Initiate long lead procurement activities by selecting the Control Rod Drive Mechanism subcontract supplier which will demonstrate the capability of the existing supply chain. ○ For the Southern Company Services project: Complete design of the fuel salt synthesis line and build and operate a non-nuclear mock-up of MCRE to de-risk fabrication of major	• The increase reflects a ramp up in activities to maintain the project schedules and increased funding required to fully fund the third budget year of the projects.

	components and operation of the fueled reactor experiment.	

Regulatory Development

Description

The Regulatory Development subprogram coordinates with the Nuclear Regulatory Commission (NRC) and industry to address and resolve key regulatory framework issues that directly impact the “critical path” to advanced reactor demonstration and deployment. Part of the subprogram focuses on regulatory modernization activities such as developing adaptations of light water reactor (LWR)-based regulations for non-LWR advanced reactors, finalizing the establishment of risk-informed and performance-based license application guidance, and establishing clear expectations for license application content and review criteria. Other regulatory development activities include resolving the technical basis to support NRC endorsement of codes and standards important for the manufacture of advanced reactor components and expanding access to priority material property data to be used in safety codes and models in support of licensing. The Regulatory Development subprogram supports limited R&D aimed at producing broadly applicable results than can be used by an array of private sector companies to inform their regulatory requirements. Design-specific regulatory gaps for advanced reactors, including fast reactors, gas-cooled reactors, and molten salt reactors, are also addressed.

Regulatory Development

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Change FY 2023 Request vs FY 2021 Enacted
Regulatory Development $15,000,000	**$10,250,000**	**-$4,750,000**
• Coordinated with industry and the NRC to identify technology gaps and high impact challenges regarding advanced reactor regulation. • Continued efforts to establish a risk-informed, advanced reactor regulatory framework. • Supported the development and submittal of an industry-driven proposal to NRC for risk-informed and "right-sized" license application content for advanced reactors to reduce regulatory uncertainty and support near-term demonstrations and deployments. • Performed a broad scope phenomena, identification, and ranking table (PIRT) exercise on liquid-fueled molten salt reactors (MSR) to identify key licensing and research and development (R&D) needs for demonstration and deployment. • Conducted experimental validation to provide reactor response data during normal and transient scenarios for high temperature reactors. • Through industry and NRC engagement, continued efforts to resolve remaining high impact NRC regulatory policy issues impacting advanced reactor licensing.	• Provide support for industry and NRC interactions that are establishing the advanced non-light water reactor regulatory framework. • Continue efforts to address unresolved and high impact NRC regulatory policy issues impacting advanced reactor licensing. • Develop the technical basis for material surveillance technologies to be used by owner/operators to implement a materials degradation management program for MSRs. • Utilize the Liquid Salt Test Loop (LSTL) at the Oak Ridge National Laboratory to test sensors and demonstrate tools in support of MSR development and deployment. • Maintain and develop the fast reactor database to archive historical data for fast reactor fuels and materials to preserve data, knowledge and experience. • Support fast reactor code validation and verification tasks and develop international benchmarks to verify and validate fast reactor design and safety analysis tools used by industry and NRC. • Continue development and testing to support inclusion of Alloy 709 (alloy with increased materials performance in high temperature advanced reactor operating environments) in the American Society of Mechanical Engineers (ASME) Code.	• The decrease reflects associated funding for Small Business Innovation Research (SBIR), Small Business Technology Transfer (STTR), Technology Commercialization Fund (TCF), and Nuclear Energy University Program (NEUP) awards being consolidated within the new Directed R&D and University Programs line.

Advanced Reactor Safeguards

Description

The Advanced Reactor Safeguards (ARS) subprogram evaluates safeguards and security issues unique to advanced reactor designs and informs and improves advanced reactor designs by addressing issues such as diversion of advanced fuel forms, protection of remotely operated plants, and other proliferation and security concerns. Broadly, the ARS subprogram also helps to reduce security costs by utilizing the latest technologies and approaches for plant monitoring and protection.

The ARS subprogram focuses on five major elements: physical protection systems, pebble bed reactor material control and accountability (MC&A), microreactor physical protection systems and MC&A, liquid fueled reactor MC&A, and international cooperation.

- Physical Protection Systems (PPS) – targets issues such as reducing number of on-site responders and upfront costs and evaluating enhanced safety systems and unique sabotage targets.

- Pebble bed reactor MC&A – focuses on evaluating the regulatory approach and determining the driving requirements, as well as evaluating new monitoring technologies.

- Microreactor PPS and MC&A – works on developing a licensing framework, developing approaches appropriate to the very small scale, and evaluating new monitoring technologies.

- Liquid fueled MC&A – targets evaluating regulatory approach, developing baseline accountancy approaches, and evaluating new measurement and monitoring technologies.

- International Cooperation – focuses on considering and incorporating international safeguards requirements, interfacing with international safeguards and security programs, and supporting the Gen-IV Proliferation Resistance & Physical Protection (PR&PP) Working Group.

The ARS subprogram also coordinates with the Nuclear Regulatory Commission (NRC), the Department of Energy's National Nuclear Security Administration (NNSA), and the nuclear industry to avoid duplication of activity and leverage nationwide expertise. Together, these safeguards activities help further advanced reactors development and deployment.

Advanced Reactor Safeguards

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Change FY 2023 Request vs FY 2021 Enacted
Advanced Reactor Safeguards $5,000,000	**$4,750,000**	**-$250,000**
• Executed FY 2021 activities identified during Advanced Reactor Safeguards development planning and subprogram execution initiated during FY 2020. • Provided physical protection system design alternatives that significantly reduces cost or need for on-site responders for advanced reactors. • Provided recommendations to advanced reactor vendors on material control and accountancy approaches. • Designed, analyzed, and proved plant protection system generic design alternatives that significantly reduce or eliminate the need for on-site responders.	• Refine and expand physical protection design alternatives for a diverse set of advanced reactors, to support cost effective, market competitive designs • Develop pebble bed burnup measurement strategy and experimental plan to assist pebble bed reactor vendors to meet key monitoring and accountancy requirements. • Engage with advanced reactor vendors, in coordination with NNSA, to advance both domestic and international safeguards and security by design.	• The decrease reflects associated funding for Small Business Innovation Research (SBIR), Small Business Technology Transfer (STTR), Technology Commercialization Fund (TCF), and Nuclear Energy University Program (NEUP) awards being consolidated within the new Directed R&D and University Programs line

Versatile Test Reactor Project

Overview

The Versatile Test Reactor (VTR) supports advancements in nuclear energy, particularly in the testing of advanced fuels, materials, and instruments and sensors in extreme environments necessary for the advanced reactor community in the U.S. to tackle the climate crisis. The VTR would help the U.S. to regain and strengthen its global technical leadership role in the development of the next generation of advanced reactors.

The Department has prepared a Final Environmental Impact Statement in accordance with National Environmental Policy Act requirements to ensure that all environmental factors are considered before the Department makes a final decision to move forward with the project.

The VTR will leverage synergies from TerraPower's Natrium project, a sodium-cooled fast reactor demonstration project selected under the Advanced Reactor Demonstration Program (ARDP), by taking advantage of design commonalities, component development and testing, supply chain development, and construction activities. This will allow optimized use of human resources/expertise and testing facilities, reduction in the overall development and testing costs for components that have similar features, and reduction in cost and schedule risk and uncertainty. To that effect a memorandum of understanding was signed with the Natrium team establishing a private public partnership encouraged by Congress.

Highlights of the FY 2023 Budget Request

In FY 2023, activities will focus on component risk reduction activities, including prototyping and testing, nuclear fuel feedstock sourcing and fabrication studies and experimental capabilities development and conceptual design optimization studies. FY 2023 activities will be prioritized and coordinated with TerraPower's Natrium project.

Versatile Test Reactor Project
Funding ($K)

	FY 2021 Enacted	FY 2022 Annualized CR	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 request vs FY 2021 Enacted (%)
Versatile Test Reactor Project					
Versatile Test Reactor – Other Project Costs	43,000	43,000	45,000	+2,000	+5%
21-E-200 VTR Project	2,000	2,000	0	-2,000	-100%
Total, Versatile Test Reactor Project	**45,000**	**45,000**	**45,000**	**0**	**0%**

Versatile Test Reactor Project
Explanation of Major Changes ($K)

	FY 2023 Request vs FY 2021 Enacted
Versatile Test Reactor – Other Project Costs:	
The increase reflects focus on risk reduction studies and coordination with TerraPower's Natrium project.	**+2,000**
21-E-200 VTR Project	
The decrease from reflects deferral of construction line item activities and coordination with TerraPower's Natrium project.	**-2,000**
Total, Versatile Test Reactor Project	**0**

Versatile Test Reactor – Other Project Costs

Description

In February 2019, the Versatile Test Reactor (VTR) Project was formally initiated with Critical Decision (CD)-0, Approve Mission Need, in accordance with Department of Energy Order 413.3B requirements. CD-1, Approve Alternative Selection and Cost Range, was approved on September 11, 2020. The Department will make a final decision on the design, technology selection and location for VTR following the completion of the VTR Environmental Impact Statement and issuance of a Record of Decision.

This budget line, Versatile Test Reactor – Other Project Costs (VTROPC), will be used to fund VTR costs that are not included in the Versatile Test Reactor - Design and Construction (VTRDC), such as supporting research and development, pre-authorization costs prior to start of preliminary design, plant support costs during design, construction, activation, and startup. VTROPC will also include funding of those activities necessary to comply with National Environmental Policy Act requirements. Specific activities to be accomplished in FY 2023 are in the Activities and Explanation of Changes section.

Versatile Test Reactor – Other Project Costs
Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Versatile Test Reactor – Operating $43,000,000	**$45,000,000**	**+$2,000,000**
• Manage VTR Project in accordance with Department of Energy Order 413.3B. • Continue to mature cost estimate. • Initiate assembly of Driver Fuel Subassembly, using fuel simulants. • Plan heavy metal shipments to support feedstock preparation for first driver fuel core. • Initiate fabrication of first Experiment Cartridge prototype.	• Manage VTR Project in accordance with Department of Energy Order 413.3B. • Identify potential coordination opportunities with TerraPower's Natrium project. • Perform fuel feedstock supply studies with National Nuclear Security Administration (NNSA). • Perform risk reduction studies.	• Reflects an increased focus on risk reduction.

21-E-200 VTR Project

Description

In February 2019, the Versatile Test Reactor (VTR) Project was formally initiated with Critical Decision (CD)-0, Approve Mission Need, in accordance with Department of Energy Order 413.3B requirements. CD-1, Approve Alternative Selection and Cost Range, was approved on September 11, 2020. CD-1 approved the selection of a sodium-cooled fast spectrum test reactor with an estimated cost range of $2.6 to $5.8 billion. The Department will make a final decision on the design, technology selection and location for VTR following the completion of the VTR Environmental Impact Statement and issuance of a Record of Decision.

This budget line, Versatile Test Reactor – Design and Construction (VTRDC), will be used to fund VTR costs that are not included in the Versatile Test Reactor – Other Project Costs, such as all engineering design costs (preliminary and final design), facility construction costs, and other costs specifically related to those construction and the procurement of VTR components and hardware. As a part of the project's overall risk reduction efforts, digital requirements management and digital design control techniques will be utilized to maximize design process efficiency and to help achieve the goal of finalizing the design prior to the start of construction. VTR will also include funding of project and construction management during preliminary and final design and construction, and funds to provide for contingency and economic escalation.

Versatile Test Reactor – Design and Construction

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
21-E-200 VTR Project $2,000,000	**$0**	**-$2,000,000**
• Manage VTR Project in accordance with Department of Energy Order 413.3B. • Continue preliminary design and expand to all mechanical, electrical, instrumentation and controls, and civil and structural disciplines. • Initiate prototype & testing for key equipment. • Initiate all design documentation.	• No activities are planned in FY 2023.	• The decrease reflects deferral of line item construction activities.

Infrastructure

Overview

Infrastructure consists of the Idaho National Laboratory (INL) Facilities Operations and Maintenance (IFM), Oak Ridge National Laboratory (ORNL) Nuclear Facilities Operations & Maintenance (O&M), and Construction subprograms.

The mission of the IFM subprogram is to manage the planning, acquisition, operation, maintenance, and disposition of the Office of Nuclear Energy (NE) owned multi-program nuclear facilities and capabilities along with the supporting infrastructure at INL. The IFM subprogram maintains Department of Energy (DOE) mission-supporting facilities and capabilities at the INL in a safe, and compliant status (with DOE Orders, federal laws and regulations, and state agreements) to enable technological advancement in the existing nuclear fleet, advanced reactor pipeline, and fuel cycle mission. The availability of these key facilities and capabilities to support NE research and development (R&D) is critical to the ongoing effort to revitalize nuclear energy in the U.S. INL facilities and capabilities also support testing of naval reactor fuels, reactor core components and a diverse range of national security technology programs for the National Nuclear Security Administration (NNSA) and other federal agencies in the area of critical infrastructure protection, nuclear nonproliferation, and incident response. The IFM subprogram integrates and closely coordinates with research programs to ensure proper alignment and prioritization of infrastructure investments, as well as availability of infrastructure for programmatic work.

The Construction subprogram plays a critical role in revitalizing the NE infrastructure. The subprogram focuses on addressing identified gaps created by either deteriorating critical infrastructure or evolving NE missions.

Highlights of the FY 2023 Budget Request

The Research Reactor Infrastructure subprogram, which provides fuel services for university research reactors, is consolidated with other university support activities under the new Directed R&D and University Programs, renamed as "University Fuel Services". As such, no funding is requested for RRI within the Infrastructure program in FY 2023.

The focus of IFM subprogram remains on the safe and compliant operation of the INL's nuclear research reactors and non-reactor nuclear and radiological research facilities while continuing to realize improvements in the condition of aging INL infrastructure. In FY 2023, the increase in IFM subprogram budget funds:

- Reliability improvements to keep facilities at INL operational to support NE's research and advanced fuel development missions. This includes infrastructure investments in the Advanced Test Reactor (ATR) Complex and Materials and Fuels Complex (MFC). Funding will also support initiating major system replacements to operate ATR through 2040 and initiating evaluation of long-term thermal neutron irradiation needs.
- Increased labor costs tied to negotiated wage agreements at the ATR Complex and MFC.
- Environmental review and data collection activities to support future permits and NEPA documentation.
- Initial transition of the Sample Preparation Laboratory (SPL) to operations.

In FY 2023, ORNL Nuclear Facilities O&M is fully funded through associated program budgets.

In FY 2023, the Construction subprogram funds the SPL Project consistent with the approved project baseline. FY 2023 is the final funding year for construction activities, including installation of scientific equipment, hot cell interior and experiment spaces, manipulator repair space, glove box and other service areas.

Infrastructure
Funding ($K) (Non-Comparable)

	FY 2021 Enacted	FY 2022 Annualized CR	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
Infrastructure					
INL Facilities Operations and Maintenance[1]	280,000	280,000	326,924	+46,924	+16.8%
ORNL Nuclear Facilities O&M	20,000	20,000	0	-20,000	-100%
Research Reactor Infrastructure[2]	11,500	11,500	0	-11,500	-100%
Construction: Sample Preparation Laboratory	26,000	26,000	7,300	-18,700	-71.9%
Total, Infrastructure	**337,500**	**337,500**	**334,224**	**-3,276**	**-1.0%**

Infrastructure
Funding ($K) (Comparable)

	FY 2021 Enacted	FY 2022 Annualized CR	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
Infrastructure					
INL Facilities Operations and Maintenance[3]	280,000	280,000	326,924	+46,924	+16.8%
ORNL Nuclear Facilities O&M	20,000	20,000	0	-20,000	-100%
Construction: Sample Preparation Laboratory	26,000	26,000	7,300	-18,700	-71.9%
Total, Infrastructure	**326,000**	**326,000**	**334,224**	**+8,224**	**+2.5%**

[1] Funding does not reflect the transfer of approximately $91M in FY 2021 from Naval Reactors for maintenance and operation of the Advanced Test Reactor.
[2] In FY 2023, the Research Reactor Infrastructure subprogram is consolidated with other university support activities under the new Directed R&D and University Programs.
[3] Funding does not reflect the transfer of approximately $91M in FY 2021 from Naval Reactors for maintenance and operation of the Advanced Test Reactor.

Infrastructure
Explanation of Major Changes ($K)

	FY 2023 Request vs FY 2021 Enacted
INL Facilities Operations and Maintenance:	
The increase from $280,000,000 to $326,924,000 fully funds the ongoing efforts to improve the reliability and availability of the Advanced Test Reactor (ATR) and key Materials and Fuels Complex (MFC) nuclear facilities through risk-informed investments in equipment and infrastructure, planned major maintenance and repair activities at the ATR, such as heat exchanger replacement; evaluation of long-term thermal neutron irradiation capability needs; support for increased labor costs tied to negotiated wage agreements; and initial transition to operations of the Sample Preparation Laboratory (SPL) project.	**+46,924**
ORNL Nuclear Facilities O&M:	
The decrease from $20,000,000 to $0 reflects completion of congressionally directed activities. In fiscal year 2023, the Office of Nuclear Energy use of these ORNL facilities is fully funded through associated program budgets.	**-20,000**
Research Reactor Infrastructure:	
The decrease from $11,500,000 to $0 reflects the transfer of fuel services previously funded under Research Reactor Infrastructure including additional TRIGA fresh fuel orders to ensure a maximum number of fuel elements per year can be purchased to minimize overall cost.	**-11,500**
Construction:	
The decrease from $26,000,000 to $7,300,000 reflects the final year of Sample Preparation Laboratory (SPL) project construction funding consistent with approved baselines. The Budget Request provides for the completion of the construction and installation of scientific equipment including interior of hot cell and experiment spaces, manipulator repair space, glove box and other service areas.	**-18,700**
Total, Infrastructure	**-3,276**

INL Facilities Operations and Maintenance

Description

INL Nuclear Research Reactor Operations and Maintenance

This subcategory supports nuclear research reactor operations and maintenance at the Advanced Test Reactor (ATR) Complex and the Materials and Fuels Complex (MFC) for the Idaho National Laboratory (INL), including the ATR, the ATR Critical Facility (ATRC), the Transient Reactor Test Facility (TREAT), and the Neutron Radiography Reactor (NRAD).

The ATR is the primary research reactor at the INL. The ATR supports the majority of the Office of Nuclear Energy (NE) research and development (R&D) programs, as well as Naval Reactors (NR) Program in support of the U.S. Navy nuclear fleet and National Nuclear Security Administration (NNSA) programs. The ATR is also used by universities, laboratories, and industry, and is the primary scientific capability of the Nuclear Science User Facilities (NSUF). R&D demand for thermal neutron irradiation at ATRC and neutron radiography and small component test irradiation at NRAD continues to be significant. The TREAT reactor, an air-cooled thermal spectrum test facility, continues to address technical challenges for reactor fuels related to nuclear-fuel performance and qualification. All programmatic work is funded by the sponsoring federal programs. The cost to other users is determined in accordance with DOE regulations and depends upon the demands on the reactor and the nature of the user.

To satisfy the irradiation needs of ATR users, efforts will continue in FY 2023 to improve the availability and reliability of the ATR. FY 2023 will be the first full year of ATR operations following the successful completion of the ATR Core Internals Change-out (CIC). The CIC was a major outage to replace all the components within the Beryllium reflector region of the core. These major outages occur every 10 to 20 years, based on the power history of the reactor. Continued investments in ATR infrastructure are still needed to sustain the improvements that have been made to date. Funding is identified in FY 2023 to begin planning for major maintenance and repair activities required to sustain ATR operations through 2040 such as the replacement of the primary heat exchangers. Additionally, work is planned in FY 2023 to evaluate the long-term capability needs for continued thermal neutron irradiation testing.

Operations at TREAT and NRAD will continue in FY 2023 to support a wide range of customers including NE R&D programs, commercial industry, and other Federal Agencies.

INL Non-Reactor Nuclear Research Facility Operations and Maintenance

This subcategory provides funding for operations, maintenance, and support for non-reactor nuclear and radiological research facilities primarily located at the Materials and Fuels Complex (MFC). Activities within this category support sustainment of unique nuclear and radiological capabilities that are required to support essential R&D programs of NE. This includes maintaining a safe operating envelope by conducting maintenance (preventative and corrective) and refurbishments to sustain or improve core infrastructure capabilities. The non-reactor nuclear research facilities support core programmatic research capabilities including:

- Post-Irradiation Examination (PIE) and Fresh Fuel Characterization – Receipt of irradiated fuels and materials, non-destructive examinations, destructive examinations and analyses, and mechanical testing of highly radioactive materials.
- Experimental Fuel Fabrication – R&D on multiple fuel types and hazard levels.
- Advanced Separation and Waste Forms – Separation and pre-treatment technology development and electrochemical separation and waste form development (engineering scale).

To enable R&D activities at the MFC, efforts will continue in FY 2023 to ensure facility availability and equipment reliability is as high as feasible. In FY 2021, cumulative facility availability for MFC was 90%. In FY 2023, MFC Plant Health investments will continue to focus on improving throughput in MFC mission facilities, such as hot cell window and manipulator replacements at Hot Fuels Examination Facility (HFEF), Fuel Conditioning Facility (FCF), and Analytical Laboratory (AL); roof repairs and lab space renovations; and control systems replacements at FCF.

This subprogram also provides funding for the management of NE-owned special nuclear material (SNM), operation and maintenance of the Remote-Handled Low-Level Waste (RHLLW) Disposal Facility and the Radioactive Waste Scrap Facility (RSWF), support for Nuclear Regulatory Commission cask certifications and Other Project Costs (OPCs) for the Sample Preparation Laboratory (SPL) Project.

In FY 2023, funds are also provided to initiate activities needed to transition SPL to operations, including development of procedures for operational readiness, updates of nuclear safety basis documentation, and development of procedures for system operability testing.

INL Engineering and Support Facility Operations and Maintenance

This subcategory provides funds for the community and technical support activities including support for the Shoshone-Bannock Tribes, Idaho Department of Environment Quality, and environmental reviews and data collection to support future permits and NEPA reviews. It also supports environmental surveillance and monitoring activities in accordance with State and Federal regulations. This subcategory also funds Payment in Lieu of Taxes (PILT), Institute of Nuclear Power Operations, and other Departmental cross-cutting infrastructure reporting requirements.

DOE has had a formal relationship via an Agreement in Principle with the Shoshone-Bannock Tribes since 1992 in recognition of the Tribes' connection and vested interest in the land upon which INL is located. Support is provided to the Tribes to participate in the review of Environmental Impact Statement and Environmental Assessments, cultural resource surveys and protection, environmental surveillance, and emergency response and preparedness.

INL Regulatory Compliance

This subcategory supports activities for continual compliance with the State and Federal environmental laws and other regulations that are under the purview of the Office of Nuclear Energy (NE). Compliance activities focus on air, soil, and water monitoring and waste disposal consistent with Federal and State permit requirements and agreements such as the INL Site Treatment Plan. Regulatory activities also include efforts that support compliance with the 1995 Settlement Agreement with the State of Idaho, which governs management and disposition of spent nuclear fuel and transuranic wastes at the INL. In November 2019, DOE and the State of Idaho signed a Supplemental Agreement to the 1995 Idaho Settlement Agreement that reaffirms DOE's and Idaho's commitment to remove Cold War legacy waste and special nuclear materials from Idaho. In FY 2023, funds are provided to support material stabilization and legacy material packaging consistent with approved plans and negotiated labor wage agreements.

INL Facilities Operations and Maintenance
Funding ($K)

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
INL Nuclear Research Reactor Operations and Maintenance $116,900,000	**$130,537,000**	**+$13,637,000**
• Maintained Advanced Test Reactor (ATR) availability greater than 80% prior to beginning the core internals change-out (CIC). • Continued investments to improve ATR availability and reliability through refurbishments and replacements of reactor systems and components such as loop refurbishment, cold waste control system refurbishment, and console display system annunciator upgrades. • Initiated the ATR CIC to replace major internal components including Beryllium reflectors. • Completed ATR reactor inspections including the reactor vessel weld and tank chain. • Continued transient testing operations at the TREAT facility. • Continued operations of the NRAD.	• Maintain ATR availability greater than 80% with a target of 161 irradiation days in the first full year of operations following completion of the CIC in FY 2022. • Continue investments to improve ATR availability and reliability through refurbishments and replacements of reactor systems and components such as warm waste pond liner replacement, canal bulkhead replacements, and regulating rod control system upgrades. • Initiate planning for major maintenance and repair activities required to sustain ATR operations through 2040 such as replacement of the primary heat exchangers. • Continue to transfer ATR spent fuel into dry storage configuration consistent with State agreements. • Evaluate long-term capability needs for continued thermal neutron irradiation testing. • Continue transient testing operations at the TREAT facility. • Continue operations of the NRAD.	• The increase supports ongoing efforts to improve the reliability and availability of the ATR, initial planning efforts for the major maintenance and repair activities required to sustain ATR operations through 2040, and evaluation of long-term capability needs for continued thermal neutron irradiation testing.
INL Non-Reactor Nuclear Research Facility Operations and Maintenance $145,845,000	**$175,649,000**	**+$29,804,000**
• Operated and maintained the Materials and Fuels Complex (MFC) infrastructure, facilities, and equipment to support facility operations and programmatic work activities. • Performed maintenance and refurbishment activities within the MFC nuclear facilities and	• Operate and maintain MFC infrastructure, facilities, and equipment to support facility operations and programmatic work activities. • Perform maintenance and refurbishment activities within the MFC nuclear facilities and	• The increase supports full funding to initiate transition to operations for the Sample Preparation Laboratory; and improving reliability and availability of key MFC nuclear facilities through a risk-based prioritization of

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
infrastructure consistent with the approved safety basis. • Performed maintenance and refurbishment on the radiological and balance-of-plant facilities necessary to support the MFC nuclear facilities and core missions. • Continued off-site disposition of surplus NE-owned Special Nuclear Materials (SNM) consistent with programmatic needs and approved nuclear material allotment forecasts. • Operated and maintained the Remote-Handled Low-Level Waste (RHLLW) Disposal Facility to provide legacy and newly - generated waste disposal capability. • Conducted construction oversight activities for the Sample Preparation Laboratory (SPL) Project. • Continued MFC infrastructure investments, such as hot cell window and manipulator replacements, criticality alarm replacements, and laboratory refurbishments.	infrastructure consistent with the approved safety basis. • Perform maintenance and refurbishment on the radiological and balance-of-plant facilities necessary to support the MFC nuclear facilities and core missions. • Continue off-site disposition of surplus NE-owned SNM consistent with programmatic needs and approved nuclear material allotment forecasts. • Operate and maintain the RHLLW Disposal Facility to provide legacy and newly - generated waste disposal capability. • Conduct construction oversight activities for the SPL Project. • Continue to support activities to maintain INL operations such as NRC certificates for cask. • Continue MFC infrastructure investments to improve reliability and availability of key facilities, such as hot cell window and manipulator replacements at HFEF, FCF, and AL; roof repairs and lab space renovations; and replace control systems at FCF. • Initiate transition to operations for SPL including procedures development, updating nuclear safety documentation and system operability testing.	plant and equipment investments, such as replacement of manipulators and windows at HFEF, FCF, and AL, replacement of hot cell HEPA filters and chiller at HFEF, and replacement of HVAC throughout MFC.
INL Engineering and Support Facility Operations and Maintenance $7,580,000	**$5,424,000**	**-$2,156,000**
• Continued to support Federally funded activities to maintain operations at the Idaho National Laboratory (INL) such as Nuclear Regulatory Commission (NRC) certificates for casks, Payment-in-Lieu of Taxes (PILT), and environmental monitoring to support State requirements.	• Continue to support federally funded activities to maintain operations at the INL such as PILT; environmental review and data collection to support future permits/NEPA assessments; and community support activities for local Shoshone-Bannock Tribes including review of Environmental Impact Statement and Environmental Assessments, cultural resource surveys and	• The decrease reflects transition of environmental surveillance activities from federal contracts to Idaho National Laboratory under INL Regulatory Compliance.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
	protection, environmental surveillance, and emergency response and preparedness.	
INL Regulatory Compliance $9,675,000	**$15,314,000**	**+$5,639,000**
• Continued regulatory compliance program management. • Met INL Site Treatment Plan milestones for treatment of two cubic meters of mixed low-level waste (MLLW) annually based on a three-year rolling average. • Completed a minimum of 10 transfers of used nuclear fuel from wet storage in accordance with the 1995 Idaho Settlement Agreement and consistent with material requirements for the treatment of Experimental Breeder Reactor (EBR)-II used nuclear fuel.	• Continue regulatory compliance program management. • Meet INL Site Treatment Plan milestones for treatment of two cubic meters of MLLW annually based on a three-year rolling average. • Complete receipt of minimum of 12 transfers of used nuclear fuel from wet storage at FCF in accordance with the 1995 Idaho Settlement Agreement and consistent with material requirements for the treatment of EBR-II used nuclear fuel. • Process a minimum of 8 treatment batches of EBR-II fuel through FCF pyro-processing. • Continue to coordinate activities and operations for the direct shipment of EBR-II fuel from the Idaho Nuclear Technology and Engineering Center to the Materials and Fuels Complex. • Conduct environmental surveillance and monitoring activities.	• The increase reflects labor wage agreements; activities associated with environmental surveillance and monitoring in accordance with State and Federal regulations; and increased support for activities associated with meeting the schedules and milestones under the Idaho Settlement Agreement.

ORNL Nuclear Facilities O&M

Description

Consistent with congressional direction, this program provided funds in FY 2021 to support Oak Ridge National Laboratory (ORNL) hot cells. In FY 2023, the Office of Nuclear Energy use of these ORNL facilities is fully funded through associated program budgets.

ORNL Nuclear Facilities O&M
Funding ($K)

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Oak Ridge Nuclear Infrastructure $20,000,000	**$0**	**-$20,000,000**
Congressionally directed activities conducted included: • maintenance and end-of-life replacement of critical hot cell equipment and infrastructure such as ventilation system monitoring equipment, manipulator repairs, installation of hot cell window and liquid waste tanks. • updated facility safety basis documentation and performed nuclear criticality safety analyses.	• No funding is requested.	• Funding is allocated through facility use charges applied to NE R&D programs utilizing ORNL hot cell capabilities.

Research Reactor Infrastructure

Description
Research Reactor Infrastructure provides fuel services for U.S. university research reactors. These activities are now funded within the University Fuel Services subprogram under Directed R&D and University Programs.

Research Reactor Infrastructure

Funding ($K)

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Research Reactor Infrastructure $11,500,000	**$0**	**-$11,500,000**
• Procured 40 and delivered 33 plate fuel elements required annually by MURR and MIT as determined by need and fuel availability. • Established the contract for the procurement of TRIGA fuel elements from the TRIGA Fuel Fabrication Facility (TFFF) in Romans, France upon resumption of operations. Due to COVID, there were delays in completing upgrades to the TFFF, gathering documentation from vendors to support the French regulator review, and significant increased time for the French regulator to complete their review. Therefore, fuel procurement will start in early FY 2022. • Procured and shipped HALEU metal to the TFFF in Romans, France, to support procurement of TRIGA fuel elements, and ship fuel elements to TRIGA reactor facilities as determined by need and fuel availability. • Completed four used fuel shipments to SRS and the INL, pending resolution of moratorium on such shipments to the INL. • Continued RRI project management, quality assurance, nuclear material accountability, and transportation cask maintenance.	• Funding is requested under University Fuel Services under Directed R&D and University Programs.	• The decrease reflects the transfer of fuel services previously funded under Research Reactor Infrastructure including additional TRIGA fresh fuel orders to ensure a maximum number of fuel elements per year can be purchased to minimize overall cost.

Construction

Description

Line-item capital projects are sometimes required at the Idaho National Laboratory (INL) to maintain its ability to support mission goals. These projects help achieve the Department's and the Office of Nuclear Energy's (NE) strategic objectives by maintaining site services and providing critical information for future decisions. This activity is focused on two primary objectives: (1) identification, planning, and prioritization of projects required to meet NE program objectives, and (2) development and execution of these projects within approved cost and schedule baselines as such projects are deemed necessary. While the Department's acquisition management process does not guarantee that a project will be completed once the initial information gathering and preliminary design phase are complete, it does provide an important decision-making framework that, when well executed, allows only the most critically necessary, cost-effective projects to proceed to construction.

The Sample Preparation Laboratory (SPL) project is a line-item capital project that will provide the capability for sample preparation to support micro-/nano-scale structural, chemical, mechanical, and thermal properties analyses. This capability will augment non-destructive examination, elemental analysis, and radiological capabilities already present or being developed at INL. The SPL will, when coupled with existing facilities and recapitalization efforts, fulfill near-term capabilities for conducting the advanced post-irradiation examination needed to improve understanding of nuclear fuels and material performance at the micro-, nano-, and atomic scales.

The most recent SPL Department of Energy Order (DOE O) 413.3B Critical Decision (CD), CD-1R/2/3 (Reaffirm Alternative Selection Process, Approve Performance Baseline, and Approve Start of Construction), was approved on January 31, 2020, with a Total Project Cost (TPC) of $166,000,000 and CD-4, Approve Project Completion, in FY 2027.

The FY 2023 Budget Request for the SPL project is $7,3000,000 to complete construction activities including installation of scientific equipment including hot cell and experiment spaces.

Construction
Funding ($K)

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Construction $26,000,000	**$7,300,000**	**-$18,700,000**
Sample Preparation Laboratory (16-E-200) ($26,000,000) • Continued SPL construction activities including equipment and hardware procurement; hot cell liner fabrication; concrete stair and elevator core construction; concrete shear wall construction; and hot cell window delivery.	*Sample Preparation Laboratory (16-E-200) ($7,300,000)* • Continue SPL construction activities consistent with approved baseline. The Budget Request reflects completion of the construction and installation of scientific equipment including interior of hot cell and experiment spaces, manipulator repair space, glove box and other service areas.	*Sample Preparation Laboratory (16-E-200) (-$18,700,000)* • The decrease reflects meeting established baseline funding requirements.

Infrastructure
Construction Projects Summary ($K)

	Total	Prior Years	FY 2021 Enacted	FY 2021 Actuals	FY 2022 Annualized CR	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted
16-E-200, Sample Preparation Laboratory, INL							
Total Estimated Cost (TEC)	144,600	69,450	26,000	26,000	26,000	7,300	-18,700
Other Project Costs (OPC)	21,400	4,647	500	500	2,500	0	-500
Total Project Cost (TPC) Project Number 16-E-200	**166,000**	**74,097**	**26,500**	**26,500**	**28,500**	**7,300**	**-19,200**
Total All Construction Projects							
Total Estimated Cost (TEC)	144,600	69,450	26,000	26,000	26,000	7,300	-18,700
Total Other Project Costs (OPC)	21,400	4,647	500	500	2,500	0	-500
Total Project Cost (TPC) All Construction Projects	**166,000**	**74,097**	**26,500**	**26,500**	**28,500**	**7,300**	**-19,200**

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

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

Summary

The FY 2023 Budget Request for the Sample Preparation Laboratory (SPL) project is $7,300,000. The most recent Department of Energy (DOE) Order 413.3 B Critical Decision (CD), CD-1R/2/3 (Reaffirm Alternative Selection Process, Approve Performance Baseline, and Approve Start of Construction), was approved on January 31, 2020, with a Total Project Cost (TPC) of $166,000,000 and CD-4, Approve Project Completion, in FY 2027.

FY 2021 and FY 2022 funding supported facility construction, which was initiated in FY 2020. Construction activities conducted include but were not limited to: completion of facility footings and slab; erection of stair and elevator cores; erection of structural steel; initiation of precast concrete exterior panels; subcontractor procurement of mechanical, plumbing, and electrical components; and initial fabrication of hot cell liners.

Capital funding requested in FY 2023 supports completion of project construction activities including completion of major building system installations, such as HVAC, hot cell, gloveboxes, and facility cranes. FY 2023 funding will also support receipt and installation of scientific facility equipment including X-ray Photoelectron Instrument, Focused Ion Beam, dual arm Robot for Mechanical Properties Test Cell, and digital microscopes.

Construction on the project began at the beginning of the COVID-19 pandemic, however, to this point, there have been no significant impacts to the cost or schedule baseline.

A Level II Federal Project Director (FPD) has been assigned to this project, and their Level III certification is in progress.

Significant Changes

The SPL project was initiated in FY 2011. The most recent DOE Order 413.3B approved Critical Decision CD-1R/2/3 was approved on January 31, 2020. This CD approval certified the continued need for the project despite escalating construction costs, approved the increase in TPC based on the actual construction bid for the project, and was agreed on by the Independent Cost Estimate. This Construction Project Data Sheet (CPDS) is an update of the FY 2022 CPDS and does not include a new start for FY 2023.

Critical Milestone History

(Fiscal Quarter or Date)

Fiscal Year	CD-0	Conceptual Design Complete	CD-1	Final Design Complete	CD-1R/2/3	D&D Complete	CD-4
FY 2016	1/31/2011	4Q FY2014	3Q FY2015	TBD	TBD	TBD	TBD
FY 2017	6/18/2015	1Q FY2016	1Q FY2016	TBD	TBD	N/A	TBD
FY 2018	6/18/2015	8/31/2016	9/30/2016	TBD	TBD	N/A	TBD
FY 2019	6/18/2015	8/31/2016	9/30/2016	TBD	TBD	N/A	TBD
FY 2020	6/18/2015	8/31/2016	9/30/2016	TBD	TBD	N/A	TBD
FY 2021	6/18/2015	8/31/2016	9/30/2016	10/24/2018	1/31/2020	N/A	1QFY2027
FY 2022	6/18/2015	8/31/2016	9/30/2016	10/24/2018	1/31/2020	N/A	1QFY2027
FY 2023	6/18/2015	8/31/2016	9/30/2016	10/24/2018	1/31/2020	N/A	1QFY2027

CD-0 – Approve Mission Need for a construction project with a conceptual scope and cost range
Conceptual Design Complete – Actual date the conceptual design was completed (if applicable)
CD-1 – Approve Alternative Selection and Cost Range
Final Design Complete – Estimated/Actual date the project design will be/was complete (d)
CD-1R/2/3 – Reaffirm Alternative Selection Process, Approve Performance Baseline, and Approve Start of Construction

D&D Complete – Completion of D&D work
CD-4 – Approve Start of Operations or Project Closeout

Fiscal Year	Performance Baseline Validation	CD-3A	CD-3B
FY 2016	N/A	N/A	N/A
FY 2017	N/A	N/A	N/A
FY 2018	N/A	N/A	N/A
FY 2019	N/A	N/A	N/A
FY 2020	N/A	N/A	N/A
FY 2021	1/31/2020	N/A	N/A
FY 2022	1/31/2020	N/A	N/A
FY 2023	1/31/2020	N/A	N/A

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

Project Cost History

(dollars in thousands)

Fiscal Year	TEC, Design	TEC, Construction	TEC, Total	OPC, Except D&D	OPC, Total	TPC
FY 2016	10,000	68,000	78,000	17,000	17,000	95,000
FY 2017	10,000	73,000	83,000	12,000	12,000	95,000
FY 2018	13,385	72,615	86,000	12,200	12,200	98,200
FY 2019	13,385	72,615	86,000	12,200	12,200	98,200
FY 2020	13,385	72,615	86,000	12,200	12,200	98,200
FY 2021	9,998	134,602	144,600	21,400	21,400	166,000
FY 2022	9,998	134,602	144,600	21,400	21,400	166,000
FY 2023	9,998	134,602	144,600	21,400	21,400	166,000

2. Project Scope and Justification

Scope

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

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

- The facility will be a Hazard Category 3, non-reactor nuclear facility designed to meet Seismic Design Category 2, Limit State B requirements. The facility has been designed to meet stringent vibration, electrical and magnetic field, acoustic, and temperature fluctuation requirements for advanced analytical equipment with the ability to support development and deployment of equipment, instruments, and models to meet future nuclear fuel development R&D needs over a 40-year period.
- The facility will be a three-story structure encompassing approximately 49,000 ft^2, comprised of two main areas: the nuclear portion (typically referred to as the hot cell gallery) and the office/support area, constituting 35,000 ft^2 and 14,000 ft^2, respectively.

