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the unobligated balances available from amounts appropriated in Public Law 111–8 under this heading, $806,831 is hereby rescinded: Provided further, That of the unobligated balances available from amounts appropriated in Public Law 111–85 under this heading, $1,433,462 is hereby rescinded: Provided further, that no amounts may be rescinded under the previous two provisos from amounts that were designated by the Congress as an emergency requirement pursuant to the Concurrent Resolution on the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 $	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.

<u>Lightweight Materials:</u> 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.

<u>Powertrain Materials</u>: 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.

<u>Computational Modeling and Simulation</u>: 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.

<u>Connectivity and Automation Technology</u>: 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

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[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.

Vehicle Technologies
Technology Integration & Deployment

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.

Vehicle Technologies
Data, Modeling, and Analysis

Description

The Data, Modeling, and Analysis subprogram provides critical information and analyses to prioritize and inform Vehicle Technologies research portfolio planning through technology-, economic-, and interdisciplinary-based analysis, including target-setting and program benefits estimation. 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**

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.

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:

<u>Terrestrial and Waste Feedstocks R&D</u>: 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.

<u>Aquatic Feedstocks R&D</u>: 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.

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.

Materials and Component R&D: 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.

Systems Integration R&D: 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.

Fuel Cell Technologies

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.

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.

<u>Thermal Systems R&D</u>: 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.

<u>Power Cycles R&D</u>: 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.

<u>Solar Collector R&D</u>: 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.

<u>Industrial Applications R&D</u>: 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.

<u>Conversion Efficiency R&D</u>: 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.

<u>Durability R&D</u>: 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

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[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..

<u>Science and Technology Innovation</u>: 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.

STEM and Workforce Development: 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.

<u>Science and Technology Innovation</u>: 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.

<u>Manufacturing and Materials</u>: 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.

<u>Environmental and Siting</u>: 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.

<u>Science and Technology Innovation</u>: 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.

<u>Testing and Reliability</u>: 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.

<u>Balance of Systems</u>: 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.

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.

Grid Integration: 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. • Develop and maintain capabilities to evaluate the impacts of innovation in land-based, distributed, and OSW technologies.	• Market data collection, analysis and reporting; including establishing technology baselines and industry benchmarks, tracking progress to goals and evaluating return on investment. • 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 from other subprograms into Data, Modeling, and Analysis. No significant change in scope. • 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.

<u>New Low Impact Hydropower</u>: 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.	• Continue to maintain and update the RAPID database allowing public users to search the FERC eLibrary database.	• No significant change.
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.	• Add more U.S. Hydro fleet data, improve automation of adding datasets, improve dissemination and sharing capabilities, expand Data Explorer, and refine use cases.	• 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.

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

[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.

System Integration and Validation: 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.

Testing & Reliability: 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.

Geothermal Technologies
Enhanced Geothermal Systems

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.	• New initiative will leverage technical, physical and workforce assets from the oil and gas industry. This initiative started in FY 2022.
	• 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 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.

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..

Advanced Manufacturing

	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.

<u>Energy-Intensive Industries</u>: 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.

<u>Cross-Cutting Technologies</u>: 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.

<u>Energy-Water Nexus</u>: 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**

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

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[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.

Building Technologies
Residential Buildings Integration

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.

<u>Systems Integration</u>: 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.

<u>Technical Assistance</u>: 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.

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	5,700	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)	19,910	0	19,910	19,910	0	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	**131,160**	**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	**221,000**	**0**	**4,000**	**4,000**	**8,000**	**91,500**	**+87,500**
Total, Capital Summary	**357,160**	**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:	Minor Construction (Direct funded)
Total Estimated Cost:	$19,910
Construction Design:	$ 1,350
Project Start:	FY 2020
Design Complete:	FY 2022
Construction Complete:	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. 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	
Planned Activities:	• Construction scheduled to start September 30, 2021. • Final Design (Preparing and finalizing drawings, specifications, and other documents describing the work to allow construction of the project) • NEPA for Design Phase activities • NEPA for Construction Phase activities • 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:	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.

Minor Construction Projects ($K)

Facilities & Infrastructure Operations & Maintenance	
Project Name: Location/Site:	34.5kV Grid Infrastructure NREL Flatirons Campus
Type: Total Estimated Cost: Construction Design:	Minor Construction (Direct funded) $8,000 $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: Location/Site:	ESIF HPC Datacenter - 7.5-Megawatt Upgrade NREL STM Campus
Type: Total Estimated Cost: Construction Design:	Minor Construction (Direct funded) $6,000 $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:	Decarbonization - Electric Heating for All New Buildings
Project Location/Site:	NREL STM Campus, NREL Flatirons Campus
Type:	Minor Construction (Direct funded)
Total Estimated Cost:	$6,000
Construction Design:	$1,200
Project Start:	FY 2023
Design Complete:	FY 2023
Construction Complete:	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