Electricity
Proposed Appropriation Language

For Department of Energy expenses including the purchase, construction, and acquisition of plant and capital equipment, and other expenses necessary for electricity activities in carrying out the purposes of the Department of Energy Organization Act (42 U.S.C. 7101 et seq.), including the acquisition or condemnation of any real property or any facility or for plant or facility acquisition, construction, or expansion, $297,386,000, to remain available until expended: Provided, That of such amount, $17,586,000 shall be available until September 30, 2024, for program direction.

[For an additional amount for "Electricity", $8,100,000,000, to remain available until expended: *Provided*, That of the amount provided under this heading in this Act, $5,000,000,000 shall be for grants under section 40101 of division D of this Act: *Provided further*, That of the funds in the preceding proviso, $1,000,000,000, to remain available until expended, shall be made available for fiscal year 2022, $1,000,000,000, to remain available until expended, shall be made available for fiscal year 2023, $1,000,000,000, to remain available until expended, shall be made available for fiscal year 2024, $1,000,000,000, to remain available until expended, shall be made available for fiscal year 2025, and $1,000,000,000, to remain available until expended, shall be made available for fiscal year 2026: *Provided further*, That of the amount provided under this heading in this Act, $50,000,000 shall be to carry out the Transmission Facilitation Program, including for any administrative expenses of carrying out the program, as authorized in section 40106(d)(3) of division D of this Act: *Provided further*, That of the funds in the preceding proviso, $10,000,000, to remain available until expended, shall be made available for fiscal year 2022, $10,000,000, to remain available until expended, shall be made available for fiscal year 2023, $10,000,000, to remain available until expended, shall be made available for fiscal year 2024, $10,000,000, to remain available until expended, shall be made available for fiscal year 2025, and $10,000,000, to remain available until expended, shall be made available for fiscal year 2026: *Provided further*, That of the amount provided under this heading in this Act and in addition to amounts otherwise made available for this purpose, $3,000,000,000, to remain available until expended, shall be to carry out activities under the Smart Grid Investment Matching Grant Program, as authorized in section 1306 of the Energy Independence and Security Act of 2007 (42 U.S.C. 17386), as amended by section 40107 of division D of this Act: *Provided further*, That of the funds in the preceding proviso, $600,000,000, to remain available until expended, shall be made available for fiscal year 2022, $600,000,000, to remain available until expended, shall be made available for fiscal year 2023, $600,000,000, to remain available until expended, shall be made available for fiscal year 2024, $600,000,000, to remain available until expended, shall be made available for fiscal year 2025, and $600,000,000, to remain available until expended, shall be made available for fiscal year 2026: *Provided further*, That of the amount provided under this heading in this Act, $50,000,000 shall be to carry out an advanced energy security program to secure energy networks, as authorized under section 40125(d) of division D of this Act: *Provided further*, That not later than 90 days after the date of enactment of this Act, the Secretary of Energy shall submit to the House and Senate Committees on Appropriations and the Senate Committee on Energy and Natural Resources and the House Committee on Energy and Commerce a detailed spend plan for fiscal year 2022: *Provided further*, That for each fiscal year through 2026, as part of the annual budget submission of the President under section 1105(a) of title 31, United States Code, the Secretary of Energy shall submit a detailed spend plan for that fiscal year: *Provided further*, That up to three percent of the amounts made available under this heading in this Act in each of fiscal years 2022 through 2026 shall be for program direction: *Provided further*, That such amount is designated by the Congress as being for an emergency requirement pursuant to section 4112(a) of H. Con. Res. 71 (115th Congress), the concurrent resolution on the budget for fiscal year 2018, and to section 251(b) of the Balanced Budget and Emergency Deficit Control Act of 1985.**]** *(Infrastructure Investment and Jobs Act)*

Public Law Authorizations

- Public Law 95–91, "Department of Energy Organization Act", 1977
- Public Law 109-58, "Energy Policy Act of 2005"
- Public Law 110-140, "Energy Independence and Security Act, 2007"
- Public Law 114-94, "Fixing America's Surface Transportation Act," 2015
- Public Law 116-260, Division Z, "Energy Act of 2020"
- Public Law 117-58, Division D, "Infrastructure Investment and Jobs Act," 2021

Electricity
($K)

FY 2021 Enacted	FY 2021 Enacted (Comparable)[a]	FY 2022 Enacted Annualized CR[b]	FY 2022 CR (Comparable)[a]	FY 2023 Request
211,720	201,720	211,720	201,720	297,386

Overview

The Office of Electricity (OE) leads the Department's efforts in developing new technologies to strengthen, transform, and improve electricity delivery infrastructure so consumers have access to resilient, secure, and clean sources of electricity. OE provides solutions to technical, market, institutional, and operational failures that go beyond any one utility's ability to solve.[c] To accomplish this critical mission, OE engages stakeholders throughout the sector on a variety of innovative technology solutions to modernize the electric grid. OE works to ensure that our Nation's electricity delivery system can accommodate all the changes at generation and load sides of the grid and ensure reliable, resilient, and secure operations of the decarbonized electric grid.

A dramatic structural transformation of the electricity delivery system is needed to ensure reliability is maintained in light of the rapid integration of renewable generation and customer-based technologies, including the electrification of transportation and building infrastructure. The future grid will be a more dynamic and structurally complex system, with bidirectional power flows. Managing this transition will require significant reengineering, involving advancements in grid technology and system architectures.

Proactive, coordinated, and innovative steps are needed to lay the foundation for economic growth, workforce development, and the creation of good-paying jobs and to ensure benefits accrue to marginalized and overburdened communities while addressing four critical challenges:

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

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

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

[a] The FY 2023 Budget Request to Congress proposes to split the Electricity appropriation account into two accounts: Electricity and Grid Deployment Office (GDO). To allow an apples-to-apples comparison with the FY 2023 request, the comparable amounts for Electricity in FY 2021 and FY 2022 exclude all funding ($7,000,000) from the Transmission Permitting and Technical Assistance program and $3,000,000 from Program Direction funding, equivalent to what would have been in GDO had the proposed structure been in place in FY 2021 and FY 2022.