- The facility will provide a source material receiving and storage area to receive and store experiment subassemblies with lengths up to 48 inches and weighs up to 20 pounds; other source material with a diameter of less than 5 inches and weighs up to 20 pounds will be accommodated.
- The facility will include a library or prepared sample storage area with the capacity to store up to 1,800 samples.
- The facility will include a shielded cell for mechanical properties testing. The initial complement of mechanical properties testing equipment will include a mechanical property testing load frame, a Charpy impact tester, a hardness tester, and a digital microscope.
- The facility design allocated space for eight separate instrument enclosures for deployment of advanced post-irradiation examination instruments; three of which will be shielded enclosures constructed as part of the initial facility buildout. The remaining five enclosure spaces are designated for future expansion: one shielded enclosure and four non-shielded enclosures for contact-handled materials. The shielded enclosures are designed for regular manned access when radioactive samples are not present. The shielded enclosures will be flexible and reconfigurable to accommodate operational requirements for use with modern characterization instruments. The minimum initial complement of shielded examination instruments will include a scanning electron microscope, a surface science instrument, and an x-ray diffraction instrument. Additional scientific capability will be considered as risk is retired during construction.
- The facility will include space for research expansion, allowing future installation of non-shielded instrument enclosures and instruments.

The initial complement of scientific instruments will be procured, modified to operate remotely through hot cell walls via telemanipulators or robotics, and tested as part of the project prior to installation in the facility. The initial complement of scientific instruments includes a scanning electron microscope, a surface science instrument (such as x-ray photoelectron spectroscopy), and micro x-ray diffraction.

The Sample Preparation Laboratory (SPL) Facility will be operated to preclude or limit introduction of alpha-emitting radioisotopes. Limitation of alpha-emitting radioisotopes will be accomplished through limitation of the types of materials that will be studied. The SPL is a separate structure, limited to receiving, processing, handling, examining, testing, storing, and packaging irradiated beta-gamma emitting materials with limited amounts of alpha contamination. In some cases, very small quantities of alpha-emitting material (i.e., fuels) may be received in the form of metallurgical mounts for examination, using unique SPL examination instruments. The sectioning and mounting of these metallurgical mounts would be performed elsewhere. The SPL will operate in conjunction with the Hot Fuel Examination Facility (HFEF), Analytical Laboratory, and Irradiated Materials Characterization Laboratory (IMCL), and offsite facilities to provide the overall capability to analyze and characterize irradiated and non-irradiated nuclear material samples. The SPL facility will not replace these facilities; it will function synergistically with them. Having most of these facilities located within a single security-protected site (i.e., MFC) supports efficient nuclear material control, security, and management.

Facility operations will include cask receipt and unloading, experiment decontamination, sample preparation (e.g., machining, grinding, and polishing), sample storage, waste packaging, and various micro-structure and thermal examinations. Majority of these operations will take place within shielded cells and enclosures due to the radioactivity of the materials handled. These include the Sample Preparation Line, the Mechanical Properties Test Cell (MPTC), and the shielded instrument rooms.

Nuclear materials and samples will be handled in containers ranging from the Battelle Energy Alliance, LLC (BEA) research reactor cask to shielded/non-shielded 55-gallon drums, incorporating a truck lock for cask and related container handling. The principal feature of the SPL design is the shielded sample preparation hot cells that include four cells with five additional stations supporting experiment handling, sizing, and grinding (two stations), decontamination/waste handling, and sample storage. Materials will be transferred to the testing and examination areas throughout the facility using a pneumatic transfer system (PTS). Samples will also be transferred within the facility and to other facilities via small, shielded pigs or casks that mate to the outside of the hot cells. Samples will be appropriately shielded and confined to protect workers, equipment, and the facility.

The MPTC will be attached to the hot cells on the first floor. Material handling operations within the MPTC and enclosures will be done through robotics, rather than using traditional telemanipulators and shielded windows like the sample preparation line.

The remaining space on the first floor will consist of office and support areas. The second-floor design provides for an auxiliary equipment area to support the scientific instruments on the first floor. Additional research space and office areas comprise the remainder of the floor. The third floor will include the bulk of the facility service and support areas including rooms associated with equipment and instrument repair.

Key Performance Parameters (KPPs)

KPPs are defined as a vital characteristic, function, requirement, or design basis that, if changed, would have a major impact on the facility or system performance, scope, schedule, cost, risk, or the ability of an interfacing project to meet its mission requirements. The threshold KPPs represent the minimum acceptable scope for successful delivery of SPL. Achievement of KPPs will be a prerequisite for approval of CD-4. The project has identified Objective KPPs that will provide expanded capabilities to meet R&D objectives, if needed. If project performance warrants, management reserve and/or contingency funds can be allocated to Objective KPP scope or infrastructure enhancements to improve facility performance. As the project progresses, project status will be assessed, and recommendations made to the FPD regarding the potential execution of objective KPP scope. Such recommendations will consider remaining project risks and will include detailed cost and schedule performance information.

Threshold and Objective KPPs

Performance Measure	Threshold	Objective*
Construct a Hazard Category-3, non-reactor nuclear laboratory facility	Minimum of 40,000 gross square feet of laboratory/support space	N/A
Provide a shielded sample preparation capability designated for beta/gamma emitting irradiated materials	Shielded hot cell with five workstations/windows and associated equipment that support cask receipt, material handling, gross source material sizing, storage, decontamination, and fine sample preparation	N/A
Provide advanced post-irradiation examination capabilities for beta/gamma emitting irradiated materials	Three shielded scientific instrument enclosures Three advanced scientific instruments that support interior (crystal) phase characterization, fracture surface analysis, and surface science	Up to five additional advanced scientific instruments and associated facility infrastructure
Provide mechanical properties testing capabilities for beta/gamma emitting irradiated materials	Mechanical Properties Test Cell with capabilities for hardness, tensile strength, and impact testing	N/A
* SPL will be baselined to the Threshold Measure. Objective KPPs will be executed if funding is available after Threshold KPPs are achieved.		

The SPL facility will be constructed using sustainable building considerations per Department of Energy Guide 413.3-6B, dated 4-5-2020, "High Performance Sustainable Buildings." The facility design includes provisions for meeting the 2016 and 2020 Guiding Principles for Sustainable Federal Buildings. Design, construction, and documentation of the 2016 Guiding Principles ensure compliance with DOE Order 436.1, Departmental Sustainability.

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

Justification

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

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

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

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

3. Financial Schedule

(Dollars in Thousands)

	Budget Authority (Appropriations)	Obligations	Costs
Total Estimated Cost (TEC)			
Design			
FY 2016	2,000	2,000	0
FY 2017	6,000	6,000	33
FY 2018	1,988	1,988	6,484
FY 2019	0	0	3,471
Total, Design (TEC)	**9,988**	**9,988**	**9,988**
Construction			
FY 2018	4,012	4,012	0
FY 2019	30,000	30,000	0
FY 2020	25,450	25,450	19,277
FY 2021	26,000	26,000	35,548
FY 2022	41,850	41,850	51,090
FY 2023	7,300	7,300	26,357
FY 2024	0	0	2,340
Total, Construction (TEC)	**134,612**	**134,612**	**134,612**
Total Estimated Costs (TEC)			
FY 2016	2,000	2,000	0

	Budget Authority (Appropriations)	Obligations	Costs
FY 2017	6,000	6,000	33
FY 2018	6,000	6,000	6,484
FY 2019	30,000	30,000	3,471
FY 2020	25,450	25,450	19,277
FY 2021	26,000	26,000	35,548
FY 2022	41,850	41,850	51,090
FY 2023	7,300	7,300	26,357
FY 2024	0	0	2,340
Total TEC	**144,600**	**144,600**	**144,600**

	Budget Authority (Appropriations)	Obligations	Costs
Other Project Costs			
FY 2012	43	43	43
FY 2013	164	164	164
FY 2014	158	158	158
FY 2015	434	434	434
FY 2016	1,072	1,072	1,072
FY 2017	408	408	408
FY 2018	2,368	2,368	477
FY 2019	0	0	1,139
FY 2020	0	0	740
FY 2021	500	500	1,308
FY 2022	2,500	2,500	2,250
FY 2023	6,903	6,903	6,132
FY 2024	6,000	6,000	5,441
FY 2025	850	850	1,634
Total OPC	**21,400**	**21,400**	**21,400**
Total Project Costs (TPC)			
FY 2012	43	43	43
FY 2013	164	164	164
FY 2014	158	158	158
FY 2015	434	434	434
FY 2016	3,072	3,072	1,072
FY 2017	6,408	6,408	441
FY 2018	8,368	8,368	6,961
FY 2019	30,000	30,000	4,610
FY 2020	25,450	25,450	20,017
FY 2021	26,500	26,500	36,856
FY 2022	44,350	44,350	53,340
FY 2023	14,203	14,203	32,489
FY 2024	6,000	6,000	7,781
FY 2025	850	850	1,634
Grand Total	**166,000**	**166,000**	**166,000**

4. Details of Project Cost Estimate

(Budget Authority in Thousands of Dollars)

	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
Total Estimated Cost (TEC)			

	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
Design			
Design	9,998	10,785	9,998
Contingency	0	2,600	0
Total, Design	9,998	13,385	9,998
Construction			
Site Work	2,505	2,230	2,505
Equipment	17,878	8,545	17,878
Construction	94,237	56,840	94,237
Other, as needed	--	--	--
Contingency	19,982	5,000	19,982
Total, Construction	134,602	72,615	134,602
Other TEC (if any)			
Cold Startup	--	--	--
Contingency	--	--	--
Total, Other TEC	--	--	--
Total **Estimated Cost**	144,600	86,000	144,600
Contingency, TEC	19,982	7,600	19,982
Other Project Cost (OPC)			
OPC except D&D			
R&D	0	4,220	0
Conceptual Planning	1,310	1,310	1,310
Conceptual Design	821	821	821
Other OPC Costs	15,743	4,549	15,743
Contingency	3,526	1,300	3,526
Total, OPC	21,400	12,200	21,400
Contingency, OPC	3,526	1,300	3,526
Total Project Cost	166,000	98,200	166,000
Total Contingency (TEC+OPC)	23,508	8,900	23,508

5. Schedule of Appropriation Requests

(Dollars in Thousands)

Request Year	Type	Prior Years	FY 2020	FY 2021	FY 2022	FY 2023	Outyears	Total
FY 2016	TEC	2,000	TBD	TBD	TBD	0	0	78,000
	OPC	1,847	TBD	TBD	TBD	0	0	17,000
	TPC	3,847	TBD	TBD	TBD	0	0	95,000

Request Year	Type	Prior Years	FY 2020	FY 2021	FY 2022	FY 2023	Outyears	Total
FY 2017	TEC	8,000	TBD	TBD	TBD	TBD	TBD	83,000
	OPC	4,647	TBD	TBD	TBD	TBD	TBD	12,000
	TPC	12,647	TBD	TBD	TBD	TBD	TBD	95,000
FY 2018	TEC	14,000	TBD	TBD	TBD	TBD	TBD	86,000
	OPC	4,647	TBD	TBD	TBD	TBD	TBD	12,200
	TPC	18,647	TBD	TBD	TBD	TBD	TBD	98,200
FY 2019	TEC	14,000	TBD	TBD	TBD	TBD	TBD	86,000
	OPC	4,647	TBD	TBD	TBD	TBD	TBD	12,200
	TPC	18,647	TBD	TBD	TBD	TBD	TBD	98,200
FY 2020	TEC	44,000	5,242	TBD	TBD	TBD	TBD	86,000
	OPC	4,647	0	0	TBD	TBD	TBD	12,200
	TPC	48,647	5,242	TBD	TBD	TBD	TBD	98,200
FY 2021	TEC	44,000	25,450	18,000	41,850	TBD	TBD	144,600
	OPC	4,647	0	2,403	2,500	TBD	TBD	21,400
	TPC	48,647	25,450	20,403	44,350	TBD	TBD	166,000
FY 2022	TEC	44,000	25,450	26,000	41,850	7,300	0	144,600
	OPC	4,647	0	500	2,500	6,903	6,850	21,400
	TPC	48,647	25,450	26,500	44,350	14,203	6,850	166,000
FY 2023	TEC	44,000	25,450	26,000	41,850	7,300	0	144,600
	OPC	4,647	0	500	2,500	6,903	6,850	21,400
	TPC	48,647	25,450	26,500	44,350	14,203	6,850	166,000

6. Related Operations and Maintenance Funding Requirements

Start of Operation or Beneficial Occupancy (fiscal quarter or date)	1Q FY 2027
Expected Useful Life (number of years)	40
Expected Future Start of D&D of this capital asset (fiscal quarter)	1Q FY 2067

Related Funding Requirements
(Budget Authority in Thousands of Dollars)

	Annual Costs		Life Cycle Costs	
	Previous Total Estimate	Current Total Estimate	Previous Total Estimate	Current Total Estimate
Operations and Maintenance	9,926	9,926	1,675,000	1,675,000

Life-cycle operations and maintenance costs include annual escalation.

7. D&D Information

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

	Square Feet
New area being constructed by this project at Idaho National Laboratory	49,000
Area of D&D in this project at Idaho National Laboratory	0
Area at Idaho National Laboratory to be transferred, sold, and/or D&D outside the project, including area previously “banked”	0
Area of D&D in this project at other sites	0

Area at other sites to be transferred, sold, and/or D&D outside the project, including area previously "banked"	0
Total area eliminated	0

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

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

8. Acquisition Approach

As a Hazard Category 3 nuclear facility, design, and construction of the Sample Preparation Laboratory (SPL) must be integrated with ongoing nuclear operations activities. Design and construction must also be coordinated/integrated with nuclear research and development programs. A design-bid-build project delivery method managed by the Idaho National Laboratory management and operating contractor was used for the design and construction of the SPL. The SPL construction subcontract is a firm, fixed-price contract.

Idaho Sitewide Safeguards and Security

Overview

The Idaho Sitewide Safeguards and Security (S&S) program supports the Idaho National Laboratory (INL) complex nuclear facility infrastructure and enables the Office of Nuclear Energy (NE) to conduct research and development (R&D) in support of multiple program missions. The S&S program benefits the site infrastructure and users by providing the safeguards and security functions required at Department of Energy (DOE) sites to enable R&D utilizing nuclear materials and protected information. In addition to NE R&D activities, S&S enables a range of national security programs that support the National Nuclear Security Administration and other Federal agencies including the Department of Homeland Security in the areas of critical infrastructure protection, nuclear nonproliferation, and incident response.

The FY 2023 Budget Request provides direct funding for the INL S&S base program. Strategic Partnership Projects (SPP) will continue to fund an allocable share of the S&S program via full cost recovery. Extraordinary security requirements, such as dedicated security for special projects or exercises, will be a direct charge to DOE and SPP customers.

Highlights of the FY 2023 Budget Request

In FY 2023, the S&S program will sustain program functionality at the level necessary to assure high confidence in the protection of INL assets and a high degree of customer service by maintaining effective staffing levels, proactive preventive and corrective maintenance programs, and a robust cybersecurity program. The FY 2023 Budget Request will focus on continued implementation of physical security infrastructure investments, capital improvements, emerging security technology investments, and enhanced cybersecurity program capabilities to adequately secure site wide assets, including:

- Completing critical physical security infrastructure investments and maintaining protective force staff levels required to maintain an effective S&S program consistent with evolving Departmental requirements, including related analyses and modifications to enhance physical security infrastructure across several INL complexes;
- Supporting physical security systems life-cycle replacement including preventive and corrective maintenance on critical security systems, subsystems, and components;
- Supporting implementation of the Design Basis Threat, Departmental Orders, and force-on-force exercises and equipment required to analyze and validate changes to security models that provide data for risk-informed decision making, and directly test the efficacy of the protection methodology and security posture; and
- Maintaining an effective cybersecurity program through the addition of lifecycle hardware/software upgrades and replacements including continuous monitoring, maintaining Industrial Control Systems, essential cybersecurity positions, and associated training.

Idaho Sitewide Safeguards and Security
Funding ($K)

	FY 2021 Enacted	FY 2022 Annualized CR	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
Idaho Sitewide Safeguards and Security					
Protective Forces	71,705	85,356	88,497	+16,792	+23.4%
Security Systems	10,075	11,575	12,203	+2,128	+21.1%
Security Infrastructure	16,618	5,618	4,100	-12,518	-75.3%
Information Security	4,674	6,174	5,016	+342	+7.3%
Personnel Security	9,554	4,714	5,593	-3,961	-41.5%
Material Control & Accountability	5,505	6,376	5,825	+320	+5.8%
Program Management	11,193	10,175	11,450	+257	+2.3%
Cybersecurity	20,476	19,812	23,916	+3,440	+16.8%
Total, Idaho Sitewide Safeguards and Security	**149,800**	**149,800**	**156,600**	**+6,800**	**+4.5%**

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

	FY 2023 Request vs FY 2021 Enacted
Protective Forces: The increase from $71,705,000 to $88,497,000 includes costs to maintain the protective force personnel staffing levels consistent with Departmental requirements and existing labor wage agreements. Funding also supports protective force equipment, training, facilities, and management consistent with Departmental requirements and the site-wide protection strategy.	**+16,792**
Security Systems: The increase from $10,075,000 to $12,203,000 reflects funds for end-of-life equipment replacement to enable intrusion detection and assessment system effectiveness and ensure protection of assets.	**+2,128**
Security Infrastructure: The decrease from $16,618,000 to $4,100,00 reflects completion of Phase IIB activities and Congressional direction for the training facility at the Central Facilities Area. This funding level includes $4,100,000 to address Design Basis Threat implementation and operational modernization at INL complexes.	**-12,518**
Information Security: No significant change.	**+342**
Personnel Security: The decrease from $9,554,000 to $5,593,000 reflects implementation of full cost recovery for security clearance activities.	**-3,961**
Material Control & Accountability: No significant change.	**+320**
Program Management: No significant change.	**+257**
Cybersecurity: The increase from $20,476,000 to $23,916,000 funds computer network tools and associated staff to protect laboratory systems against dynamic cyber security threats and activities to implement Executive Order 14028, *Improving the Nation's Cybersecurity.*	**+3,440**
Total, Idaho Sitewide Safeguards and Security	**+6,800**

Idaho Sitewide Safeguards and Security

Description

The Idaho Sitewide Safeguards and Security (S&S) program funds Office of Nuclear Energy (NE) base physical and cybersecurity activities for the Idaho National Laboratory (INL), providing protection of the Department of Energy's (DOE) nuclear materials, classified and unclassified matter, government property, personnel, and other vital assets from theft, diversion, sabotage, espionage, unauthorized access, compromise, and other hostile acts that may cause adverse impacts on our national security; program continuity; or the health and safety of employees, the public, or the environment.

Protective Forces

Protective Forces provides security police officers and other specialized personnel, equipment, training, and management needed during normal and security emergency conditions for the adequate protection of site assets consistent with site security plans. Protective force personnel are deployed 24 hours a day, 7 days a week, across 890 square miles to deter, detect, delay, and respond to adversarial threats.

Security Systems

Physical Security Systems provides preventive and corrective maintenance and performance testing of intrusion detection and assessment systems, entry and search control equipment, barriers, secure storage, lighting, sensors, entry/access control devices, locks, explosives detection, and tamper-safe monitoring. Ensures operation of approximately 4,600 security alarms and 6,100 security locks at multiple security areas, 24 hours a day, 7 days a week.

Security Infrastructure

Security Infrastructure provides critical security infrastructure investments and protection enhancements necessary to ensure adequate protection of assets consistent with Departmental requirements. These include, but are not limited to, upgrades, refurbishments, or replacement of security facilities.

Information Security

Information Security provides for the protection and control of classified and sensitive matter that is generated, received, transmitted, used, stored, reproduced, and/or destroyed. Information Security subprogram includes the Technical Security Countermeasures program.

Personnel Security

Personnel Security provides access to classified and sensitive information and assignment of personnel in sensitive positions through the clearance program, adjudication, security awareness and education, U.S. citizen and foreign visitor control, Human Reliability Program, psychological/medical assessments, and administrative review costs.

Material Control and Accountability

Material Control & Accountability (MC&A) provides the personnel, equipment, and services required to account for and control special nuclear materials (SNM) from diversion.

Program Management

Program Management includes policy oversight, development, and update of site security plans; vulnerability assessments, and performance testing to ensure adequate protection of SNM; investigations into incidents of security concern; and issuance of security infractions. Program management also ensures activities are conducted to analyze and identify the impacts of changes to Departmental policies and requirements on the site-wide safeguards and security program.

Cybersecurity

Cybersecurity maintains the staffing, computing infrastructure, and network security configuration necessary to support classified and unclassified information and electronic operations. Cybersecurity uses a graduated risk approach based on data sensitivity and impact of loss/compromise to ensure that electronic or computer information systems are protected in a manner consistent with upholding key priorities, including importance to national security, support of DOE missions and programs, vulnerability to threats, and the magnitude of harm that would result from an information system and industrial control systems compromise.

Idaho Sitewide Safeguards and Security

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Protective Forces $71,705,000	**$88,497,000**	**+$16,792,000**
• Maintained protective force staff levels, including planned hires for Phase IIB Implementation Plan protective force staffing requirements. • Purchased Protective Force equipment, including ammunition, weapons, protective gear, and vehicles.	• Maintains protective force staffing levels, consistent with the Site Security Plan and approved site labor wage agreements. • Purchases Protective Force equipment such as ammunition, weapons, protective gear, and vehicles.	• Increase reflects funds to support protective force staffing levels consistent with Departmental security requirements and approved security strategy.
Security Systems $10,075,000	**$12,203,000**	**+$2,128,000**
• Planned and conducted preventive and corrective maintenance on physical security systems across multiple Idaho National Laboratory (INL) security areas. • Operated and maintained the INL central alarm stations, including life-cycle replacement of security alarm systems.	• Maintains preventive and corrective maintenance programs for physical security systems across INL multiple security areas. • Operates and maintains INL central alarm stations, including life-cycle replacement of security alarm systems.	• Increase reflects funds for end-of-life equipment replacement to enable intrusion detection and assessment system effectiveness and ensure protection of assets.
Security Infrastructure $16,618,000	**$4,100,000**	**-$12,518,000**
• Continued Implementation Plan Phase IIB activities, including the performance of design work, construction, and related analyses required by Departmental Orders.	• Supports pre-conceptual planning activities for Design Basis Threat requirements and modernization of personnel and vehicle inspection facilities at INL complexes.	• The decrease reflects completion of Phase IIB activities and congressional direction for the Central Facilities Area training facility , off-set by funding to address Design Basis Threat requirements and operational modernization at INL complexes.
Information Security $4,674,000	**$5,016,000**	**+$342,000**
• Operated information security activities to protect classified and sensitive unclassified matter including Classified Matter Protection and Control, Technical Surveillance Countermeasures, Classification/Declassification, and Operations Security programs.	• Conducts information security activities to protect classified and sensitive unclassified matter including Classified Matter Protection and Control, Technical Surveillance Countermeasures, Classification/Declassification, and Operations Security programs.	• No significant change.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Personnel Security $9,554,000	**$5,593,000**	**-$3,961,000**
• Conducted federal contractor personnel security programs to process clearances; operated Idaho National Laboratory (INL) badging office; processed foreign visits and assignments; and managed human reliability program activities.	• Conducts federal and contractor personnel security programs to process clearances; operating INL badging office; coordinating foreign visits and assignments; and managing human reliability program activities.	• Decrease reflects implementation of full cost recovery for security clearance activities by requesting program organizations.
Material Control & Accountability (MC&A) $5,505,000	**$5,825,000**	**+$320,000**
• Maintained INL's nuclear material database and tracking systems, coordinated on-and off-site material movements, and conducted accountable special nuclear material inventories.	• Maintains INL's special nuclear material database and tracking systems, manages on-and off-site material movements, and conducts accountable special nuclear material inventories. • Procures and installs equipment to ensure accountability of special nuclear materials.	• No significant change.
Program Management $11,193,000	**$11,450,000**	**+$257,000**
• Updated INL security plans to meet Design Basis Threat and Departmental security requirement changes. • Assessed impacts due to COVID-19 and provided revised security plans to ensure continued operation of the INL.	• Conducts force-on-force exercises to verify the INL security posture. • Develops and maintains site security documentation, including vulnerability and risk assessments, to ensure alignment to Departmental requirements.	• No significant change.
Cybersecurity $20,476,000	**$23,916,000**	**+$3,440,000**
• Provided 24/7 intrusion detection and prevention monitoring to ensure incidents and breaches are discovered and remediated. • Implemented cybersecurity vulnerability management tools to monitor INL network systems. • Completed life-cycle replacement of network boundary protection firewalls.	• Provide 24/7 intrusion detection and prevention monitoring to ensure incidents and breaches are discovered and remediated. • Implement Executive Order (EO) 14028 requirements in privileged access management in support of moving towards Zero Trust principles. • Upgrade Industrial Control System (ICS) firewalls and internet routers for INL systems consistent with current threat environment.	• The increase funds computer network tools and associated staff to protect laboratory systems against dynamic cyber security threats and activities to implement Executive Order 14028, *Improving the Nation's Cybersecurity Activities.*

Idaho Sitewide Safeguards and Security
Capital Summary ($K)

	Total	Prior Years	FY 2021 Enacted	FY 2021 Actuals	FY 2022 Request	FY 2023 Request	FY 2023 Request vs FY 2021 Request ($)	FY 2023 Request vs FY 2021 Request (%)
Capital Operating Expenses Summary (including Major Items of Equipment)								
Minor Construction	n/a	26,377	16,618	16,618	5,618	0	-16,618	-75.3%
Total, Capital Operating Expenses	**n/a**	**26,377**	**16,618**	**16,618**	**5,618**	**0**	**-16,618**	**-75.3%**
Minor Construction Projects								
Internet Pipeline Monitoring Infrastructure	1,800	0	1,800	1,800	0	0	-1,8000	-100%
Materials and Fuels Complex Protective Forces Building	15,600	15,600	0	0	0	0	0	0%
Security Infrastructure Phase IIB	13,913	5,477	2,818	2,818	5,618	0	-2,818	-100%
Consolidated training facility at the Central Facilities Area	12,000	0	12,000	12,000	0	0	-12,000	-100%
Total, Minor Construction Projects	**70,613**	**26,377**	**16,618**	**16,618**	**5,618**	**0**	**-16,618**	**-75.3%**
Total, Capital Summary	**n/a**	**26,377**	**16,618**	**16,618**	**5,618**	**0**	**-16,618**	**-75.3%**

International Nuclear Energy Cooperation

Overview

The International Nuclear Energy Cooperation (INEC) program leads the Department's international engagement for civil nuclear energy, including analysis, development, coordination, and implementation of U.S. civil nuclear energy policy integrated with the Office of Nuclear Energy's (NE) international nuclear technical activities. INEC's strategic partnerships contribute to bilateral and multilateral civil nuclear research and development (R&D) with countries that have advanced nuclear programs, while providing the expertise to better inform emerging countries on safety and security issues that should be considered before developing a civilian nuclear program. INEC also contributes financial support and technical expertise to international organizations, including the Nuclear Energy Agency (NEA), International Framework for Nuclear Energy Cooperation (IFNEC), the Clean Energy Ministerial (CEM) and the International Atomic Energy Agency (IAEA) and its International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO). INEC employs a suite of tools, including workshops and other expert-based exchanges to engage industry, stakeholders, and foreign governments on issues such as nuclear energy as an integral part of a climate change strategy, infrastructure development, financing for nuclear builds, nuclear safety and multinational cooperation on the back end of the nuclear fuel cycle, including disposal.

INEC's mission has expanded its focus to develop strategic partnerships which overlay commercial opportunities for the U.S. nuclear industry. INEC actively works with industry and international partners to consider how advanced U.S. reactor designs, including traditional large reactor designs and small modular reactors, might be incorporated into established and growing energy grids. INEC's efforts contribute to increased nuclear exports which support U.S. leadership in the global nuclear market and expand U.S. job creation.

In conclusion, INEC enables the Department to effectively engage with international partners on civil nuclear policy, research, development, and demonstration (RD&D) and advancing U.S. technology exports. In close coordination with the Office of International Affairs, INEC's bilateral and multilateral engagement addresses broader U.S. strategic interests that support U.S. nuclear industry in the safe and secure deployment of nuclear energy worldwide while remaining sensitive to nonproliferation policy. INEC executes its international mission in coordination with the National Nuclear Security Administration; the National Security Council; the Department of State; the Department of Commerce; and the Nuclear Regulatory Commission to better support U.S. nuclear energy RD&D, civil nuclear policy, and U.S. commercial interests internationally.

Highlights of the FY 2023 Budget Request

In FY 2023 the INEC budget will be transferred from the NE Program Direction Budget Request to a program level activity within the overall NE Congressional Budget Request. This change will enable NE to better focus financial and personnel resources toward international priorities while providing improved transparency to Congress.

International Nuclear Energy Cooperation
Funding ($K)

	FY 2021 Enacted	FY 2022 Full Year CR	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted
International Nuclear Energy Cooperation				
International Nuclear Energy Cooperation	0	0	$3,000	+$3,000
Total, International Nuclear Energy Cooperation	**0**	**0**	**$3,000**	**+$3,000**

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

	FY 2023 Request vs FY 2021 Enacted
International Nuclear Energy Cooperation:	
• The increase from $0 to $3,000,000 reflects INEC's transfer from NE Program Direction to a program level activity within the FY 2023 NE Congressional Budget Request.	**+3,000**
Total, International Nuclear Energy Cooperation	**+3,000**

International Nuclear Energy Cooperation

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs. FY 2022 Full Year CR
International Nuclear Energy Cooperation $0	**$3,000,000**	**+$3,000,000**
• In FY 2021, INEC was funded within the NE Program Direction budget.	• Organize and host an INPRO Dialogue Forum on nuclear workforce development and deployment. • Host a course on planning methodologies for a civil nuclear program. • Organize a nuclear energy management school. • Expand collaboration with small and emerging nuclear states through internships, educational exchanges, professional technical exchanges and training, and feasibility studies. • Continue bilateral coordination of technical cooperation with France, India, and the United Kingdom through mechanisms such as R&D Agreements, implementing arrangements and Action Plans. • Initiate bilateral coordination of technical cooperation with small and emerging nuclear states in Africa, the Baltic states and Eastern Europe. • Coordinate Fukushima Forensics activities that support improved operation and safety of U.S. domestic nuclear power plants. • Coordinate with U.S. interagency to support increased U.S. civil nuclear exports. • Manage International Nuclear Research Initiatives (INERI) collaborative partnerships on RD&D projects with the EURATOM and Republic of Korea focusing on advanced nuclear technologies to improve cost, safety, and proliferation-resistance.	• The new activities for FY23 reflect INEC's transfer from NE Program Direction to a program level activity within the FY 2023 NE Congressional Budget Request.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs. FY 2022 Full Year CR
	• Leverage U.S. strategic policy goals in multilateral organizations by providing staff to support the mission of these agencies. • Leverage role of Chair of IFNEC to better promote the use of nuclear energy for peaceful purposes while ensuring the highest standards for safety, security, and nonproliferation. • Continue to support infrastructure development and safety culture in Armenia and Ukraine.	

Program Direction

Overview

Program Direction provides the federal staffing resources and associated costs required to support the overall direction and execution of the Office of Nuclear Energy (NE) programs. NE has staff strategically located in multiple locations: Washington, D.C. Headquarters, Nevada Field Office, and the Idaho Operations Office. Activities within the site offices support inherently federal functions that facilitate the efficient execution of Department of Energy (DOE) programs or directly execute DOE mandated safety, security, business functions, and public outreach. In addition to NE federal personnel, Program Direction supports select federal staff and support for the Office of Human Capital Service Center.

The Support Services subprogram allows the Department to cost-effectively hire the best available industry experts to support federal staff in managing the nuclear programs and complex activities. The ability to acquire expertise quickly and on an “as needed basis” provides flexibility in team composition as the needs of NE evolve. Program Direction also includes the Other Related Expenses subprogram, which provides NE’s directed funding contribution to the Department’s Working Capital Fund (WCF). The WCF supports specific Departmental services and activities that are shared across DOE including: employee health and testing services, and consolidated training and recruitment initiatives; all established in previous fiscal years and supported in FY 2023.

In addition to appropriated funds, NE also manages approximately $200 million annually from other activities including: Strategic Partnerships Program and reimbursable funding from the National Aeronautics and Space Administration (NASA) and the Department of Defense (DOD).

Over the last four years, NE’s program direction funding has remained level and overall federal staffing levels have declined by more than a quarter. Over the same period, the size of NE’s programs have doubled. NE is now at a critical moment where it must replace retiring staff, increase staffing in areas of priority, and support career enhancing opportunities that allow us to attract and retain new staff. As such the FY 2023 request reflects the first funding increase for program direction in 9 years to support a multiyear effort, started in FY 2021, to restore staffing levels to the 2016 level.

The FY 2023 Program Direction Budget Request reflects NE’s continued effort to optimize support for its federal programs through continued efficiency and cost-effectiveness; and to ensure a measured and effective oversight of NE mission activities. Federal staff supported by the Program Direction account are responsible for ensuring the appropriate planning, oversight, and execution of all activities within NE. The Program Direction Budget Request also implements Executive Order 14035, *Diversity, Equity, Inclusion, and Accessibility in the Federal Workforce (DEIA)*, through hiring and training new and existing staff.

Highlights of the FY 2023 Budget Request

The FY 2023 Program Direction Budget Request includes a transfer of the International Nuclear Energy Cooperation (INEC) program within the NE Program Direction Budget Request to a program level activity within the overall NE Congressional Budget Request.

The Request also includes funding to support an additional 83 federal staffing positions onboarding between FY 2021 and FY 2023. These positions will be allocated across NE’s site office locations as appropriate. This increase will allow NE to rebuild its workforce to levels consistent with our FY 2017 profile, which is necessary to execute the robust Research and Development, and Infrastructure activities that NE is responsible for overseeing.

Program Direction
Funding ($K)

	FY 2021 Enacted	FY 2022 Annualized CR	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted
Program Direction				
Salaries and Benefits	45,637	50,637	57,926	12,289
Travel	198	330	1,200	1,002
Support Services	11,029	8,529	12,431	1,402
Other Related Expenses	13,517	11,017	13,900	383
International Nuclear Energy Cooperation	4,750	4,618	0	-4,750
Total, Program Direction	**75,131**	**75,131**	**85,457**	**10,326**

Program Direction
Explanation of Major Changes ($K)

	FY 2023 Request vs FY 2021 Enacted
Salaries and Benefits:	
The increase from $45,637 to $57,926 reflects the funds necessary to support 27 new FTE positions that occurred in FY 2022 as well as an additional 56 new positions planned across the Headquarters and Idaho Operations Offices in FY 2023.	**12,289**
Travel:	
The increase from $198 to $1,200 reflects a return to normal travel spending levels post COVID-19 restrictions.	**1,002**
Support Services:	
The increase from $11,029 to $12,431 reflects additional funding allocated for contractual support as needed to aid and support the increased federal workforce responsible for executing NE's requirements.	**1,402**
Other Related Expenses:	
The increase from $13,517 to $13,900 reflects funding to support other expenses related to the increase of NE's workforce that occurred in FY 2022 and planned hires in FY 2023.	**383**
International Nuclear Energy Cooperation	
The decrease from $4,750 to $0 reflects the International Nuclear Energy Cooperation's transfer from Nuclear Energy (NE) Program Direction to a program level activity within the FY 2023 NE Congressional Budget Request.	**-4,750**
Total, Program Direction	**10,326**

Program Direction
Funding ($K)

	FY 2021 Enacted	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted
Program Direction Summary			
Washington Headquarters			
Salaries and Benefits	22,081	28,374	6,293
Travel	108	1,000	892
Support Services	6,944	8,346	1,402
Other Related Expenses	7,687	8,070	383
International Nuclear Energy Cooperation	4,750	0	-4,750
Total, Washington Headquarters	**41,570**	**45,790**	**4,220**
Nevada Field Office			
Salaries and Benefits	1,622	1,782	160
Travel	0	0	0
Support Services	0	0	0
Other Related Expenses	115	115	0
Total, Nevada Field Office	**1,737**	**1,897**	**160**
Idaho Operations Office			
Salaries and Benefits	21,934	27,770	5,836
Travel	90	200	110
Support Services	4,085	4,085	0
Other Related Expenses	5,715	5,715	0
Total, Idaho Operations Office	**31,824**	**37,770**	**5,946**
Total Program Direction			
Salaries and Benefits	45,637	57,926	12,289
Travel	198	1,200	1,002
Support Services	11,029	12,431	1,402
Other Related Expenses	13,517	13,900	383
International Nuclear Energy Cooperation	4,750	0	-4,750
Total, Program Direction	**75,131**	**85,457**	**10,326**
Federal FTEs	**256**	**283**	**356**

	FY 2021 Enacted	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted
Support Services			
Technical Support			
Mission Related	661	746	85
Advisory and Assistance	1,544	1,740	196
Total, Technical Support	2,205	2,486	281
Management Support			
Administrative	2,647	2,984	337
IT	6,177	6,961	784
Total Management Support	8,824	9,945	1,121
Total, Support Services	**11,029**	**12,431**	**1,402**
Other Related Expenses			
Working Capital Fund	5,214	6,296	1,082
Training	115	150	35
Miscellaneous	6,151	5,417	-734
Rents and Utilities	2,037	2,037	0
Total, Other Related Expenses	**13,517**	**13,900**	**383**

Program Direction
Funding

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Program Direction $75,131,000	**$85,457,000**	**$10,326,000**
Salaries and Benefits $45,636,749	**$57,926,000**	**$12,289,251**
• Provides salaries and benefits for 256 FTEs.	• Provides salaries and benefits for 339 FTEs.	• The increase reflects 27 FTEs during FY 2022 as well as an additional 83 FTEs to be onboarded in FY 2023.
Travel $198,021	**$1,200,000**	**$1,001,979**
• Provides for travel of the federal staff including any necessary permanent change of duty status costs.	• Provides for travel of the federal staff including any necessary permanent change of duty status costs.	• The increase reflects a normalization of federal travel activities post COVID-19 restrictions.
Support Services $11,029,481	**$12,431,019**	**$1,401,538**
• Provides for technical and administrative support services for the Nuclear Energy (NE) federal staff.	• Provides for technical and administrative support services for the NE federal staff.	• The increase reflects additional funding allocated for contractual support as needed to aid and support the increased federal workforce responsible for executing NE's requirements.
Other Related Expenses $13,516,749	**$13,899,981**	**$383,232**
• Provides for NE's share of goods and services procured through the Department's Working Capital Fund (WCF); rents and utilities associated with the Idaho Operations Office; federal training expenses; and other miscellaneous expenses.	• Provides for NE's share of goods and services procured through the Department's WCF; rents and utilities associated with the Idaho Operations Office; federal training expenses; and other miscellaneous expenses.	• The increase reflects funding to support other expenses related to the increase of NE's workforce that occurred in FY 2021 and planned hires in FY 2022.
International Nuclear Energy Cooperation (INEC) $4,750,000	**$0**	**-$4,750,000**
• Plan and organize 2022 IAEA Nuclear Power Ministerial, including venue reservation, primary contractor selection and coordination between primary contractor, venue and IAEA, NEA co-sponsors. • Support the Secretary of Energy and NE leadership in all international nuclear events, including participation in bilateral meetings and	• This activity will be reestablished as its own program within the FY 2023 Congressional Budget Request.	• The decrease reflects INEC's transfer from Nuclear Energy (NE) Program Direction to a program level activity within the FY 2023 NE Congressional Budget Request.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
multilateral events such as the IAEA General Conference and Clean Energy Ministerial. • Expand collaboration with small and emerging nuclear states through internships, educational exchanges, professional technical exchanges and training, and feasibility studies. • Continue bilateral coordination of technical cooperation with France, India, and the United Kingdom through mechanisms such as R&D Agreements, implementing arrangements and Action Plans. • Coordinate Fukushima Forensics activities that support improved operation and safety of U.S. domestic nuclear power plants. • Coordinate with U.S. interagency to support increased U.S. civil nuclear exports. • Manage International Nuclear Research Initiatives (INERI) collaborative partnerships on RD&D projects with the EURATOM and Republic of Korea focusing on advanced nuclear technologies to improve cost, safety and proliferation-resistance. • Leverage U.S. strategic policy goals in multilateral organizations by providing staff to support the mission of these agencies. • Leverage role of Chair of IFNEC to better promote the use of nuclear energy for peaceful purposes while ensuring the highest standards for safety, security and nonproliferation. • Continue to support infrastructure development and safety culture in Armenia and Ukraine.		

Nuclear Energy
Research and Development ($K)

	FY 2021 Enacted	FY 2022 Annualized CR	FY 2023 Request
Basic	0	0	0
Applied	770,756	770,756	1,096,648
Development	258,926	258,926	338,365
Subtotal, R&D	**1,029,682**	**1,029,682**	**1,435,013**
Equipment	0	0	0
Construction	37,000	37,000	7,300
Total, R&D	**1,066,682**	**1,066,682**	**1,442,313**

DEPARTMENT OF ENERGY
Funding by Site Detail
Nuclear Energy FY 2023
(Dollars in Thousands)

	FY 2021 Enacted Requested Total	FY 2022 Annualized CR Requested Total	FY 2023 Request Detail Requested Total
Ames Laboratory			
Crosscutting Technology Development	462	462	500
Nuclear Energy Enabling Technologies	462	462	500
Total Ames Laboratory	**462**	**462**	**500**
Argonne National Laboratory			
LWR Sustainability	0	0	250
Advanced Reactor Technologies	6,385	6,385	7,500
Reactor Concepts RD&D	6,385	6,385	7,750
Materials Recovery and Waste Form Development	1,060	1,060	1,625
Accident Tolerant Fuels	120	120	131
Triso Fuel and Graphite Qualification	0	450	330
Fuel Cycle Laboratory R&D	2,440	2,440	5,685
Used Nuclear Fuel Disposition R&D	1,500	1,500	1,500
Integrated Waste Management System	200	200	1,900
Fuel Cycle Research & Development	5,320	5,770	11,171
Crosscutting Technology Development	825	825	1,000
Joint Modeling and Simulation Program	5,675	5,675	4,800
Nuclear Science User Facilities	200	200	300
Transformational Challenge Reactor	1,100	1,100	0
Nuclear Energy Enabling Technologies	7,800	7,800	6,100
Regulatory Development	4,760	4,760	3,700
Advanced Reactors Safeguards	700	700	250
Advanced Reactors Demonstration Program	5,460	5,460	3,950
International Nuclear Energy Cooperation	0	0	250
Program Direction - Nuclear Energy	8	8	0
Total Argonne National Laboratory	**24,973**	**25,423**	**29,221**
Argonne Site Office			
National Reactor Innovation Center	391	391	4,000
Advanced Reactors Demonstration Program	391	391	4,000
Total Argonne Site Office	**391**	**391**	**4,000**
Brookhaven National Laboratory			
Accident Tolerant Fuels	656	656	715
Fuel Cycle Laboratory R&D	300	300	699
Fuel Cycle Research & Development	956	956	1,414
Crosscutting Technology Development	17	17	20
Nuclear Energy Enabling Technologies	17	17	20
Advanced Reactors Safeguards	445	445	350
Advanced Reactors Demonstration Program	445	445	350
Total Brookhaven National Laboratory	**1,418**	**1,418**	**1,784**
Chicago Operations Office			
Joint Modeling and Simulation Program	234	234	0
Nuclear Science User Facilities	2	2	2
Nuclear Energy Enabling Technologies	236	236	2
Program Direction - Nuclear Energy	2	2	0
Total Chicago Operations Office	**238**	**238**	**2**
Idaho National Laboratory			
University Led Research & Development	0	0	3,500
University Fuel Services (RRI)	0	0	17,430

DEPARTMENT OF ENERGY
Funding by Site Detail
Nuclear Energy FY 2023
(Dollars in Thousands)

	FY 2021 Enacted Requested Total	FY 2022 Annualized CR Requested Total	FY 2023 Request Detail Requested Total
Advanced SMR R&D	1,388	1,388	1,200
LWR Sustainability	17,683	17,683	15,470
Advanced Reactor Technologies	10,665	10,665	16,000
Reactor Concepts RD&D	29,736	29,736	32,670
Mining, Conversion, and Transportation	450	0	0
Materials Recovery and Waste Form Development	17,988	17,988	27,400
Accident Tolerant Fuels	22,103	22,103	24,070
Triso Fuel and Graphite Qualification	18,950	29,000	21,100
Fuel Cycle Laboratory R&D	8,000	8,000	18,640
HALEU Availability	0	0	7,281
Used Nuclear Fuel Disposition R&D	1,075	1,075	1,075
Integrated Waste Management System	1,000	1,000	3,000
Fuel Cycle Research & Development	69,566	79,166	102,566
Crosscutting Technology Development	11,896	11,896	18,203
Joint Modeling and Simulation Program	11,823	11,823	8,300
Nuclear Science User Facilities	25,445	25,445	33,408
Transformational Challenge Reactor	1,853	1,853	0
Nuclear Energy Enabling Technologies	51,017	51,017	59,911
National Reactor Innovation Center	28,279	28,279	68,780
Demonstration 1 (X-Energy)	77,288	77,288	0
Demonstration 2 (Natrium)	77,135	77,135	0
Risk Reduction for Future Demonstration	0	0	20,000
Regulatory Development	3,176	3,176	2,200
Advanced Reactors Safeguards	264	264	400
Advanced Reactors Demonstration Program	186,142	186,142	91,380
Other Project Costs	42,435	42,435	44,435
21-E-200, Versatile Test Reactor	2,000	2,000	0
Versatile Advanced Test Reactor R&D	44,435	44,435	44,435
INL Facilities Operations and Maintenance	273,712	275,325	322,855
16-E-200 Sample Preparation Laboratory	26,000	26,000	7,300
Research Reactor Infrastructure	11,430	11,430	0
Infrastructure	311,142	312,755	330,155
Idaho Sitewide Safeguards & Security (050)	145,850	148,175	155,075
Program Direction - Nuclear Energy	3,916	3,916	4,500
Total Idaho National Laboratory	**841,804**	**855,342**	**841,622**
Idaho Operations Office			
University Led Research & Development	0	0	500
University Scholarships and Fellowships	0	0	5,991
University Fuel Services (RRI)	0	0	50
Integrated University Program	5,000	4,991	0
Advanced SMR R&D	111,455	111,455	37,600
LWR Sustainability	12,306	12,306	9,965
Advanced Reactor Technologies	6,738	6,738	400
Reactor Concepts RD&D	130,499	130,499	47,965
Materials Recovery and Waste Form Development	3,358	3,358	5,140
Accident Tolerant Fuels	56,265	56,265	61,323
Triso Fuel and Graphite Qualification	7,912	2,550	1,900
Fuel Cycle Laboratory R&D	1,700	1,700	3,961
HALEU Availability	0	0	44,810
Used Nuclear Fuel Disposition R&D	13,500	13,500	3,000
Integrated Waste Management System	2,000	2,000	12,000
Fuel Cycle Research & Development	84,735	79,373	132,134
Crosscutting Technology Development	3,656	3,656	3,000
Joint Modeling and Simulation Program	5,542	5,542	4,300

DEPARTMENT OF ENERGY

Funding by Site Detail

Nuclear Energy FY 2023

(Dollars in Thousands)

	FY 2021 Enacted Requested Total	FY 2022 Annualized CR Requested Total	FY 2023 Request Detail Requested Total
Nuclear Science User Facilities	760	760	800
Transformational Challenge Reactor	3,069	3,069	0
Nuclear Energy Enabling Technologies	13,027	13,027	8,100
National Reactor Innovation Center	220	220	220
Risk Reduction for Future Demonstration	0	0	70,000
Regulatory Development	2,826	2,826	200
Advanced Reactors Safeguards	978	978	0
Advanced Reactors Demonstration Program	4,024	4,024	70,420
Other Project Costs	500	500	500
Versatile Advanced Test Reactor R&D	500	500	500
INL Facilities Operations and Maintenance	5,476	3,678	3,134
Research Reactor Infrastructure	50	50	0
Infrastructure	5,526	3,728	3,134
Idaho Sitewide Safeguards & Security (050)	3,900	1,400	1,400
International Nuclear Energy Cooperation	0	0	750
Program Direction - Nuclear Energy	27,909	27,909	33,270
Total Idaho Operations Office	**275,120**	**265,451**	**304,214**
Lawrence Berkeley National Laboratory			
Materials Recovery and Waste Form Development	33	33	51
Used Nuclear Fuel Disposition R&D	3,500	3,500	3,500
Fuel Cycle Research & Development	3,533	3,533	3,551
Crosscutting Technology Development	74	74	75
Joint Modeling and Simulation Program	200	200	150
Nuclear Energy Enabling Technologies	274	274	225
Total Lawrence Berkeley National Laboratory	**3,807**	**3,807**	**3,776**
Lawrence Livermore National Laboratory			
LWR Sustainability	307	307	0
Reactor Concepts RD&D	307	307	0
Accident Tolerant Fuels	345	345	376
Used Nuclear Fuel Disposition R&D	550	550	550
Fuel Cycle Research & Development	895	895	926
Crosscutting Technology Development	208	208	200
Nuclear Energy Enabling Technologies	208	208	200
Total Lawrence Livermore National Laboratory	**1,410**	**1,410**	**1,126**
Livermore Site Office			
Advanced Reactor Technologies	50	50	25
Reactor Concepts RD&D	50	50	25
Total Livermore Site Office	**50**	**50**	**25**
Los Alamos National Laboratory			
Advanced Reactor Technologies	2,452	2,452	3,500
Reactor Concepts RD&D	2,452	2,452	3,500
Accident Tolerant Fuels	4,230	4,230	4,606
Fuel Cycle Laboratory R&D	2,000	2,000	4,660
HALEU Availability	0	0	5,745
Used Nuclear Fuel Disposition R&D	3,400	3,400	3,400
Fuel Cycle Research & Development	9,630	9,630	18,411
Crosscutting Technology Development	352	352	400
Joint Modeling and Simulation Program	2,128	2,128	3,000
Nuclear Science User Facilities	252	252	300
Nuclear Energy Enabling Technologies	2,732	2,732	3,700

DEPARTMENT OF ENERGY
Funding by Site Detail
Nuclear Energy FY 2023
(Dollars in Thousands)

	FY 2021 Enacted Requested Total	FY 2022 Annualized CR Requested Total	FY 2023 Request Detail Requested Total
Risk Reduction for Future Demonstration	0	0	200
Advanced Reactors Safeguards	500	500	400
Advanced Reactors Demonstration Program	500	500	600
Total Los Alamos National Laboratory	**15,314**	**15,314**	**26,211**
Los Alamos Site Office			
Transformational Challenge Reactor	269	269	0
Nuclear Energy Enabling Technologies	269	269	0
Total Los Alamos Site Office	**269**	**269**	**0**
National Energy Technology Lab			
LWR Sustainability	117	117	0
Advanced Reactor Technologies	100	100	0
Reactor Concepts RD&D	217	217	0
Crosscutting Technology Development	209	209	210
Nuclear Energy Enabling Technologies	209	209	210
Total National Energy Technology Lab	**426**	**426**	**210**
National Renewable Energy Laboratory			
Crosscutting Technology Development	142	142	142
Nuclear Energy Enabling Technologies	142	142	142
Total National Renewable Energy Laboratory	**142**	**142**	**142**
Nevada Field Office			
Program Direction - Nuclear Energy	1,737	1,737	1,897
Total Nevada Field Office	**1,737**	**1,737**	**1,897**
Oak Ridge Institute for Science & Education			
University Scholarships and Fellowships	0	0	500
Idaho Sitewide Safeguards & Security (050)	0	100	0
Program Direction - Nuclear Energy	45	45	0
Total Oak Ridge Institute for Science & Education	**45**	**145**	**500**
Oak Ridge National Laboratory			
LWR Sustainability	5,101	5,101	4,000
Advanced Reactor Technologies	2,835	2,835	5,500
Reactor Concepts RD&D	7,936	7,936	9,500
Materials Recovery and Waste Form Development	942	942	1,442
Accident Tolerant Fuels	6,707	6,707	7,304
Triso Fuel and Graphite Qualification	1,200	3,000	2,200
Fuel Cycle Laboratory R&D	1,500	1,500	3,495
HALEU Availability	0	0	5,745
Used Nuclear Fuel Disposition R&D	8,250	8,250	5,725
Integrated Waste Management System	4,000	4,000	6,000
Fuel Cycle Research & Development	22,599	24,399	31,911
Crosscutting Technology Development	2,069	2,069	3,000
Joint Modeling and Simulation Program	4,210	4,210	3,900
Transformational Challenge Reactor	18,098	18,098	0
Nuclear Energy Enabling Technologies	24,377	24,377	6,900
National Reactor Innovation Center	157	157	1,000
Risk Reduction for Future Demonstration	0	0	2,000
Regulatory Development	2,400	2,400	3,450
Advanced Reactors Safeguards	475	475	500

DEPARTMENT OF ENERGY
Funding by Site Detail
Nuclear Energy FY 2023
(Dollars in Thousands)

	FY 2021 Enacted Requested Total	FY 2022 Annualized CR Requested Total	FY 2023 Request Detail Requested Total
Advanced Reactors Demonstration Program	3,032	3,032	6,950
ORNL Nuclear Facilities O&M	19,926	19,926	0
Infrastructure	19,926	19,926	0
International Nuclear Energy Cooperation	0	0	250
Program Direction - Nuclear Energy	338	338	0
Total Oak Ridge National Laboratory	**78,208**	**80,008**	**55,511**
Oak Ridge National Laboratory Site Office			
Advanced SMR R&D	395	395	200
Reactor Concepts RD&D	395	395	200
Total Oak Ridge National Laboratory Site Office	**395**	**395**	**200**
Oak Ridge Office			
Civilian Nuclear Enrichment	40,000	0	0
Fuel Cycle Research & Development	40,000	0	0
Total Oak Ridge Office	**40,000**	**0**	**0**
Pacific Northwest National Laboratory			
Advanced Reactor Technologies	780	780	3,075
Reactor Concepts RD&D	780	780	3,075
Mining, Conversion, and Transportation	450	0	0
Materials Recovery and Waste Form Development	581	581	889
Accident Tolerant Fuels	85	85	93
Fuel Cycle Laboratory R&D	1,000	1,000	2,330
HALEU Availability	0	0	5,745
Used Nuclear Fuel Disposition R&D	7,825	7,825	7,825
Integrated Waste Management System	3,500	3,500	16,000
Fuel Cycle Research & Development	13,441	12,991	32,882
Crosscutting Technology Development	494	494	500
Nuclear Science User Facilities	229	229	350
Nuclear Energy Enabling Technologies	723	723	850
National Reactor Innovation Center	230	230	1,000
Regulatory Development	385	385	400
Advanced Reactors Safeguards	260	260	300
Advanced Reactors Demonstration Program	875	875	1,700
International Nuclear Energy Cooperation	0	0	250
Program Direction - Nuclear Energy	275	275	0
Total Pacific Northwest National Laboratory	**16,094**	**15,644**	**38,757**
Sandia National Laboratories			
STEP R&D	4,311	4,311	0
LWR Sustainability	1,625	1,625	3,900
Reactor Concepts RD&D	1,625	1,625	3,900
Accident Tolerant Fuels	136	136	149
Used Nuclear Fuel Disposition R&D	19,600	19,600	17,000
Integrated Waste Management System	4,000	4,000	1,500
Fuel Cycle Research & Development	23,736	23,736	18,649
Crosscutting Technology Development	1,529	1,529	2,000
Joint Modeling and Simulation Program	250	250	250
Nuclear Energy Enabling Technologies	1,779	1,779	2,250
Regulatory Development	300	300	300
Advanced Reactors Safeguards	1,133	1,133	2,050
Advanced Reactors Demonstration Program	1,433	1,433	2,350
Total Sandia National Laboratories	**32,884**	**32,884**	**27,149**

DEPARTMENT OF ENERGY
Funding by Site Detail
Nuclear Energy FY 2023
(Dollars in Thousands)

	FY 2021 Enacted Requested Total	FY 2022 Annualized CR Requested Total	FY 2023 Request Detail Requested Total
Sandia Site Office			
Fuel Cycle Laboratory R&D	800	800	1,864
Fuel Cycle Research & Development	800	800	1,864
Total Sandia Site Office	**800**	**800**	**1,864**
Savannah River Operations Office			
HALEU Availability	0	0	22,400
Used Nuclear Fuel Disposition R&D	300	300	300
Integrated Waste Management System	500	500	800
Fuel Cycle Research & Development	800	800	23,500
Total Savannah River Operations Office	**800**	**800**	**23,500**
SLAC National Accelerator Laboratory			
Crosscutting Technology Development	48	48	0
Nuclear Energy Enabling Technologies	48	48	0
Total SLAC National Accelerator Laboratory	**48**	**48**	**0**
Washington Headquarters			
University Led Research & Development	0	0	133,029
University Scholarships and Fellowships	0	0	9
University Fuel Services (RRI)	0	0	20
Integrated University Program	0	9	0
STEP R&D	689	689	0
Advanced SMR R&D	1,762	1,762	1,000
LWR Sustainability	9,861	9,861	11,415
Advanced Reactor Technologies	15,995	15,995	14,000
Reactor Concepts RD&D	27,618	27,618	26,415
Mining, Conversion, and Transportation	1,100	2,000	1,500
Civilian Nuclear Enrichment	0	40,000	0
Materials Recovery and Waste Form Development	1,038	1,038	1,453
Accident Tolerant Fuels	15,153	15,153	15,133
Triso Fuel and Graphite Qualification	7,938	1,000	1,470
Fuel Cycle Laboratory R&D	2,260	2,260	5,166
HALEU Availability	0	0	3,274
Used Nuclear Fuel Disposition R&D	3,000	3,000	3,000
Integrated Waste Management System	2,800	2,800	11,800
Fuel Cycle Research & Development	33,289	67,251	42,796
Crosscutting Technology Development	6,019	6,019	6,000
Joint Modeling and Simulation Program	4,938	4,938	3,627
Nuclear Science User Facilities	3,112	3,112	4,000
Transformational Challenge Reactor	5,480	5,480	0
Nuclear Energy Enabling Technologies	19,549	19,549	13,627
National Reactor Innovation Center	723	723	0
Demonstration 1 (X-Energy)	2,712	2,712	0
Demonstration 2 (Natrium)	2,865	2,865	0
Risk Reduction for Future Demonstration	40,000	40,000	48,038
Regulatory Development	1,153	1,153	0
Advanced Reactors Safeguards	245	245	500
Advanced Reactors Demonstration Program	47,698	47,698	48,538
Other Project Costs	65	65	65
Versatile Advanced Test Reactor R&D	65	65	65
ORNL Nuclear Facilities O&M	74	74	0
INL Facilities Operations and Maintenance	812	997	935

DEPARTMENT OF ENERGY
Funding by Site Detail
Nuclear Energy FY 2023
(Dollars in Thousands)

	FY 2021 Enacted Requested Total	FY 2022 Annualized CR Requested Total	FY 2023 Request Detail Requested Total
Research Reactor Infrastructure	20	20	0
Infrastructure	906	1,091	935
Idaho Sitewide Safeguards & Security (050)	50	125	125
International Nuclear Energy Cooperation	0	0	1,500
Program Direction - Nuclear Energy	40,901	40,901	45,790
Total Washington Headquarters	**170,765**	**204,996**	**312,849**
Total Funding by Site - Nuclear Energy	**1,507,600**	**1,507,600**	**1,675,060**

Nuclear Waste Disposal

Nuclear Waste Disposal

Nuclear Waste Disposal
Appropriation Language

For Department of Energy expenses necessary for activities to carry out the purposes of the Nuclear Waste Policy Act of 1982, Public Law 97–425, as amended, *$10,205,000,* to remain available until expended, to be derived from the Nuclear Waste Fund.

Note.—A full-year 2022 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2022 (Division A of P.L. 117-43, as amended). The amounts included for 2022 reflect the annualized level provided by the continuing resolution.

Nuclear Waste Fund Oversight

Overview

Under the Nuclear Waste Policy Act of 1982 (NWPA), the Department of Energy (DOE) is responsible for legal services and other support for nuclear waste disposal activities, including managing the Nuclear Waste Fund (NWF), administering the Standard Contract, providing legal services for nuclear waste disposal, and maintaining the security of the Yucca Mountain site.

Highlights of the FY 2023 Budget Request

The Nuclear Waste Fund Oversight program's FY 2023 Budget Request supports activities that include the following:

- Implementation of an appropriate investment strategy and prudent management of the NWF investment portfolio,
- Administration of the Standard Contract for the disposal of spent nuclear fuel (SNF) and high-level radioactive waste (HLW) between nuclear utilities and the government,
- Provision of legal services for activities related to nuclear waste disposal, including but not limited to interim storage,
- Management of the physical security requirements for the Yucca Mountain site under DOE Order 473.3A as well as site maintenance and fulfillment of environmental requirements.
- Execution of the annual agency financial report and audit.

These funds are inclusive of program direction activities and management and technical costs necessary to carry out the mission.

The Interim Storage program's FY 2023 Budget Request is included in the Integrated Waste Management System subprogram within Fuel Cycle Research and Development.

Nuclear Waste Fund Oversight
Funding ($K)

	($K)				
	FY 2021 Enacted	FY 2022 Annualized CR	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted	
				$	%
Nuclear Waste Fund Oversight					
Nuclear Waste Fund Oversight	7,500	7,500	10,205	+2,705	+36%
Interim Storage[1]	20,000	20,000	0	-20,000	-100%
Total	**27,500**	**27,500**	**10,205**	**-17,295**	**-63%**

Future Year Energy Program

($K)					
	' 2023 Request	FY 2024	FY 2025	FY 2026	FY 2027
Nuclear Waste Disposal	10,205	10,000	10,000	11,000	11,000

Outyear funding for the Nuclear Waste Fund Oversight program will continue support for the implementation of an appropriate investment strategy and prudent management of the NWF investment portfolio, the administration of the Standard Contract, the management of physical security requirements for the Yucca Mountain site, legal services for activities related to nuclear waste disposal, the annual agency financial report and audit, and associated federal staff.

[1] The Interim Storage program's FY 2023 Budget Request is included in the Integrated Waste Management System subprogram within Fuel Cycle Research and Development.

Explanation of Major Changes
Funding ($K)

	FY 2023 Request vs FY 2021 Enacted
Nuclear Waste Fund Oversight:	
The decrease from $27,500,000 to $10,205,000 reflects FY 2021 funding for the Interim Storage program's activities appropriated within the Interim Storage and Nuclear Waste Fund Oversight program (Nuclear Waste Disposal account). The Interim Storage program's FY 2023 Budget Request is proposed to instead be included as part of the Office of Nuclear Energy's Integrated Waste Management System subprogram within Fuel Cycle Research and Development.	**-17,295**
Total, Nuclear Waste Fund Oversight	**-17,295**

Nuclear Waste Fund Oversight

Description

The United States (U.S.) utilizes nuclear technology for national defense, research and development, and electric power generation. These activities produce and create quantities of SNF and HLW that require safe storage and eventual disposal. Commercial electricity generation, the largest generator of SNF, accounts for almost 90,000 metric tons of uranium (MTU) of SNF. With the current reactor fleet, commercial generation has the potential to produce an additional 50,000 MTU, for a total of approximately 140,000 MTU. Nearly all existing commercial SNF is stored at the reactor site where it was produced. Of the over 70 commercial power reactor sites storing SNF, approximately a quarter of these sites no longer have an operating reactor. The U.S. inventory of HLW includes HLW produced from commercial activities stored in one state and HLW produced from defense activities stored in three states.

Under the NWPA, the Federal government, specifically DOE, is responsible for the disposal of SNF and HLW. The Nuclear Waste Fund Oversight program is responsible for providing legal and other support for nuclear waste disposal activities associated with carrying out the purposes of the NWPA. The program will ensure the prudent management of the NWF investment portfolio and the administration of the Standard Contract. The program will also support legal services related to nuclear waste disposal activities, including but not limited to the NWF and the Standard Contract. Lastly, the program will continue to support requirements for the management and operation of physical security at the Yucca Mountain site under the Protection Program Operations Directive (DOE Order 473.3A).

Nuclear Waste Fund Oversight

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Interim Storage and Nuclear Waste Fund Oversight $27,500,000	**Nuclear Waste Fund Oversight $10,205,000**	**-$17,295,000**
• Initiated processes to identify potential interim storage sites. • Developed an integrated waste management program plan. • Developed preliminary design concepts for interim storage. • Conducted analyses, leveraged expertise from other programs, and engaged with stakeholders as appropriate to develop and evaluate interim storage and associated transportation capabilities. • Maintained engagement with regional, state, and Tribal transportation authorities to prepare for future SNF and HLW shipments. • Maintained support for logistical requirements, packaging and transportation hardware, and analytical capabilities. • Implemented an appropriate investment strategy for the NWF investment portfolio and prudently managed the NWF portfolio. • Maintained physical security requirements for the Yucca Mountain site under DOE Order 473.3A as well as provided site maintenance and fulfilled environmental requirements. • Supported associated Federal staff and support.	• Implement an appropriate investment strategy for the NWF investment portfolio and prudently manage the NWF portfolio. • Administer the Standard Contract between nuclear utilities and the government. • Maintain physical security requirements for the Yucca Mountain site under DOE Order 473.3A as well as provide site maintenance and fulfill environmental requirements. • Provide legal services for nuclear waste disposal activities. • Support the agency financial report and audit. • Support associated Federal staff and support.	Funding decrease reflects the FY 2021 Enacted funding for Interim Storage activities appropriated within the Interim Storage and Nuclear Waste Fund Oversight program (Nuclear Waste Disposal account) and the FY 2023 Budget Request for Interim Storage activities instead included in the Office of Nuclear Energy's Integrated Waste Management System subprogram within Fuel Cycle Research and Development.

DEPARTMENT OF ENERGY

Funding by Site Detail

Nuclear Waste Disposal Fund FY 2023

(Dollars in Thousands)

	FY 2021 Enacted Requested Total	FY 2022 Annualized CR Requested Total	FY 2023 Request Detail Requested Total
Argonne National Laboratory			
Interim Storage	500	500	0
Total Argonne National Laboratory	**500**	**500**	**0**
Idaho Operations Office			
Interim Storage	1,000	1,000	0
Total Idaho Operations Office	**1,000**	**1,000**	**0**
Pacific Northwest National Laboratory			
Interim Storage	6,000	6,000	0
Total Pacific Northwest National Laboratory	**6,000**	**6,000**	**0**
Sandia National Laboratories			
Interim Storage	7,000	7,000	0
Oversight Activities Nuclear Waste Disposal	500	500	500
Total Sandia National Laboratories	**7,500**	**7,500**	**500**
Washington Headquarters			
Interim Storage	5,500	5,500	0
Oversight Activities Nuclear Waste Disposal	7,000	7,000	9,705
Total Washington Headquarters	**12,500**	**12,500**	**9,705**
Total Funding by Site - Nuclear Waste Disposal Fund	**27,500**	**27,500**	**10,205**

Fossil Energy and Carbon Management

Fossil Energy and Carbon Management

Fossil Energy and Carbon Management (FECM)
($K)

FY 2021 Enacted	FY 2022 Annualized CR	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
750,000	750,000	893,160	+$143,160	+19.1%

Overview

The Office of Fossil Energy and Carbon Management (FECM) conducts research, development, demonstration, and deployment (RDD&D) that focuses on technologies to reduce carbon emissions and other environmental impacts of fossil fuel production and use, particularly the hardest-to-decarbonize applications in the electricity and industrial sectors. Furthermore, the program advances technologies that convert and durably store CO_2 into value-added products and technologies on carbon dioxide (CO_2) removal (CDR) to remove atmospheric and legacy emissions of CO_2.

To meet these challenges, the FECM Budget focuses on technology priority areas of point-source carbon capture, carbon transport and storage, carbon dioxide conversion, hydrogen with carbon management, methane emissions reduction, critical minerals (CM) production, and CDR. FECM recognizes that global decarbonization is essential to meeting climate goals—100% carbon pollution free electricity by 2035 and net-zero greenhouse gas (GHG) emissions economy-wide by 2050—and works to engage with international colleagues to leverage expertise in these areas. FECM is also committed to improving the conditions of communities impacted by the legacy of fossil fuel use and to supporting a healthy economic transition that accelerates the growth of good-paying jobs.

FECM is dedicated to implementing the principles of climate and clean energy and environmental justice in the planning, processes, and outcomes of its work in alignment with Executive Orders (EO) 14008, *Tackling the Climate Crisis at Home and Abroad,* and EO 13985, *Advancing Racial Equity and Support for Underserved Communities Through the Federal Government*. FECM focuses on: (1) the meaningful participation of communities, with special focus on disadvantaged communities; (2) a just distribution of benefits; and (3) emphasis on remediating legacy harms while also mitigating new impacts. These principles will be at the center of funding decisions, including implementation of the Justice40 Initiative, and partnership development.

The FY 2023 Budget Request for FECM will extend the impact of the Department of Energy's (DOE) RDD&D funding by leveraging creative funding mechanisms—such as prizes, competitions, technical assistance, and programs targeted to small businesses. The goal is to enable the commercialization of climate change and clean energy innovations that will activate job creation, expand other public impact outcomes, and yield a more geographically-diverse and impactful research portfolio. This request also includes funding for the basic operating costs of FECM and investment at the National Energy Technology Laboratory (NETL).

FECM's FY 2023 priorities follow:

- **Point-Source Carbon Capture:** Reduce the cost, increase the efficacy, and advance the deployment of commercial-scale point-source capture technologies in the power and industrial sectors, coupled to permanent storage.
- **Methane Mitigation:** Develop technologies and deploy regional initiatives to monitor and reduce methane emissions from fossil fuel infrastructure including coal, oil, and gas.
- **Carbon Dioxide Removal (CDR):** Invest in a diverse set of CDR approaches to support DOE's Carbon Negative Shot of just, sustainable, and scalable CDR at costs below $100/net metric ton of CO_2-equivalent (CO_2e).
- **Domestic Critical Minerals Production:** Support demonstrations for extraction and remediation to processing and refining for building a strong CM supply chain while creating good-paying jobs.
- **Reliable Carbon Storage and Transport:** Make advancements in storage technologies and transport mechanisms, provide technical assistance in Class VI well permitting, and support large-scale transport and storage facilities and regional hubs.
- **Carbon Dioxide Conversion:** Accelerate capabilities for large-scale conversion of CO_2 into products that advance net-zero and justice goals, facilitated by markets for CO_2 as a feedstock.

- **Hydrogen with Carbon Management:** Research, development, deployment, and demonstration (RDD&D) for hydrogen production coupled with carbon capture and storage (CCS) using sustainably sourced carbon-based feedstocks. Invest in the advancement and utility-scale demonstration of hydrogen storage, reversible solid oxide fuel cells, and 100 percent hydrogen fired turbines (with NOx mitigation), supporting DOE's Hydrogen Shot target.
- **Justice, Labor, and Domestic and International Collaboration:** Collaborate with domestic and international partners to create a sustainable energy infrastructure with equity and justice at the core of FECM's work.

Highlights and Major Changes in the 2023 Budget Request
Recognizing recent developments in the United States (U.S.) and global energy landscape, the FY 2023 FECM RDD&D Budget Request is adjusted relative to the FY 2021 Enacted Level:

- There is a need for the advancement of next-generation decarbonized technologies to achieve a net-zero carbon economy. This requires a deep investment and prioritization of carbon management, including point-source carbon capture, direct air capture (DAC), CO_2 conversion approaches, and dedicated and reliable CO_2 storage.
- There is growing importance for the U.S. to focus on zero-carbon and carbon-neutral hydrogen. In partnership with the Office of Energy Efficiency and Renewable Energy (EERE) Hydrogen and Fuel Cell Technologies Office (HFTO), DOE will invest in a wide array of hydrogen technologies to expedite the hydrogen energy economy.
- Methane is one of the most potent GHG. It is critical that we reduce methane leakage. To that end, FECM will invest in approaches that reduce methane emissions from the oil, gas (e.g., fugitive methane and flaring), and coal (methane emissions from active and abandoned mines and wells) industries toward the production of useful chemicals such as hydrogen and ammonia.
- The U.S. must become a leader in CM and rare earth elements (REE) supply. FECM will increase focus on the extraction of CM and REE from coal feedstocks and byproducts of the industry, which will also serve as an economic transition strategy in regions of the U.S. that are heavily dependent on this industry today.
- The FY 2023 Budget continues the process from FY 2022 of ensuring that its programs do not directly subsidize fossil fuels, not funding RDD&D focused on unabated fossil combustion, traditional fossil-fueled power generation, or increased production of fossil fuels while also investing in technologies to improve energy security and lower energy prices. The Budget focuses on other activities that support clean energy development and deployment (including carbon management), environmental benefits, and the creation of good-paying jobs that provide a free and fair chance to join a labor union.

For comparability, all discussions of funding changes that follow assume the FY 2023 proposed budget structure. Funding crosswalks in the Budget Structure Crosswalks chapter of this narrative provide details of the proposed changes.

<u>Office of Carbon Management Technologies ($478.905M)</u>
The Office of Carbon Management (OCM) facilitates a just and environmentally sustainable transition toward a net-zero carbon economy by focusing on CO_2—its storage, permanent containment, and capture. OCM addresses emissions associated with the power and industrial sectors, as well as legacy emissions in the atmosphere, and seeks to permanently store CO_2 in geologic formations and/or convert CO_2 to reduce negative climate impacts.

Descriptions of major funding and programmatic changes and highlights within the Carbon Management Technologies (CMT) program for the FY 2023 Budget Request are as follows:

Hydrogen with Carbon Management ($74M)
The Hydrogen with Carbon Management (HCM) subprogram invests in RDD&D to evaluate carbon-based clean H_2 (i.e., coupled to CCS) as a fuel and support development of technologies to use clean H_2 from any source. The subprogram's efforts are an integral part of DOE's recently launched Hydrogen Shot, with a goal of clean H_2 costs of $1/kg within one decade (1-1-1) while expanding employment of the U.S. energy workforce. Seeking a cost-competitive decarbonized alternative to traditional fossil fuels, the subprogram has a research and development (R&D) portfolio consisting of a new generation of carbon neutral or net-negative GHG emissions technologies. Gasification, reversible solid oxide fuel cells (RSOFCs), technologies in H_2 turbines, and advanced materials, sensors and controls all support this goal.

The FY 2023 Budget Request for HCM of $74 million for these activities will provide research with a platform for developing the advanced systems of the future, while reducing emissions. In FY 2023, the subprogram will not fund RDD&D specific to traditional fossil power generation, but rather, will narrow the focus to work on H_2-fueled turbines, fuel cells, CCS-relevant technologies, and production of clean H_2 through gasification. Improvements to these technologies are also applicable to other energy systems. These improvements to new and existing plants will also make them less carbon intensive and allow these assets to provide continued low-cost baseload power and resilient flexible grid services. This subprogram aligns with the Administration's priority to reduce the environmental impact of the power sector, especially regarding disadvantaged communities. As such, the subprogram is working to address local air quality issues associated with Nitrous Oxide emissions that could be produced as a byproduct Hydrogen combustion – and working to ensure that impacts to disadvantaged communities are robustly considered when siting new hydrogen infrastructure.

Carbon Transport and Storage ($122M)
The Carbon Transport and Storage (CTS) subprogram is uniquely positioned to support the U.S. as it develops a carbon transport and storage industry at the scale necessary to decarbonize the economy while considering environmental and social benefits and associated impacts these efforts may have. This RDD&D subprogram is making key investments in advanced technology RDD&D, large-scale transport scenarios, commercial-scale storage facilities, and regional hubs, all to support a foundation for carbon storage in support of both carbon mitigation and removal. Critical components that will help catalyze the growth of CCS deployment at-scale include, but are not limited to, strategies to develop the infrastructure for reliable carbon storage, RDD&D to improve performance and reduce costs, educational partnerships to grow the workforce, technology transfer, and technical assistance to stakeholders.

The FY 2023 Budget Request provides $122 million for the CTS subprogram and RDD&D activities that address the performance challenges of operating and monitoring commercial scale CO_2 storage sites. The RDD&D supported by the CTS subprogram will aim to improve storage and operational efficiency, improve understanding of overall cost and de-risking strategies to reduce it. Achieving each of these elements through site characterization and developing advanced monitoring and modeling tools is critical for enabling a CCS industry that is safe, economically viable, and environmentally benign.

Carbon Dioxide Removal ($65M) and Carbon Dioxide Conversion ($50M)
The CDR subprogram advances a diverse set of CDR approaches in service of facilitating gigatonne-scale removal by mid-century. It emphasizes rigorous analysis of life cycle impacts and has a deep commitment to justice. The subprogram invests in CDR technologies, such as DAC and direct ocean capture (DOC) with durable storage; biomass with carbon removal and storage (BiCRS); and mineralization concepts to remove legacy emissions and address emissions from hard-to-abate sectors.

The Carbon Dioxide Conversion (CDC) subprogram invests in research, development, and demonstration (RD&D). It supports the ecosystem to deploy technologies that recycle CO_2 into value-added products. To create products such as CO_2-based building materials, fuels, and chemicals, the subprogram focuses on mineralization, catalytic conversion, and biological approaches. Through these investments, the CDC subprogram can help the U.S. achieve the goals of a net-zero carbon economy by 2050, while simultaneously developing the industries of the future in equitable and just ways.
In FY 2023, the Budget Request provides $65 million for CDR and $50 million in the CDC subprograms. CDR funding will support continued development of novel DAC and DOC materials and processes to help optimize and reduce the cost, R&D, and Front End Engineering and Design (FEED) studies for BiCRS, and novel approaches that can leverage industrial waste minerals and naturally occurring minerals that can capture atmospheric CO_2.

CO_2 conversion technologies for the CDC subprogram have the potential to develop additional markets for CO_2-based products. Areas of research include, but are not limited to, new projects focused on the catalytic conversion to higher value products such as fuels, chemicals, polymers, and nutraceuticals; mineralization to building products; generation of solid carbon products; and algal systems designed to integrate CO_2. Specific focus on catalysts made from low-cost materials and improved reactor designs will be pursued to lower the energy penalty and capital cost of the conversion process.

Point-Source Carbon Capture ($162.905M)
The Point-Source Carbon Capture RDD&D subprogram focuses on committed emissions associated with infrastructure that are expected to persist through mid-century. Natural gas power generation and CO_2-emitting industrial sectors, such as cement, steel, and H_2 production are particular priorities. FY 2023 activities will focus on new capture technologies in

addition to the demonstration of more proven capture approaches. The FY 2023 Budget Request provides $162.905 million in the Point-Source Carbon Capture subprogram for pre- and post-combustion capture RDD&D on transformational gas separation technologies that can help achieve decarbonization goals.