[b] FY 2022 amounts shown reflect the P.L. 117–87 continuing resolution level through March 11, 2022, annualized to a full year.

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

- Efficiency—low losses in electricity delivery and more optimal use of system assets
- Energy Justice— investing in research and development that addresses energy resilience in disadvantaged and energy-burdened communities

Within the Request, OE funds:

- Research, Development and Demonstration (RD&D)—pursuing research and demonstrations for technologies to improve grid reliability, resilience, efficiency, flexibility, and functionality
- Power Grid Modeling and Analytics—developing core analytic, assessment, and engineering capabilities that can evolve as the technology and policy needs mature to support decision making within the Department and for stakeholders; analyses explore complex interdependencies among energy infrastructure systems, such as between electricity and natural gas systems
- Data Platforms and advanced control and communications designs—pursuing national-scale sensor, data, and secure communication architecture platforms to mitigate risk and improve the economic efficiency of grid operations such as improved asset management
- Cyber Resilience—designing next-generation systems that are built from inception to automatically detect, reject, and withstand cyber incidents, regardless of the threat to the electricity delivery system
- Coordination with the Power Marketing Administrations to develop relevant RD&D solutions

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

- Grid flexibility through Megawatt-Scale Grid Storage—pursuing megawatt-scale storage capable of supporting voltage and frequency regulation, ramping, and energy management for bulk and distribution power systems
- Improved Observability and Deep Learning via Sensing Technology Utilization—driving integration of high-fidelity sensing technology for predictive and correlation modeling for electricity and interdependencies with oil and natural gas (ONG) systems
- Expanding Transmission Capacity and Advanced Grid Architectures— developing the vision for the future grid and pursuing electricity-related policy issues by carrying out statutory and executive requirements, while also providing policy design and analysis expertise to Federal, State, Tribal, territorial, and regional entities
- North American Energy Resilience Model—using the integrated North American Energy Resilience Model (NAERM), developed from 2019–2021 in partnership with the national laboratories and relevant stakeholders, to aid in energy planning, transmission planning, and contingency analyses to drive infrastructure investment in the North American energy system
- Building in Cybersecurity—accelerating and expanding cybersecurity and secure communications for electricity infrastructure and mitigating vulnerabilities
- Integrated Grid Planning to Ensure Coherence—formulating coherent grid investment strategies that apply advanced technologies for meeting reliability, resilience, decarbonization, efficiency, equity, and flexibility objectives through the advancement of integrated planning practices in concert with the electric industry.

OE's FY 2023 Budget Request will extend the impact of our research, development, and demonstration (RD&D) funding by leveraging creative funding mechanisms—such as prizes, competitions, and programs targeted to small businesses. The goal is to enable the commercialization of climate change and clean energy innovations that will stimulate job creation, expand other public impact outcomes, and yield a more geographically diverse and impactful research portfolio.

Energy Storage Grand Challenge (ESGC): DOE is taking a holistic approach to accelerate the development, commercialization, and utilization of next-generation energy storage technologies. The ESGC will deploy the Department's extensive resources and expertise to address technology development, commercialization, manufacturing, valuation, and workforce challenges. The vision for the ESGC is to create and sustain global leadership in energy storage utilization and exports, with a secure domestic manufacturing supply chain that is independent of foreign sources of critical materials, by 2030.

OE's Energy Storage program's request supports grid-related ESGC objectives along with other OE R&D efforts that will also complement ESGC goals.

Grid Modernization Initiative and Grid Modernization Laboratory Consortium: The Grid Modernization Initiative (GMI) is a crosscutting strategic partnership between DOE and the national laboratories to bring together leading experts, technologies, and resources to collaborate on the goal of modernizing the Nation's grid. The benefits of the GMI include more efficient use of resources; shared networks; improving learning and preservation of knowledge; enhanced lab coordination and collaboration; and regional perspective and relationships with local stakeholders and industry. One of the main components of the GMI portfolio has been multiple Grid Modernization Lab Calls, which reflected comprehensive grid research across 14 national laboratories and coordinated through the Grid Modernization Laboratory Consortium (GMLC).[a]

Highlights and Major Changes in the FY 2023 Budget Request

Transmission Reliability and Resilience (TRR) ($37,300,000; -$10,920,000) is focused on ensuring the reliability and resilience of the U.S. electric grid through R&D on measurement and control of the electricity system, including mitigation of widescale, cascading blackouts. TRR is also assessing evolving system needs, identifying pathways to achieve an equitable transition to decarbonization and electrification, and risk assessment to address challenges across integrated energy systems. Funding decreases due to the FY 2021 completion of funding for NAERM Phase II development, as well as for fully funded FY 2021 congressionally directed projects for sensors and analytics technologies, a composite utility pole assessment, and the Grid Research Integration and Demo Center. These funding decreases in FY 2023 offset growth in other TRR activities. NAERM operations and maintenance are funded in the Energy Delivery Grid Operations Technology (EDGOT) program in FY 2023.

Energy Delivery Grid Operations Technology (EDGOT) ($39,000,000; +$39,000,000) starting in FY 2022, will support operations, further development, and maintenance for NAERM. EDGOT develops national-scale planning models for energy and interdependent infrastructure and real-time situational awareness capabilities that rely on large-scale networked communication and data infrastructures across multiple utility boundaries. NAERM will help us transition from the current reactive state-of-practice to a new energy planning, investment, and operations paradigm that is capable of proactively informing infrastructure investment strategies. The EDGOT technology portfolio will enable assessment of risks and uncertainty, evaluation and identification of effective mitigation strategies, and support of more informed infrastructure planning and investment decisions by both public and private sectors, thereby enhancing U.S. energy and economic security.