Additionally, the Point-Source Carbon Capture subprogram will leverage its prior and current RDD&D experience on carbon capture technology development for application to industrial applications, specifically, cement, steel and H_2 production. RDD&D will focus on optimization of technologies for these applications to reduce cost and improve performance. A continued focus will be on decarbonization of natural-gas based systems for power generation.

Carbon Management – Policy and Analysis ($4M)
The Office of Carbon Management conducts systems, economic, and environmental analysis that is primarily focused on: cost and performance for carbon management technologies; the role of carbon management in energy markets; life cycle analysis; energy markets assessments; integration of carbon management technologies with the U.S. power grid; and effects of carbon management deployment in local communities.

A variety of analysis methodologies are used in combination to provide a robust understanding of the cost, performance, and barriers to the deployment of carbon management technologies. Through a system of coordinated efforts and thoughtfully engaging with stakeholders, realistic scenarios can be crafted using market and technology-based information. The FY 2023 Budget Request for Policy and Analysis is $4 million.

Carbon Management – Justice and Engagement ($1M)
The FY 2023 Request of $1 million supports research, development, demonstration, and deployment (RDD&D) of carbon management technologies through engagement with key partners within the U.S. and globally. Funding will support domestic engagement and justice efforts as well as international collaboration with various partners through bi-lateral and multi-lateral agreements. The Office of Fossil Energy and Carbon Management (FECM) will focus on building capacity and working with interagency partners to ensure safe, effective, and efficient implementation of its RDD&D programs. FECM will work with various stakeholders to build a foundation for expeditiously administering several new investments, leveraging existing programs and developing new relationships with stakeholder networks and communities.

<u>Office of Resource Sustainability ($182.694M)</u>
The Resource Sustainability Office addresses critical issues associated with reducing the environmental impacts of the historical and continued use of fossil fuels. This includes conducting RDD&D that reduces environmental impact from the extraction, development, transportation, distribution, and storage of fossil fuels and reducing emissions throughout the supply chain. Descriptions of major programmatic changes and highlights within the Resource Sustainability program for the FY 2023 Budget Request, which totals $182.694 million, are as follows:

Advanced Remediation Technologies ($12.964M) (New Control Point)
The Advanced Remediation Technologies program will focus on technologies that can be applied to the remediation and prevention of environmental impacts from fossil fuel extraction activities. This will include research to address wellbore integrity, induced seismicity, water use, produced water treatment, water management, and offshore safety and spill prevention. The program will leverage previous research, to include field laboratory efforts, to assess the viability of converting expended unconventional oil and gas wells to carbon storage sites.

Methane Mitigation Technologies ($100M) (New Control Point)
The Methane Mitigation Technologies program will develop technologies to reduce emissions from fossil fuel production, transmission, distribution, processing, and storage infrastructure. This program will also focus on developing technologies to detect, locate, and measure emissions, including the development and validation of measurement sensor technologies for the collection, dissemination, and analysis of emissions data which will inform efforts such as the Environmental Protection Agency's (EPA) Greenhouse Gas Inventory, Life Cycle Analysis (LCA), and other remediation programs. The program will develop advanced modular technologies, capable of being deployed near wellheads and natural gas processing and transportation infrastructure, for the purpose of beneficially utilizing otherwise flared, vented, or stranded natural gas. It will also conduct research to develop advanced materials, sensors, data management systems, and more efficient and flexible compressors.

Natural Gas Decarbonization and Hydrogen Technologies ($26M) (New Control Point)
The new Natural Gas Decarbonization and Hydrogen Technologies program will focus on technologies for carbon-neutral H_2 production as well as hydrogen (and ammonia) transportation, and geologic storage technologies that leverage existing natural gas infrastructure as well as supporting analytical tools and models. Hydrogen research will focus on improving natural gas steam methane reforming (SMR), blending H_2 with natural gas, and leveraging existing transportation and storage infrastructure. The program will also develop analytical tools and models that are able to evaluate potential advanced technologies, technology performance metrics, technoeconomic and lifecycle analyses, and resource evaluations.

Mineral Sustainability ($44M)
The Mineral Sustainability program will support the sustainable economic, environmental, and geopolitical production of CM. The integration of extraction of carbon ore and CM is naturally part of the upstream process; therefore, the integration of the CM and Carbon Ore Processing activities will result in more efficient and economic technology development and deployment. This mission will be accomplished by prioritizing the use of unconventional resources such as coal waste and by-products from industry feedstocks for domestic CM, REE and carbon ore to products production.

The Carbon Ore Processing activity (formerly Advanced Coal Processing) is focused on utilizing materials to be recycled from previously mined resources outside of traditional thermal and metallurgical markets that can contribute to the U.S. gross domestic product. The activity is focused on developing transformational technologies to enable domestic manufacturing of strategic materials and superior building products from carbon ore at competitive market prices. These transformational technologies have minimal emissions, superior product performance, and better lifecycle for new and existing products in the market.

Resource Sustainability – Policy and Analysis ($0)
These activities will be completed with available resources; no additional funding is requested in FY 2023. The Policy and Analysis Division supports all program areas in the Office of Resource Sustainability through the drafting of studies and reports, conducting economic and environmental analysis, and reviewing legislation, regulations, and executive orders.

Resource Sustainability – Justice and Engagement ($0)
These activities will be completed with available resources; no additional funding is requested in FY 2023. This Justice and Engagement Division conducts and provides support to leadership's engagement with a wide set of domestic and international stakeholders, to include frontline and disadvantaged communities, government agencies, non-government entities, non-profits, academia, and foreign governments.

Other FECM Program Activities
Repurposing Fossil Energy Assets ($6M)
The Repurposing Fossil Assets program will support leveraging and transforming fossil assets, including coal power plants, coal mines, and abandoned oil and gas wells, through repurposing them for clean energy and manufacturing. This is one of the best ways to unite private sector and energy community interests in places where employment and opportunity is on the decline. Many fossil asset sites can offer private sector actors looking to repurpose with access to a skilled workforce with knowledge of industrial operations, community relationships, access to rail lines, ports, and waterways, highway transportation, transmission and distribution infrastructure, electrical interconnect equipment and direct grid connections, industrial land, facilities, and potentially even site and permitting licenses among other assets. As innovative clean energy and manufacturing companies fan out across the country, it increasingly makes sense for them to choose to locate in energy communities. In turn, repurposing considerably addresses the potential resistance to the decommissioning of coal plants and ensures that historic energy communities have a path forward. For energy communities, repurposing fossil assets can provide a variety of both short-term and permanent family-wage jobs, opportunities for worker retraining programs, access to local work that does not require relocation, and opportunities to work in cutting-edge technology sectors. Importantly, repurposing allows communities to claim control of their own narratives and become active participants in the energy transition.

The FY 2023 Budget Request of $6 million will develop case studies of fossil assets across the U.S. that are being repurposed. The program will fund concept development followed by pre-FEED studies where the assets can be transformed to use other sources of clean energy such as solar, geothermal, wind, and nuclear sources and repurpose the existing fossil asset. The case studies and the pre-FEED work will serve as powerful examples for other communities to emulate and transition in a phased and methodical manner to achieve the clean energy goals.

University Training and Research ($13M)
The request of $13 million provides funding for University Training and Research (UTR), which comprises funding for University Carbon Research (UCR), Historically Black Colleges and Universities (HBCU) and other Minority Serving Institutions (MSI).

The Transformational Coal Pilots, STEP, and Unconventional FE Technologies programs are at the end of their scheduled programming and will not require additional funding in FY 2023.

National Energy Technology Laboratory (NETL)

	($K)		
	FY 2021 Enacted	**FY 2022 Annualized CR**	**FY 2023 Request**
NETL Program Direction	27,780	27,780	29,900
NETL Infrastructure	55,000	55,000	55,000
NETL Research and Operation	83,000	83,000	83,000
Interagency Working Group	0	0	3,000
Subtotal, NETL	**165,780**	**165,780**	**170,900**
Special Recruitment	700	700	1,000
HQ Program Direction (includes Import/Export)	33,720	33,720	40,391
Subtotal, Remaining Programs	**34,420**	**34,420**	**41,391**

FECM is committed to supporting NETL's capabilities and competitiveness. NETL, whose primary funding source is FECM, is the only Government-Owned, Government-Operated (GOGO) Laboratory in the DOE National Laboratory system. The FY 2023 Budget Request for NETL is $170.9M and an additional $41.4M for HQ Program Direction and Special Recruitment – see table above for funding breakdown.

- **<u>NETL and Headquarters (HQ) Program Direction and Special Recruitment Programs:</u>** The Request of $70.291 million for NETL/HQ program direction and $1 million for Special Recruitment provides for the FECM organization's headquarters federal workforce and contractor support including salaries and benefits, support service contracts, travel, training, the working capital fund, and other employee costs. These staff are responsible for the oversight and administration of the FECM programs and natural gas regulatory activities. In addition, funding for NETL federal technical staff and contractor support that provide Acquisition, Finance and Legal functions is supported.
- **<u>NETL Infrastructure:</u>** The FY 2023 Budget Request of $55 million supports the fixed costs of maintaining NETL's lab footprint in three geographic locations: Morgantown, WV; Pittsburgh, PA; and Albany, OR. The footprint of these sites is approximately 240 acres, including 165 research laboratories. The Request provides funding for general plant projects to maintain research capabilities and combat deferred maintenance, the lease of NETL's next generation high performance computer, and for information technology (IT) development, modernization, and enhancement.
- **<u>NETL Research and Operations:</u>** The Request of $83 million supports the salaries, benefits, travel, and other employee costs for the NETL staff of scientists, engineers and technical professionals who conduct onsite research and project management activities for FECM programs. The Request also funds partnership, technology transfer, and other collaborative research activities and supports the variable operating costs of NETL's research sites.
- **<u>Interagency Working Group:</u>** The FY 2023 Budget Request of $3 million for the DOE-led Interagency Working Group on Coal and Power Plant Communities and Economic Revitalization will support the IWG's capacity building activities conducted at NETL, including research and analysis to inform investment decisions and the coordination of interagency efforts to deliver Federal resources to those communities hard-hit by coal, oil and gas, and power plant closures. Capacity building activities will focus not only on promoting investments that support economic revitalization and job

creation in these communities but will also proactively promote investments in communities likely to be impacted by these closures in the near-term.

Cybersecurity: DOE is engaged in two categories of cyber-related activities: (1) safeguarding the DOE enterprise IT systems from a range of cyber threats that can adversely impact mission capabilities, and (2) enhancing the security of U.S. critical energy infrastructure to all hazards, mitigate the impacts of disruptive events and risk to the sector overall through preparedness and innovation, and respond to and facilitate recovery from energy disruptions in collaboration with other Federal agencies, the private sector, and State, local, tribal, and territory governments. FECM's IT cybersecurity efforts in FY 2023 targets critical cybersecurity needs across FECM enterprise, prioritizing cybersecurity enhancements, including: zero trust architecture implementation, transition to ongoing authorization, adoption of DOE Order 205.1C, establish a privacy continuous monitoring, cloud migration and security, support Federal Information Security Modernization Act (FISMA) remediation, establish security operations center, and DOE cyber retention incentive program.

Energy Storage Grand Challenge (ESGC): DOE is participating in the ESGC and provides $6 million of support relevant to that program from within FECM's Repurposing Fossil Energy Assets program.

FY 2023 Crosscuts ($K)

	Cybersecurity	Energy Storage Grand Challenge	Total
NETL Infrastructure	9,378	0	9,378
Program Direction	1,800	0	1,800
Repurposing Fossil Energy Assets	0	6,000	6,000
Total, Crosscuts	**11,178**	**6,000**	**17,178**

Fossil Energy and Carbon Management
Funding by Congressional Control ($K)
(Comparable)

	FY 2021 Enacted	FY 2022 Annualized CR	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
Carbon Management Technologies					
Hydrogen with Carbon Management	122,300	122,300	74,000	-48,300	-39.5%
Carbon Transport and Storage	79,000	79,000	122,000	+43,000	+54.4%
Carbon Dioxide Removal	40,000	40,000	65,000	+25,000	+62.5%
Carbon Dioxide Conversion	23,000	23,000	50,000	+27,000	+117.4%
Point-Source Carbon Capture	86,300	86,300	162,905	+76,605	+88.8%
Carbon Management - Policy and Analysis	500	500	4,000	+3,500	+700.0%
Carbon Management - Justice and Engagement	650	650	1,000	+350	+53.8%
Transformational Coal Pilots	10,000	10,000	0	-10,000	-100.0%
Supercritical Transformational Electric Power (STEP)	14,500	14,500	0	-14,500	-100.0%
Subtotal, Carbon Management Technologies	**376,250**	**376,250**	**478,905**	**+102,655**	**+27.3%**
Resource Sustainability					
Advanced Remediation Technologies	44,500	44,500	12,964	-31,536	-70.9%
Methane Mitigation Technologies	20,000	20,000	100,000	+80,000	+400.0%
Natural Gas Decarbonization and Hydrogen Technologies	0	0	26,000	+26,000	N/A
Mineral Sustainability	53,000	53,000	44,000	-9,000	-17.0%
Subtotal, Resource Sustainability	**117,500**	**117,500**	**182,964**	**+ 65,464**	**+55.7%**
Unconventional Fossil Energy Technologies from Petroleum - Oil Technologies	**46,000**	**46,000**	**0**	**-46,000**	**-100.0%**
Repurposing Fossil Energy Assets	**5,000**	**5,000**	**6,000**	**+1,000**	**+20.0%**
University Training and Research	**5,050**	**5,050**	**13,000**	**+7,950**	**+157.4%**
Special Recruitment	**700**	**700**	**1,000**	**+300**	**+42.9%**
Program Direction	**61,500**	**61,500**	**70,291**	**+8,791**	**+14.3%**
NETL Infrastructure	**55,000**	**55,000**	**55,000**	**0**	**0%**
NETL Research and Operations	**83,000**	**83,000**	**83,000**	**0**	**0%**
Interagency Working Group	**0**	**0**	**3,000**	**+3,000**	**N/A**
Total, Fossil Energy and Carbon Management	**750,000**	**750,000**	**893,160**	**+143,160**	**+19.1%**
Federal FTEs	**679**	**679**	**719**	**40**	

SBIR/STTR:

- FY 2021 Enacted: SBIR $12,970; STTR: $2,256
- FY 2022 Annualized CR: SBIR $12,970; STTR: $2,256
- FY 2023 Request: SBIR $17,300; STTR: $2,433

Fossil Energy and Carbon Management
Funding by Congressional Control ($K)
(Non-Comparable)

	FY 2021 Enacted	FY 2022 Annualized CR	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
Carbon Management Technologies					
Hydrogen with Carbon Management	0	0	74,000	+74,000	N/A
Carbon Transport and Storage	0	0	122,000	+122,000	N/A
Carbon Dioxide Removal	0	0	65,000	+65,000	N/A
Carbon Dioxide Conversion	0	0	50,000	+50,000	N/A
Point-Source Carbon Capture	0	0	162,905	+162,905	N/A
Carbon Management - Policy and Analysis	0	0	4,000	+4,000	N/A
Carbon Management - Justice and Engagement	0	0	1,000	+1,000	N/A
Transformational Coal Pilots	0	0	0	0	N/A
Supercritical Transformational Electric Power (STEP)	0	0	0	0	N/A
Subtotal, Carbon Management Technologies	**0**	**0**	**478,905**	**+478,905**	N/A
Resource Sustainability					N/A
Advanced Remediation Technologies	0	0	12,964	+12,964	N/A
Methane Mitigation Technologies	0	0	100,000	+100,000	N/A
Natural Gas Decarbonization and Hydrogen Technologies	0	0	26,000	+26,000	N/A
Mineral Sustainability	0	0	44,000	+44,000	N/A
Subtotal, Resource Sustainability	**0**	**0**	**182,964**	**+182,964**	N/A
Unconventional Fossil Energy Technologies from Petroleum - Oil Technologies	0	0	**0**	**0**	N/A
Repurposing Fossil Energy Assets	0	0	**6,000**	**+6,000**	N/A
University Training and Research	0	0	**13,000**	**+13,000**	N/A
Special Recruitment	0	0	**1,000**	**+1,000**	N/A
Program Direction	0	0	**70,291**	**+70,291**	N/A
NETL Infrastructure	0	0	**55,000**	**+55,000**	N/A
NETL Research and Operations	0	0	**83,000**	**+83,000**	N/A
Interagency Working Group	0	0	**3,000**	**+3,000**	N/A
Total, Fossil Energy and Carbon Management	**0**	**0**	**893,160**	**+893,160**	N/A
Federal FTEs	**0**	**0**	**719**	**+719**	N/A

	FY 2021 Enacted	FY 2022 Annualized CR	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
CCUS and Power Systems					
Carbon Capture	126,300	126,300	0	-126,300	-100.00%
Carbon Utilization	23,000	23,000	0	-23,000	-100.00%
Carbon Storage	79,000	79,000	0	-79,000	-100.00%
Advanced Energy Systems	122,000	122,000	0	-122,000	-100.00%
Cross Cutting Research	72,000	72,000	0	-72,000	-100.00%
Transformational Coal Pilots	10,000	10,000	0	-10,000	-100.00%
Supercritical Transformational Electric Power (STEP)	14,500	14,500	0	-14,500	-100.00%
Subtotal, CCUS and Power Systems	**446,800**	**446,800**	**0**	**-446,800**	**-100.00%**
Natural Gas Technologies	**51,000**	**57,000**	**0**	**-57,000**	**-100.00%**
Unconventional Fossil Energy Technologies from Petroleum - Oil Technologies	**46,000**	**46,000**	**0**	**-46,000**	**-100.00%**
Special Recruitment	**700**	**700**	**0**	**-700**	**-100.00%**
Program Direction	**61,500**	**61,500**	**0**	**-61,500**	**-100.00%**
NETL Infrastructure	**55,000**	**55,000**	**0**	**-55,000**	**-100.00%**
NETL Research and Operations	**83,000**	**83,000**	**0**	**-83,000**	**-100.00%**
Total, Fossil Energy and Carbon	**750,000**	**750,000**	**0**	**-750,000**	**-100.00%**
Federal FTEs	**679**	**679**	**0**	**-679**	**-100.00%**

Outyear Funding
($K)

	FY 2023 Request	FY 2024 Request	FY 2025 Request	FY 2026 Request	FY 2027 Request
Office of Fossil Energy and Carbon Management	893,160	913,703	934,718	955,282	976,298

Outyear Priorities and Assumptions

In the FY 2012 Consolidated Appropriations Act (P.L. 112-74), Congress directed the Department to include a future-years energy program (FYEP) in subsequent requests that reflects the proposed appropriations for five years. This FYEP shows outyear funding for each account for FY 2024 - FY 2027. The outyear funding levels use the growth rates in outyear account totals published in the FY 2023 President's Budget for both the 050 and non-050 accounts. Actual future budget request levels will be determined as part of the annual budget process.

Bipartisan Infrastructure Law (BIL) Investments

FECM was appropriated funds through the Bipartisan Infrastructure Law (BIL) (P.L. 117-58). Not all BIL activities will be managed by the organization to which funds were appropriated. Activities that FECM will manage that are appropriated to other organizations are discussed below.

Fossil Energy and Carbon Management	($K)		
	FY 2022 BIL Appropriation	FY 2023 BIL Appropriation	Managing Organization
Regional Direct Air Capture Hubs	700,000	700,000	OCED
Carbon Storage Validation and Testing	500,000	500,000	OCED
Carbon Dioxide Transportation Infrastructure Finance and Innovation (CIFIA)	3,000	2,097,000	LPO
Critical Material Innovation, Efficiency, and Alternatives Activities	230,000	100,000	FECM
Critical Material Supply Chain Research Facility	40,000	35,000	FECM
Rare Earth Elements Demonstration Facility	140,000	0	OCED
Rare Earth Mineral Security Activities	23,000	24,200	FECM
Carbon Capture Technology Program	20,000	20,000	FECM
Carbon Utilization Program	41,000	65,250	FECM
Commercial Direct Air Capture Technology Prize Competitions	100,000	0	FECM
Precommercial Direct Air Capture Technology Prize Competitions	15,000	0	FECM
Orphaned, Abandoned, or Idled Wells on Federal Land Activities	30,000	0	FECM
Total, Fossil Energy and Carbon Management	**1,842,000**	**3,541,450**	

- **In consultation with other offices:**
  - **Regional Direct Air Capture Hubs (with OCED) –** The goal of this investment is to establish a program under which the Secretary shall provide funding for eligible projects that contribute to the development of 4 regional direct air capture hubs.
  - **Carbon Storage Validation and Testing (with OCED) –** The goal of this investment is to establish a program of research, development, and demonstration for carbon storage. Specifically, the activity will focus on development of new or expanded commercial large-scale carbon sequestration projects and associated carbon dioxide transport infrastructure, including funding for the feasibility, site characterization, permitting, and construction stages of project development.
  - **Carbon Dioxide Transportation Infrastructure Finance and Innovation (CIFIA) (with LPO)** – The goal of this investment is to provide flexible, low-interest loans for CO_2 transport infrastructure projects and grants for initial excess capacity on new infrastructure to facilitate future growth. Modeled after the existing TIFIA and WIFIA programs for highway and water infrastructure, CIFIA will help facilitate private sector investment in infrastructure critical for reaching net-zero emissions.
  - **Rare Earth Elements Demonstration Facility (with OCED)** – The goal of this investment is to demonstrate the feasibility of a full-scale integrated rare earth element extraction and separation facility and refinery. The facility established shall-- (A) provide environmental benefits through use of feedstock derived from acid mine drainage, mine waste, or other deleterious material; (B) separate mixed rare earth oxides into pure oxides of each rare earth element; (C) refine rare earth oxides into rare earth metals; and (D) provide for separation of rare earth oxides and refining into rare earth metals at a single site. OCED will manage FECM's rare earth elements demonstration facility.

- **Managed by FECM:**
  - **Critical Material Innovation, Efficiency, and Alternatives Activities** – The goal of this investment is to conduct a program of research, development, demonstration, and commercialization to develop alternatives to critical

materials, to promote their efficient production and use, and ensure a long-term secure and sustainable supply of them.

- **Critical Material Supply Chain Research Facility** – The goal of this investment is to support construction of a Critical Materials Supply Chain Research Facility.
- **Rare Earth Mineral Security Activities** – The goal of this investment is to conduct a program of research and development to improve the security of rare earth elements.
- **Carbon Capture Technology Program** – The goal of this investment is to expand DOE's Carbon Capture Technology program to include a program for carbon dioxide transport infrastructure necessary to deploy Carbon Capture Utilization and Storage technologies.
- **Carbon Utilization Program** – The goal of this investment is to establish a grant program for state and local governments to procure and use products derived from captured carbon oxides.
- **Commercial Direct Air Capture Technology Prize Competitions** – The goal of this investment is to support large-scale pilot projects and demonstration projects and test carbon capture technologies. Prizes will be awarded to projects that demonstrate the technical and commercial viability of technologies to reduce carbon dioxide emissions released from coal electric generation facilities and natural gas electric generation facilities for commercial deployment.
- **Precommercial Direct Air Capture Technology Prize Competitions** – The goal of this investment is to advance research, development, demonstration, and commercial application of carbon capture technologies. Prizes will be awarded to projects that demonstrate the technical and commercial viability of technologies to reduce carbon dioxide emissions released from coal electric generation facilities and natural gas electric generation facilities for commercial deployment.
- **Orphaned, Abandoned, or Idled Wells on Federal Land Activities** – The goal of this investment is to administer a program for plugging wells on Federal land, and for issuing grants to States and Tribes on State, private, and Tribal land.

Carbon Management Technologies (CMT)
($K)

FY 2021 Enacted	FY 2022 Annualized CR	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
376,250[1]	**376,250**	**478,905**	**+102,655**	**+27.3%**

Overview
The Carbon Management Technologies (CMT) program invests in transformational technologies that will help achieve the Administration's goals to decarbonize the electricity sector by 2035 and the economy by 2050. The program focuses its efforts on carbon capture, utilization, and storage (CCUS); carbon dioxide removal (CDR); hydrogen with carbon management (HCM); systems analysis; and justice and engagement activities. There is a long history of federal research, development, demonstration, and deployment (RDD&D) investment in technologies to reduce emissions from power plants and industrial sources.

The Carbon Management Technologies RDD&D activities are focused on the following key priorities:

- **Demonstrate and Deploy Point Source Carbon Capture:** Conduct RDD&D for CCUS in the power and industrial sectors to enable wider, strategic commercial deployment to meet goals of zero carbon pollution power by 2035 and net-zero emissions by 2050.
- **Accelerate Carbon-Neutral Hydrogen (H_2):** Conduct RDD&D to evaluate carbon-neutral hydrogen (i.e., coupled to carbon capture and storage (CCS)) as a fuel and support development of technologies to use carbon-neutral hydrogen from any source.
- **Develop Low-Carbon Supply Chains for Industries:** Develop novel approaches to recycle carbon oxide (CO) emissions, principally carbon dioxide, into value-added products such as cement, concrete, steel, chemicals, and fuels using systems-based carbon management approaches.
- **Advance Carbon Dioxide Removal (CDR) and Conversion:** Research, develop, demonstrate, and deploy CDR technologies and approaches by investing in direct air capture (DAC), direct ocean capture (DOC), biomass with carbon removal and storage (BiCRS), and mineral carbonation projects.
- **Invest in Thoughtful Transition Strategies:** Invest in technologies and approaches and deploy regional initiatives to help in the transition to a net-zero greenhouse gas economy, especially in fossil infrastructure host communities. These approaches such as co-firing fossil fuels with waste biomass, coupled to carbon capture, in addition to mineral and carbon extraction from coal using safe and sustainable technologies, will leverage both regional resources and existing labor forces to achieve a clean energy economy.
- **Increase Efficient Use of Big Data and Artificial Intelligence (AI):** Use AI, machine learning (ML), and data analysis to create learning algorithms within large datasets to help discover new materials, optimize processes, and run autonomous systems. Specifically, research passive sensor platforms, data management and systems, and tools that employ AI to help adapt varying pipeline conditions and additional fluids, and to optimize dedicated CO_2 storage. Partner with academic institutions and the Department of Energy (DOE) National Laboratories to focus on the application of AI and ML to improve infrastructure operations, technology testing, systems analysis, and technology transfer to industry.

Highlights of the FY 2023 Budget Request
The Carbon Management Technologies program will pursue the following major activities in FY 2023:

Hydrogen with Carbon Management
The FY 2023 Budget Request for the HCM program is $74 million. The program comprises six activities: (1) Gasification Systems, (2) Advanced Turbines, (3) Reversible Solid Oxide Fuel Cells (R-SOFCs), (4) Advanced Energy Materials, (5) Sensors, Controls,

[1] Does not include $70.55 million that was enacted in Advanced Energy Systems ($30 million) and Crosscutting Research ($40.55 million). This table is showing a comparable budget breakdown to the FY 2023 Congressional Budget Request ($7.5 million in Advanced Remediation Technologies, $53 million in Mineral Sustainability, $5 million in Repurposing Fossil Energy Assets, and $5.05 million in University Training and Research).

and Other Novel Concepts, and (6) Simulation-Based Engineering (SBE). In FY 2023, these activities will provide a research platform for developing future advanced systems while reducing emissions. In FY 2023, the HCM subprogram will primarily focus its work on hydrogen-fueled turbines, fuel cells, CCUS-relevant technologies, and production of clean hydrogen through waste/biomass gasification. Improvements to these technologies are also applicable to other energy systems. These sub-programs will align with the administration's priority to reduce the environmental impact of the power sector, especially regarding disadvantaged communities.

Carbon Transport and Storage

The FY 2023 Budget Request provides $122 million for the Carbon Transport and Storage Program addresses the performance challenges of operating and monitoring commercial scale CO_2 storage sites. The RDD&D activities in FY 2023 will aim to improve: (1) storage and operational efficiency; (2) understanding of overall cost; and (3) de-risking strategies. Achieving each of these elements is critical for enabling a CCUS and CDR industry that is safe, economically viable, and environmentally benign.

Carbon Dioxide Removal (New Control Point)

Many modeling scenarios to achieve economy-wide decarbonization suggest that CDR will be required in the future. CDR refers to approaches that remove CO_2 from the atmosphere and store it in geologic formations, products, terrestrial sinks, or in the ocean. The FY 2023 Budget Request for CDR is $65 million and includes: DAC, DOC, BiCRS, and mineralization concepts. It will focus on lab- and bench-scale development, pilot-scale tests, front-end engineering design (FEED) studies, and life cycle analysis (LCA) and techno-economic analysis (TEA) studies of these approaches.

Carbon Dioxide Conversion

In FY 2023, the Budget Request provides $50 million for the Carbon Dioxide Conversion subprogram for lab- and bench-scale CO_2 conversion technologies that have the potential to develop environmentally and socially responsible CO_2-based products. Areas of research include, but are not limited to, new projects focused on the catalytic conversion to higher value products such as fuels, chemicals, and polymers; mineralization to building materials; generation of synthetic aggregates; and algal systems with high CO_2 utilization efficiency to various bioproducts. Funding will support laboratory and bench-scale technologies to convert CO_2 into valuable products such as chemicals, fuels, bioproducts and building materials; increased field-scale testing of technologies to pilot scale, and standardized benchmarking for catalytic conversion systems.

Point-Source Carbon Capture

The Point-Source Carbon Capture activity has completed its efforts in first-generation technology through successful demonstration projects. FY 2023 activities represent a focus on next-generation capture technologies in addition to the demonstration of more proven capture approaches. The FY 2023 Budget Request provides $163 million to the Point-Source Carbon Capture activity for pre- and post-combustion capture RDD&D on transformational gas separation technologies that can help achieve decarbonization goals. Specifically, the FY 2023 Budget Request provides funding for pre- and post-combustion capture RDD&D on transformational gas separation technologies capable of deep decarbonization (at least 95% purity of CO_2).

Carbon Management – Policy and Analysis

The Carbon Management - Policy and Analysis subprogram has a Budget Request of $4 million and evaluates potential economic, jobs, and environmental benefits and impacts from the deployment of carbon management and fossil technologies. This subprogram supports strategic planning by identifying major challenges and opportunities to improve efficiency, cost, and environmental performance for the deployment of carbon management applications.

Carbon Management – Justice and Engagement

The FY 2023 Request of $1 million will support domestic engagement and environmental justice efforts as well as international collaboration with various partners through existing and newly established bi-lateral and multi-lateral efforts. The Office of Fossil Energy and Carbon Management (FECM) will focus on building capacity across the federal government by working with interagency partners to ensure safe, effective, and efficient implementation of DOE's carbon management RDD&D programs. FECM will work with various stakeholders to build a foundation for expeditiously administering several new investments, leveraging existing programs, and developing new relationships with stakeholder networks and communities. These efforts will prioritize activities and strategies to maximize the impact of FECM's research dollars and help ensure that the clean energy economy benefits all Americans.

Additional Areas of Focus

The FY 2023 Budget continues the process from FY 2022 of ensuring that its programs do not directly subsidize fossil fuels, not funding RDD&D focused on unabated fossil combustion, traditional fossil-fueled power generation, or increased production of fossil fuels while also investing in technologies to improve energy security and lower energy prices. The Budget focuses on other activities that support clean energy development and deployment (including carbon management), environmental benefits, and the creation of good-paying jobs that provide a free and fair chance to join a labor union.

Carbon Management Technologies
Funding by Congressional Control ($K)
(Comparable)

	FY 2021 Enacted	FY 2022 Annualized CR	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
Carbon Management Technologies					
Hydrogen with Carbon Management					
Gasification Systems	19,000	19,000	26,000	7,000	36.8%
Advanced Turbines	27,000	27,000	27,000	0	0.0%
Reversible Solid Oxide Fuel Cells	30,000	30,000	5,000	(25,000)	-83.3%
Advanced Energy Materials	16,100	16,100	5,000	(11,100)	-68.9%
Sensors, Controls and Other Novel Concepts	8,000	8,000	5,000	(3,000)	-37.5%
Simulation-Based Engineering	6,200	6,200	6,000	(200)	-3.2%
Transformative Power Generation	16,000	16,000	0	-16,000	-100.0%
Subtotal Hydrogen with Carbon Management	**122,300**	**122,300**	**74,000**	**(48,300)**	**-39.5%**
Carbon Transport and Storage					
Storage Infrastructure	57,500	57,500	90,000	32,500	56.5%
Advanced Storage RDD&D	15,700	15,700	32,000	16,300	103.8%
Sub-disciplinary Storage RDD&D	5,800	5,800	0	(5,800)	-100.0%
Subtotal Carbon Transport and Storage	**79,000**	**79,000**	**122,000**	**43,000**	**54.4%**
Carbon Dioxide Removal	**40,000**	**40,000**	**65,000**	**25,000**	**62.5%**
Carbon Dioxide Conversion	**23,000**	**23,000**	**50,000**	**27,000**	**117.4%**
Point-Source Carbon Capture					
Post-Combustion Capture Systems	73,300	73,300	144,405	71,105	97.0%
Pre-Combustion Capture Systems	10,000	10,000	15,000	5,000	50.0%
Emissions Control	3,000	3,000	3,500	500	16.7%
Subtotal Point-Source Carbon Capture	**86,300**	**86,300**	**162,905**	**76,605**	**88.8%**
Carbon Management - Policy and Analysis	**500**	**500**	**4,000**	**3,500**	**700.0%**
Carbon Management - Justice and Engagement	**650**	**650**	**1,000**	**350**	**53.8%**
Transformational Coal Pilots	**10,000**	**10,000**	**0**	**(10,000)**	**-100.0%**
Supercritical Transformational Electric Power (STEP)	**14,500**	**14,500**	**0**	**(14,500)**	**-100.0%**
Total, Carbon Management Technologies	**376,250**[1]	**376,250**	**478,905**	**102,655**	**27.3%**

[1] Does not include $70.55 million that was enacted in Advanced Energy Systems ($30 million) and Crosscutting Research ($40.55 million). This table is showing a comparable budget breakdown to the FY 2023 Congressional Budget Request ($7.5 million in Advanced Remediation Technologies, $53 million in Mineral Sustainability, $5 million in Repurposing Fossil Energy Assets, and $5.05 million in University Training and Research).

SBIR/STTR:

- FY 2021 Enacted: SBIR $8,820; STTR: $1,535
- FY 2022 Annualized CR: SBIR $8,820; STTR: $1,535
- FY 2023 Request: SBIR $12,454; STTR: $1,751

Carbon Management Technologies
Funding by Congressional Control ($K)
(Non-Comparable)

	FY 2021 Enacted	FY 2022 Annualized CR	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
CARBON MANAGEMENT TECHNOLOGIES					
Hydrogen with Carbon Management					
Gasification Systems	0	0	26,000	26,000	N/A
Advanced Turbines	0	0	27,000	27,000	N/A
Reversible Solid Oxide Fuel Cells	0	0	5,000	5,000	N/A
Advanced Energy Materials	0	0	5,000	5,000	N/A
Sensors, Controls and Other Novel Concepts	0	0	5,000	5,000	N/A
Simulation-Based Engineering	0	0	6,000	6,000	N/A
Transformative Power Generation	0	0	0	0	N/A
Subtotal Hydrogen with Carbon Management	**0**	**0**	**74,000**	**74,000**	**N/A**
Carbon Transport and Storage					
Storage Infrastructure	0	0	90,000	90,000	N/A
Advanced Storage RDD&D	0	0	32,000	32,000	N/A
Sub-disciplinary Storage RDD&D	0	0	0	0	N/A
Subtotal Carbon Transport and Storage	**0**	**0**	**122,000**	**122,000**	**N/A**
Carbon Dioxide Removal	**0**	**0**	**65,000**	**65,000**	**N/A**
Carbon Dioxide Conversion	**0**	**0**	**50,000**	**50,000**	**N/A**
Point-Source Carbon Capture					
Post-Combustion Capture Systems	0	0	144,405	144,405	N/A
Pre-Combustion Capture Systems	0	0	15,000	15,000	N/A
Emissions Control	0	0	3,500	3,500	N/A
Subtotal Point-Source Carbon Capture	**0**	**0**	**162,905**	**162,905**	**N/A**
Carbon Management - Policy and Analysis	**0**	**0**	**4,000**	**4,000**	**N/A**
Carbon Management - Justice and Engagement	**0**	**0**	**1,000**	**1,000**	**N/A**
Transformational Coal Pilots	**0**	**0**	**0**	**0**	**N/A**
Supercritical Transformational Electric Power (STEP)	**0**	**0**	**0**	**0**	**N/A**
Total, CARBON MANAGEMENT TECHNOLOGIES	**0**	**0**	**478,905**	**478,905**	**N/A**

	FY 2021 Enacted	FY 2022 Annualized CR	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
CCUS AND POWER SYSTEMS					
Carbon Capture					
Post-Combustion Capture Systems	108,300	108,300	0	-108,300	-100.00%
Pre-Combustion Capture Systems	15,000	15,000	0	-15,000	-100.00%
Emissions Control	3,000	3,000	0	-3,000	-100.00%
Total, Carbon Capture	**126,300**	**126,300**	**0**	**-126,300**	**-100.00%**
Carbon Utilization					
Carbon Use and Reuse	23,000	23,000	0	-23,000	-100.00%
Total, Carbon Utilization	**23,000**	**23,000**	**0**	**-23,000**	**-100.00%**
Carbon Storage					
Storage Infrastructure	57,500	57,500	0	-57,500	-100.00%
Advanced Storage RDD&D	15,700	15,700	0	-15,700	-100.00%
Sub-disciplinary Storage RDD&D (formerly Focus Area for Carbon Sequestration Science)	5,800	5,800	0	-5,800	-100.00%
Total. Carbon Storage	**79,000**	**79,000**	**0**	**-79,000**	**-100.00%**
Advanced Energy Systems					
Gasification Systems	19,000	19,000	0	-19,000	-100.00%
Advanced Turbines	27,000	27,000	0	-27,000	-100.00%
Reversible Solid Oxide Fuel Cells (formerly Solid Oxide Fuel Cells)	30,000	30,000	0	-30,000	-100.00%
Advanced Coal Processing (formerly Coal Beneficiation)	30,000	30,000	0	-30,000	-100.00%
Transformative Power Generation	16,000	16,000	0	-16,000	-100.00%
Total, Advanced Energy Systems	**122,000**	**122,000**	**0**	**-122,000**	**-100.00%**
Crosscutting Research					
Plant Optimization Technologies					
Sensors, Controls and Other Novel Concepts	*8,000*	*8,000*	*0*	*-8,000*	*-100.00%*
Cross-cutting Materials RDD&D	*16,100*	*16,100*	*0*	*-16,100*	*-100.00%*
Advanced Ultrasupercritical	*0*	*0*	*0*	*0*	*N/A*
Water Management RDD&D	*7,500*	*7,500*	*0*	*-7,500*	*-100.00%*
Subtotal, Plant Optimization Technologies	31,600	31,600	0	-31,600	-100.00%
Coal Utilization Science					
Simulation Based Engineering	*6,200*	*6,200*	*0*	*-6,200*	*-100.00%*
Subtotal, Coal Utilization Science	6,200	6,200	0	-6,200	-100.00%

	FY 2021 Enacted	FY 2022 Annualized CR	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
Energy Analyses					
Technical and Economic Analysis	*500*	*500*	*0*	*-500*	*-100.00%*
Subtotal, Energy Analyses	500	500	0	-500	-100.00%
University Training and Research					
University Coal Research	*3,000*	*3,000*	*0*	*-3,000*	*-100.00%*
HBCU's, Education, and Training	*2,050*	*2,050*	*0*	*-2,050*	*-100.00%*
Subtotal, University Training and Research	5,050	5,050	0	-5,050	-100.00%
International Activities					
International Program Support	*650*	*650*	*0*	*-650*	*-100.00%*
Subtotal International Activities	650	650	0	-650	-100.00%
Energy Storage Grand Challenge (formerly Advanced Energy Storage Initiative)	5,000	5,000	0	-5,000	-100.00%
Feasibility of Recovering Rare Earth Elements	23,000	23,000	0	-23,000	-100.00%
Total Cross Cutting Research	**72,000**	**72,000**	**0**	**-72,000**	**-100.00%**
Transformational Coal Pilots	**10,000**	**10,000**	**0**	**-10,000**	**-100.00%**
Supercritical Transformational Electric Power (STEP)	**14,500**	**14,500**	**0**	**-14,500**	**-100.00%**
TOTAL CCUS AND POWER SYSTEMS	**446,800**	**446,800**	**0**	**-446,800**	**-100.00%**

SBIR/STTR:

- FY 2021 Enacted: SBIR $8,820; STTR: $1,535
- FY 2022 Annualized CR: SBIR $8,820; STTR: $1,535
- FY 2023 Request: SBIR $12,454; STTR: $1,751

Carbon Management Technologies
Explanation of Major Changes ($K)

	FY 2023 Request vs FY 2021 Enacted
Hydrogen with Carbon Management: At the decreased level of funding, work will focus on: (1) developing modular systems for hydrogen production, advanced gas turbines for 100% hydrogen fired turbines, and high-efficiency natural gas turbines with CCS; (2) materials development for extreme conditions; and (3) reversible solid oxide fuel cell systems.	**-$48,300**
Carbon Transport and Storage: Funding prioritizes CarbonSAFE Phase II storage opportunities and CarbonSTORE field labs, continues the four Regional Initiative projects to provide technical assistance to their respective stakeholders, and supports priority RDD&D that enable AI/ML-based technologies and approaches for optimizing performance of commercial-scale storage operations.	**+$43,000**
Carbon Dioxide Removal: The increase in funding expands efforts on DOC, mineralization and enhanced weathering. The increase in funding also allows for field studies of BiCRS concepts.	**+$25,000**
Carbon Dioxide Conversion: The increase in funding allows continued development of at least one CO_2 utilization integrated system and allows for scale up and higher-TRL field testing of promising conversion technologies, such as that being performed at the National Carbon Capture Center (NCCC).	**+$27,000**
Point-Source Carbon Capture: The increase in funding supports expanding the carbon capture FEED studies to new industrial sources of CO_2 including H2 production and additional support for pilot testing at natural gas-fired electric utilities including both natural gas combined cycle (NGCC) systems and simple cycle power plants. The increase in funding is for FEED studies of pre-combustion carbon capture on Steam Methane Reformer (SMR) and Autothermal Reforming (ATR).	**+$76,605**
Carbon Management – Policy and Analysis: The increase in funding will expand the capabilities of the analysis division, allowing work on Hydrogen storage and infrastructure, CCUS, and general systems-based energy and carbon management modeling. The funding increase will also enable analysis of opportunities in the industrial sector for carbon management and will provide additional analysis to support multi-agency task forces as directed by Consolidated Appropriations Act of 2021**.**	**+$3,500**
Carbon Management – Justice and Engagement: Additional funding will support International Agreements supporting the Administration's de-carbonization priorities.	**+$350**
Transformational Coal Pilots: No funding is requested for FY 2023.	**-$10,000**
Supercritical Transformational Electric Power: No funding is requested for FY 2023.	**-$14,500**
Total, Carbon Management Technologies	**+$102,655**

Carbon Management Technologies
Hydrogen with Carbon Management

Introduction

The Hydrogen with Carbon Management (HCM) subprogram invests in research, development, demonstration, and deployment (RDD&D) to evaluate carbon-neutral hydrogen (i.e., coupled to carbon capture and storage (CCS)) as a fuel and also support development of technologies to use carbon-neutral hydrogen from any source. The subprogram's efforts are an integral part of the Department of Energy's (DOE) recently launched Hydrogen Shot, with a goal of reducing clean hydrogen costs by 80% to $1 per 1 kilogram (kg) within 1 decade (1-1-1), while expanding employment of the U.S. energy workforce. They Hydrogen Shot establishes a framework and foundation for clean hydrogen deployment in the American Jobs Plan, which includes support for demonstration projects. Seeking a cost-competitive decarbonized alternative to traditional fossil fuels, the subprogram has a research and development portfolio consisting of a new generation of carbon neutral or net-negative greenhouse gas emissions technologies. The program comprises of six RDD&D activities: (1) Gasification Systems, (2) Advanced Turbines, (3) Reversible Solid Oxide Fuel Cells (R-SOFCs), (4) Advanced Energy Materials, (5) Sensors, Controls, and Other Novel Concepts, and (6) Simulation-Based Engineering.

This subprogram provides a platform for developing the advanced systems of the future while reducing carbon dioxide (CO_2) and other emissions. While the primary focus is on thermal and electrochemical power systems and hydrogen production, improvements to these technologies are also applicable to other energy systems such as concentrated solar, nuclear, and the chemical industry. Improvements to new and existing plants will also support their efforts to be carbon neutral and allow these assets to provide continued low-cost baseload power and resilient flexible grid services. These activities align with the Administration's priority of reducing environmental impacts from the power sectors, especially in disadvantaged communities.

A description of each HCM activity is presented below:

Gasification Systems

Gasification technologies can turn any carbonaceous feedstocks/mixtures into syngas and other chemical building blocks such as carbon-neutral hydrogen, liquid fuels, chemicals (e.g., ammonia), and carbon products. Additionally, feedstock blends that consist of legacy coal waste, waste plastics, and biomass may afford a carbon neutral emissions profile when used in combination with CCS. Gasification technology with integrated carbon capture is a strong path forward for rapid clean hydrogen rollout to meet ambitious goals including the Hydrogen Shot target. Also, flexible feedstock gasification technology can promote environmental justice by consuming various forms of environmental liability waste materials that other hydrogen production technologies cannot address. Strategic siting of new hydrogen production can improve economic conditions of marginalized communities by bringing steady, well-paying jobs in the clean energy sector.

The FY 2023 Budget Request provides $26 million for RDD&D with industry, universities, and DOE National Laboratories to develop technologies that could overcome the constraints that have been inhibiting the deployment of conventional gasification-based plants. The Request will enable technology development in the following areas:

- **Carbon-Neutral Hydrogen production**: Improve and advance the maturity of novel technologies capable of producing carbon-neutral hydrogen. The focus of this research element is systems for gasification of legacy coal wastes, mixed waste plastics, municipal solid waste, and biomass, the use of which accomplish remediation and reduction of legacy pollution.
- **Mapping of resources and infrastructure requirements for a decarbonized economy using waste streams**: An assessment of the available waste streams (opportunity waste products) to make electricity and useful products in a decarbonized economy.
- **Using microwaves for enhanced gasification**: Develop small-scale, fuel-flexible microwave reactor technologies that expand the capability of gasification to use non-traditional feedstocks like waste materials

such as waste plastics, municipal solid waste, legacy coal waste, and biomass. Incorporating microwave technology can bring operational resiliency and boost the efficiency of carbon-neutral hydrogen generation.

- **Gasification for supercritical CO_2 (sCO_2) power cycles:** The direct sCO_2 power cycle is ideal for carbon capture because it inherently co-produces high pressure CO_2 ready for storage. A special purpose, ultra-high-pressure gasifier would maximize the benefit of this innovative cycle. Such a special purpose gasifier could co-produce carbon-neutral hydrogen for pipeline export, and carbon monoxide as fuel input to a direct sCO_2 power cycle. Early-stage RDD&D is needed to enable ultra-high-pressure capability for the gasification front-end.

Advanced Turbines

The FY 2023 Budget Request provides $27 million in funding to develop gas turbine combustion systems to accommodate hydrogen and hydrogen-natural gas fuel blends while minimizing nitrogen oxide (NOx) emissions and maintaining machine efficiency. RDD&D investments will also support efficiency goals of 67% (lower heating value (LHV), natural gas (NG)) and 50% (LHV, NG) for combined cycle (CC) and simple cycle machines, respectively. The program will also invest in a long-term goal of a 70% efficient CC machine (LHV, NG).

Investments will be made in the application of advanced manufacturing and machine learning/artificial intelligence to attain efficiency goals. The activity will be executed in cost-shared collaboration with capital equipment manufacturers, the vast secondary market supporting turbine technology, U.S. universities, and the U.S. National Laboratory complex.

The Advanced Turbines activity supports four key technologies that will advance clean, low-cost power production while providing options for CO_2 mitigation. These key technologies include: (1) Advanced Combustion Turbines, (2) Pressure Gain Combustion (PGC), (3) Modular Turbine-Based Hybrid Heat Engines, and (4) Supporting the University Turbine Systems Research (UTSR) program. DOE's RDD&D in advanced turbines technology develops and facilitates low-cost advanced energy options for energy ecosystems. Sub-elements of this program include:

- **Advanced Combustion Turbines:** The Request will support a significant investment in the development of hydrogen combustion systems for hydrogen and hydrogen carriers like ammonia for retrofit applications and new gas turbines. The Request will also support new designs for gas turbine components, advanced cooling techniques, aerodynamics, sealing, combustion systems and materials.
- **Pressure Gain Combustion:** Pressure gain combustion (PGC) has the potential to significantly improve gas turbine performance by realizing a pressure increase versus a pressure loss through the combustor of the turbine. Hydrogen is a particularly attractive fuel for PGC and is being explored in this program.
- **Modular Turbine-based Hybrid Heat Engine:** Projects seek to develop modular turbine-based hybrid heat engines that integrate with modular gasifiers, promote the clean use of stranded fuels, support energy storage cycles, make hydrogen generation more affordable, improve the efficiency and environmental performance of natural gas compression stations, and provide an affordable cost of electricity.
- **University Turbine Systems Research:** The Request also supports the UTSR sub-activity within the Advanced Turbines activity, which achieves the Department's and gas turbine industry goals by supporting research at U.S. universities. This cost shared activity, with industry endorsement, supports fundamental and applied RDD&D projects that improve the efficiencies of turbines and related turbine technologies. Additionally, this program helps train the workforce of combustion turbine scientists, engineers, and technicians.

Reversible Solid Oxide Fuel Cells

Reversible SOFCs (R-SOFCs) use natural gas and up to 100% hydrogen to produce electricity, water and CO_2 when operating in a fuel cell mode. Solid Oxide Fuel Cells (SOFCs) can be configured to operate in reverse as an electrolyzer using power and water as inputs to produce hydrogen, with oxygen as a byproduct. This electrolyzer mode turns the SOFC into a Solid Oxide Electrolyzer Cell (SOEC). SOECs essentially function as an SOFC in reverse and optimize the use of these system to reduce overall costs. The carbon dioxide produced from the process with natural gas as a fuel in a fuel cell mode can then be sequestered for storage or use in other applications.

R-SOFCs can both store and produce energy in a single system and can contribute to clean energy generation/storage when paired with a renewable fuel such as hydrogen (in SOFC mode) or renewable electricity (in SOEC mode). Hydrogen created from R-SOFCs is a promising fuel source and can be stored for future use when renewable energy sources are not available. When the grid demands power, the R-SOFC consumes the stored hydrogen to produce electricity. R-SOFCs allow for a continuous stream of clean energy into the grid.

The focus areas for SOFCs/SOECs include:

- Field-testing of 10–25 kilowatt (kW) SOFC systems running on both natural gas and hydrogen in a real environment at third-party data center locations;
- Carbon neutral hydrogen production from SOEC systems;
- Developing and validating the materials proposed for improving the cost, performance, and reliability of R-SOFC systems; and
- RDD&D for degradation at start-up of SOEC operation and enabling technologies for dynamic operation of SOEC/SOFC Systems.

The Request provides $5 million to conduct additional basic RDD&D to mature R-SOFC technologies, including operating as SOECs. This activity will identify advanced R-SOFC configuration concepts that enable the generation of ultra-efficient, low-cost electricity for the near-term deployment of distributed generation/modular power systems.

<u>**Advanced Energy Materials**</u>

The Advanced Energy Materials activity focuses primarily on material discovery and development that will lower the cost and improve flexibility and reliability while enabling high efficiency, low-carbon performance. Materials of interest are those that enable components and equipment to perform in the high temperature, high pressure, corrosive environments of an advanced energy system with specific emphasis on durability, availability, and cost. The activity also seeks to enhance the nation's supply chain for high-temperature materials to support a competitive U.S. industry base and create a skilled workforce.

The activity has four main themes:

- **Advanced Materials Development**: This sub-activity creates cost-effective structural and functional materials for advanced fossil energy power generation technologies, and reduces the cost and time needed to develop and commercialize new materials for FECM applications in extreme operating environments. Development focuses on advanced manufacturing methods for high-performance materials and computational materials modeling as enabling technologies. The National Energy Technology Lab (NETL) leads a national laboratory consortium, Extreme Environment Materials (eXtremeMAT or XMAT), dedicated to changing how materials are conceived and developed. In addition, this sub-activity will evaluate the impact of hydrogen on materials to develop models critical to understanding hydrogen-related impacts to establish a new domestic supply chain of hydrogen resistant materials.
- **Supply Chain Development**: The Advanced Ultra-Supercritical (A-USC) consortium developed high temperature materials and manufacturing technologies that are now being exploited in applications such as natural gas combined cycles, concentrated solar, and high efficiency plants. The recently completed supply chain development effort included RDD&D, large-scale component manufacturing trials, American Society of Mechanical Engineers (ASME) code cases, and techno-economic analyses (TEA) that readied the domestic supply chain to support construction of advanced power generation technology power plants.
- **Work Force Development:** This sub-activity supports the education and training of advanced technical workers who are trained in skills necessary to manufacture and repair components suitable for applications and industries that will be necessary for a decarbonized electricity sector by 2035 and economy by 2050. This sub-activity provides funding to eligible applicants proposing to provide training in target skills while addressing the employment and training needs of the local and regional workforce. These training programs are created in collaboration with community partners and in coordination with existing economic development strategies to support worker training for coal and powerplant communities.

- **High-Performance Computing for Materials (HPC4Mat)**: This sub-activity aims to utilize the high-performance computing (HPC) resources of DOE's National Laboratories to help industry develop new or improved materials and resolve materials challenges for their applications.

The FY 2023 Request of $5 million will provide funding for supply chain RDD&D to develop ceramic matrix composite materials for turbine applications (thermal barrier coatings or turbine blade materials) and carbon management (CM) advanced manufacturing methods to reduce fabrication costs and improve cyclic durability. The Request supports the NETL-led XMAT National Lab Consortium to incorporate material-hydrogen interactions in materials models, develop prediction methods for component lifetimes, and accelerate the design of new materials.

Sensors, Controls, and Other Novel Concepts
This activity provides $5 million to provide funding for early-stage RDD&D efforts on low-cost, reliable wired and wireless technologies to measure process temperature, pressure, and concentration of gas species. With additional investment by industry, these technologies could be capable of providing real-time information critical to the operation, reliability, and efficiency of next generation power systems. This is needed as a part of greater efforts to achieve a carbon pollution-free power sector by 2035.

Advances in RDD&D will enable industry to shift from time-based preventive maintenance schedules to predictive condition-based maintenance to improve reliability and overall plant economics. Advanced sensors and controls can also be used to monitor, identify, and mitigate transients associated with a cyber-attack, providing increased asset security, safety, and grid stability. Novel instrumentation that can withstand harsh process environments can replace inferred process conditions with actual measurements. This facilitates optimized performance, improved component health monitoring, and faster/safer response times during flexible operations.

RDD&D will focus on advanced data analytics and controls development for power plants of the future. This activity builds off lessons learned from testing at existing power plants, emphasizing integration of materials lifetime modeling and control algorithms. By advancing research and development, technology prototypes are designed, packaged, ruggedized, and readied for plant integration. Other novel/emerging technologies will be developed to support future energy applications essential for energy security and efficiency. Technologies developed by this program could also be applied to hydrogen production and utilization; carbon-capture, utilization and storage; flexible-fuel boiler systems; and energy storage.

Focus areas include:

- **Real Time Monitoring & Diagnostics:** Early-stage RDD&D on low-cost and reliable multi-sensing wired and wireless technologies to conduct process monitoring and component health by measuring critical process parameters that, with additional investment by industry, could be capable of providing real-time information critical to the operation, reliability, and efficiency of next-generation power systems.
- **Advanced Controls:** Advanced control algorithm development is critical in the optimization of systems with highly coupled, nonlinear interactions. Dynamic controls and integration will enable flexible operation of energy systems, including load following, demand response, and hybrid energy integration, while enhancing safety and grid stability.
- **Condition-Based Maintenance:** Advances in sensor RDD&D will enable industry to shift from time-based preventive maintenance to predictive condition-based maintenance with improved reliability and overall plant economics. This could save millions of dollars in maintenance costs across all power cycles.
- **Cyber Security:** Consists of a range of project areas that focus on the protection of fossil-based power generation assets from cyber threats. This focus area conducts gap analyses to develop automated awareness technologies, data integration tools, and blockchain technologies to harden potential targets. Some sub-areas are:
    - **Machine Learning (ML):** Develops technologies that monitor power plant networks to identify abnormal behaviors because of operational issues or a malicious cybersecurity event.
    - **Blockchain and Distributed Ledger Technology**: Blockchain can facilitate detection of manipulated data. It's ability to secure data in a distributed and decentralized manner gives

utilities protection against unauthorized access. Testing programs are needed to properly evaluate blockchain-based concepts.

Simulation-Based Engineering

The Simulation-Based Engineering (SBE) activity includes computational software development, HPC, advanced optimization, TEA, and artificial intelligence (AI) and ML. Simulations generate information beyond the reach of experiments alone, rapidly, and inexpensively. They enable the discovery of new materials, optimization and troubleshooting of novel devices, and the design and optimization of complex process systems. This activity also comprises modeling, simulation, and TEA to resolve challenges and optimize power plants as they integrate with a dynamic, evolving electricity grid. Key objectives include improving the reliability, flexibility, and economics of the next generation fleet and the industrial and manufacturing sectors.

In FY 2023, the Budget Request for SBE provides $6 million to continue funding for DOE National Laboratory RDD&D, including existing modeling and analysis projects funded under the Grid Modernization Initiative (GMI); and the NETL-led Institute for the Design of Advanced Energy Systems (IDAES) in collaboration with Sandia National Laboratory (SNL) and Lawrence Berkeley National Laboratory (LBNL), which develops process systems engineering tools and optimized approaches in the conceptual design and process intensification of innovative systems. The Multiphase Flow with Interphase exchanges (MFiX) element, led by NETL, will also support computational efforts, including ML, in collaboration with industry, to gain deep insight into plant operation to improve performance outcomes and reduce unexpected, forced outages. In addition, the funding will allow the upkeep of capabilities associated with the Computational Fluid Dynamics (CFD) for Advanced Reactor Design (CARD) and IDAES activities. The CARD activities include the development of models that allow the production of hydrogen from biomass and plastics. The physics-based model will allow for proper scale-up when the technology is ready for commercialization. IDAES activities will focus on continuing support for the stakeholder communities and developing new features and capabilities to address the challenges associated with the design and operation of integrated energy systems to enable deep decarbonization of the energy and industrial sectors.

HCM closely coordinates its hydrogen RDD&D with the Office of Energy Efficiency and Renewable Energy (EERE) Hydrogen and Fuel Cell Technology Office (HFTO) to work collaboratively where appropriate and to ensure no duplication of effort. Intra-agency coordination includes the following DOE Offices: EERE, FECM, Office of Science (SC), Office of Nuclear Energy (NE), Advanced Research Projects Agency (ARPA-E) and the Office of Electricity (OE). The Science and Energy Technology Team (SETT) will strengthen collaboration with all DOE offices, including the crosscutting offices (such as the Office of Technology Transitions (OTT) and the Loans Program Office (LPO)) involved with various hydrogen initiatives.

Carbon Management Technologies
Hydrogen with Carbon Management

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Hydrogen with Carbon Management: $122,300,000	**$74,000,000**	**-$48,300,000**
Gasification Systems $19,000,000	**$26,000,000**	**+$7,000,000**
• Announced funding opportunity announcement (FOA) Enabling Gasification of Blended Coal, Biomass and Plastic Wastes to Produce Hydrogen with Potential for Net Negative Carbon Dioxide (CO_2) Emissions. • Research, development, demonstration, and deployment (RDD&D) focusing on early-stage research of carbon-neutral or carbon-negative transformational technologies (e.g., chemical looping, topping cycles, magnetohydrodynamic (MHD), etc.) that will allow the coal-fired fleet to evolve and maintain a viable source of clean and secure energy. • Innovate technologies to enable Ultra High Pressure (UHP) gasifier (up to 300 bar) suitable for use in a direct-supercritical carbon dioxide ((s)CO_2) power cycles.	• Develop robust, fuel-flexible, load-following modular gasification systems, specifically for community-scale gasification of legacy coal waste and opportunity feedstock. • Develop process technology that integrates oxygen separation from air and uses advanced techniques for gasification of waste feedstocks. • Develop small-scale, modular microwave reactor technologies that expand the capability to use low value and waste feedstocks (including waste plastics and legacy coal waste and biomass).	• Additional funding will accelerate development gasification systems that utilize legacy coal waste, plastics, and waste biomass with carbon capture and storage (CCS) to reach negative emissions. • Development of materials for hydrogen and ammonia turbines. • Support hydrogen retrofit packages for existing turbines. • Support reversible solid oxide fuel cells (R-SOFC) systems capable of continuous operation.
Advanced Turbines $27,000,000	**$27,000,000**	**$0**
• Funding for hydrogen gas (H_2) front-end engineering design (FEED) studies and Critical Components. • University Turbine Systems Research (UTSR) FOA.	• Support new designs for hydrogen, ammonia, and gas with carbon capture turbine components, advanced cooling techniques, aerodynamics, sealing, combustion systems and materials. • Supports UTSR.	• The funding will be utilized for FOAs addressing topic areas in 100% hydrogen turbines. • Development of hydrogen combustion systems for retrofit applications and new gas turbines.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Reversible Solid Oxide Fuel Cells $30,000,000	**$5,000,000**	**-$25,000,000**
• Integrated Energy Systems work with the Idaho National Laboratory (INL). • Funding for National Energy Technology Laboratory (NETL) and other National Labs for electrode engineering innovation, systems analysis on SOFC (solid oxide fuel cell)/SOEC (solid oxide electrolyzer cell)/R-SOFC as part of an energy system. • FOA on SOEC Technology Development for Hydrogen Production.	• Investigate reversible SOFC/SOEC operation and system studies to integrate heat required for SOEC operation from other processes (e.g., nuclear). • Mature SOFC technologies and advance RDD&D on SOECs. • Focus on carbon neutral hydrogen production from SOECs.	• The decrease in funding will not impact ongoing RDD&D. Significant investment has been made with industry in previous fiscal years – results from this RDD&D will be known in FY 2023.
Advanced Energy Materials $16,100,000	**$5,000,000**	**-$11,100,000**
• Completed ComTEST R&D. • FOA on nickel (Ni) Alloy Cost & Cycling. • Appalachian Regional Commission Welding Workforce Training partnership.	• Funding is shifted to focus on areas that will have a significantly greater impact on achieving a net-zero carbon economy by mid-century. • Evaluate the impacts of hydrogen on materials to develop models critical to understanding hydrogen-related impacts to establish a new domestic supply chain of hydrogen resistant materials.	• Continue development of models critical to understanding hydrogen-related materials impacts to establish a new domestic supply chain of hydrogen resistant materials.
Sensors and Controls and other Novel Concepts $8,000,000	**$5,000,000**	**-$3,000,000**
• Development and deployment of wireless sensor systems. • RDD&D on optical fiber sensors, applied diagnostics, and quantum sensing.	• RDD&D on low-cost and reliable multi-sensing wired and wireless technologies. • Develop technologies that monitor power plant networks to identify abnormal behaviors because of operational issues or a malicious cybersecurity event.	• The decrease in funding is a result of less focus on advanced coal plants, however, FECM continues to maintain focus on the industrial sector and continue funding for NETL and other National Labs efforts in this area.
Simulation Based Engineering $6,200,000	**$6,000,000**	**-$200,000**
• Supports the development of interactive visualization technology and data communication optimization methods to improve the design and operation of advanced	• Supports the development of interactive visualization technology and data communication optimization methods to improve the design and operation of advanced	• Funding will allow the program to work directly with stakeholders of existing power generation units to validate the models and provide valuable information to make the models robust.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
power systems with carbon capture and sequestration. • Provides first principle and physics-based modeling of phenomenon for complex energy conversion and carbon capture processes.	power systems with carbon capture and sequestration to meet decarbonization goals. • Provides first principle and physics-based modeling of phenomenon for complex energy conversion and carbon capture processes. • Continue the development, validation, application, and support of the multiphase flow with Interphase eXchanges (MFiX) computational fluid dynamics (CFD) software suite. • Continue working on the design, scale-up, and optimization of pyrolysis and gasification reactors for Hydrogen production from biomass and plastics.	• The funding allows the application of these models to integrate the waste heat from heavy industries including steel and cement. • Continue supporting the stakeholder communities and developing new features and capabilities to address the challenges associated with the design and operation of integrated energy systems to enable deep decarbonization of the energy and industrial sectors.
Transformative Power Generation $16,000,000	**$0**	**-$16,000,000**
• Selected four FEED studies to support the 21st Century Power Plant that includes the Critical Components FOA that is funded by relevant programs.	• No funding requested.	• Funds are re-allocated to higher priority activities.

Carbon Management Technologies
Carbon Transport and Storage

Description

The Carbon Transport and Storage (CTS) subprogram is focused on the development of infrastructure and carbon management technologies for the safe and secure transport and geologic storage of CO_2 captured from point sources and the air. Research, development, demonstration, and deployment (RDD&D) in this area is critical to validating and increasing confidence in the safety, affordability, and permanence of CO_2 injection and storage and the associated transport infrastructure necessary to connect source and storage resources. This area of research is in the national interest since it has long-term economic and environmental benefits for the U.S. and industry, and it contributes to the Administration's decarbonization goals. These benefits may be realized through financial incentives to store CO_2, such as the California Low Carbon Fuel Standard and changes to the Section 45Q tax credit as amended in the 2018 Bipartisan Budget Act. Further advancements in CO_2 transport and storage technology and performance will help ensure that industry has verifiable information to economically plan and monitor the necessary CO_2 transport infrastructure and safely assess and monitor long-term storage of CO_2 at commercial volumes and timeframes and ensure the viability of geologic carbon storage to enable CO_2 mitigation and removal that can be widely implemented. This includes supporting dedicated storage in saline formations, mineralization, depleted oil and gas fields, and existing natural deposits of CO_2 that could be repurposed for dedicated storage.

Carbon Transport and Storage

Carbon Capture, Utilization[1], and Storage (CCUS) is a critical component of the Administration's broad efforts to meet net-zero CO_2 emissions by 2050. Geological storage of CO_2 has been a natural process in the Earth's upper crust for hundreds of millions of years, and while this supports the concept that CO_2 can be securely and safely contained in the deep subsurface, having the technical means to identify suitable sites and monitor stored CO_2 to verify secure containment and regulatory compliance is vitally important. The U.S. Department of Energy (DOE) Office of Fossil Energy and Carbon Management (FECM) has supported a Carbon Transport and Storage RDD&D subprogram to develop the technologies and capabilities for widespread commercial deployment of geologic storage. FECM's investments have made DOE a world leader in CCUS technology development. Carbon transport is also a demonstrated industry in the United States with over 5,000 miles of operational CO_2 pipelines constructed over the past 50 years that today service the transport of about 60 million metric tons of CO_2 per year, currently associated primarily with Enhanced Oil Recovery (EOR). One of the challenges to broadly deploying CCUS and carbon dioxide removal (CDR) nation-wide to meet the Administration's decarbonization targets will be the need to construct a concomitant CO_2 transport system, primarily pipelines, designed to connect capture from sources of direct air capture to dedicated storage to eventual service injection rates of up to 1.5 billion metric tons of CO_2 per year by 2050.

CCUS projects supported by DOE and other organizations around the world, which injected more than 25 million metric tons of CO_2 in 2019, have demonstrated secure geologic storage of CO_2 in many different geologic formations with a diversity of depositional environments and shown to be safe to human health and the environment. Increasing years of experience and a preponderance of successful RDD&D projects will promote even further confidence in secure geological storage for operators, regulators, insurers, financial institutions, environmental groups, and the public. The Regional Carbon Sequestration Partnership (RCSP) Initiative has demonstrated the technical viability of secure geologic storage of CO_2 through their successful injection and validation of secure storage of over 11 million metric tons of CO_2 into a variety of reservoir types. The success of the RCSP initiatives has provided the lessons learned and technology validation for scaling up to commercial operations. This transition began in 2016 when FECM launched the multi-phase Carbon Storage Assurance Facility Enterprise (CarbonSAFE) Initiative. Additionally, the successors of the original seven RCSPs, now consolidated to four projects and referred to as the Regional Initiative projects, will continue to serve their broad stakeholder base with technical assistance and project development. These initiatives and other RDD&D activities are advancing storage security and performance and are driving the CTS subprogram forward to accelerate commercial CCUS deployment.

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[1] Utilization refers to uses of CO_2 as a feedstock for developing products with market value, excluding CO_2-enhanced hydrocarbon recovery.

The Budget Request provides $122 million for RDD&D activities that address the performance challenges of operating and monitoring commercial scale CO_2 storage sites. The RDD&D supported by the CTS subprogram in FY 2023 will improve storage and operational efficiency, improve understanding of overall cost and de-risking strategies to reduce it. Achieving each of these elements is critical for enabling a CCUS industry that is safe, affordable, and environmentally benign.

Storage Infrastructure

The Storage Infrastructure activity is expected to make a substantial contribution toward meeting the Administration's decarbonization goals. The critical part of this contribution is investing in activities that will help expand the commercial on- and offshore CO_2 storage capacity as defined by the Society of Petroleum Engineers (SPE) CO_2 Storage Resources Management System (SRMS) that will serve as the storage sites and hubs for CO_2 captured from point sources and the air. In this effort, the Storage Infrastructure activity will focus primarily on broadening field activities that advance commercial-scale storage projects through the feasibility process of project development, which will include community engagement and environmental justice considerations. The sub-activities within the Storage Infrastructure activity will be designed to support and align with congressional direction on CCUS as outlined in the Bipartisan Infrastructure Law (BIL).

The CTS Budget Request includes $90 million for Storage Infrastructure that will leverage active field projects supported by prior year funding and conduct RDD&D as part of the multi-phase CarbonSAFE efforts to characterize, analyze and evaluate storage opportunities for onshore and offshore formations that will support the deployment of CCUS in the power, hydrogen, and hard-to-decarbonize industrial sectors, as well as CDR. The funding will also support the Regional Initiative to select additional technical assistance projects to develop hubs, regional characterization, and technical assistance to stakeholders in state governments that may be responsible for regulating or overseeing carbon transport and storage efforts. The Regional Initiative projects are playing an important role in providing technical, regulatory, and project development assistance to their respective regional stakeholders. Historically, FECM has funded field projects to conduct regional and site-specific characterization and validation; simulation and risk assessment; and applied monitoring, verification, accounting, and assessment technologies (MVAA) to various onshore and offshore storage reservoirs. These projects have been successful in improving our understanding of CO_2 injection, fluid and pressure migration, and geochemical and geomechanical impacts from CO_2 injection. In an effort to make further improvements in the cost and performance of applied monitoring technologies the Storage Infrastructure activity will competitively seek to award several Carbon Storage Technology and Operational Research (CarbonSTORE) facilities that will be linked with active commercial-scale CCUS projects and serve as field laboratories for testing new technologies and providing real-world data for program-wide RDD&D efforts. FY 2023 activities will also leverage the experience and findings of on-going and new field efforts to improve understanding of national infrastructure and transport needs, onshore/offshore deployment, leveraging existing oil and gas infrastructure and natural CO_2 deposits to convert these systems for dedicated storage; impacts of financial incentive to deployment, and storage hub resource assessments and efficiencies. Research will also be conducted through national laboratories in support of new field projects and to complete on-going field studies that were initiated with prior year appropriations. Systems modeling of a transportation system to support the wide scale transport and storage of CO_2 will also be supported to determine opportunities for developing the most efficient transport system.

Advanced Storage RDD&D

The Advanced Storage RDD&D activity is focused on developing and validating CO_2 storage technologies that lower cost and improve capabilities in plume detection, storage efficiency, secure storage verification, subsurface stress assessments, and legacy wellbore integrity assessment and repurposing in oil, gas, and natural CO_2 domes. Current CO_2 storage technologies have largely been developed and tested at the laboratory, pilot, and large field test scale. In anticipation that the Bipartisan Infrastructure Law (BIL) will accelerate the growth of commercial-scale carbon capture and storage (CCS) and DAC projects, the Advanced Storage RDD&D activity will focus primarily on the optimization of monitoring systems applied at commercial scale projects that reduce cost, improve performance, and enable more rapid decision making for storage operators.

The CTS Budget Request includes $32 million for the Advanced Storage RDD&D activity. Previous efforts in this activity have supported the development of new machine learning/artificial intelligence (ML/AI) tools and technologies through the Science-informed Machine learning to Accelerate Real-Time decisions for Carbon Storage (SMART-CS) initiative. FY 2023 funds for the Advanced Storage RDD&D activity will continue to support SMART-CS through the development of new or improved sensors, power and telemetry systems, and data analytics and integration methods that will generate data streams needed by SMART-CS ML-based algorithms. FY 2023 funds will also support priority RDD&D on site/hub characterization tools and techniques for improved assessment of contingent and commercial storage capacity as defined by the CO_2 SRMS. Additional activities include RDD&D to advance fault/fracture networks characterization and associated stress state, fluid/pressure migration management, legacy wellbore assessment and repurposing or oil, gas, CO_2 production, and waste-water injection well; and intelligent systems for adaptive reservoir management. The program will also be supporting investment in the materials and retrofitting existing CO_2 transport systems that are currently used for other fluids such as methane. FY 2023 funds will also continue to support the curation of data from CTS supported projects into the DOE National Energy Technology Laboratory (NETL) Energy Data Exchange (EDX), which has been serving as the portal for public access to CTS data products.

Sub-disciplinary Storage RDD&D (formerly Carbon Sequestration Science)
All efforts from this control point are redirected towards Advanced Storage RDD&D.

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Carbon Transport and Storage: $79,000,000	**$122,000,000**	**+$48,800,000**
Storage Infrastructure: $57,500,000	**$90,000,000**	**+$32,500,000**
• Support Phase III of the Carbon Storage Assurance Facility Enterprise (CarbonSAFE) Initiative and the Regional Carbon Capture, Utilization, and Storage (CCUS) Deployment Initiative projects. • Perform infrastructure network studies and analyses for carbon dioxide (CO_2) source and Enhanced Oil Recovery/storage matching, and early-stage research, development, demonstration and deployment (RDD&D) for high priority activities.	• Supports competitive selection of additional Phase II CarbonSAFE projects to characterize, evaluate, and analyze the feasibility of onshore and offshore storage sites and hubs for dedicated storage in saline formations, depleted oil and gas assets, CO_2 domes, and deposits for mineralization. • Supports competitive selection of Carbon Storage Technology and Operational Research (CarbonSTORE) projects to serve as field laboratories at commercial CO_2 storage sites for dedicated storage, which will be critical for testing new and potentially lower-cost storage monitoring technologies and systems and providing real-world data for program-wide RDD&D efforts. • Supports Regional Initiative as regional technical assistance to carbon capture and storage stakeholders and project developers. • Supports capabilities development in support of national transport network planning and cost analyses. • Supports economic and market analysis for commercial-scale onshore and offshore geologic storage of CO_2.	• Funding prioritizes CarbonSAFE Phase II storage opportunities and CarbonSTORE field labs that will have broad applicability to support the hydrogen, power, industry, and negative emission technology applications. • Funding also continues the Regional Initiative to provide technical assistance to their respective stakeholders to help facilitate CCUS deployment within their regions for projects and hubs.
Advanced Storage: RDD&D: $15,700,000	**$32,000,000**	**+$16,300,000**
• Supports RDD&D to advance sensing and data telemetry capabilities, and high priority studies on fault/fracture networks characterization, stress state, fluid/pressure migration, and wellbore	• Supports competitive selection of RDD&D projects on high priority topics including legacy well assessment, above-zone monitoring methods and	• The increase supports priority RDD&D that enable Artificial Intelligence/ML-based technologies and approaches for optimizing performance of commercial-scale storage operations. Increase also

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
integrity monitoring that advance adaptive reservoir management capabilities. • Continue support for National Risk Assessment Partnership (NRAP). • Continue machine learning (ML) RDD&D to advance forecasting capabilities and improve real-time operational performance.	tools, existing well and pipeline repurposing for CO_2 transport and storage. • Supports RDD&D on advance tools, sensors and monitoring systems that create data and data streams compatible with Science-informed Machine learning to Accelerate Real-Time's (SMART) ML algorithms and capabilities. Topics of interest include advanced fiber optic sensing, wireless power systems, data integration/inversion methods, low-cost continuous monitoring systems. • Support RDD&D on the characterization and analysis of mineralization of CO_2 in geologic deposits with reactive materials, such as serpentines. • Continued support for Energy Data Exchange data curation and platform maintenance.	supports priority RDD&D on improving site/hub characterization tools and techniques critical for assessing contingent and commercial storage capacity as defined by the Special Petroleum Engineer's CO_2 Storage Resource Management System. Increase support for RDD&D on mineralization of CO_2 in geologic deposits.
Sub-disciplinary Storage R&D: $5,800,000	**$0**	**$0**
• The National Energy Technology Laboratory (NETL) and other National Laboratory funding for RDD&D activities on reservoir performance, applied monitoring, verification, accounting, and assessment technologies (MVAA), geomechanics, wellbore integrity, and risk assessment.	• No funding is requested for FY 2023.	• All efforts from this control point are redirected towards Advanced Storage RDD&D.

Carbon Management Technologies
Carbon Dioxide Removal

Description

Many modeling scenarios to achieve economy-wide decarbonization suggest that carbon dioxide (CO_2) removal (CDR) will be required in the future. CDR refers to activities that remove CO_2 from the atmosphere and store it in geologic formations, products, terrestrial sinks, or in the ocean. CDR activities include direct air capture (DAC), direct ocean capture (DOC), biomass with carbon removal and storage (BiCRS), mineralization, terrestrial carbon removal and sequestration (e.g., agricultural land management, afforestation, reforestation), and coastal blue carbon (e.g., CO_2 storage in wetlands).

The U.S. Department of Energy's (DOE) Office of Fossil Energy and Carbon Management (FECM) supported a 2019 study by the National Academies of Sciences, Engineering, and Medicine (NASEM) on CDR. Two key findings of the report are:

- Negative emissions technologies (NETs) or CDR, are best viewed as part of a decarbonization portfolio that first achieves maximal emissions mitigation.
- NETs/CDR would likely need to play a large role on the order of gigaton removal assisting us in meeting our net-zero greenhouse gas emissions goal.

FECM has been working on carbon capture, utilization, and storage (CCUS) projects for almost 20 years and has invested heavily in the development of technologies to capture relatively high concentrations of CO_2 from power plants and industrial sources. More recently, the Department has been applying this technology development to various NETs, including BiCRS and DAC, which requires capture of extremely low concentration CO_2 from the atmosphere.