Resilient Distribution Systems (RDS) ($50,000,000; $0) develops transformative technologies, tools, and techniques to enable industry to modernize the distribution system, supports transformation of the electric grid through the growing convergence of transmission and distribution portions of the electricity delivery system, and develops solutions that enable all consumers to participate in the clean energy economy. RD&D addresses equity in both the social and economic participation in the energy system and improves energy resilience in disadvantaged and energy-burdened communities. The FY 2023 Request supports a competitive award process to harness emerging sources of energy for balance, reliability, and control such as EVs, connected homes and buildings, increasing distributed solar, and energy storage. Activities include research in microgrids, transactive controls, distribution management systems, and resilience tools, as well as working with States, regional planners, and the electric industry to advance integrated planning approaches to ensure the formulation and implementation of coherent grid strategies to enable grid modernization.

Cyber Resilient and Secure Utility Communications Networks (SecureNet) ($20,00,000; +$20,000,000) was called Cyber R&D in the FY 2022 Request to Congress. SecureNet addresses R&D for energy sector cybersecurity associated with electricity delivery systems and will focus on developing security-by-design solutions based on data and physics to address vulnerabilities of the grid and critical operational data processing, management, and communications systems that could expose the electricity system to cyber threats. SecureNet will pursue coordinated engagement with DOE's other cyber-related activities, including in CESER and the Office of Intelligence and Counterintelligence. An important part of the SecureNet portfolio will be academic R&D for technology-focused activities that, in combination with industry guidance, result in impactful real-world solutions while helping train and develop the next generation of cybersecurity specialists.

Energy Storage ($81,000,000; +$1,000,000) is designed to develop new and advanced technologies that will ensure the stability, reliability, and resilience of electricity infrastructure. The Request supports a new emerging technology FOA focused on ultra-low-cost chemistries, a new Grid Storage Launchpad (GSL) fellowship program, and continued development of the Rapid Operational Validation Initiative. The GSL construction project, which will accelerate materials development,

[a] https://www.energy.gov/grid-modernization-initiative

testing, and independent evaluation of battery materials and battery systems for grid applications, is fully funded in FY 2022 through the completion of construction and commissioning of the facility, and no funding is requested in FY 2023, offsetting increases in Energy Storage R&D.

Transformer Resilience and Advanced Components (TRAC) ($22,500,000; +$15,000,000) develops innovations for grid hardware that carries, controls, and converts electricity, helping achieve decarbonization goals, ensure reliability and resilience of electric infrastructure, adapt the electricity delivery system to the evolution of the electric power grid, and provide the foundation to invigorate domestic transformer manufacturing and grid-related supply chains. TRAC develops hardware solutions in coordination with TRR and RDS. The FY 2023 Request supports the testing and field validation of Grid Enhancing Technologies (GETs), such as dynamic line rating and power flow controls, to accelerate deployment for optimal transmission asset utilization and to facilitate renewable energy and carbon-neutral technology system integration. GETs have been shown to improve the energy transfer capabilities of existing transmission paths and are able to be deployed more quickly than building new lines at costs significantly below traditional upgrades. TRAC will also address critical research needs for solid-state power substations (SSPS) with an emphasis on advanced materials, embedded intelligence for equipment monitoring, and validation of prototype converter building blocks.

Applied Grid Transformation Solutions (AGTS) ($30,000,000; +$30,000,000) is a new program in FY 2023 to address the pressing need for rapidly validating and deploying new systems by integrating technology suites in controlled pilot environments to drive new technology adoption. Applied integrated pilots are needed to validate how new technologies for transmission and distribution will achieve community, state, and national objectives. AGTS will initiate 3–4 integrated pilots to show how new technologies can help achieve stakeholder objectives. For each applied demonstration area, AGTS will consult stakeholders to ensure that the project scope and outputs will be immediately useful to targeted decisionmakers.

Defense Critical Electric Infrastructure (DCEI) Energy Mission Assurance ($0; -$1,000,000) was established in FY 2021 to identify, evaluate, prioritize, and assist in developing executable strategies to ensure that critical national defense and security missions have reliable access to power as energy supply disruptions threaten the civilian grid due to intensifying cybersecurity threats as well as other hazards. In the FY 2022 Request, DOE proposed to integrate the functions of the DCEI Energy Mission Assurance program into CESER's suite of activities partnering with, supporting, and sharing information with the electric utility industry to enhance energy resilience through its energy assurance planning efforts. No FY 2023 funding is requested in OE for DCEI Energy Mission Assurance.

Transmission Permitting and Technical Assistance activities are transferred to the Grid Deployment Office in the FY 2023 Request.

FY 2021 Key Accomplishments

Energy Storage Efficiency: The Energy Storage program demonstrated a kW-scale prototype stack of aqueous soluble organic flow battery technology operating at 225 mA/cm², a 50 percent improvement over the FY 2020 target and capable of meeting a $200/kWh cost target for a 1MW/4MWh system.

Microgrids: The Resilient Distribution Systems program completed microgrid simulation testing of integrated software capabilities for resilient distribution design and restoration control on a distribution utility feeder circuit and developed a methodology to quantify the resilience value under extreme weather, cyber, and physical events.

Distributed Energy Resource Technologies: The Resilient Distribution System program successfully developed cost-effective technologies to increase the utilization of clean distributed energy resources (DERs) demonstrating the feasibility of using microgrid building blocks (MBB) as fundamental units for microgrids to reduce costs and project implementation time, focusing on integration of power conversion and microgrid communication and control as a standard, modular unit and developing the Beyond Distributed Energy Resource Management System (DERMS) software platform to provide automated scheduling of DERs to offset costs associated with peak loads. The DERMS platform successfully demonstrated the integration of over 300 DERs with two utility partners for peak load reduction and load shaping for real-time energy price arbitrage.

Small Business Projects for Enhanced Grid Operations: Two Phase I Small Business Innovation Research (SBIR) projects were successfully completed under the Transformer Resilience and Advanced Components program. Terves developed a prototype low-mass magnesium-based conductor for use in transmission infrastructure, which promises a low-cost, high-

strength alternative that will reduce system losses, improve system resilience, and decrease costs. Achillea Research developed a scalable method to optimize Flexible AC Transmission System controller placement, enhancing power flows across the entire grid to increase system efficiency and reducing customer rates, enabling an affordable scenario under deep renewable penetration.

Flexible Transformer Energization: In November 2021, GE and Cooperative Energy announced the energization of the world's first flexible transformer that adapts to a range of voltage ratios and impedance levels. Flexible transformers significantly reduce the manufacturing cost and time needed for today's custom-made transformers. By allowing damaged transformers to be replaced more quickly, flexible transformers will be an important tool in increasing the grid's resilience to extreme weather events or cyber incidents. This field demonstration markets the final phase of a multi-year project originally awarded in 2018 through an OE FOA on flexible and modular large power transformers.

North American Energy Resiliency Model (NAERM): OE developed the NAERM platform, a first-of-a-kind advanced modeling and analysis tool focusing on the Nation's energy infrastructure and interdependent systems. OE continues to demonstrate its capabilities internally and externally to other Federal agencies and stakeholders.

Wildfire Mitigation: In April 2021, OE sponsored 4 Wildfire Mitigation webinars attended by 1,196 participants. The webinars were designed to enable the rapid transfer or deployment of mature laboratory capabilities. As a result of these webinars and industry interest, DOE announced $2.25 million in awards to develop and deploy technologies to address the growing and severe threat of wildfires to the electric grid. The webinar presentations and transcripts are available at https://www.energy.gov/oe/wildfire-mitigation-webinar-series.

Transmission Innovation: In March 2021, OE hosted a Transmission Innovation Symposium focused on modernizing the U.S. power grid. The symposium featured presentations and panel discussions about 5 DOE-commissioned white papers on transmission R&D priorities, featuring the technologies required to address current and future challenges facing transmission infrastructure. The white papers guided a dialogue focused on preparing the industry for the transmission system of the future and are available at https://www.energy.gov/oe/transmission-innovation-symposium.

Energy Storage Grand Challenge Roadmap: In December 2020, DOE released the Energy Storage Grand Challenge Roadmap, the Department's first comprehensive energy storage strategy.[a] The Roadmap's approach includes accelerating the transition of technologies from the lab to the marketplace, focusing on ways to competitively manufacture technologies at scale in the United States, and ensuring secure supply chains to enable domestic manufacturing. The Roadmap includes an aggressive but achievable goal: to develop and domestically manufacture energy storage technologies that can meet all U.S. market demands by 2030.

Energy Storage for Social Equity: OE launched the Energy Storage for Social Equity Initiative to assist up to 15 underserved and frontline communities in leveraging energy storage to increase resilience and lower energy burdens, helping to deliver affordable electricity to disadvantaged communities.

Long Duration Storage Energy Earthshot: In July 2021, DOE announced the Long Duration Storage Energy Earthshot. The initiative establishes a target to reduce the cost of grid-scale energy storage by 90 percent within a decade for systems that deliver 10+ hour durations. Developing the technology and manufacturing to reach the Long Duration Storage Shot cost targets will establish a new, U.S.-based manufacturing industry for storage products. In September 2021, in conjunction with World Energy Storage Day, DOE held a series of events to engage communities, industry, and other stakeholders, including a Long Duration Storage Shot Summit.

[a] https://www.energy.gov/energy-storage-grand-challenge/downloads/energy-storage-grand-challenge-roadmap

Electricity
Funding by Congressional Control ($K)

	FY 2021 Enacted	FY 2021 Enacted (Comparable)[a]	FY 2022 Enacted Annualized CR[b]	FY 2022 CR (Comparable)[ab]	FY 2023 Request	FY 2023 Request vs FY 2021 Comp. ($)	FY 2023 Request vs FY 2021 Comp. (%)
Grid Controls and Communications							
Transmission Reliability and Resilience	48,220	48,220	48,220	48,220	37,300	-10,920	-22.6%
Energy Delivery Grid Operations Technology	0	0	0	0	39,000	+39,000	N/A
Resilient Distribution Systems	50,000	50,000	50,000	50,000	50,000	0	0.0%
Cyber Resilient and Secure Utility Communications Networks	0	0	0	0	20,000	+20,000	N/A
Total, Grid Controls and Communications	98,220	98,220	98,220	98,220	146,300	+48,080	+49.0%
Grid Hardware, Components, and Systems							
Energy Storage							
Research	57,000	57,000	57,000	57,000	81,000	+24,000	+42.1%
Construction: 20-OE-100 Grid Storage Launchpad	23,000	23,000	23,000	23,000	0	-23,000	-100.0%
Total, Energy Storage	80,000	80,000	80,000	80,000	81,000	+1,000	+1.3%
Transformer Resilience and Advanced Components	7,500	7,500	7,500	7,500	22,500	+15,000	+200.0%
Applied Grid Transformation Solutions	0	0	0	0	30,000	+30,000	N/A
Total, Grid Hardware, Components, and Systems	87,500	87,500	87,500	87,500	133,500	+46,000	+52.6%
DCEI Energy Mission Assurance	1,000	1,000	1,000	1,000	0	-1,000	-100.0%
Transmission Permitting and Technical Assistance	7,000	0[a]	7,000	0[a]	0	0	0.0%
Program Direction	18,000	15,000[a]	18,000	15,000[a]	17,586	+2,586	+17.2%
Total, Electricity	**211,720**	**201,720[a]**	**211,720**	**201,720[a]**	**297,386**	**+95,666**	**+47.7%**

[a] The FY 2023 Budget Request to Congress proposes to split the Electricity appropriation account into two accounts: Electricity and GDO. To allow an apples-to-apples comparison with the FY 2023 request, the comparable amounts for Electricity in FY 2021 and FY 2022 exclude all funding ($7,000,000) from the Transmission Permitting and Technical Assistance program and $3,000,000 from Program Direction funding, equivalent to what would have been in GDO had the proposed structure been in place in FY 2021 and FY 2022.