An objective of CDR is to advance technologies to make significant progress towards reaching DOE's Carbon Negative Shot target of less than $100/net metric ton CO_2 equivalent for both capture and durable storage. Investments in various CDR approaches—DAC, DOC, BiCRS, and mineralization—can help reduce cost and optimize performance. Through these investments, DOE will help advance promising technologies in partnership with industry, academia, and national laboratories, while maintaining focus on ensuring future deployments are conducted in a manner that ensures social and environmental justice.

The FECM CDR subprogram was a new budget line in the FY 2022 Budget Request. The FY 2023 Budget Request is focused on DAC, DOC, BiCRS, and mineralization concepts. However, it builds upon past CCUS efforts, which have been funded through FECM's CCUS activities, such as past work on mineralization, co-firing of biomass, and capture technology development.

Activities to develop and commercialize DAC systems largely follow known chemical and physical methods (e.g., solvents and solid sorbents). Due to the low concentration of CO_2 in the air, the volume of gas flow per ton of CO_2 captured is much larger for DAC systems compared to point sources. Subsequently, the power requirements to overcome the pressure drop in vertical packed tower configurations would contribute to both significant capital and operating costs. Therefore, designs based on conventional scrubbing technology are now recognized as not broadly applicable to DAC systems, motivating separate subprograms in point-source capture and CDR.

Concerted research, development, demonstration, and deployment (RDD&D) is needed to reduce costs and the energy penalty, and improve scalability, siting, and operations. Efforts will focus on conducting materials and components RDD&D, pilot-scale testing, front-end engineering and design (FEED) studies, and large-scale extended tests. It should be noted that first generation technologies will also continue to improve, and RDD&D conducted for transformational technologies may also improve the processes and components of first-generation technologies.

BiCRS offers an opportunity for near-term deployment of CDR technologies. Biomass can be used to produce various products—power, fuels, chemicals—similar to other carbon-containing feedstocks such as coal, oil, and natural gas. The biomass consumes CO_2 from the atmosphere, through photosynthesis, during its growing phase and releases this CO_2 when it is subsequently processed and consumed (i.e., power generation, fermentation, etc.). However, if this CO_2 is captured and permanently stored, the CO_2 is removed from the atmosphere.

The point-source carbon capture technologies that currently exist and are being developed for power generation and industrial sources through the Point-Source Carbon Capture subprogram can be applied to biomass conversion facilities. Technology improvements in capital and operating costs, energy penalty, and integration are directly applicable in the case of power generation and gasification processes.

The NASEM report characterizes carbon mineralization as occurring at the surface (ex situ) as well as subsurface (in situ). Carbon mineralization has the potential to use alkaline-containing rocks and minerals, including materials such as mine tailings and wastes, to react with CO_2 and permanently store it as a solid material.

In-situ mineralization is part of the Carbon Transport and Storage subprogram's activities where there has been an extensive RDD&D program on geologic carbon storage over the past two decades. This work has included studies and field tests on injection of CO_2 into subsurface formations such as basalts. In addition to this subsurface (i.e., in situ) RDD&D, FECM previously conducted various studies and experimental work on surface/ex situ carbon mineralization. A more recent analysis by the United States Geological Survey (USGS),[1] provides a summary of the potential for ex situ and in situ carbon mineralization opportunities in the United States. The study suggests that the use of mine tailing and alkaline industrial wastes already at the surface can be a competitive option for CO_2 removal.

For all the CDR approaches, life cycle analyses (LCA) are critical to ensuring the viability of the various technologies to confirm the process is removing more CO_2 from the atmosphere than generated by the process over its lifecycle. While LCA is a common tool and approach in many industries and for many processes, it is currently evolving in the CDR area. Many technologies are relatively new, and the energy inputs required can significantly impact the LCA. Further RDD&D on the CDR approach is necessary to provide the fundamental scientific and technical basis for LCA tools and methodologies. Coupling together RDD&D, LCAs and techno-economic analyses (TEAs) will ensure assessments can be made on the best available information, which will also inform global assessment models and decarbonization scenario analyses.

[1] Blondes, M.S., Merrill, M.D., Anderson, S.T., and DeVera, C.A., 2019, Carbon dioxide mineralization feasibility in the United States: U.S. Geological Survey Scientific Investigations Report 2018–5079, 29 p., https://doi.org/10.3133/sir20185079

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Carbon Dioxide Removal: $40,000,000	**$65,000,000**	**+$25,000,000**
• Supported continued development of transformational direct air capture (DAC) materials and structural components, and initial feasibility studies of current DAC systems. • National Laboratory research, development, demonstration, and deployment (RDD&D) evaluated challenges and concepts for ex situ mineralization and enhanced weathering concepts. • Evaluated coal-biomass co-feeding concepts coupled with carbon capture, utilization, and storage at existing facilities.	• Continue development of transformational DAC materials and components, and feasibility studies of current DAC systems. • Continue RDD&D on mineralization and enhanced weathering concepts. • Evaluate biomass with carbon removal and storage (BiCRS) concepts at existing facilities.	• The increase in funding expands efforts on mineralization and enhanced weathering concepts. • The increase in funding allows for field testing of BiCRS concepts.

Carbon Management Technologies
Carbon Dioxide Conversion

Description

The Carbon Dioxide Conversion subprogram develops technologies to convert carbon dioxide (CO_2) into economically valuable products manufactured in a just and sustainable manner. Research, development, demonstration, and deployment (RDD&D) activities within the subprogram address the challenges and potential opportunities associated with maturing conversion technologies, scaling systems to commercial deployment, and integrating systems with various emission point sources or carbon capture systems. RDD&D in this area is critical to validating the emissions reduction of CO_2-based products, producing economically viable technologies, and supporting the broader ecosystem for technology deployment. This is an area of national research interest since it has long-term economic and environmental benefits for the U.S. and industry. These benefits may be realized by financial incentives to utilize or convert CO_2 such as the California Low Carbon Fuel Standard, regional procurement policies for lower-carbon or sustainably produced materials, and the incorporation of utilization pathways to the Section 45Q tax credit, as amended in the Bipartisan Budget Act of 2018. Further advancements in carbon conversion technology will help ensure that industry has verifiable information to assess economically and accurately the greenhouse gas (GHG) life cycle of CO_2-based products. In addition, the creation of widely implementable platform technologies for emissions solutions can capitalize on a variety of opportunities such as excess low-carbon electrons, industrial waste heat, and byproduct streams such as waste heat integration, wastewater reduction, flue gas contaminant reduction, and reduced energy demand.

Given the variety of challenges in CO_2 conversion technologies, there are many opportunities to improve systems. For example, RDD&D aims to enhance product yields by improving catalyst selectivity and energy efficiency, integrate carbon neutral hydrogen production, and advance process engineering and design. Other challenges include the energy-intensive preparation of reactants to achieve feasible conversion or required additives that must be regenerated and recycled, which requires energy. The result is an energy penalty for the utilization system. Other hurdles include higher cost for novel processes, conservative risk attitudes in established product markets such as the building sector, and limited field trials and demonstrations to prove viability and diminish risk.

Carbon Dioxide Conversion

The Carbon Dioxide Conversion subprogram focuses on novel approaches to recycle carbon oxide (CO_x) emissions, principally CO_2, into value-added products. Potential feedstocks include flue gas from power generation, industrial point sources, captured/concentrated CO_2, aqueous sources, mixed gas streams, or the atmosphere. These carbon sources are then converted through a bio-mediated, catalytic, mineralization, or hybrid pathway. Some processes are already commercially available while others are in the very early stages of RDD&D.

Each conversion technology comes with challenges and opportunities. A critical challenge across conversion technology pathways (mineralization, catalytic conversion, and bio-mediated) is the cost-effective, energy-efficient, and selective upgrading of CO_2. This subprogram will work to address the need for enabling technologies including using carbon-neutral hydrogen (H_2) as a reactant in the synthesis of fuels and chemicals and maintaining an alkalinity source for mineralization. The efficiency of reaction conversion, amount of CO_2 stored in a product and energy use of these utilization processes also represent a critical challenge that the Office of Fossil Energy and Carbon Management (FECM) can address as it is uniquely positioned to efficiently assess and invest in the life cycles of these developing technologies.

The FY 2023 Budget Request provides $50 million for this subprogram and supports lab- and bench-scale CO_2 conversion technologies that have the potential to develop environmentally and socially responsible CO_2-based products. Areas of research include, but are not limited to, new projects focused on the catalytic conversion to higher value products such as fuels, chemicals, and polymers; mineralization to building materials; generation of synthetic aggregates; and algal systems with high CO_2 utilization efficiency to various bioproducts. The subprogram aims to continue investment activities from FY 2022, such as reactive capture and conversion, and progress first generation conversion technologies to field-scale testing. Additional efforts will include guidance on benchmarking prototypical catalytical conversion, such as electrochemical reduction, for CO_2 utilization as well as developing techno-economic analysis (TEA) guidance for screening various technology pathways or product markets. Funding will support the development of at least one, fully integrated field-test continuous system as well as continued support for carbon conversion test facilities at the National Carbon Capture Center (NCCC).

Carbon Management Technologies
Carbon Dioxide Conversion

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request Level	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Carbon Dioxide Conversion: $23,000,000	**$50,000,000**	**+$27,000,000**
• Lab- and bench-scale technologies to convert carbon oxides (CO_x), principally carbon dioxide (CO_2) into valuable products such as chemicals, fuels, and building products. • Support development of at least one integrated CO_2 utilization system.	• Lab- and bench-scale technologies to convert CO_2 into valuable products such as chemicals, fuels, bioproducts and building materials. • Increased field-scale testing of technologies to pilot scale. • Standardized benchmarking for catalytic conversion systems.	• The increase in funding allows continued development of at least one CO_2 utilization integrated system. • The increase allows for scale up and higher-technology readiness level field testing of promising conversion technologies, such as at the National Carbon Capture Center.

Carbon Management Technologies
Point-Source Carbon Capture

Description

Advancements in carbon capture technologies can support United States (U.S.) efforts to decarbonize power generation and industry. Carbon capture from power generation is a technology approach for mitigating carbon dioxide (CO_2) emissions, and for concentrating CO_2 for applications such as conversion to products. Transformational carbon capture technologies will advance U.S. leadership in low-emission generation and clean hydrogen (H_2) innovation, supporting its efforts in achieving a decarbonized power sector by 2035 and a decarbonized economy by 2050. CO_2 capture technologies can be applied to a wide variety of sources such as power plants, ethanol, ammonia, cement, steel, chemical facilities, and other sources. Research, development, demonstration, and deployment (RDD&D) is focused on adapting technologies to under-investigated applications like natural gas power and industry and making them robust enough to capture greater than 95% of the CO_2 emissions from a wide variety of sources. RDD&D is needed on both the materials and systems configurations to address challenges such as differences in pollution control systems, oxygen content, CO_2 concentrations, and unique integration issues.

RDD&D is needed to improve economies of scale and address the technical challenges posed by increased capture efficiency, such as improved thermodynamics (reduced energetic requirements, lower pressure drops, lower temperature, process optimization), and kinetics (faster, more selective chemical/physical separation pathways). Process intensification and advanced manufacturing can reduce capital and operating costs. Scalability, durability, and flexibility are challenges that must be met to ensure long-term performance and the ability to work with variable power and capture rates.

The Department of Energy's (DOE) Office of Fossil Energy and Carbon Management's (FECM) Point-Source Carbon Capture (PSCC) subprogram is focused on RDD&D of carbon capture technologies that play a key role in decarbonizing committed emissions associated with the power sector and hard-to-decarbonize industries. The PSCC subprogram is developing capture technologies that are flexible to complement the ever-changing power grid while simultaneously capable of achieving deep decarbonization of emission sources.

- The PSCC subprogram has completed its efforts in 1st generation technology through successful demonstration projects. FY 2023 activities represent a focus on next-generation capture technologies to enable clean H_2 and allow for the integration of advanced carbon capture technologies with both power and diverse industrial emission sources. Specifically, the FY 2023 Budget Request provides $163 million to the PSCC activities for pre- and post-combustion capture RDD&D on transformational gas separation technologies capable of deep decarbonization (at least 95% of CO_2 at 95% purity). These investments can improve energy efficiency, reduce capital costs, and achieve high capture rates.

These transformational technologies will be designed to adapt to the operational demands of current and future power systems including the increasing need for thermal power plants to, at times, be load-following/demand-responsive electricity generators. The activity will investigate approaches to optimize the capture process for all point sources such as natural gas-based power systems including both natural gas combined cycle (NGCC) systems and simple cycle operations.

Additionally, the PSCC subprogram will leverage its prior and current RDD&D experience on carbon capture technology development for application to industrial applications. RDD&D will focus on optimization of technologies for these applications to reduce cost and improve performance.

Key RDD&D challenges for PSCC include:

- Improving Scalability – providing economic viability at all relevant process scales across all types of CO_2 emissions sources in the power and industrial sectors.
- Improving Thermodynamics – reducing energetic requirements through better regeneration energy, lower pressure drops, lower required temperatures, and process optimization.
- Improving Kinetics – improving equipment through faster, more selective chemical/physical separation pathways.

- Reducing Capital Cost – reducing equipment size and costs through advanced manufacturing, process intensification, integration, and optimization.
- Improving Durability – providing rugged long-term performance with slow degradation rates.
- Improving Flexibility – improving process dynamics by improving turn down and operation at variable capture rates.
- Minimizing Environmental Impact – providing technologies that minimize air pollution release and minimizing waste generation.

The PSCC subprogram will also focus on carbon capture front-end engineering design (FEED) studies for power plants and industrial sources. FEED studies are a critical step in the process for eventual technology deployment. They help define the design of the system and provide valuable technical input for eventual investment decisions. FEED studies also help identify potential areas for RDD&D and information to validate techno-economic studies and lifecycle analyses. The PSCC also supports FEED studies of highly efficient carbon capture technologies for natural gas and waste-to-energy powerplants. One study of interest is emissions sources co-located with the Carbon Storage Assurance Facility Enterprise (CarbonSAFE) projects, which is funded by the Carbon Transport and Storage subprogram.

Post-Combustion Capture Systems

Post-combustion capture refers to the capture and separation of CO_2 after fuel is combusted. The FY 2023 PSCC subprogram Budget Request includes $144.4 million for RDD&D in Post-Combustion Capture Systems, for transformational CO_2 capture RDD&D at both new and existing power plants, and industrial systems such as steel, cement, hydrogen production, and chemicals. Critical RDD&D milestones have been achieved since 2008 in laboratories through pilot-scale testing of 2nd generation CO_2 capture approaches through multiple small-scale (0.5-1 MWe) slipstream tests and several large-scale (13 MWe) tests on flue gases from different power systems and industrial sources. It is expected that government-industry partnerships will continue the development, adoption, and commercialization of these technologies.

Activities in FY 2023 will continue to focus on RDD&D for novel CO_2 capture technologies such as non-aqueous solvents, membranes, advanced sorbents, and cryogenic processes. This will be achieved using advanced computational tools for rational material discovery, design of advanced capture systems components, use of advanced manufacturing, and synthesis of these materials with characterization of their physical properties. Funding will continue to support the National Carbon Capture Center (NCCC) to provide testing on actual flue gas.

Pre-Combustion Capture Systems

Pre-combustion capture refers to separation of CO_2 from the syngas (or other high-pressure streams) prior to its combustion for power production, or the separation of CO_2 to produce H_2 or other products.[1] Specifically, two systems can generate H_2 from natural gas—steam methane reformers (SMR) and autothermal reformers (ATR). SMRs remain the most economical and widespread way to produce H_2 and currently account for over 90% of the H_2 produced globally. Pre-combustion technologies can be used to lower the carbon intensity of H_2 from these systems. Discussion regarding new ATR construction is becoming increasingly more common as the inherent ATR process concentrates CO_2 and allows for deeper decarbonization using pre-combustion technologies at lower cost than SMRs.

DOE's pre-combustion PSCC activity is focused on pursuing transformational capture goals which require capture greater than 95%. Technologies for pre-combustion capture complement research that is ongoing in creating new fundamental knowledge of advanced gasification systems, including the 21st Century Power Plant, and could be applied to H_2 production and other industrial processes.

Emissions Control

The Emission Control subprogram, created in FY 2020, focuses on reducing the costs and emissions of non-CO_2 pollutants associated with the use and combustion of carbon-containing fuels. This effort would conduct systems analyses and technical assessments to identify and address issues associated with non-CO_2 emissions from power plants as well as industrial applications (i.e., trace and heavy metal emissions in solid, liquid, and gaseous effluents that are potential areas

[1] Syngas is primarily hydrogen (H_2) and carbon monoxide (CO) but can include other gaseous constituents. After the syngas is produced, it is further processed in a Water Gas Shift (WGS) reactor to prepare it for pre-combustion capture. WGS converts CO and water to additional H_2 and CO_2.

of concern). Additional broad research objectives include technologies to reduce and analyze environmental legacy issues related to ash storage facilities. Where applicable, the impacts of and the correlation between feedstocks, their content of basic and trace elements, and geochemical interactions in situ, and the correlation of geology on ash composition are topics of consideration.

Additionally, advanced concepts and new technologies will be developed to determine the environmental uses of combustion residuals from all ash residuals not just restricted to pure coal combustion residuals (CCR). Examples could include ash resulting from co-fire or biomass combustion activities. RDD&D will be directed at: (1) the fraction of combustion products that are not currently being recycled or beneficially reused at high levels such as non-gypsum, wet- and dry-flue gas desulfurization (FGD) materials and bottom ash; (2) materials used in current combustion residual facilities that may be impacted by new regulations; (3) improvements in the performance and cost of beneficiation/upgrading of technology associated with high-volume reuse materials (i.e., fly ash and synthetic gypsum); (4) advanced cost-effective approaches for removing, upgrading, and beneficially recycling combustion residuals from active and inactive storage impoundments will be developed; and (5) risk pathways via construction risk management frameworks will be developed as appropriate for ash management facilities.

Carbon Management Technologies
Point-Source Carbon Capture

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Point-Source Carbon Capture[2] $86,300,000	**$162,905,000**	**+$76,605,000**
Post-Combustion Capture Systems $73,300,000	**$144,405,000**	**+$71,105,000**
• Supported up to four Small Scale and/or Bench Scale Carbon Capture Tests on Actual Flue Gases from coal and natural gas. • Implemented Congressional direction on industrial capture research, development, demonstration, and deployment (RDD&D) and front-end engineering design (FEED) studies. • National Carbon Capture Center (NCCC): Funded and operated the NCCC post combustion carbon capture test facility. • Supported 21st century power plant design and component testing.	• Continue support for several transformational bench scale carbon capture tests on actual flue gases from coal and natural gas, focused on capture rates >95% and determination of co-benefits of capture. • Support transformational RDD&D and pilot-scale carbon capture projects for industrial sources of carbon dioxide (CO_2). • NCCC: Fund and operate the NCCC post-combustion carbon capture test facility for transformational technology development. • Support up to 10 carbon capture FEED studies for industrial and natural gas sources of CO_2.	• The increase in funding supports expanding the carbon capture FEED studies to new industrial sources of CO_2 including hydrogen (H_2) production and additional support for pilot testing at natural gas-fired electric utilities including both natural gas combined cycle (NGCC) systems and simple cycle.
Pre-Combustion Capture Systems: $10,000,000	**$15,000,000**	**$5,000,000**
• Supported Lab, bench, pilot scale Transformational Carbon Capture. • Supported 21st century power plant design and component testing.	• Conduct transformational carbon capture RDD&D for H_2 production from gasification-based systems using fossil fuels, biomass, and waste plastics. • Conduct transformational carbon capture development that supports hydrogen production and other industrial applications.	• The increase in funding is for FEED studies of carbon capture on steam methane reforming (SMR) and autothermal reforming (ATR).

[2] $40M for Negative Emissions Technologies described in the Carbon Dioxide Removal justification. Actual Carbon Capture Budget Request in FY 2021 was $126.3M.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Emissions Control: $3,000,000	**$3,500,000**	**+$500,000**
• Conducted systems analyses and technical assessments to identify and address non-CO_2 emissions from coal-fired power plants (i.e., trace metals emissions in solid, liquid, and gaseous effluents that are potential areas of concern).	• Conduct RDD&D, systems analyses and technical/economic assessments to identify and address non-CO_2 emissions from power plants and industrial sources (i.e., trace metals emissions in solid, liquid, and gaseous effluents that are potential areas of concern) as well as legacy storage facilities such as ash impoundments and landfills.	• This increase in funding further expands efforts to address high-priority solid and liquid waste streams from coal combustion residuals (CCR). Efforts will be primarily focused on reducing potential environmental issues associated with geochemical and physical concerns of ash impoundments and landfills (legacy and active), as well as development of novel technologies to create environmentally-benign byproducts from combustion residuals with potential for reducing environmental impacts and/or avoided emissions. Definition of ash and combustion residuals also include ash resulting from comingled or biomass combustion activities.

Description

The Carbon Management - Policy and Analysis subprogram evaluates potential economic, employment, and socioenvironmental benefits and impacts from the deployment of carbon management technologies. This subprogram supports strategic planning by identifying major challenges and opportunities to improve efficiency, cost, and socioenvironmental performance for the deployment of carbon management applications.

The Office of Strategic Planning, Analysis and Engagement, within the Office of Carbon Management, supports high-impact, crosscutting, integrative activities through close coordination with the Office of Fossil Energy and Carbon Management (FECM) technology programs, other DOE offices, DOE's efforts to meet the Administration's climate and energy goals as well as the Justice40 Initiative and support for the transition of fossil host communities. This includes support for activities to inform key FECM audiences and stakeholders about FECM's work to transition the U.S. to a clean energy economy and fight the global climate crisis. Strategic Analysis provides evidence-based, portfolio-wide analysis for decision-makers. FECM will lead activities to provide extensive data, tools, and technical assistance to relevant stakeholders as the Nation embarks on an unprecedented build-out of carbon management research, development, demonstration, and deployment (RDD&D) efforts in support of the Administration's goals. Strategic analysis and engagement efforts will help ensure that FECM maximizes the impact of its research dollars, tracks the impacts of FECM investments, and strives to ensure that the clean economy benefits all Americans.

Siting and permitting of carbon management projects will be critically important. The analysis and engagement efforts will evaluate key environmental and siting considerations through research to understand impacts to and engagement with communities and environments, development of technical solutions, and issues that cause permitting uncertainty and risks for the carbon management projects. FECM supports social science and socio-economic research to understand impacts of carbon management on communities and provide technical assistance to communities considering carbon management (e.g., DOE's Communities Local Energy Action Program (LEAP)). Activities will aid in proactive, place-based community engagement and planning processes that include consideration of carbon capture and storage (CCS) and carbon dioxide removal (CDR) development, in the context of broader decarbonization options, to both ensure that carbon management projects work for communities and to characterize siting processes for future development.

Analysis and engagement activities are described in more detail below:

Energy and Regulatory Analysis Support

- Performs economic and environmental impact assessments for the Office of Carbon Management's RDD&D portfolio using advanced modeling methodologies. Advanced modeling methodologies include the use of modified versions of the Energy Information Administration's (EIA's) National Energy Modeling System (NEMS), big data analytics on key energy and industrial market metrics, and use of production cost modeling to understand market dynamics.
- Informs Carbon Management's RDD&D strategic planning and decision-making by studying current and potential future market and regulatory conditions which might affect future viability. These studies seek to identify potential market driven opportunities which will aid in the deployment of carbon management technologies. It also seeks to identify gaps in decarbonization needs which can be addressed by RDD&D activities.
- Disseminates best practices and approaches for evaluating and analyzing carbon management technologies and strategies to external entities and stakeholders. Entities like the Environmental Protection Agency (EPA), EIA, and others depend on FECM systems analysis to drive their analyses into potential future decarbonization opportunities.
- Analyzes crosscutting issues which have the potential to affect the deployment of Carbon Management technologies like electric power grid integration, hard to decarbonize sectors, and competitiveness implications of changing energy and industrial markets as they transition to a net-zero greenhouse gas emission economy.
- Provides technical and policy analyses as part of intergovernmental support in areas of expertise (e.g., EPA, Internal Revenue Service (IRS) Section 45Q).

Carbon Management Technologies
Carbon Management - Policy and Analysis

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Carbon Management - Policy and Analysis: $500,000	**$4,000,000**	**+$3,500,000**
• Support for analysis efforts with potential economic, employment, and environmental benefits and impacts from the deployment of carbon management and fossil technologies.	• Support program strategic planning by identifying major challenges, technologies, and advanced concepts that have the potential to improve the efficiency, cost, and environmental performance of carbon management applications including hydrogen production and carbon removal. • Evaluate potential economic, jobs, and environmental benefits and impacts from the deployment of carbon management and fossil technologies.	• The increase in funding will expand the capabilities of the analysis division, allowing work on Hydrogen technologies and infrastructure, carbon capture and storage, and general systems-based energy and carbon management modeling. This includes integration of enhancements to the National Energy Modeling System in order to analyze potential future deep decarbonization scenarios. • Funding increase will also enable analysis of opportunities in the industrial sector for carbon management. This will enable further inventory and systems analyses to highlight lower cost opportunities for decarbonization. • Increase will also be used to develop tools and methodologies to assist stakeholders in integrated planning of decarbonization strategies which leverage potential cross-sectorial contributions to greenhouse gas mitigation and removal from Carbon Management technologies. • Additional analysis to support multi-agency task forces as directed by Consolidated Appropriations Act of 2021.

Carbon Management Technologies
Carbon Management - Justice and Engagement

Description

Carbon Management - Justice and Engagement supports research, development, demonstration, and deployment (RDD&D) of carbon management technologies through engagement with key partners within the U.S. and globally. Funding will support domestic engagement and justice efforts as well as international collaboration with various partners through bi-lateral and multi-lateral agreements. The Office of Fossil Energy and Carbon Management (FECM) will focus on building capacity and working with interagency partners to ensure safe, effective, and efficient implementation of its RDD&D programs. FECM will work with various stakeholders to build a foundation for expeditiously administering several new investments, leveraging existing programs and developing new relationships with stakeholder networks and communities.

The FY 2023 Budget Request of $1 million is to prioritize RDD&D activities and strategies to maximize the impact of research dollars, track the impacts of FECM investments, and strive to ensure that the clean energy economy benefits all Americans. Efforts will be closely coordinated with the Department of Energy's (DOE) activities to meet the goals of the Justice40 Initiative, to work with states and local communities to deliver benefits from Federal investments in climate and clean energy to disadvantaged communities.

The Budget Request also supports social science and socioeconomic research to understand impacts of carbon management on communities and provide technical assistance to communities considering carbon management technologies such as carbon capture and storage (CCS), carbon dioxide (CO_2) conversion, and carbon dioxide removal (CDR). Research will aid in the understanding of impacts of carbon management on communities and allow for strategies that reduce impacts and increase environmental justice for carbon management development. The work will support deployed carbon management technologies, to ensure disadvantaged communities have access to objective information regarding the benefits and costs of carbon management technologies.

International

- Leverages decades of experience in working successfully with global governments, organizations, and stakeholders through a variety of bi-lateral and multi-lateral mechanisms to accelerate the advancement and responsible deployment of carbon management technologies through both policy and technical expertise, along with forward-looking RDD&D, and capacity building.
- Works with international partners committed to carbon management as a long-term climate strategy and partnerships that prioritize a decarbonized economy by 2050 through concerted global actions. These partners are willing and able to work with FECM to move their countries and regions toward net-zero goals, and where FECM expertise can provide leverage, develop long-term projects and relationships for technical exchange and joint RDD&D with these willing partners.
- Makes targeted investments in international carbon management efforts with select countries that can accelerate technological development for climate mitigation, as well as prime major global markets for American technologies and services, to have the greatest value for potential emissions reductions and creating American jobs.

Domestic

- Works with stakeholders to build a foundation for expeditiously administering several new investments such as increases for CCS, CDR, and other carbon management deployment focused programs that will rely on new and existing relationships with American networks and communities.
- Facilitates and regularly engages in exchanges of information and insights with partners and stakeholders on RDD&D progress and needs, as well as policy tools and public-private partnerships in the U.S.
- Serves as a key focal point across the U.S. Government for interagency collaboration on technical, policy, and regulatory issues related to CCS and CDR.
- Works with other agencies to develop and improve accounting frameworks and tools to accurately measure carbon removal and sequestration methods and technologies. The Secretary of Energy shall collaborate with the Administrator of the EPA and the heads of other relevant Federal agencies to develop and improve accounting

frameworks and tools to accurately measure carbon removal and sequestration methods and technologies. (Title IV—Carbon Management and Title V— Carbon Removal, Section 5001, Energy Act of 2020, Division Z of P.L. 116-260).

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Carbon Management - Justice and Engagement: $650,000	**$1,000,000**	**+$350,000**
• Support for international efforts with various international partners through bilateral and multi-lateral agreements.	• Support Domestic and International justice and engagement Activities and Agreements, and other collaborative international efforts.	• Additional funding will support expanded domestic justice and engagement as well as new International Agreements supporting the administration's de-carbonization priorities.

Carbon Management Technologies
Transformational Coal Pilots

Overview
The Consolidated Appropriations Act of 2017, H.R. 244, provided $50 million "*to remain available until expended, shall be for the transformational coal technologies pilot program described in the explanatory statement described in section 4 (in the matter preceding division A of this consolidated Act)*. Per the FY 2017 Congressional direction, funding is to support a new solicitation for two large-scale pilots that focus on transformational coal technologies representing a new way to convert energy that would enable a step change in performance, efficiency, and the cost of electricity compared to today's technologies. Such technologies include thermodynamic improvements in energy conversion and heat transfer, such as pressurized oxygen combustion and chemical looping, and improvements in carbon capture systems technology. In directing any ongoing activities, the Department of Energy (DOE) will prioritize activities that are consistent with this Administration's goal of 100% carbon-pollution-free electricity by 2035.

In accordance with this legislation, the solicitation was announced by DOE in August of 2017, with successful completion of Phase I (feasibility) and Phase II (design). Evaluation of the final applications for Phase III (construction/operations) is currently ongoing. Since FY 2017, a total of $140 million has been appropriated by Congress for the program, with approximately $23 million utilized for Phase I and Phase II. FY 2022 funds will be carried over into FY 2023.

Description
No funding is requested in the FY 2023 Budget. Prior year funding will be used to award up to 2 final Phase III projects.

Carbon Management Technologies
Transformational Coal Pilots

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Transformational Coal Pilots $10,000,000	**$0**	**-$10,000,000**
• Funding was utilized for Phase III downselect.	• No funding is requested.	• No funding is requested. Unobligated funds will be used for Phase III selections.

Carbon Management Technologies
Supercritical Transformational Electric Power (STEP)

Description

The Supercritical Transformational Electric Power (STEP) activity line was created within the Carbon Capture, Utilization and Storage (CCUS) and Power Systems Program by the Consolidated and Further Continuing Appropriations Act, 2015 (P.L. 113-235).

The STEP program focuses on research, development, demonstration, and deployment (RDD&D) to advance higher efficiency, lower cost technologies that use supercritical CO_2 (sCO_2) for power cycles. In FY 2023, the program will continue to work toward design, construction, start-up, shakedown, and operation of the 10 Mwe pilot facility and support initial testing to establish operability and performance of selected sCO_2 cycles. This effort includes the design, development, and fabrication of all components in the cycle (i.e., turbomachinery, recuperators, heat source integration, etc.). During operation, the test facility will validate operability of a sCO_2 Recompression Brayton Cycle at the 10 Mwe test facility in San Antonio, Texas.

No funding is requested for the STEP 10 Mwe pilot in the FY 2023 Budget Request. Currently, the project is fully funded for Phase 2 of the original scope of work (SOW) and will complete the existing SOW in FY 2023.

The FY 2023 Budget Request does not provide additional funds for this activity.

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Supercritical Transformational Electric Power (STEP) **$14,500,000**	**$0**	**-$14,500,000**

• Funded Budget Period (BP) 2 of project:
  • Completed site construction and civil works.
  • Fabricated/Installed major equipment.
  • Simple Cycle commissioned and tested.
	• No funding is requested in FY 2023.	• Funding in the FY 2021 Enacted is sufficient to complete BP2.

Resource Sustainability
($K)

FY 2021 Enacted	FY 2022 Annualized CR	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
117,500	117,500	182,964	+65,464	+55.7%

Overview
Reducing the environmental impacts, especially methane leakage, associated with the production, transportation, and storage of oil, natural gas, and coal is critical to achieving net-zero emissions. Looking ahead, innovative technologies will provide alternative solutions for aspects of fossil fuel production, such as conversion of flared methane to high-value products and cleaning water produced from hydraulic fracturing operations for agriculture use.

The United States has the most extensive natural gas production, gathering, processing, storage, and delivery infrastructure systems in the world. The natural gas pipeline network includes more than 300,000 miles of interstate and intrastate pipelines and the infrastructure is facing operational challenges including leaking emissions into the atmosphere, risks of delivery disruptions, and public safety. It is critical to safely monitor and repair pipeline infrastructure and develop new technologies and solutions for reducing the risks of future leaks and delivery disruptions as the infrastructure system grows and pipelines age.

The Resource Sustainability Program addresses the critical environmental and safety issues associated with the United States' historical and continued use of fossil fuels. Specifically, the Program's mission is to conduct research, development, demonstration, and deployment (RDD&D) that reduces environmental impact from the development, extraction, transportation, distribution, and storage of fossil fuels. The Program comprises four subprograms: Advanced Remediation Technologies, Methane Mitigation Technologies, Natural Gas Decarbonization and Hydrogen Research, and Mineral Sustainability.

The Advanced Remediation Technologies program will focus on developing solutions that address the environmental and social impacts of oil and natural gas exploration and production. The domestic production of oil and natural gas has contributed to America's economy and provides fuel for vehicles, heat for homes, industrial products, plastics, and other important products. Although there are many benefits from oil and natural gas, it comes with risks to the environment. Oil and gas development results in large volumes of produced water which could be cleaned and used to benefit local communities or safely disposed of without causing induced seismic events. Offshore oil development carries the risk of oil spills and contamination to important ecological environments. Many communities that rely on oil and natural gas development for jobs and economic activity are also the same communities who are affected by the negative impacts of poor air quality, water contamination, oil spills or induced seismicity.

The Methane Mitigation Technologies program supports research, development, demonstration, and deployment (RDD&D) focused on innovative sensors, compressors, infrastructure components, and analytical technologies that enable the detection and mitigation of leaks, and improve the reliability of natural gas transmission, distribution, and storage facilities. The program will develop innovative technologies to reduce flaring and venting of natural gas, during production and transportation, through conversion of the flared and vented natural gas to high-value, readily transportable products. Given the Nation's reliance on natural gas, it is critical to ensure the safety and reliability of related infrastructure. This program will also develop advanced technologies to detect, locate, and measure emissions that will inform research, analytics, and remediation efforts. Finding and measuring emissions from natural gas production fields, transportation and storage systems, and legacy infrastructure, including abandoned and orphaned wells, is critical to reducing emissions and addressing the negative impacts, like ground water contamination, that plague communities.

The Natural Gas Decarbonization and Hydrogen Research program supports the development of hydrogen technologies that help contribute to a carbon-pollution-free economy. The fastest and most reliable path to advance a hydrogen economy is to build on low-cost, readily available natural gas and existing natural gas infrastructure. The Natural Gas Decarbonization and Hydrogen Technologies subprogram will focus on advancing technologies for the "carbon-neutral" production, transportation, and storage of hydrogen sourced from natural gas. The program will also leverage the Office of Fossil Energy and Carbon Management's (FECM's) extensive experience with underground storage of natural gas to develop technologies for underground storage of hydrogen.

The FY 2023 Budget continues the process from FY 2022 of ensuring that its programs do not directly subsidize fossil fuels, not funding RDD&D focused on unabated fossil combustion, traditional fossil-fueled power generation, or increased production of fossil fuels while also investing in technologies to improve energy security and lower energy prices. The Budget focuses on other activities that support clean energy development and deployment (including carbon management), environmental benefits, and the creation of good-paying jobs that provide a free and fair chance to join a labor union.

Highlights of the FY 2023 Budget Request
The Resource Sustainability Program will pursue the following major activities in FY 2023:

Advanced Remediation Technologies
The Advanced Remediation Technologies activity will address wellbore integrity, induced seismicity, water use, produced water treatment, and offshore safety and spill prevention. The program will leverage previous research, to include field laboratory efforts, to assess the viability of converting expended unconventional oil and gas wells to carbon storage sites.

Methane Mitigation Technologies
The Methane Mitigation Technologies program is focused on developing next-generation natural gas technologies for detecting, quantifying and mitigating methane emissions, including enhancing both the cyber and physical security across the entire natural gas infrastructure system—from production through end use. FY 2023 supports the following activities:

- Develop technologies in advanced materials, sensors, data management tools, in-pipe inspection and repair technologies, and dynamic compressor research and development.
- Develop advanced modular technologies, capable of being deployed near wellheads and natural gas processing and transportation infrastructure, for the purpose of beneficially utilizing otherwise flared, vented, or stranded natural gas.
- Develop advanced sensor technologies to detect and locate emissions from pipelines, storage facilities, and abandoned wells.
- Develop modular technologies, materials, and solutions to aid remediation of orphaned wells.
- Develop and validate emissions detection and measuring technologies.
- Collect, analyze, and distribute emissions data, information, and knowledge to inform efforts on orphaned well remediation, Life Cycle Analysis (LCA) studies, and the Environmental Protection Agency's (EPA) Greenhouse Gas (GHG) Inventory.

Natural Gas Decarbonization and Hydrogen Technologies
The Natural Gas Decarbonization and Hydrogen Technologies subprogram focus is on research, development and deployment (RD&D) of technologies to produce clean hydrogen from fossil feedstocks, the transport of hydrogen and hydrogen carriers (e.g., Ammonia) through natural gas infrastructure, and the geologic bulk storage of hydrogen and related technologies for subsurface storage evaluation.

FY 2023 activities include developing analytical tools and models that are able to evaluate potential advanced technologies, technology performance metrics, technoeconomic and LCA, and resource evaluations. The subprogram will also develop technologies for "carbon-neutral" hydrogen production, transportation (including advanced pipeline materials), and geologic storage technologies that leverage existing natural gas infrastructure.

Mineral Sustainability

The Mineral Sustainability program will support domestic supply chain networks required for the economically, environmentally, and geopolitically sustainable production of critical minerals (CM). This mission will be accomplished by prioritizing the use of unconventional resources such as coal waste and by-products from industry feedstocks for domestic CM, rare earth elements (REE) and carbon ore to products production.

The Carbon Ore Processing activity (formerly Advanced Coal Processing) is focused on utilizing materials to be recycled from previously mined resources outside of traditional thermal and metallurgical markets that can contribute to the U.S. gross domestic product.

Resource Sustainability – Policy and Analysis

These activities can be completed within already available resources and no additional funding is requested in FY 2023. The Policy and Analysis Division supports all program areas in the Office of Resource Sustainability through the drafting of studies and reports, conducting economic and environmental analysis, and reviewing legislation, regulations, and executive orders.

Resource Sustainability – Justice and Engagement

These activities can be completed within already available resources and no additional funding is requested in FY 2023. The Justice and Engagement Division conducts and provides support to leadership's engagement with a wide set of domestic and international stakeholders, to include frontline and disadvantaged communities, government agencies, non-government entities, non-profit, academia, and foreign governments.