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

	FY 2021 Enacted	FY 2021 Enacted (Comparable)[a]	FY 2022 Enacted Annualized CR[b]	FY 2022 CR (Comparable)[ab]	FY 2023 Request	FY 2023 Request vs FY 2021 Comp. ($)	FY 2023 Request vs FY 2021 Comp. (%)
Federal Full Time Equivalent Employees (FTEs)	**63**	**56**	**–**	**–**	**63**	**+7**	**+12.5%**
Additional FE FTEs at NETL supporting OE[a]	11	10	–	–	10	0	0.0%
Total OE-funded FTEs	74	66	–	–	73	+5	+10.6%

SBIR/STTR:
FY 2021 Enacted: SBIR/STTR: $4,646
FY 2023 Request: SBIR/STTR: $6,151

Comparability Matrices
The tables below show the funding allocation between OE and GDO in FY 2021 through FY 2023 under the prior and the proposed budget structures.

FY 2021 Enacted Appropriation Comparability Matrix
($K)

	FY 2023 Proposed Budget Structure				Total
	Electricity	Grid Deployment Office			
		Grid Technical Assistance	Program Direction	Total, GDO	
FY 2022 and Prior Budget Structure					
Transmission Permitting & Technical Assistance	0	7,000	0	7,000	**7,000**
Program Direction	15,000	0	3,000	3,000	**18,000**
Other on-going OE programs	186,720	0	0	0	**186,720**
Total	**201,720**	**7,000**	**3,000**	**10,000**	**211,720**

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

FY 2022 Annualized CR Comparability Matrix
($K)

	FY 2023 Proposed Budget Structure				Total
	Electricity	Grid Deployment Office			
		Grid Technical Assistance	Program Direction	Total, GDO	
FY 2022 and Prior Budget Structure					
Transmission Permitting & Technical Assistance	0	7,000	0	7,000	**7,000**
Program Direction	15,000	0	3,000	3,000	**18,000**
Other on-going OE programs	186,720	0	0	0	**186,720**
Total	**201,720**	**7,000**	**3,000**	**10,000**	**211,720**

FY 2023 Request to Congress Comparability Matrix
($K)

	FY 2023 Proposed Budget Structure							Total
	Electricity	Grid Deployment Office						
		Grid Planning & Develop-ment	Grid Technical Assistance	Wholesale Electricity Market TA & Grants	Interregional & Offshore Transmission Planning	Program Direction	Total, GDO	
FY 2022 and Prior Budget Structure								
Transmission Permitting & Technical Assistance	0	16,200	29,500	0	0	0	45,700	**45,700**
Program Direction	17,586	0	0	0	0	5,521	5,521	**23,107**
Other on-going OE programs	279,800	0	0	0	0	0	0	**279,800**
New GDO programs in FY 2023	0	0	0	19,000	20,000	0	39,000	**39,000**
Total	**297,386**	**16,200**	**29,500**	**19,000**	**20,000**	**5,521**	**90,221**	**387,607**

Bipartisan Infrastructure Law and Programmatic Realignment
OE was appropriated funds through the Bipartisan Infrastructure Law (BIL) (P.L. 117-58). BIL activities appropriated in the Electricity account will be implemented by the Grid Deployment Office (GDO) as part of the Department's efforts to best execute the BIL mission. In FY 2023, the following BIL programs appropriated to OE will be executed by GDO:

- Preventing Outages and Enhancing the Resilience of the Electric Grid (Section 40101)
- Transmission Facilitation Fund (Section 40106)
- Deployment of Technologies to Enhance Grid Flexibility (Section 40107)

In addition, GDO will continue to execute the Advanced Energy Security Program to Secure Energy Networks, Modeling and Assessing Energy Infrastructure Risk (Section 40125(d)) program, which was appropriated funds under OE in FY 2022 only.

DOE created new offices for the Under Secretary for Infrastructure and realigned some existing offices and components to better execute the BIL appropriation and the overall DOE mission. For OE, activities under the Transmission Permitting and Technical Assistance program, as well as a corresponding portion of the Program Direction program, were realigned under the newly formed GDO, which reports to the Under Secretary for Infrastructure. The remaining OE programs report to the Under Secretary for Science and Innovation and will continue to fulfill their current roles and responsibilities.

Future Years Energy Program
($k)

	FY 2023 Request	FY 2024	FY 2025	FY 2026	FY 2027
Electricity	297,386	304,000	311,000	318,000	325,000

Outyear Priorities and Assumptions

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

OE priorities in the outyears include the following:

- Continued development of long duration energy storage technologies consistent with the 2030 Long Duration Storage Shot goal of $0.05/kwh Levelized Cost of Storage for 10+ hour systems
- Continued development of materials, components, and systems that enable advanced grid capabilities through Grid Enhancing Technologies, HVDC, modular and flexible large power transformers, etc.

Transmission Reliability and Resilience

Overview

The Transmission Reliability and Resilience (TRR) program provides the electric sector with the necessary tools and analyses to achieve decarbonization, reliability, resilience, and energy justice by assessing risks, informing decisions, and improving power system planning and performance including mitigating the risks of large-scale blackouts and adapting to evolving system needs.

TRR focuses on:

- Ensuring the reliability and resilience of the U.S. electric grid through research and development (R&D) concentrated on measurement and control of the electricity system
- Developing and validating models to assess evolving system needs and identify pathways for achieving an equitable energy transition towards decarbonization and electrification
- Mitigating risks across integrated energy systems

TRR brings together energy stakeholders from government, industry, and academia to generate ideas and develop solutions to the Nation's energy infrastructure challenges.

Transmission Reliability and Renewable Integration (TRRI) is developing transmission system tools and data analytics to inform planning and operational decisions that maintain and improve system reliability while accelerating the integration of renewable energy for the electricity industry. Advances in data analytics ensure utilities are getting the full value from new and existing sensors and enable inference of complex underlying dynamics and diagnosis of system behavior and abnormalities, while providing situational awareness for operators to make informed and equitable decisions. TRRI is developing tools that help system operators understand and adapt to changes in supply and load, including expanded growth in clean generation, decarbonization, access to distributed energy resources, and increased electrification. TRRI is modernizing transmission system tools through human factor and cognitive science research for system operations to allow for more timely mitigation of reliability events, such as blackouts, and allow for the development of training simulators for operator workforce development. TRRI R&D will enable determining the state of the power system with the greater speed, accuracy, and precision that are required to manage the increasing complexity of grid operations and assets and to monitor and manage the interconnected and interdependent effects among the Nation's critical infrastructures.

Advanced Grid Modeling (AGM) supports building the capacity and capability within the electric sector to analyze the electricity delivery system using Big Data, advanced mathematical theory, and high-performance computing to assess the current state of the grid, mitigate reliability risks, and understand future needs to facilitate decarbonization and energy justice, and to ensure the reliability and resilience of the electric grid. AGM aims to lead the research activities in better understanding the issues surrounding the current and future electric power grid and developing robust model-based solutions that result in new software, analytical toolsets for operators and planners. Successful research in this area will enable grid operators and planners to optimize their decision-making, giving the electric industry sophisticated tools to dramatically improve electric delivery system efficiency, reliability, resilience, and security.

Protective relaying is required at all levels of the electric grid with the purpose of quickly identifying and isolating faults such that the remaining system will continue to operate under normal conditions. This prevents or reduces damage to equipment and potential injury to utility personnel and the public. Originally developed as a last line of defense, protective relaying is becoming more integrated with normal operations of the grid such as stabilizing voltage and frequency. Protective relaying complexity varies by function and vendor and, with many senior technicians and engineers retiring, the burden on the remaining workforce is increasing. The Protective Relaying subprogram will address ongoing issues in the industry, such as misoperations of relays, while advancing state-of-the-art technology that will function in an evolving environment that includes bi-directional power flow, a need for faster response times, and enhanced detection methods. The subprogram will also develop guidelines, best practices, and toolsets to support workforce development of relaying professionals across the Nation.

Building and maintaining effective public-private partnerships is a key strategy for the TRR program. In achieving its vision, TRR also fosters strategic, university-based power system research. Partnerships with universities focus on developing state of the art tools and analytic methods, while simultaneously providing important opportunities for the next generation of

scientists and researchers in power systems. Such partnerships facilitate innovations in R&D and enable industry (and ultimately consumers) to capitalize on the outcomes. TRRI, for example, will continue work to develop research datasets and data platforms that reduce utility burden from data requests and facilitate tool development with real data. This will set the groundwork for catalyzing artificial intelligence and machine learning in the transmission system. Advancing analytics to be capable of fully capturing and understanding new system dynamics from the integration of renewable energy, inverter-based technologies, and advanced transmission control schemes (such as dynamic line rating and transmission topology control) will further develop the electricity system as a resource.

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

Highlights of the FY 2023 Budget Request
The TRR program continuously investigates ways to make the present and future grid resilient, reliable, efficient, and secure. In FY 2023, TRR's will concentrate on:

- Developing high-fidelity sensing technologies and analytics that manage uncertainty associated with data and decision support capabilities
- Advancing the application of cognitive science and human factors to identify and develop tools needed for decision making and training
- Advancing protective relaying methods to improve the functional integrity and effectiveness at preventing and mitigating power outages
- Researching the impact of changes in the grid with a concentration on transmission planning to accommodate large deployment of renewables to facilitate decarbonization
- Identifying and mitigating risk across the integrated energy system
- Increasing collaboration between OE and other public and private entities
- Increasing the level of understanding and industry awareness related to energy justice
- Continuing the partnership with the National Science Foundation (NSF) on the Algorithms for Modern Power Systems (AMPS) program
- Managing and understanding the impact of changes in the grid amid increasing complexity and accelerated grid technology development.
- Developing integrated risk-based, measurement-model approaches to improve detection, mitigation, and recovery/ restoration from system failure, weather events and man-made attacks to the electric power system, and plan to enable the operation of degraded or damaged electricity systems while sustaining critical functionality

Technology, tools, and applications developed under TRR will be evaluated for security risks including cybersecurity. Testing and evaluations will be conducted to ensure that security is built-in and new security risks are not being introduced into the electric sector.

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

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

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

Transmission Reliability and Resilience
Funding ($K)

	FY 2021 Enacted	FY 2022 Enacted Annualized CR[a]	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
Transmission Reliability and Resilience					
Transmission Reliability and Renewable Integration	3,586	–	10,500	+6,914	+192.8%
Advanced Modeling Grid Research	17,810	–	21,800	+3,990	+22.4%
Protective Relaying	0	–	5,000	+5,000	N/A
North American Energy Resilience Model	19,905	–	0	-19,905	-100.0%
Transmission Sensors	419	–	0	-419	-100.0%
Sensors and Analytic Technologies	1,000	–	0	-1,000	-100.0%
Composite Utility Pole Assessment	500	–	0	-500	-100.0%
Grid Research Integration & Demonstration Center	5,000	–	0	-5,000	-100.0%
Total, Transmission Reliability and Resilience	**48,220**	**48,220**	**37,300**	**-10,920**	**-22.6%**

SBIR/STTR:

- FY 2021 Enacted: SBIR/STTR: $1,527
- FY 2023 Request: SBIR/STTR: $1,155

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

	FY 2023 Request vs FY 2021 Enacted
• Transmission Reliability and Renewable Integration: The increase supports modernization of transmission system tools through human factor and cognitive science research for system operations to allow for more timely mitigation of reliability events, such as blackouts, and allow for the development of training simulators for operator workforce development.	+6,914
• Advanced Modeling Grid Research: The increase supports R&D to increase the net power flowing through transmission lines, develop analytical methods to manage impact of uncertainty associated with increase in the deployment of renewables on the bulk power system, and increase the level of understanding and industry awareness related to energy justice.	+3,990