Resource Sustainability
Funding ($K)

	FY 2021 Enacted	FY 2022 Annualized CR	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
RESOURCE SUSTAINABILITY					
Advanced Remediation Technologies					
Environmentally Prudent Stewardship	12,000	12,000	12,964	964	8.0%
Gas Hydrates	25,000	25,000	0	-25,000	-100.0%
Water Management Technologies	7,500	7,500	0	-7,500	-100.0%
Subtotal Advanced Remediation Technologies	**44,500**	**44,500**	**12,964**	**-31,536**	**-70.9%**
Methane Mitigation Technologies	**20,000**	**20,000**	**100,000**	**80,000**	**400.0%**
Natural Gas Decarbonization and Hydrogen Technologies	**0**	**0**	**26,000**	**26,000**	**N/A**
Mineral Sustainability					
Critical Minerals	23,000	23,000	40,000	17,000	73.9%
Carbon Ore Processing	30,000	30,000	4,000	-26,000	-86.7%
Subtotal Mineral Sustainability	**53,000**	**53,000**	**44,000**	**-9,000**	**-17.0%**
TOTAL, RESOURCE SUSTAINABILITY	**117,500**	**117,500**	**182,964**	**+65,464**	**+55.7%**

SBIR/STTR:

- FY 2021 Enacted: SBIR $2,905: STTR: $505
- FY 2022 Annualized CR: SBIR $2,905: STTR: $505
- FY 2023 Request: SBIR $4,664: STTR: $656

Resource Sustainability
Explanation of Major Changes ($K)

	FY 2023 Request vs FY 2021 Enacted
<u>Resource Sustainability</u>	
Methane Mitigation Technologies: Funding increase reflects research on advanced materials, data management tools, sensors, compressors, and analysis technologies for emissions reduction in oil and gas infrastructure; conversion technologies for stranded and vented gas; advanced remote detection technologies; and modular remediation materials. Funding increase also reflects development and validation of measurement sensor technologies for: the collection, dissemination, and analysis of emissions data; data collection and support to EPA's GHG Inventory; and data collection, analysis and support related to quantifying emissions from legacy infrastructure and orphan wells.	**+$80,000**
Natural Gas Decarbonization and Hydrogen Technologies: Funding increase reflects new research on developing and advancing technologies for the production, transportation, and storage of domestically produced Hydrogen.	**+$26,000**
Advanced Remediation Technologies: Overall funding decrease reflects the elimination of direct fossil fuel subsidies from the FY 2023 Budget, offset by a funding increase in Environmentally Prudent Stewardship to reflect research to develop solutions that address the environmental impacts of oil and natural gas development. These topics include wellbore integrity, oil spill prevention, and produced water treatment and reuse technologies.	**-$31,536**
Mineral Sustainability: Funding decrease reflects reduced funding for coal-based building composed of 51% carbon ore, while maintains partial funding for supporting large-scale pilot development through FEED studies to produce large quantities of high purity, commercial grade REE and other CMs, and maturation of transformational processing from unconventional resource.	**-$9,000**
Total, Resource Sustainability	**+$65,464**

Resource Sustainability
Advanced Remediation Technologies

Overview
Fossil fuels have contributed to America's economy and have provided fuel for vehicles, heat for homes, industrial products, plastics, and other important products. Although there are many benefits from oil, natural gas, and coal, these benefits come with significant negative environmental impacts. The Advanced Remediation Technologies Program addresses these critical environmental and safety issues. The Program conducts research, development, demonstration and deployment (RDD&D) that reduces the environmental impact from the development, transportation, distribution, and storage of fossil energy resources.

The Environmentally Prudent Stewardship subprogram will focus on developing solutions that address the environmental and social impacts of fossil fuel development. Hydraulic fracturing requires the use of large amounts of water and chemicals, which needs to be cleaned and safely disposed of without inducing seismic events. Offshore oil development carries the risk of oil spills and contamination to important ecological environments. Many communities that rely on oil, natural gas, and coal development for jobs and economic activity are also the same communities who are affected by the negative impacts from air quality, water contamination, oil spills and/or induced seismicity.

There is no funding requested for the Gas Hydrates subprogram in FY 2023.

There is no funding requested for the Water Management Technologies subprogram in FY 2023.

Highlights of the FY 2023 Budget Request
The Environmentally Prudent Stewardship subprogram will conduct RDD&D technologies to address wellbore integrity, induced seismicity, water use, produced water treatment, and offshore safety and spill prevention.

Resource Sustainability
Advanced Remediations Technologies
Funding ($K)

	FY 2021 Enacted	FY 2022 Annualized CR	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
Advanced Remediations Technologies					
Environmentally Prudent Stewardship	12,000	12,000	12,964	+964	+8.0%
Gas Hydrates	25,000	25,000	0	-25,000	-100%
Water Management Technologies	7,500	7,500	0	-7,500	-100%
Total, Advanced Remediations Technologies	**44,500**	**44,500**	**12,964**	**-31,536**	**-70.9%**

Resource Sustainability
Advanced Remediation Technologies
Explanation of Major Changes ($K)

	FY 2023 Request vs FY 2021 Enacted
Advanced Remediation Technologies	
Environmentally Prudent Stewardship: Funding increase reflects research to develop solutions that address the environmental impacts of oil and natural gas development. These topics include wellbore integrity, oil spill prevention, and produced water treatment and reuse technologies	**+$964**
Gas Hydrates: No funding requested in FY 2023	**-$25,000**
Water Management Technologies: No funding requested in FY 2023	**-$7,500**
Total, Advanced Remediation Technologies	**-$31,536**

Resource Sustainability
Advanced Remediation Technologies

Description

Environmentally Prudent Stewardship

The Environmentally Prudent Stewardship subprogram will focus on addressing the environmental impacts from oil and natural gas development, to include unconventional development and offshore safety and spill prevention. The program will build on research conducted and data collected from the Department of Energy's (DOE) 17 National Laboratory projects to inform future research. These field projects conducted research on multiple facets of the production process in unique geological basins, including capturing environmental data before, during, and after hydraulic fracturing operations. Research included mapping and visualization of the subsurface, wellbore integrity, produced water research, groundwater contamination, air quality, and data analytics.

Produced water is a byproduct from the extraction of oil and natural gas using hydraulic fracturing techniques. Shale rock that contains oil and gas also holds water. As the oil and natural gas is produced, water is brought to the surface and will contain fracturing fluid mixed with the naturally-occurring water. This produced water will often contain sand, oils, salts, chemicals, bacteria, organic compounds, and even naturally-occurring radioactive materials. DOE is transforming produced water from a waste to a resource by developing treatment technologies that allow for its safe re-use in applications such as agriculture.

DOE's offshore safety and spill prevention research focuses on: 1) identifying and mitigating risks from ocean currents and seafloor hazards such landslides; 2) reducing risks associated with infrastructure used to deliver chemicals to the well and to bring produced fluids to the platform; and 3) assessing, predicting, and mitigating the risks associated with an aging offshore infrastructure. DOE is working with the Department of the Interior (DOI), under a Memorandum of Collaboration, to pursue collaborative offshore research to increase safety and reduce environmental risk.

Gas Hydrates

There is no funding requested for the Gas Hydrates subprogram in FY 2023.

Water Management Technologies

There is no funding requested for the Water Management Technologies subprogram in FY 2023.

Resource Sustainability
Advanced Remediation Technologies

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Advanced Remediation Technologies $44,500,000	**$12,964,000**	**-$31,536,000**
Environmentally Prudent Stewardship $12,000,000	**$12,964,000**	**+$964,000**
• Research on reducing the environmental footprint of unconventional oil and gas development.	• Funding will support research that address the environmental impacts of fossil fuel development. These topics include wellbore integrity, oil spill prevention, and produced water treatment and reuse technologies.	• Funding will support research that addresses the environmental impacts of fossil fuel development. These topics include wellbore integrity, oil spill prevention, and produced water treatment and reuse technologies.
Gas Hydrates $25,000,000	**$0**	**-$25,000,000**
• Conducted early-stage research such as numerical simulations, fundamental property characterization, and pore-scale visualization of hydrate bearing sediments. • Prepared for long-term reservoir flow test on the North Slope of Alaska. • Prepared for phase two expedition in the Gulf of Mexico.	• No funding is requested within the Advanced Remediation Technologies Budget Request.	• Funds are reallocated to higher Administration priorities.
Water Management Technologies $7,500,000	**$0**	**-$7,500,000**
• Awarded Funding Opportunity Announcement for Water Management for Thermal Power Generation. • Conducted tests at the Energy and Environmental Research Center Brine Extractions and Storage Test Site. • Funded the National Energy Technology Laboratory and other National Labs for research and development on impacts of water demand and water availability for power generation, Carbon Capture, Utilization, and Storage (CCUS), and hydrogen.	• No funding is requested within the Advanced Remediation Technologies Budget Request.	• Funds are reallocated to higher Administration priorities.

Resource Sustainability
Methane Mitigation Technologies

Overview

The Methane Mitigation Technologies Program addresses critical environmental and safety issues associated with the production and transmission of domestic oil and natural gas. Specifically, the Program's mission is to conduct research, development, demonstration, and deployment (RDD&D) of technologies and solutions that detect, quantify, reduce, and mitigate methane emissions.

The program supports RDD&D focused on innovative sensors, compressors, infrastructure components, and analytical technologies that enable the detection and mitigation of leaks, and improve the reliability of natural gas transmission, distribution, and storage facilities. The program will develop innovative technologies to reduce flaring and venting of natural gas, during production and transportation, through conversion of the flared and vented natural gas to high-value, readily transportable products. The program will develop advanced technologies to detect, locate, and measure emissions that will inform research, analytics, and remediation efforts. Finding and measuring emissions from natural gas production fields, transportation and storage systems, and legacy infrastructure, is critical to reducing emissions and addressing the negative impacts, like ground water contamination, that plague communities.

Highlights of the FY 2023 Budget Request

The Methane Mitigation Technologies Program will pursue the following major activities in FY 2023:

- Developing technologies in advanced materials, sensors, data management tools, in-pipe inspection and repair technologies, and dynamic compressor research and development.
- Developing advanced modular technologies, capable of being deployed near wellheads and natural gas processing and transportation infrastructure, for the purpose of beneficially utilizing otherwise flared, vented, or stranded natural gas.
- Developing advanced sensor technologies to detect and locate emissions from production fields, pipelines, storage facilities, and abandoned wells.
- Developing and validating emissions detection and measuring technologies.
- Collecting, analyzing, and distributing emissions data, information, and knowledge to inform efforts on orphaned well remediation, Life Cycle Analysis studies, and the Environmental Protection Agency's (EPA) Greenhouse Gas (GHG) Inventory.

Resource Sustainability
Methane Mitigation Technologies
Funding ($K)

	FY 2021 Enacted	FY 2022 Annualized CR	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
Methane Mitigation Technologies	20,000	20,000	100,000	+$80,000	+400%
Total, Methane Mitigation Technologies	**20,000**	**20,000**	**100,000**	**+$80,000**	**+400%**

Resource Sustainability
Methane Mitigation Technologies
Explanation of Major Changes ($K)

	FY 2023 Request vs FY 2021 Enacted
Methane Mitigation Technologies:	
• Funding increase reflects research on advanced materials, data management tools, sensors, compressors, and analysis technologies for emissions reduction in oil and gas infrastructure; conversion technologies for stranded and vented gas; advanced remote detection technologies; and modular remediation materials. Additionally, funding reflects development and validation of measurement sensor technologies for the collection, dissemination, and analysis of emissions data; data collection and support to EPA's GHG Inventory; and data collection, analysis and support related to quantifying emissions from legacy infrastructure.	**+$80,000**
Total, Methane Mitigation Technologies	**+$80,000**

Resource Sustainability
Methane Mitigation Technologies

Description
The Methane Mitigation Technologies program is committed to developing advanced, cost-effective technologies to reduce emissions from fossil energy infrastructure. Priority areas for the program include research on technologies to detect, measure, and mitigate emissions. This includes remote sensors, advanced materials for pipeline integrity, data management and systems, tools that employ artificial intelligence, and more efficient and flexible compressors to adapt to varying pipeline conditions and additional fluids.

The program will accelerate advances in remote sensor technologies that can detect and locate emissions from pipelines, natural gas storage, and legacy infrastructure. The program will conduct research on materials and remediation technologies that can be deployed by states, industry, or other government agencies to aid in the remediation of legacy emitters.

The program will accelerate advances in materials science that can enhance pipe integrity, reduce leaks, and improve the efficiency of infrastructure operations. Research will support the development of low cost, low maintenance sensor technologies that can provide predictive analytics on pipeline corrosion rates via detection and monitoring of temperature, pressure, chemical composition of materials, vibration, and strain.

The program will develop advanced modular technologies capable of being deployed near wellheads and natural gas processing and transportation infrastructure for the purpose of beneficially utilizing otherwise flared, vented, or stranded natural gas. The program envisions an RDD&D effort focused on developing and field testing new and disruptive technologies aimed at converting the otherwise wasted resource, consisting primarily of methane and ethane into electricity or value-added, easily transportable products.

The program will focus on developing advanced technologies to detect, locate, and measure emissions. This will include the development and validation of measurement sensor technologies for the collection, dissemination, and analysis of emissions data; data collection and support to EPA’s GHG Inventory; and data collection. This work will inform future research efforts and priorities; improve analytics, data collection and modeling; and inform mitigation and remediation efforts for natural gas pipelines, storage facilities, and legacy infrastructure.

Resource Sustainability
Methane Mitigation Technologies

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Methane Mitigation Technologies $20,000,000	**$100,000,000**	**+$80,000,000**
• Research on materials, coatings, and sensors to improve the reliability, safety, and reduce emissions from natural gas supply and delivery infrastructure. • New and innovative technologies aimed at converting flared and vented methane into value-added products. • Advanced methane detection and measurement technology validation. • Field scale methane emissions detection and quantification technology development and validation.	• Funding for advanced remote detection technologies for natural gas infrastructure. • Funding to develop technologies in advanced materials, data management tools, in-pipe inspection and repair technologies, and dynamic compressor research and development. • Funding to develop advanced modular conversion technologies for stranded and flared natural gas. • Funding for the development of modular remediation materials and solutions. • Funding will support the development of direct and remote measurement sensor technologies for the collection, dissemination, and analysis of emissions data. • Research, data collection and analytics that support the Environmental Protection Agency's (EPA) Greenhouse Gas (GHG) Inventory.	• Increase in funding will support new advanced remote detection technologies for natural gas infrastructure and the development of modular remediation materials and solutions. • Increase in funding will expand research, development, demonstration and deployment (RDD&D) solutions for mitigating emissions throughout the natural gas supply chain, from reducing flaring in production fields to detecting and mitigating legacy infrastructure. • Increase in funding will support the development of advanced materials, data management tools, in-pipe inspection and repair technologies, and dynamic compressor research and development. • Increase in funding will support the development of direct and remote measurement sensor technologies for the collection, dissemination, and analysis of emissions data, including support to EPA's GHG Inventory.

Resource Sustainability
Natural Gas Decarbonization and Hydrogen Technologies

Overview

The new Natural Gas Decarbonization and Hydrogen Technologies program will focus on technologies for carbon-neutral hydrogen production as well as hydrogen (and ammonia) transportation, and geologic storage technologies that leverage existing natural gas infrastructure as well as supporting analytical tools and models. Hydrogen research will focus on cutting-edge conversion technologies (including pyrolysis, microwave or plasma assisted catalytic conversion and other potential future in-situ conversion processes), blending hydrogen with natural gas, and leveraging existing transportation and storage infrastructure. The program will also develop analytical tools and models that are able to evaluate potential advanced technologies, technology performance metrics, technoeconomic and lifecycle analyses (LCA), and resource evaluations.

Highlights of the FY 2023 Budget Request

The Natural Gas Decarbonization and Hydrogen Technologies Program will focus on technologies for "carbon-neutral" hydrogen production as well as hydrogen (and ammonia) transportation and geologic storage technologies that leverage existing natural gas infrastructure in coordination with the Department of Energy's (DOE) Office of Energy Efficiency and Renewable Energy (EERE) Hydrogen and Fuel Cell Technologies Office (HFTO).

Resource Sustainability
Natural Gas Decarbonization and Hydrogen Technologies
Funding ($K)

	FY 2021 Enacted	FY 2022 Annualized CR	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
Natural Gas Decarbonization and Hydrogen Technologies	0	0	26,000	+$26,000	N/A
Total, Natural Gas Decarbonization and Hydrogen Technologies	**0**	**0**	**26,000**	**+$26,000**	**N/A**

Resource Sustainability
Natural Gas Decarbonization and Hydrogen Technologies
Explanation of Major Changes ($K)

	FY 2023 Request vs FY 2021 Enacted
Natural Gas Decarbonization and Hydrogen Technologies:	
• The FY 2023 Budget Request reflects new research on developing and advancing technologies for the production, transportation, and storage of domestically produced, carbon-neutral Hydrogen.	**+$26,000**
Total, Natural Gas Decarbonization and Hydrogen Technologies	**+$26,000**

Resource Sustainability
Natural Gas Decarbonization and Hydrogen Technologies

Description

The United States (U.S.) is well positioned to transition to a hydrogen economy and DOE is committed to advancing technology solutions that utilize fossil energy to enable this transition. Steam methane reforming (SMR) is an advanced and mature production process that builds upon the existing natural gas pipeline delivery infrastructure. However, traditional SMR has a heavy carbon footprint. Hydrogen production research will focus on the development of novel technologies for more efficient conversion of methane to hydrogen. Hydrogen transportation research will focus on blending hydrogen with natural gas and leveraging existing transportation and storage infrastructure. Research will include materials compatibility, compressor and pneumatic controller suitability, separation technologies, and life cycle and techno-economic analysis (TEA). Storage research will include reservoir assessment and response tests, impacts on geochemistry, physics, and geological structure of existing reservoirs when used for hydrogen storage. The program will also develop analytical tools and models that are able to evaluate potential advanced technologies, technology performance metrics, TEA, LCA, and resource evaluations. This analysis will provide potential technology pathways and aid in predicting future market penetration of different development strategies.

Resource Sustainability
Natural Gas Decarbonization and Hydrogen Technologies

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Natural Gas Decarbonization and Hydrogen Technologies $0	**$26,000,000**	**+$26,000,000**
• No FY 2021 enacted funding.	• Research on production of carbon-neutral hydrogen from methane, including novel conversion technologies. • Develop blending and separation technologies for natural gas with hydrogen and materials and components for dual use of infrastructure. • Research on utilizing natural gas storage for hydrogen.	• Increase reflects research on new natural gas hydrogen research program. • Research includes natural gas related research on carbon-neutral hydrogen production, transportation, and storage.

vefResource Sustainability
Mineral Sustainability

Overview
The Mineral Sustainability program will support domestic supply chain networks required for the economically, environmentally, and geopolitically sustainable production of critical minerals (CM). This mission will be accomplished by prioritizing the use of unconventional resources such as coal waste and by-products from industry feedstocks for domestic CM, rare earth elements (REE) and carbon ore to products production.

These unconventional resources are defined as coal waste and industrial by-products—coal refuse (mineral matter that is removed from coal), clay/sandstone over/under-burden materials, ash (coal combustion or gasification residuals), aqueous effluents such as Acid Mine Drainage (AMD), and associated solids and precipitates resulting from AMD treatment, as well as legacy, ponded, impoundment remediation/reclamation coal-based materials. In addition, CM extraction associated with produced water from the fossil fuel industry and industrial byproducts associated with steel, cement, and refining industries will also be considered.

It is imperative that the U.S. continue to invest in clean energy technologies. However, building these and other clean technologies will require ever larger quantities of minerals and metals than are currently being consumed. Unfortunately, the United States (U.S.) import dependency on many of the minerals and metals needed for clean energy technology—major stepping stones toward an improved climate quality—has continued to increase dramatically over the past 30 years.

The Mineral Sustainability subprogram activities in the Department of Energy's (DOE) Office of Fossil Energy and Carbon Management (FECM), along with complementary investments in DOE's Office of Energy Efficiency and Renewable Energy (EERE) are reversing this trend and providing the U.S. a path to reestablish itself as a leader in developing extraction and processing technologies to support a domestic supply chain for clean energy and national defense.

Developing more domestic CM resources in the most sustainable manner for meeting current and future demand has become a national priority. Development of sustainable and resilient CM supply chains has the potential to address adverse environmental concerns, revitalize domestic manufacturing capabilities, and create good paying jobs with a free and fair chance to join a labor union. Production of waste from coal and industrial sectors has the potential to create a mineral processing workforce in local disadvantaged coal and power plant communities by building co-production of CM and carbon products. Moreover, unconventional co-production provides our country with the added advantage of removing environmentally adverse materials that might disproportionately harm residents of these disadvantaged communities that are seeking opportunities to contribute to the transition to a clean energy economy.

Critical Minerals
The development of a domestic, economically competitive supply of CMs are needed to help fuel the Nation's economic growth; transition to clean energy technologies; secure energy independence by reducing reliance on foreign CM and REE sources; and increase U.S. national security. The CM subprogram focuses on the sustainable recovery of all CM, including REEs, throughout the upstream, midstream, and downstream supply chain by prioritizing the use of unconventional resources as the most environmentally sustainable primary feedstock resource for domestic production.

The CM subprogram activities will continue to develop advanced technologies throughout the supply chain, improve the economics of future projects through the evaluation of co-production of other valuable products (both critical and noncritical), and enable large-scale processing, separation, and metallization pilot-projects.

Other activities within the CM subprogram leverages the success of the former, fully integrated "Feasibility of Recovery of Rare Earth Element" research and development (R&D) project that developed separation and recovery technologies and the capability to assess and characterize feedstocks, but also demonstrated the technical feasibility of recovering CMs from a diversity of carbon ore feedstocks in small quantities. Building on this success, this activity will continue to enable future commercial technologies while minimizing land disturbance and maximizing environmental stewardship. This will be accomplished through technology development and validation—including machine learning (ML) and artificial intelligence, small- and large-scale pilot projects—including public-private partnerships, and existing basin partnerships developed through Carbon Ore Rare Earth-Critical Mineral Initiative (CORE-CM).

Since 2014, research, development, demonstration and deployment (RDD&D) activities have provided successful results from one Bench-scale REE-CM Separation facility at the University of North Dakota and three Pilot-Scale REE-CM Separation facilities at the University of Kentucky, West Virginia University and at Physical Sciences Inc. in Massachusetts, which have demonstrated the technical feasibility of extracting CMs and REEs from carbon ore and by-products in small quantities. These facilities were the first ever projects to demonstrate the capability to extract CMs/REEs from coal refuse, coal ash, and AMD. These small-scale projects were the foundation for the development of the large-scale pilots. Currently, pre-front end engineering and design (FEED) studies are underway and will be a pre-cursor to new FEED studies for the development of large-scale pilot facilities that will produce 1-3 tonnes/day mixed REEs and other CMs. In addition to this groundbreaking RDD&D, mineral characterization and analysis has been conducted on four to five thousand samples from fourteen coal-producing states, and initial geologic characterization research activities have shown positive indicators for finding materials (in Appalachia and other basins) associated with carbon ore beds that exceed the ore grades of some REE mining projects under development worldwide. Results from this activity's laboratory characterization work of the samples has indicated REE presence in the materials in the form of conventional minerals, such as monazite and xenotime. However, the work has also found the presence of materials from which REEs can be recovered using an ion-exchange solution, a technique that accounts for about 30% of Chinese REE production. Minerals of this type has been previously unknown to exist in the U.S., and thus offers an opportunity for REE production with less intensive processing steps required to produce REEs from conventional ores.

There are four key focus areas in which RDD&D will be conducted:

- **Resource Characterization and Technology Development**– Technology development and validation for environmentally sustainable exploration and production from various sources. This includes regional opportunities and assessments, the economic recovery of CMs through identification (including physical and chemical properties), mineral assays, prediction and assessment of resources and volumes of CMs/REEs from various feedstocks. It also includes development of new technologies for assessment of recoverable resources (drones, real time sensing and analytics, and micro drilling technologies). This work is coordinated with the U.S. Geological Survey (USGS) at the Department of Interior and the Environmental Protection Agency.
- **Sustainable Resource Extraction and Beneficiation Technology Development** – Novel technology development and validation for sustainable conventional and unconventional extraction to enable the recovery of CMs/REEs from sources that are not currently being recovered or that could be recoverable with more sustainable practices. This includes the extraction of CMs from unconventional feedstocks such as abandoned mining or other industrial process residuals while maximizing environmental controls.
- **Extractive Metallurgy, Reduction, and Alloying Technology Development**– Advanced technology development for concentration and processing of CMs and REEs. This includes development of models to use as virtual test platforms to optimize process separation designs. This area also includes technology development of individual high-purity separation and metallization. High purity elements will be critical to future metallization technology development and eventual use in manufactured products. This work is coordinated with ongoing work in EERE.
- **International Engagements, Standards, Supply Chain Development, and Characterization Technology Development**–Prioritize working with international allies to address sustainable practices throughout the world.

Highlights of the FY 2023 Budget Request

- Further advance facilities to produce large quantities of high purity, commercial grade REEs and other CMs, through FEED, the next stage of development to broadly enable extraction of REEs and other CMs from unconventional feedstocks (such as coal refuse and acid mine drainage) towards a commercial industry.
- Further regional basin projects (the CORE-CM Initiative), and the development of transformational technologies for individually separated highly purified, individual CMs/REEs, including individual separation, reduction to metals, and alloying. This work is coordinated with ongoing work in EERE.

- Support the maturation of transformational separation and extraction technologies, characterization of CMs/REEs, ML, and optimization modeling. Modeling and validation of models for optimization and efficiency improvements would improve process economics and are a necessary step in design and operation of larger scale facilities with continuous production.

Carbon Ore Processing

This Carbon Ore Processing subprogram (formally Advanced Coal Processing) is focused on utilizing materials to be recycled from previously mined resources outside of traditional thermal and metallurgical markets that can contribute to the U.S. gross domestic product. Activities in Carbon Ore Processing is focused on developing transformational technologies to enable domestic manufacturing of strategic materials and superior building products from carbon ore at competitive market prices. These transformational technologies have minimal emissions, superior product performance, and better lifecycle for new and existing products in the market.

RDD&D activities in the Carbon Ore Processing subprogram will further efforts for the development of existing and new technologies and identify projected markets for everyday and high value stream carbon products generated predominantly from coal waste and refuse; and identify the potential markets for carbon products if production costs are reduced to make it more competitive with current state of the art. Transformational technology development and validation will be conducted to enable future commercial industries in three areas:

- High-value carbon products, such as graphene, synthetic graphite, quantum dots, conductive inks, enhanced textiles, battery anodes, and supercapacitor materials from carbon ore;
- Universal infrastructure components, such as components for mass transit, sewers and tunnel, roads and bridges; and,
- Continuous industrial processes to reduce capital and operating costs for future carbon products.

The FY 2023 Budget Request of $4 million for Carbon Ore Processing combines basic chemistry and combustion science along with basic and fundamental research on thermo-physical properties, materials interactions, and heat transfer to improve how carbon ore and coal waste is processed and utilized to expand market opportunities. This work is coordinated with DOE's EERE. The funding will be used to:

- Develop new technologies for creating products such as supercapacitors and other electronic components, nanomaterials such as quantum dots, conductive specialty inks, as well as the production of synthetic graphite.
- Support new technologies for carbon fiber and nanomaterials, infrastructure such as foams, composites, building materials, and 3D printing materials.
- Support techno-economic characterization, life cycle analyses, and health and safety studies to assess the environmental impacts for coal waste-derived carbon products, composites, and 3D printing fluids in addition to continuing fundamental research in developing new advanced materials.

Resource Sustainability
Mineral Sustainability

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Mineral Sustainability $53,000,000	**$44,000,000**	**-$9,000,000**
Critical Minerals $23,000,000	**$40,000,000**	**+$17,000,000**
• Pre-front end engineering and design (FEED) Studies for large-scale pilot projects that will produce large quantities of high purity, commercial grade mixed rare earth elements (REE) and other critical minerals (CMs) including individual separation and metallization. • Research, Development, Demonstration, and Deployment (RDD&D) to enable Carbon Ore, Rare Earth, and Critical Mineral (CORE-CM) Initiative, supporting over 13 basins across the U.S. • Continued maturation of transformational separation and extraction technologies, characterization of CMs/REEs, machine learning and optimization modeling. • Funding opportunity announcement (FOA) on April 29, 2021 for Initiatives to Produce REEs and CMs.	• RDD&D to support FEED studies for technology development of CM including REE from unconventional feedstocks to produce large quantities of high purity, commercial grade REE and other CMs. • Further development of regional basin projects (the CORE-CM Initiative), and the development of transformational technologies for individually separated highly purified, individual CMs/REEs, including individual separation, reduction to metals, and alloying. • Support the maturation of transformational separation and extraction technologies, characterization of CMs/REEs, machine learning and optimization modeling.	• Support large-scale pilot development through FEED studies to produce large quantities of high purity, commercial grade REE and other CMs. • Additional support to maturation of transformational processing from unconventional resources.
Carbon Ore Processing $30,000,000	**$4,000,000**	**-$26,000,000**
• Develop existing and new technologies to turn coal waste and refuse into synthetic graphite and graphene. • RDD&D on carbon fiber production at Oak Ridge National Laboratory's (ORNL) Carbon Fiber Technology Facility (CFTF). • Support the development of next generation carbon-based building materials and infrastructure products with superior mechanical properties.	• Support safe and environmentally sustainable coal waste to products work. • Continue to support additive manufacturing of products using coal refuse via 3D printing to reclaim abandoned coal mining land. • Continue to support RDD&D of high value carbon-based products such as quantum dots and memristor computer chips, using novel technologies.	• Reduced funding for coal-based building composed of 51% carbon ore. • Maintain partial funding to support the development of synthetic graphite, carbon-based battery anodes, nanomaterials, and graphene in addition to ORNL's CFTF.

NETL Infrastructure
($K)

FY 2021 Enacted	FY 2022 Annualized CR	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
55,000	**55,000**	**55,000**	**+$0**	**0%**

Overview

The National Energy Technology Laboratory (NETL) Infrastructure Program supports the fixed costs of NETL's laboratory footprint in three geographic locations: Morgantown, WV; Pittsburgh, PA; and Albany, OR. Table 1 provides information on the size of each site.

The NETL Infrastructure Program comprises the following subprograms:

(1) **High-Performance Computer (Super Computer)** provides funding for the 3-year lease of Joule, NETL's high-performance computer (HPC) at Morgantown, WV. The FY 2023 Budget Request includes $6.0 million for the continuation of a 3-year lease.

(2) **Laboratory and Sitewide Facilities** includes repairs to existing laboratory facilities, general-purpose buildings, and sitewide infrastructure and the continued management of deferred maintenance balances. Priorities for funding are established to ensure compliance with life safety standards, ensure critical laboratory research facilities and infrastructure, and comply with High Performance Sustainable Building (HPSB) goals.

(3) **Safeguards and Security** provides funds to ensure protection of workers (physical and cyber), the public, the environment, facilities, and operations in performing the Office of Fossil Energy and Carbon Management (FECM) research, development, demonstration, and deployment (RDD&D) mission.

(4) **Environmental Restoration** supports NETL's obligations to the Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) across all NETL sites and one off-site location in Wyoming.

Table 1[1]: Comparison of Physical Footprint, Workforce, and Value of Assets by Campus and in Total, National Energy Technology Laboratory as of August 31, 2021

	Morgantown	Pittsburgh	Albany	Total NETL
Buildings	42	30	35	**107**
Sq. Ft. of Building Space (000s)	445	431	243	**1,119**
Acres	136	57.4	43.9	**237.3**
NETL Federal Workforce	214	230	46	**493**[2]
NETL Contractor Workforce (FTEs)	324	399	90	**843**[3]
Assets Replacement Value	$292.8M	$243.9M	$180.8M	**$717.5M**

[1] Table 1 reflects on board employees as of February 28, 2022 and Table 2 reflects authorized and requested FTEs.

[2] Total NETL includes two employees located in Houston, TX and one located in Germantown, MD.

[3] Total NETL includes three contractors located in Houston, TX And 27 located offsite.

Table 2: Reconciliation of FECM RDD&D Federal Employees (FTEs)

	FY 2021 Enacted	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted
NETL Program Direction	125	138	+13
NETL Research & Operations	430	440	+10
TOTAL, NETL	**555**	**578**	**+23**
FECM-HQ Program Direction	124	141	+17
TOTAL, FECM RDD&D	**679**	**719**	**+40**

Highlights of the FY 2023 Budget Request

The FY 2023 Budget Request for NETL Infrastructure is $55 million. This request includes $19 million for General Plant Projects (GPP), prioritizing research laboratory upgrades in key FECM areas such as Materials Characterization, Materials Engineering Manufacturing, and Geological Environmental Sciences. Additional GPP investments include deferred maintenance management projects and investments in reducing NETL's carbon footprint. An additional $6 million is requested for NETL's high performance computer lease. High performance computing is an essential element in more than 50% of NETL's research projects. The balance of the request is for investments in information technology (IT) development, modernization, enhancements, and fixed operational costs such as utilities, IT licenses and agreements, safeguards and security, environmental compliance and remediation, and routine building maintenance.

FY 2023 Departmental Crosscuts ($K)

	Cybersecurity	
	2021 Enacted	**2023 Request**
NETL Infrastructure	4,772	9,178

The FY 2023 Budget Request supports one Departmental crosscut: Cybersecurity. For FECM RDD&D, this includes operation and enhancement of the FECM RDD&D cybersecurity policy and program as it relates to the enterprise computing environment at field locations. Key activities include cybersecurity policy implementation, governance and oversight activities, incident detection and response through continuous monitoring and diagnostics, and meeting Departmental requirements for the Identity, Credential, and Access Management (ICAM) Initiative. Within the FY 2023 Budget Request for NETL Infrastructure, $9.178 million will be used to support these crosscutting cyber activities. Cybersecurity is funded under the Safeguards and Security subprogram.

NETL Infrastructure
Funding ($K)

	FY 2021 Enacted	FY 2022 Annualized CR	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
NETL Infrastructure					
Super Computer	6,000	6,000	6,000	0	0%
Laboratory- & Site-Wide Facilities	39,500	39,000	39,000	-500	-1.2%
Safeguards and Security	7,500	8,000	8,000	+500	+6.7%
Environmental Restoration	2,000	2,000	2,000	0	0%
Total, NETL Infrastructure	**55,000**	**55,000**	**55,000**	**0**	**0%**

NETL Infrastructure
Explanation of Major Changes ($K)

	FY 2023 Request vs FY 2021 Enacted
NETL Infrastructure: No change from FY 2021 Enacted	**0**
Total, NETL Infrastructure	**0**

NETL Infrastructure

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
NETL Infrastructure $55,000,000	**$55,000,000**	**$0**
High Performance Computer (Super Computer) $6,000,000	**$6,000,000**	**$0**
• Funding is for the 3-year lease of Joule, National Energy Technology Laboratory's (NETL) high performance computer (HPC) at Morgantown, WV.	• Funding is for the 3-year lease of Joule, NETL's HPC at Morgantown, WV.	• No change.
Laboratory and Site wide Facilities $39,500,000	**$39,000,000**	**-$500,000**
• Funding includes repairs to existing laboratory facilities and general-purpose buildings and site-wide infrastructure. Priorities for funding are established to ensure compliance with life safety standards, ensure critical laboratory research facilities and infrastructure and comply with High Performance Sustainable Building (HPSB) goals.	• Funding includes repairs to existing laboratory facilities and general-purpose buildings and site-wide infrastructure. Priorities for funding are established to ensure compliance with life safety standards, ensure critical laboratory research facilities and infrastructure and comply with HPSB goals. Funding also includes information technology (IT) development, modernization, and enhancement (DME) investment.	• The FY 2023 Budget Request includes a slight reduction in General Plant Projects. The request also includes $2.5 million for IT DME.
Safeguard and Securities $7,500,000	**$8,000,000**	**+$500,000**
• Funding is to ensure protection of workers (physical and cyber), the public, the environment, facilities, and operations in performing the FECM RDD&D mission.	• Funding is to ensure protection of workers (physical and cyber), the public, the environment, facilities, and operations in performing the FECM RDD&D mission.	• Slight increase in security costs.
Environmental Restoration $2,000,000	**$2,000,000**	**$0**
• Continue active operation and maintenance of the air sparge ground water remediation systems at Rock Springs, Wyoming, Sites 4, 6, 7, 9, and 12 under the guidance of the Wyoming Department of Environmental Quality (DEQ). • Continue all NETL on-site Resource Conservation and Recovery Act (RCRA) hazardous waste compliance and management activities. • Continue all NETL Albany ground water investigation and compliance activities.	• Continue active operation and maintenance of the air sparge ground water remediation systems at Rock Springs, Wyoming, Sites 4, 6, 7, 9, and 12 under the guidance of the Wyoming DEQ. • Continue all NETL on-site RCRA hazardous waste compliance and management activities. • Continue all NETL Albany ground water investigation and compliance activities.	• No change.

Plant and Capital Equipment
Capital Summary ($K)

	Total	Prior Years	FY 2021 Enacted	FY 2021 Actuals	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted
Capital Operating Expenses Summary (including Major Items of Equipment (MIE))						
Capital Equipment >$500K (including MIE)	n/a	0	0	0	0	0
Minor Construction Project (>$5M)	44,372	0	12,000	12,000	0	-12,000
Total, Capital Operating Expenses	**44,372**	**0**	**12,000**	**12,000**	**0**	**-12,000**
Capital Equipment > $500K (including MIE)						
Total Non-MIE Capital Equipment	n/a	0	0	0	0	0
Total, Capital Equipment (including MIE)	**n/a**	**0**	**0**	**0**	**0**	**0**
Minor Construction Projects (>$5M)						
Computational Science & Engineering Center	19,372	0	12,000	12,000	0	-12,000
Direct Air Capture Center	25,000	0	0	0	0	0
Total, Minor Construction Projects	**44,372**	**0**	**12,000**	**12,000**	**0**	**-12,000**
Total, Capital Summary	**44,372**	**0**	**12,000**	**12,000**	**0**	**-12,000**

NETL Research and Operations
($K)

FY 2021 Enacted	FY 2022 Annualized CR	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
83,000	**83,000**	**83,000**	**+$0**	**0%**

Overview

The National Energy Technology Laboratory (NETL) is an integral part of the U.S. Department of Energy (DOE) national laboratory system. There are 17 National Laboratories in the DOE laboratory system; NETL is unique in that it is the only government-owned, government-operated laboratory. NETL supports the DOE mission by addressing energy and environmental challenges through transformative science and technology solutions. NETL is recognized for its capabilities in applied material science, computation science, chemical and systems engineering, subsurface science, decision science, as well as its expertise in government contract and project management.

The NETL Research and Operations Program comprises three subprograms:

(1) **Research, Development, Demonstration, and Deployment** (RDD&D) funding supports Federal researcher salaries and benefits, travel, personal protective equipment, and other employee costs for the NETL staff of scientists and engineers who conduct in-house research activities for Fossil Energy and Carbon Management (FECM) RDD&D programs. This subprogram also funds the salaries, benefits, travel, and other employee costs for the NETL staff of engineers and technical professionals who conduct project management for FECM RDD&D programs. This subprogram also funds partnership, technology transfer, and other collaborative research activities with universities, other National Laboratories, state and local governments, and industry, as well as strategic energy analysis and research data management.

(2) **Site Operations** includes funding for: (a) building operations and maintenance such as structural repairs, routine upkeep, and pandemic protocols; and (b) grounds maintenance including parking lot repair, lighting, groundskeeping, snow removal, etc.

(3) **Program Oversight** includes funding for Federal employees and contractors performing research-enabling functions such as managing financial assistance and providing legal and finance oversight of research grants and awards.