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

	FY 2023 Request vs FY 2021 Enacted
• Protective Relaying: This subprogram addresses ongoing issues in the industry, such as misoperations of relays, while advancing state-of-the-art technology that will function in an evolving environment that includes bi-directional power flow, a need for faster response times, and enhanced detection methods. The increase also supports development of guidelines, best practices, and toolsets to support workforce development of relaying professionals across the Nation. Related activities were supported in AGM in FY 2021.	+5,000
• North American Energy Resilience Model: The FY 2021 appropriation included support to complete phase 2 NAERM development. NAERM transitions to a transmission planning tool under the EDGOT program in FY 2023.	-19,905
• Transmission Sensors: Funding supporting both transmission and distribution sensors is consolidated under the Resilient Distribution Systems program in FY 2023.	-419
• Sensors and Analytics Technologies: Planned activities for this Congressionally directed activity are completed with funding provided in FY 2021.	-1,000
• Composite Utility Pole Assessment: Planned activities for this Congressionally directed activity are completed with funding provided in FY 2021.	-500
• Grid Research Integration and Demonstration Center: Planned activities for this Congressionally directed activity are completed with funding provided in FY 2021.	-5,000
Total, Transmission Reliability and Resilience	**-10,920**

Transmission Reliability and Resilience

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Transmission Reliability and Resilience $48,220,000	**$37,300,000**	**-$10,920,000**
Transmission Reliability and Renewable Integration $3,586,000	*$10,500,000*	*+$6,914,000*
• Continue technical support for the North American SynchroPhaser Initiative (NASPI) to conduct information sharing and joint problem solving among utilities, vendors, universities, and the Federal Government	• Continue technical support for NASPI to conduct competitions, information sharing and joint problem solving among utilities, vendors, universities, and the Federal Government	• Initiate a Prize program for AI/ML tool development utilizing open transmission system data sets, facilitated by industry partnerships with DOE, to catalyze independent academic research and equitable workforce development

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
	• Develop and demonstrate management tools for Grid Enhancing Technologies like Dynamic Line Rating and Power Flow Control to facilitate integration of renewable energy and better utilize existing transmission infrastructure • Support operating strategies, dynamic load modeling, contingency analysis, and control approaches that recognize and incorporate the control capabilities offered by, and attributes of, wind and solar generation • Develop transmission system data modernization of for wide area situational awareness, to prevent cascading power outages, through prizes, data set creation, and AI/ML research. • Advance cognitive science and human factors research to catalyze development and adoption of new tools for workforce training and development, control room application improvements, and robust decision making	• Improve load modeling to support transmission planning studies that include distributed energy resources and the development of standards articulating grid-friendly behavior • Advance contingency analysis and improve simulations of dynamic behavior related to inverter-based resources • Develop advanced operating strategies and control approaches that allow greater utilization of existing lines to support renewable integration
Advanced Modeling Grid Research $17,810,000	*$21,800,000*	*+$3,990,000*
• Initiate assessment of research needs for a new university-based engineering research center related to electric power systems in coordination with NSF • Continue exploring the mathematical and computational research to manage uncertainty, associated with data, modeling, and model validation • Continue development, co-funded with NSF's AMPS program, of next-generation mathematical and statistical algorithms to improve the security, reliability, and resilience of the electric power system	• Continue mathematical and computational research to manage uncertainty, associated with data, modeling, and model validation • Continue development, co-funded with NSF's AMPS program, of next-generation mathematical and statistical algorithms to improve the security, reliability, and resilience of the electric power system • Continue exploring alternative methods for transmission planning to increase the amount of energy delivered using existing rights of way	• Identify and mitigate grid risks to accommodate increasing levels of renewables to facilitate decarbonization while ensuring grid reliability, resilience, security, and efficiency • Increase the level of understanding and industry awareness related to energy justice while exploring mitigation through R&D

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
• Continue conducting research in protective relaying. These approaches will include efforts to improve system resilience against modern threats while enhancing recovery operations following natural disasters	• Continue exploring the impact of changes in the grid with a concentration on transmission planning to accommodate large deployment of renewables to facilitate decarbonization • Increase the level of understanding and industry awareness related to energy justice while exploring mitigation through R&D • Identify and mitigate grid risk to accommodate increasing levels of renewables to facilitate decarbonization while ensuring grid reliability, resiliency, security, and efficiency	
Protective Relaying $0	*$5,000,000*	*+$5,000,000*
	• Develop mitigations that reduce misoperations at both transmission and distribution levels • Develop solutions to distinguish between momentary and permanent faults for reclosers at the distribution level • Develop cybersecurity solutions for protective relaying at both the transmission and distribution levels • Continue research on adaptive relay settings that address bi-directional power flow • Address best practices and toolsets that will support the protective relaying workforce in an evolving grid environment	• Advancing state-of-the-art protective relaying technology that will function in an evolving environment that includes bi-directional power flow, a need for faster response times, and enhanced detection methods • Related activities were supported in AGM in FY 2021
Transmission Sensors $419,000	*$0*	*-$419,000*
• Continue support for existing sensor activities		• Funding supporting both transmission and distribution sensors is consolidated under the Resilient Distribution Systems program in FY 2023

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Sensors and Analytics Technologies $1,000,000	*$0*	*-$1,000,000*
• Sensors and data analytics work, in alignment with sensor's roadmap was performed at NREL and ORNL		• Planned activities for this Congressionally directed activity are completed with funding provided in FY 2021
Composite Utility Pole Assessment $500,000	*$0*	*-$500,000*
• Field testing of utility poles constructed of composite materials to determine the benefit to overall grid infrastructure resilience from environmental factors was completed at ORNL		• Planned activities for this Congressionally directed activity are completed with funding provided in FY 2021
Grid Research Integration and Demonstration Center (GRID-C) $5,000,000	*$0*	*-$5,000,000*
• Multiple laboratory activities were completed at ORNL's GRID-C facility • Work supported energy and electrification research, enabling study of dynamic interactions across buildings, vehicles, manufacturing, and the utility sectors		• Planned activities for this Congressionally directed activity are completed with funding provided in FY 2021

Energy Delivery Grid Operations Technology

Overview

The Nation's energy resilience strategy would benefit from advancements in national-scale energy planning and situational awareness capabilities to better characterize risk and uncertainty across multiple utility and infrastructure boundaries. Built around rigorous and quantitative assessment, sensing, prediction, and deep learning, the Energy Delivery Grid Operations Technology (EDGOT) program enhances the analytical capability needed to ensure reliable and resilient energy delivery, and provides the architecture and process for identifying a range of scalable mitigation solutions to changing climate conditions and other emerging threats.