Highlights of the FY 2023 Budget Request

The NETL Research and Operations Request is consistent with the FY 2021 Enacted level. Areas of increasing costs are offset by operational efficiencies. In addition to an increase in salary and benefit levels, increases include 10 additional research FTEs, consistent with NETL's special hiring authority to add up to 10 accepted service term appointments to enhance recruitment through the temporary infusion of highly talented individuals who can assist in meeting a specific project/research need and possess advanced scientific or engineering backgrounds or business backgrounds that can assist in specific technology-to-market needs. Additional increases allow NETL to reduce operational risk in site operations. Funding will be used to enhance: (1) cleaning and disinfecting services, site access screening, and other activities in response to the pandemic; (2) controls around engineering drafting and drawing, shipping and receiving, and industrial hygiene sampling; and (3) predictive and preventative maintenance. Offsetting these cost increases are reductions in contractor support in the areas of fleet and transportation management, warehouse and property management, and business integration support. Also, costs under an expiring Energy Savings Performance Contract (ESPC) discontinue after FY 2022.

NETL Research and Operations
Funding ($K)

	FY 2021 Enacted	FY 2022 Annualized CR	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
NETL Research and Operations					
Research, Development, Demonstration, and Deployment	51,000	51,000	54,000	+$3,000	+6%
Site Operations	21,000	21,000	18,000	-$3,000	-14%
Program Oversight	11,000	11,000	11,000	0	0%
TOTAL, NETL Research and Operations	**83,000**	**83,000**	**83,000**	**0**	**0%**
Federal FTEs	**430**	**430**	**440**	**+10**	**+2.3%**

Federal FTEs shown above include technical project managers and procurement and finance personnel providing support to DOE's Office of Energy Efficiency and Renewable Energy (EERE), Office of Cybersecurity, Energy Security, and Emergency Response (CESER), and Office of Electricity (OE). These NETL personnel are funded by those non-FECM RDD&D offices to the extent that their time is spent supporting those offices.

NETL Research and Operations
Explanation of Major Changes
($K)

	FY 2023 Request vs FY 2021 Enacted
NETL Research and Operations:	
• The FY 20203 Budget Request is the same as FY 2021 Enacted. Increases in Federal headcount and salary and benefit levels, along with increased costs for including pandemic response activities, enhancement of controls, and predictive and preventative maintenance are offset by contractor support cost savings and the expiration of an ESPC.	**$0**
Total, NETL Research and Operations	**$0**

NETL Research and Operations
Funding

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
NETL Research and Operations $83,000,000	**$83,000,000**	**+$0**
Research, Development, Demonstration, and Deployment $51,000,000	**$54,000,000**	**+$3,000,000**
• Research, Development, Demonstration, and Deployment (RDD&D) funding supports salaries and benefits, travel, personal protective equipment, and other employee costs for the NETL staff of scientists and engineers who conduct in-house research activities for the Office of Fossil Energy and Carbon Management (FECM) RDD&D programs. Funding also supports NETL's Research & Innovation Center strategic efforts such as the FECM Roadmap and NETL Science & Technology competency assessments. • RDD&D funding also provides for collaborative research, development, demonstration, and deployment activities, including Federal salaries/benefits, travel and employee costs for engineers, and technical project managers associated with the FECM programs. • Funding provides for costs targeted toward collaboration, strategic energy analysis and research data management areas. Funding also provides for ongoing operation and maintenance of project management information systems.	• RDD&D funding supports salaries and benefits, travel, personal protective equipment, and other employee costs for the NETL staff of scientists and engineers who conduct in-house research activities for FECM RDD&D programs. Funding also supports NETL's Research & Innovation Center strategic efforts such as the FECM Roadmap and NETL Science & Technology competency assessments. • RDD&D funding also provides for collaborative research, development, demonstration, and deployment activities, including Federal salaries/benefits, travel and employee costs for engineers, and technical project managers associated with the FECM programs. • Funding provides for costs targeted toward collaboration, strategic energy analysis and research data management areas. Funding also provides for ongoing operation and maintenance of project management information systems.	• Increase reflects an increase of 10 federal FTEs and a 2.7% salary and benefit increase for existing staff in 2022 and an additional 4.6% in 2023.
Site Operations $21,000,000	**$18,000,000**	**-$3,000,000**
• Site Operations funding supports variable costs of operating NETL's laboratories and research sites. Funding provides for operations personnel along with support contractors for building operations, grounds maintenance, etc.	• Site Operations funding supports variable costs of operating NETL's laboratories and research sites. Funding provides for operations personnel along with support contractors for building operations, grounds maintenance, etc.	• The net reduction reflects decreased contractor support in the areas of fleet and transportation management, warehouse and property management, and business integration support. The net reduction also reflects the expiration of

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
		an Energy Savings Performance Contract. These reductions are partially offset by increased costs for enhanced: (1) cleaning and disinfecting services, site access screening, and other activities in response to the pandemic; (2) controls around engineering drafting and drawing, shipping, and receiving, and industrial hygiene sampling; and (3) predictive and preventative maintenance.
Program Oversight $11,000,000	**$11,000,000**	**+$0**
• Program Oversight funding at NETL supports salaries/benefits for federal employees performing research-enabling support functions necessary for the performance of NETL's research activities.	• Program Oversight funding at NETL supports salaries/benefits for federal employees performing research-enabling support functions necessary for the performance of NETL's research activities.	• No change.

Interagency Working Group
($K)

FY 2021 Enacted	FY 2022 Annualized CR	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
0	0	3,000	+$3,000	N/A

Overview
On January 27, 2021, President Biden signed Executive Order (EO) 14008, "*Tackling the Climate Crisis at Home and Abroad*". EO 14008, Section 218, established an Interagency Work Group (IWG) on Coal and Power Plant Communities and Economic Revitalization to be co-chaired by the Director of the National Economic Council and the National Climate Advisor and administered the Secretary of Energy. In April 2021, the IWG prepared an Initial Report to the President on Empowering Workers through Revitalizing Energy Communities and identified 25 communities across the country hard-hit by coal mine and power plant closures. The IWG will promote investments that support economic revitalization and job creation in these and other energy communities and will also proactively promote investments in communities likely to be impacted by these closures in the near-term. These communities include workers directly employed in coal mining and power generation, those in related jobs in logistics and services, and residents who are dependent on coal and power plant-related tax revenue to fund schools, public services, and infrastructure as well as fenceline communities and other communities impacted by the environmental and health effects of fossil energy generation.

Highlights of the FY 2023 Budget Request
The FY 2023 Budget Request of $3 million for the DOE-led IWG on Coal and Power Plant Communities and Economic Revitalization will support targeted investments across the Federal government to help communities impacted by the climate crisis and shift to a clean energy economy. Other highlights include connecting targeted communities with funding from the following sources:

- Grant funding for infrastructure projects, including, roads, broadband, water and sewer system improvements, and local transportation—creating immediate good-paying union jobs and laying the foundation for economic development.
- Resources to deploy innovative low-carbon technologies on power plants and industrial facilities—capitalizing on technological advances to prepare traditional energy infrastructure for the clean energy economy.
- Financing and grant funding programs to remediate abandoned mine lands, orphaned oil and gas wells, mine-impacted water, and brownfields—restoring natural assets and curbing toxic emissions that pose serious safety hazards and contaminate air and water.
- Funding for small businesses, community development financial institutions, local non-profit organizations, and economic innovation hubs—supporting the local economic infrastructure necessary for economic revitalization.
- Grant funding for regional economic development-aligned workforce development—enabling energy communities to prepare workers for new markets and industries.

Interagency Working Group
Explanation of Major Changes ($K)

	FY 2023 Request vs FY 2021 Enacted
Interagency Working Group:	
• The FY 2023 Budget Request will support targeted investments across the Federal government to help affected communities impacted by the climate crisis and shift to a clean energy economy.	**+$3,000**
Total, Interagency Working Group	**+$3,000**

Interagency Working Group

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Interagency Working Group $0	**$3,000,000**	**+$3,000,000**
• Using available resources, the Interagency Working Group (IWG) conducted over 100 in-person and virtual workshops, webinars, and stakeholder meetings. • Developed a public-facing website (EnergyCommunities.Gov) to serve energy communities. • Developed a searchable clearinghouse of Federal funding opportunities available to energy communities.	• Continue targeted, place-based interventions using an interagency approach that leverages existing federal and technical assistance resources to assist energy communities, including displaced energy workers. • Establish a concierge function to provide direct technical assistance to energy communities on how to access Federal resources. • Streamline the process for applying Federal funding. Create a pilot that uses a common application for two or more agencies. • Maintain the clearinghouse on Federal funding opportunities available to energy communities.	• The IWG will support targeted investments across the Federal government to help affected communities impacted by the climate crisis and shift to a clean energy economy.

Special Recruitment Programs
($K)

FY 2021 Enacted	FY 2022 Annualized CR	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
700	700	1,000	+$300	+43%

Overview
The Office of Fossil Energy and Carbon Management (FECM) emphasizes educational programs to support an increase in the number of females and under-represented minorities entering science (including social science), technology, engineering, mathematics (STEM) career fields within the U.S. workforce. FECM programs, including the Mickey Leland Energy Fellowship (MLEF) and other educational programs, offer undergraduate, graduate, and post-graduate students majoring in STEM disciplines opportunities to learn about programs, policies, and research, development, demonstration, and deployment (RD^3) initiatives within FECM and the challenges in providing clean, affordable energy for future generations. FECM also utilizes Departmental program such as the Minority Educational Institution Student Partnership Program (MEISPP), the Department of Energy (DOE) Scholars Program, and the DOE Science, Technology and Policy (STP) Program to provide students the opportunity to gain work experience and learn about the FECM and DOE missions to support preparation for careers with DOE and in the STEMS workforce. The Special Recruitment Programs aligns with the Administration’s Justice40 Initiative and equity priorities.

Highlights of the FY 2023 Budget Request
In FY 2023, FECM will recruit and select a diverse group of undergraduate, graduate, and post-graduate students in STEM majors to participate in FECM and DOE educational programs such as the MLEF, MEISPP, DOE Scholars, STP, and other student programs. Recruitment emphasis will be on Historically Black Colleges and Universities (HBCUs) and other Minority Serving Institutions (MSIs). All participants in the MLEF, MEISPP, DOE Scholars, STP, and other FECM and DOE educational programs will complete challenging assignments supporting the FECM mission through hands-on research and development (R&D) projects under the mentorship of an FECM scientist, researcher, or program official.

Special Recruitment Programs
Funding ($K)

	FY 2021 Enacted	FY 2022 Annualized CR	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
Special Recruitment Programs	700	700	1,000	+$300	+43%
Total, Special Recruitment Programs	**700**	**700**	**1,000**	**+$300**	**+43%**

Special Recruitment Programs
Explanation of Major Changes ($K)

	FY 2023 Request vs FY 2021 Enacted
Special Recruitment Programs: • The FY 2023 Budget Request level supports administration of the MLEF, MEISPP, DOE Scholars, STP, or other educational programs.	**+$300**
Total, Special Recruitment Programs	**+$300**

Special Recruitment Programs

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Special Recruitment Programs $700,000	**$1,000,000**	**+$300,000**
• A diverse group of undergraduate, graduate, and post-graduate students in STEM majors will be recruited and selected to participate in the MLEF, MEISPP, DOE Scholars, DOE STP, or other educational programs. Provides students opportunity to gain hands-on research and work experience and learn more about the DOE and the FECM missions.	• A diverse group of undergraduate, graduate, and post-graduate students in STEM majors will be recruited and selected to participate in the MLEF, MEISPP, DOE Scholars, DOE STP, or other educational programs. Provides students opportunities to gain hands-on research and work experience and learn more about the DOE and FECM missions.	• The increased funding will provide for additional fellowships, increased financial support (i.e., higher stipends) to participants, and enhanced recruitment engagements with HBCUs and MSIs.

Program Direction
($K)

FY 2021 Enacted	FY 2022 Annualized CR	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
61,500	**61,500**	**70,291**	**+$8,791**	**+14.3%**

Overview
Program Direction provides for the Headquarters (HQ) workforce responsible for the oversight and administration of the Fossil Energy and Carbon Management (FECM) Research, Development, Demonstration, and Deployment (RDD&D) program. It also provides for technical staff at the National Energy Technology Laboratory (NETL) who perform Procurement, Finance and Legal functions, as well as Federal workforce and contractor support for Communications. It does not include NETL scientific researchers or project managers.

Also included in Program Direction is funding for the operations of the Import/Export Authorization Office, which is managed by the Division of Natural Gas Regulation within the Office of Resource Sustainability. The program has responsibility for regulating natural gas and liquefied natural gas (LNG) imports and exports under the Natural Gas Act of 1938, section 3, using both Federal staff and contractor support.

Each of these elements also fund the Department of Energy's (DOE) Oak Ridge Human Resources Shared Service Center and the FECM program office contribution to the DOE Working Capital Fund.

Highlights of the FY 2023 Budget Request
The FY 2023 Budget Request is $70.291 million and reflects a $8.791 million increase from the FY 2021 Enacted level. This 14.3% increase is driven by a 2.7% pay increase in 2022 and a 4.6% pay increase for 2023, and a requested 19.1% increase in FECM funding. An increased federal staffing level is required to maintain appropriate program oversight and administration of FECM programs, including support efforts at NETL to oversee, award, manage, and closeout RDD&D programs and projects. These efforts increase the effectiveness of government sponsored RDD&D and reduce the risk of noncompliance. This funding level also supports the Department's efforts to evaluate ways to improve operational efficiency.

Program Direction
Funding ($K)

Program Direction Summary	FY 2021 Enacted	FY 2022 Annualized CR	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
Washington Headquarters					
Salaries and Benefits	21,937	21,937	25,732	+3,795	+17.3%
Travel	394	394	400	+6	+1.5%
Support Services	546	546	2,911	+2365	+433.2%
Other Related Expenses	8,476	8,476	8,418	-58	-0.7%
Total, Washington Headquarters	**31,353**	**31,353**	**37,461**	**+6,108**	**+19.5%**
National Energy Technology Laboratory					
Salaries and Benefits	17,000	17,000	19,300	+2,300	+13.5%
Travel	400	400	400	0	0.0%
Support Services	7,280	7,280	7,100	-180	-2.5%
Other Related Expenses	3,100	3,100	3,100	0	0.0%
Total, National Energy Technology Laboratory	**27,780**	**27,780**	**29,900**	**+2,120**	**+7.6%**
Import/Export Authorization					
Salaries and Benefits	1,554	1,554	1,930	+376	+24.2%
Travel	18	18	20	+2	+11.1%
Support Services	231	231	450	+219	+94.8%
Other Related Expenses	564	564	530	-34	-6.0%
Total, Import/Export Authorization	**2,367**	**2,367**	**2,930**	**+563**	**+23.8%**
Total Program Direction					
Salaries and Benefits	40,491	40,491	46,962	+6,471	+16.0%
Travel	812	812	820	+8	+1.0%
Support Services	8,057	8,057	10,461	+2,404	+29.8%
Other Related Expenses	12,140	12,140	12,048	-92	-0.8%
Total Program Direction	**61,500**	**61,500**	**70,291**	**+8,791**	**+14.3%**

Program Direction Summary	FY 2021 Enacted	FY 2022 Annualized CR	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
Federal FTEs – HQ	**121**	**121**	**141**	**+20**	**+16.5%**
Federal FTEs – NETL[1]	**121**	**121**	**138**	**+17**	**+14.0%**
Federal FTEs – Total	**242**	**242**	**279**	**+37**	**+15.3%**
Support Services					
Technical Support					
Headquarters	546	546	2,911	+2,365	+433.2%
NETL	0	0	0	0	0.0%
Import/Export Authorization	231	231	450	+219	+94.8%
Total, Technical Support	**777**	**1,035**	**3,361**	**+2,584**	**+332.6%**
Management Support					
Headquarters	0	0	0	0	0.0%
NETL	7,280	7,280	7,100	-180	-2.5%
Import/Export Authorization	0	0	0	0	0.0%
Total Management Support	**7,280**	**7,280**	**7,100**	**-180**	**-2.5%**
Total, Support Services	**8,057**	**8,057**	**10,461**	**+2,404**	**+29.8%**
Other Related Expenses					
Headquarters	8,476	8,476	8,418	-58	-0.07%
NETL	3,100	3,100	3,100	0	0.00%
Import / Export Authorization	564	564	530	-34	-6.0%
Total, Other Related Expenses	**12,140**	**12,140**	**12,048**	**-92**	**-0.8%**

[1] Additional NETL FTEs are funded within the NETL Research and Operations budget line.

Program Direction
Funding

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Program Direction $61,500,000	**$70,291,000**	**+$8,791,000**
Salaries and Benefits $40,491,000	**$46,962,000**	**+$6,471,000**
• The funding supports Headquarters (HQ) Federal staff who provide monitoring (oversight and audit) activities for the Office of Fossil Energy and Carbon Management (FECM) research, development, demonstration and deployment (RDD&D) portfolio. • The funding supports the technical Federal staff at the National Energy Technology Laboratory (NETL). The staff covered in this area provide for management of the Lab, communications, legal, acquisition and finance activities.	• The funding supports HQ Federal staff who provide monitoring (oversight and audit) activities for the FECM RDD&D portfolio. • The funding supports the technical Federal staff at NETL. The staff covered in this area provide for management of the Lab, communications, legal, acquisition and finance activities.	• The HQ increase reflects the addition of 20 full-time equivalents (FTE) to support FECM's mission as well as a 4.6% pay raise for federal staff in 2023, the Federal Employees Retirement System (FERS) increase, and awards pool funding increase in FY 2022. • NETL increase reflects the addition of 17 FTEs to support FECM's mission as well as a 2.7% pay raise for federal staff in 2022 and a 4.6% pay raise, FERS increase, and awards pool funding increase in FY 2023.
Travel $812,000	**$820,000**	**+$8,000**
• Travel includes funding for management meetings, training, etc.	• Travel includes funding for management meetings, training, etc.	• Travel increase is a minimal addition.
Support Services $8,057,000	**$10,461,000**	**+$2,404,000**
• Support Services at HQ includes technical support, information technology (IT) support, site operations support, administrative support. • Support services at NETL include management and communications support, as well as finance and acquisition technicians.	• Support Services at HQ includes technical support, IT support, site operations support, administrative support. • Support services at NETL include management and communications support, as well as finance and acquisition technicians.	• The HQ request is a slight increase over the FY 2021 Request. • The NETL decrease of $0.68 million reflects a shift of 5 FTEs from contractor staff to federal staff; these positions represent permanent needs (rather than cyclical) in direction-setting roles appropriately staffed with Federal employees. Reduction also reflects efficiencies gained through continuous process improvement and automation.

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Other Related Expenses $12,140,000	**$12,048,000**	**-$92,000**
• The activities supported by this line item include E-Government initiatives, Working Capital Fund (WCF), computer systems and support, contractual services for HQ and environmental, security, safety, and health requirements at HQ and Human Resources shared service center payments.	• The activities supported by this line item include E-Government initiatives, WCF computer systems and support, contractual services for HQ and environmental, security, safety, and health requirements at HQ and Human Resources shared service center payments.	• Request reflects a decrease due to re-prioritization.

Repurposing Fossil Energy Assets
($K)

FY 2021 Enacted	FY 2022 Annualized CR	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
5,000	5,000	6,000	+$1,000	+20%

Description
Over the next few decades, the United States (U.S.) and the world will need to dramatically reduce greenhouse gas (GHG) emissions to avoid the worst effects of climate change. This imperative implies an unprecedented transition in the energy system away from GHG-emitting fuels (unabated coal, oil, and natural gas) and toward clean energy sources, such as wind, solar, and nuclear, along with emerging technologies, such as large-scale energy storage and carbon capture, use, and storage. This transition will be challenging for a variety of technical, political, and socio-economic reasons.

In the U.S., fossil resources (coal, natural gas, and oil) play a major role in meeting energy needs. Yet, accelerated penetration of renewable energy-based generation into the energy grids has resulted in a decline in fossil-based generation over the past decade. Coal communities have faced major challenges in recent years. In parts of Appalachia, coal-related employment has declined for decades due to increased automation and reduced demand. In the Powder River Basin, the largest source of U.S. coal, production began declining in 2008 and has fallen more sharply in recent years.

Coal-unit retirements, driven by changing economics, may leave valuable features of communities on the table, such as a skilled workforce, community relationships, transmission and distribution infrastructure, electrical interconnect equipment, and site and permitting licenses. As the Nation alters its carbon footprint, repurposing fossil energy assets, such as coal and natural gas plants and oil and gas wells, may address potential resistance to decommissioning coal plants and allow newer technologies to replace them. Repurposing fossil energy assets also allows communities to be active participants in the current and coming energy transition. Benefits are very clear since projects that transition fossil assets may utilize the local skilled workforce, keep sites economically active, leverage the value of infrastructure, and provide grid stability benefits (such as rotational inertia) as retiring assets are repurposed.

Energy storage is critical to advance a flexible and resilient electric grid. Achieving net-zero carbon emissions by 2050 in the U.S. will rely primarily on renewables for the electricity sector, but some fossil fuels coupled with carbon capture and reliable storage as well as strategic storage that includes hydrogen or ammonia will likely be required for near-term baseload applications. FECM will leverage its expertise in the geologic storage of carbon dioxide (CO_2) to explore and invest in approaches to store hydrogen and ammonia in significant quantities required for grid demand. This subprogram takes a technology agnostic approach to long-duration energy storage that is scalable from small applications to full-scale commercial power plants. The subprogram focuses on the integration of long-duration energy storage technologies with a variety of fossil assets, including large-scale coal and gas power plants as well as smaller assets like single-cycle peaking gas turbines and microgrid applications. Co-locating energy storage with fossil assets provides many benefits including improved asset flexibility and efficiency, improved grid reliability, and reduced GHG emissions. Additionally, energy storage enables many heavily decarbonized use cases; for example, the integration of a hydrogen energy storage system with hydrogen turbine power production. Analytical results and stakeholder input suggest this activity will emphasize energy storage technologies that are thermal, chemical (including hydrogen/ammonia), mechanical, or long-duration electrochemical (e.g., flow battery) in nature. FECM's activities are coordinated with the Department of Energy's crosscut activities across the Office of Electricity (OE), Energy Efficiency and Renewable Energy (EERE), Nuclear Energy (NE), Advanced Research Projects Agency -Energy (ARPA-E), and Office Technology Transitions (OTT). FECM's energy storage activities are documented in the Energy Storage Grand Challenge (ESGC) roadmap and regularly communicated among the Department's participating offices.

This request provides $6 million to develop case studies that leverage the Use Cases indicated in the ESGC Roadmap and their associated metrics and to support feasibility studies of co-located energy storage technologies with fossil assets.

Repurposing Fossil Energy Assets

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Repurposing Fossil Energy Assets $5,000,000	**$6,000,000**	**+$1,000,000**
• Research and development is focused on DOE's efforts to take a broad, more holistic view of energy storage as a set of capabilities that enable temporal flexibility in the conversion of energy resources to useful energy services.	• Develop early-stage concepts with some pre-front end engineering design (FEED) studies to integrate technologies (e.g., chemical, thermal, mechanical and electrochemical) with fossil assets as they transition to meet decarbonization goals.	• The increased funding will help to move some of the selected pre-FEED work to prepare case studies including the initial assessment of technologies at potential fossil sites.

Fossil Energy and Carbon Management Workforce Development
University Training and Research

Description
As part of President Biden's commitment to advance environment justice and spur economic opportunity for disadvantaged communities, the Administration established the Justice40 Initiative. The Department of Energy's (DOE) FY 2023 Budget Request proposes historic increases in funding for foundational research and development (R&D) to train the next generation of students at historically black colleges and universities (HBCU) and minority-serving institutions (MSI) majoring in science, technology, engineering, and mathematics (STEM), and humanities (including social and behavioral) disciplines to strengthen the workforce. The University Training and Research (UTR) subprogram focuses on introducing students to the diversity of research topics pursued in support of the Administration's goals and the inseparability of the humanities and human element in new technology deployment. The FY 2023 Budget will provide $13 million for new competitive funding opportunity announcements (FOA) for U.S. academic institutions of higher learning to support fundamental research that cuts across the Office of Fossil Energy and Carbon Management's (FECM) research focus areas, including exploration and education of the integration of cultural sensitivities, design and esthetics, and other community issues, into the development and deployment of new technology. The funding aims to sustain a national university program of research in energy, environmental, science, social science, engineering, and humanities that focuses on innovative and fundamental investigations pertinent to advancing the Administration's research, development, demonstration and deployment (RDD&D) and equity goals.

The UTR subprogram comprises of two areas, which are competitively funded on an annual basis to encourage broad participation:

- **University Carbon Research (UCR) $5M:** This sub-activity provides funding to colleges and universities to support early-stage research and education into societal and human impacts of new technology development and deployment consistent with the program's goals including Advancing Carbon Dioxide Removal, Accelerating Clean Hydrogen, Demonstrating and Deploying Point-Source Carbon Capture, and Advancing Critical Minerals (CM), Rare Earth Elements (REEs), Coal Waste to Products, and Mine Remediation. This sub-activity provides a threefold benefit: (1) conducting directed energy research in an innovative environment; (2) expanding the research capabilities and education of students in STEM and humanities disciplines; and (3) developing research-based solutions to support Administration RDD&D and equity goals.

- **Historically Black Colleges and Universities (HBCU) and other Minority Serving Institutions (MSI) $8M**: This sub-activity also supports early-stage mission-focused research and investigations and education into the societal and human impacts of new technology deployment related to the FECM mission. Grants awarded under this program are intended to maintain and upgrade the educational, training, and research capabilities of HBCUs/MSIs in the fields of STEM and humanities with project results being used to further DOE's commitment to fossil energy and carbon management and further Administration equity priorities.

Fossil Energy and Carbon Management Workforce Development
University Training and Research

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
University Training and Research $5,050,000	**$13,000,000**	**+$7,950,000**
University Carbon Research $3,000,000	**$5,000,000**	**+$2,000,000**
• Released competitive funding opportunity announcements (FOA) for U.S. academic institutions of higher learning to support fundamental research that cuts across the Office of Fossil Energy and Carbon Management's (FECM) research focus areas.	• Funding increase through a FOA(s) to the national university program for research in energy, environmental, science, social science, engineering, and humanities that focus on innovative and fundamental investigations pertinent to advancing the goals of the program.	• The request level significantly increases historical funding levels, in part, to accommodate the Administration's Justice40 Initiative. • Support curriculum design, research on successful recruitment and retention methods, development of outreach or mentorship programs, fellowships, and building science, engineering research, and education capacity.
HBCUs, Education, and Training $2,050,000	**$8,000,000**	**+$5,950,000**
• Released competitive FOAs for U.S. academic institutions of higher learning to support fundamental research that cuts across FECM's research focus areas.	• Funding increase through a FOA(s) to the national university program for research in energy, environmental, science, social science, engineering, and humanities that focus on innovative and fundamental investigations pertinent to advancing the goals of the program.	• The request level significantly increases historical funding levels, in part, to accommodate the Administration's Justice40 Initiative. • Support curriculum design, research on successful recruitment and retention methods, development of outreach or mentorship programs, fellowships, and building science, engineering research, and education capacity.

Fossil Energy and Carbon Management
Facilities Maintenance and Repair

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

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

	FY 2021 Actual Cost	FY 2021 Planned Cost	FY 2022 Planned Cost	FY 2023 Planned Cost
National Energy Technology Laboratory	19,282	10,915	19,780	19,780
Total, Direct-Funded Maintenance and Repair	**19,282**	**10,915**	**19,780**	**19,780**

Report on FY 2021 Expenditures for Maintenance and Repair

This report responds to legislative language set forth in Conference Report (H.R. Conf. Rep. No. 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 2021 to the amount planned for FY 2021, including Congressionally directed changes.

Total Costs for Maintenance and Repair ($K)

	FY 2021 Actual Cost	FY 2021 Planned Cost
National Energy Technology Laboratory	19,282	10,915
Total, Direct-Funded Maintenance and Repair	**19,282**	**10,915**

In review of the planned vs actual costs for FY 2021, the primary reason for higher than planned costs is pandemic-related delays in project execution. Certain costs originally planned for FY 2019 and FY 2020 were not incurred until FY 2021. Larger dollar projects that were delayed included NETL's sensitive compartmented information facility and water line replacement at the Pittsburgh site. A fire at the Albany site also contributed to higher actual FY 2021 maintenance and repair costs.

Fossil Energy and Carbon Management
Excess Facilities

Excess Facilities are facilities no longer required to support the Department's needs, present or future missions or functions, or the discharge of its responsibilities. In this table, report the funding to deactivate and dispose of excess infrastructure, including stabilization and risk reduction activities at high-risk excess facilities, resulting in surveillance and maintenance cost avoidance and reduced risk to workers, the public, the environment, and programs. This includes 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 Excess Facilities ($K)

	FY 2021 Actual Cost	FY 2021 Planned Cost	FY 2022 Planned Cost	FY 2023 Planned Cost
National Energy Technology Laboratory (All)	54	45	40	40
NA	0	0	0	0
Total, Direct-Funded Excess Facilities	54	45	40	40

Fossil Energy and Carbon Management
Capital Summary ($K)

	Total	Prior Years	FY 2021 Enacted	FY 2021 Actuals	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted
Capital Operating Expenses Summary (including Major Items of Equipment (MIE))						
Capital Equipment >$500K (including MIE)	n/a	0	0	0	0	0
Minor Construction Project (>$5M)	44,372	0	12,000	12,000	0	-12,000
Total, Capital Operating Expenses	**44,372**	**0**	**12,000**	**12,000**	**0**	**-12,000**
Capital Equipment > $500K (including MIE)						
Total Non-MIE Capital Equipment	n/a	0	0	0	0	0
Total, Capital Equipment (including MIE)	**n/a**	**0**	**0**	**0**	**0**	**0**
Minor Construction Projects (>$5M)						
Computational Science & Engineering Center	19,372	0	12,000	12,000	0	-12,000
Direct Air Capture Center	25,000	0	0	0	0	0
Total, Minor Construction Projects	**44,372**	**0**	**12,000**	**12,000**	**0**	**-12,000**
Total, Capital Summary	**44,372**	**0**	**12,000**	**12,000**	**0**	**-12,000**

Fossil Energy and Carbon Management
Small Business Innovation Research/Small Business Technology Transfer (SBIR/STTR)
($K)

	FY 2021 Enacted	FY 2022 Annualized CR	FY 2023 Request/ Projected Transfer	FY 2023 Request vs FY 2021 Enacted ($)
Carbon Management Technologies				
SBIR	8,820	8,820	12,454	+3,634
STTR	1,535	1,535	1,751	+216
Resource Sustainability				
SBIR	2,905	2,905	4,664	+1,759
STTR	505	505	656	+151
Unconventional FE Technologies				
SBIR	1,116	1,116	0	-1,116
STTR	194	194	0	-194
Repurposing Fossil Energy Assets (RFEA)[1]				
SBIR	129	129	182	+53
STTR	22	22	26	+4
Total, SBIR/STTR	**15,226**	**15,226**	**19,733**	**+4,507**

[1] SBIR and STTR is shown here for the new FECM control point. RFEA CJ does not have a funding table.

DEPARTMENT OF ENERGY
Funding by Site Detail
Fossil Energy and Carbon Management FY 2023
(Dollars in Thousands)

	FY 2021 Enacted Requested Total	FY 2022 Annualized CR Requested Total	FY 2023 Request Detail Requested Total
Ames Laboratory			
Advanced Energy Systems	730	730	0
Cross Cutting Research	806	806	0
FECM_PreBY23	1,536	1,536	0
Total Ames Laboratory	**1,536**	**1,536**	**0**
Argonne National Laboratory			
Unconventional Fossil Energy from Petroleum - Oil Technologies	150	150	0
Total Argonne National Laboratory	**150**	**150**	**0**
Idaho National Laboratory			
Carbon Capture	110	110	0
Advanced Energy Systems	1,603	1,603	0
Cross Cutting Research	641	641	0
FECM_PreBY23	2,354	2,354	0
Total Idaho National Laboratory	**2,354**	**2,354**	**0**
Lawrence Berkeley National Laboratory			
Unconventional Fossil Energy from Petroleum - Oil Technologies	1,672	1,672	0
Carbon Capture	465	465	0
Carbon Storage	2,115	2,115	0
Cross Cutting Research	1,734	1,734	0
FECM_PreBY23	4,314	4,314	0
Total Lawrence Berkeley National Laboratory	**5,986**	**5,986**	**0**
Lawrence Livermore National Laboratory			
Unconventional Fossil Energy from Petroleum - Oil Technologies	1,000	1,000	0
Carbon Capture	720	720	0
Carbon Storage	2,000	2,000	0
Cross Cutting Research	306	306	0
Natural Gas Technologies Research	500	500	0
FECM_PreBY23	3,526	3,526	0
Total Lawrence Livermore National Laboratory	**4,526**	**4,526**	**0**
Los Alamos National Laboratory			
Unconventional Fossil Energy from Petroleum - Oil Technologies	1,279	1,279	0
Carbon Capture	1,264	1,264	0
Carbon Storage	2,794	2,794	0
Advanced Energy Systems	128	128	0
Cross Cutting Research	306	306	0
FECM_PreBY23	4,492	4,492	0
Total Los Alamos National Laboratory	**5,771**	**5,771**	**0**
National Energy Technology Lab			
Carbon Dioxide Removal & Conversion	1,000	1,000	0
STEP Supercritical CO2	14,500	14,500	0
Transformational Coal Pilots	10,000	10,000	0
Carbon Management Technologies	25,500	25,500	0
Mineral Sustainability	7,357	7,357	0
Resource Sustainability	7,357	7,357	0
Unconventional Fossil Energy from Petroleum - Oil Technologies	38,489	38,489	0
Program Direction - Fossil Energy	27,780	27,780	0
NETL Research and Operations - Fossil Energy	83,000	83,000	0
NETL Infrastructure - Fossil Energy	55,000	55,000	0
Carbon Capture	8,562	8,562	0

DEPARTMENT OF ENERGY
Funding by Site Detail
Fossil Energy and Carbon Management FY 2023
(Dollars in Thousands)

	FY 2021 Enacted Requested Total	FY 2022 Annualized CR Requested Total	FY 2023 Request Detail Requested Total
Carbon Utilization	4,365	4,365	0
Carbon Storage	15,509	15,509	0
Advanced Energy Systems	20,994	20,994	0
Cross Cutting Research	18,731	18,731	0
Natural Gas Technologies Research	25,000	25,000	0
FECM_PreBY23	93,161	93,161	0
Total National Energy Technology Lab	**330,287**	**330,287**	**0**
National Renewable Energy Laboratory			
Carbon Utilization	2,250	2,250	0
Cross Cutting Research	306	306	0
FECM_PreBY23	2,556	2,556	0
Total National Renewable Energy Laboratory	**2,556**	**2,556**	**0**
Oak Ridge National Laboratory			
Carbon Dioxide Removal & Conversion	900	900	0
Carbon Management Technologies	900	900	0
Mineral Sustainability	10,325	10,325	0
Resource Sustainability	10,325	10,325	0
Carbon Capture	1,380	1,380	0
Carbon Storage	450	450	0
Advanced Energy Systems	878	878	0
Cross Cutting Research	786	786	0
Natural Gas Technologies Research	250	250	0
FECM_PreBY23	3,744	3,744	0
Total Oak Ridge National Laboratory	**14,969**	**14,969**	**0**
Pacific Northwest National Laboratory			
Unconventional Fossil Energy from Petroleum - Oil Technologies	500	500	0
Carbon Capture	2,636	2,636	0
Carbon Storage	1,901	1,901	0
Advanced Energy Systems	256	256	0
Cross Cutting Research	456	456	0
Natural Gas Technologies Research	1,000	1,000	0
FECM_PreBY23	6,249	6,249	0
Total Pacific Northwest National Laboratory	**6,749**	**6,749**	**0**
Sandia National Laboratories			
Unconventional Fossil Energy from Petroleum - Oil Technologies	1,800	1,800	0
Total Sandia National Laboratories	**1,800**	**1,800**	**0**
Sandia Site Office			
Carbon Storage	798	798	0
Cross Cutting Research	1,206	1,206	0
FECM_PreBY23	2,004	2,004	0
Total Sandia Site Office	**2,004**	**2,004**	**0**
SLAC National Accelerator Laboratory			
Unconventional Fossil Energy from Petroleum - Oil Technologies	252	252	0
Total SLAC National Accelerator Laboratory	**252**	**252**	**0**
Washington Headquarters			
Carbon Dioxide Removal & Conversion	38,100	38,100	0
Carbon Management Technologies	38,100	38,100	0
Mineral Sustainability	35,318	35,318	0
Resource Sustainability	35,318	35,318	0

DEPARTMENT OF ENERGY
Funding by Site Detail
Fossil Energy and Carbon Management FY 2023
(Dollars in Thousands)

	FY 2021 Enacted Requested Total	FY 2022 Annualized CR Requested Total	FY 2023 Request Detail Requested Total
Unconventional Fossil Energy from Petroleum - Oil Technologies	858	858	0
Program Direction - Fossil Energy	31,353	31,353	0
Special Recruitment Programs	700	700	0
Carbon Capture	71,163	71,163	0
Carbon Utilization	16,385	16,385	0
Carbon Storage	53,433	53,433	0
Advanced Energy Systems	67,411	67,411	0
Cross Cutting Research	23,722	23,722	0
Import Export Authorization	2,367	2,367	0
Natural Gas Technologies Research	30,250	30,250	0
FECM_PreBY23	264,731	264,731	0
Total Washington Headquarters	**371,060**	**371,060**	**0**
Undesignated LPI			
Carbon Dioxide Removal & Conversion	0	0	65,000
Carbon Management Technologies	0	0	65,000
Mineral Sustainability	0	0	44,000
Resource Sustainability	0	0	44,000
Program Direction - Fossil Energy	0	0	70,291
Special Recruitment Programs	0	0	1,000
NETL Research and Operations - Fossil Energy	0	0	83,000
NETL Infrastructure - Fossil Energy	0	0	55,000
NETL Interagency Working Group	0	0	3,000
Carbon Capture	0	0	163,000
Carbon Utilization	0	0	50,000
Carbon Storage	0	0	122,000
Advanced Energy Systems	0	0	66,869
Cross Cutting Research	0	0	31,000
Resource Technologies and Sustainability	0	0	139,000
FECM_PreBY23	0	0	571,869
Total Undesignated LPI	**0**	**0**	**893,160**
Total Funding by Site for TAS_0213 - Fossil Energy and Carbon Management	**750,000**	**750,000**	**893,160**

GENERAL PROVISIONS—DEPARTMENT OF ENERGY

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) The amounts made available by this title may be reprogrammed for any program, project, or activity, and the Department shall notify the Committees on Appropriations of both Houses of Congress at least 30 days prior to the use of any proposed reprogramming that would cause any program, project, or activity funding level to increase or decrease by more than $5,000,000 or 10 percent, whichever is less, during the time period covered by this Act.

(e) 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.

(f)

(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.

(g) 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 2023 until the enactment of the Intelligence Authorization Act for fiscal year 2023.

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. 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. 306. Subparagraphs (B) and (C) of section 40401(a)(2) of Public Law 117–58, paragraph (3) of section 16512(r) of title 42, United States Code, and section (l) of section 17013 of title 42, United States Code, shall not apply for fiscal year 2023.

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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. 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. 503. (a) None of the funds made available in this Act may be used to maintain or establish a computer network unless such network blocks the viewing, downloading, and exchanging of pornography. (b) Nothing in subsection (a) shall limit the use of funds necessary for any Federal, State, Tribal, or local law enforcement agency or any other entity carrying out criminal investigations, prosecution, or adjudication activities.

SEC. 504. Of the unavailable collections currently in the United States Enrichment Corporation Fund, $405,421,000 shall be transferred to and merged with the Uranium Enrichment Decontamination and Decommissioning Fund and shall be available only to the extent provided in advance in appropriations Acts.