The core of the EDGOT portfolio is the North American Energy Resilience Model (NAERM). NAERM development was funded under the Transmission Reliability and Resilience program in FY 2019–2021. NAERM is a hybrid data/model platform for the quantitative assessment of the significant interdependencies that have evolved within the energy sector and that could affect reliability. NAERM allows for the simulation of impacts to the energy system from natural and manmade events and through collaborative partnerships, strategic insights will be accessible to utilities and other Federal agencies. NAERM will provide for enhanced planning and analysis capabilities that can be leveraged to facilitate grid investments that address disproportionate health, environmental, economic, and climate impacts on disadvantaged communities; and increase the reliability and resilience of the energy infrastructure, inform national security investments, and enhance decision making under DOE's authorities to respond to grid security emergencies.

EDGOT's tools will support several private and public efforts:

- Utilizing a systems perspective to compare and collectively plan for impacts across organizational, geographic, sector, and jurisdictional boundaries.
- Targeting collaboration on mitigations with the Department's Power Marketing Administrations (PMAs) and other energy infrastructure owners and operators to effectively address multi-regional-scale natural threats and national security concerns.
- Supporting and advising on better utilization of optical power ground wire (OPGW) to support grid timing and synchronization, and potentially enabling rural broadband expansion.

The EDGOT portfolio leverages previous national laboratory efforts to fully understand the resilience risks associated with the regionally diversified North American electric system and associated infrastructure systems. National laboratories, including Argonne, Idaho, Lawrence Livermore, Los Alamos, National Renewable Energy, Oak Ridge, Pacific Northwest, Sandia, and Savannah River, have a long history of developing system-wide modeling and analysis tools, as well as transformational sensing and communications technology.

Impacts of FY 2022 Appropriations

Due to the level of funding provided and direction under the FY 2022 Energy and Water Development and Related Agencies Appropriations Act, NAERM operational aspects in FY 2022 are limited to maintenance support and all development work is deferred.

Highlights of the FY 2023 Budget Request

Predicting the impact of a specific event on energy system operations, restoration, and recovery is vexing due to the scale of the North American energy system—crossing organizational, geographic, sector, and jurisdictional boundaries—and the underlying physics of energy transport. Our current ability to analyze extreme events in this context is limited due to the lack of key information and capabilities:

- Unclassified details regarding potential threats
- Data and predictions on resulting impacts
- Tools and expertise to characterize and analyze the relationships between electricity and associated infrastructures, such as natural gas, communications, transportation, carbon management, and water
- Scripting interfaces to allow users to quickly build co-simulations and planning models
- Data availability to support infrastructure grid planning across seams, including transmission and distribution as well as grid-edge devices such as customer-owned distributed energy resources (DERs) and electric vehicles (EVs)

The FY 2023 Request focuses on developing and enhancing the portfolio of tools to help address these limitations and to transition the underlying capabilities to a robust, secure operational state:

- Incorporating the best available information on threat characteristics and their evolution over time
- Integrating the Situational Awareness Network (SAN) and the availability of real-time data feeds into the NAERM platform
- Formalizing procedures and establish partnerships for sharing data with utilities and independent system operators (ISOs)
- Hardening and integrating research innovations in advanced analytics to rapidly identify system vulnerabilities and enhance decision support for system analysis
- Initiating development of complex multi-infrastructure contingency analyses providing snapshots of the national resilience posture
- Enhancing infrastructure models and facilitating their integration into the NAERM architectural framework
- Expanding NAERM's operational capability in protecting and supporting the increase in data sources and access to the NAERM
- Collaborating with PMAs on implementation and validation of mitigation approaches
- Engaging with industry experts to get a better understanding of issues and practices on a regional basis to ensure that threat and consequence models are realistic and representative of actual system responses
- Supporting short- and long-term planning activities necessary to achieve a significant and early decarbonization of the power sector while meeting increasing electrical loads and bridging extreme events on a pathway to a net-zero carbon economy
    - These activities could include analysis of interstate transmission corridors, intraday flexibility within the grid, dispatchability of zero-carbon generation and associated supply chain and carbon management interdependencies, and optimal siting and expanded use of DERs such as energy storage, transportation electrification, and transformative resilience-by-design system solutions

Technology, tools, and applications developed under the EDGOT program will be evaluated for security risks including cybersecurity. Testing and evaluations will be conducted to ensure that security is built in.

Energy Delivery Grid Operations Technology
Funding ($K)

	FY 2021 Enacted	FY 2022 Enacted Annualized CR[a]	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
Energy Delivery Grid Operations Technology					
North American Energy Resilience Model (NAERM)					
NAERM Operations	0	—	14,000	+14,000	N/A
NAERM Upgrades	0	—	20,000	+20,000	N/A
Total, NAERM	0	—	34,000	+34,000	N/A
Synchronization, Timing, and Sensors	0	—	5,000	+5,000	N/A
Total, Energy Delivery Grid Operations Technology	**0**	**0**	**39,000**	**+39,000**	**N/A**

Energy Delivery Grid Operations Technology
Explanation of Major Changes ($K)

	FY 2023 Request vs FY 2021 Enacted
• NAERM:	
• NAERM Operations: Supports operations and maintenance of existing data infrastructure, models, communications network, and software platform	+14,000
• NAERM Upgrades: Supports the development and incorporation of enhanced planning model capabilities into the NAERM platform	+20,000
• Synchronization, Timing, and Sensors: Development continues for communications flexibility in providing synchronization environments and the potential coverage area and sensor sites for Advanced Sensor Technology Systems (ASTS) will be assessed while development continues for sensor technology from data received	+5,000
Total, Energy Delivery Grid Operations Technology	**+39,000**

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

Energy Delivery Grid Operations Technology

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Energy Delivery Grid Operations Technology $0	**$39,000,000**	**+$39,000,000**
NAERM Operations $0	*$14,000,000*	*+$14,000,000*
	• NAERM begins expected operations in FY 2023	• Development costs for NAERM in FY 2021 were funded in the Transmission Reliability and Resilience program
NAERM Upgrades $0	*$20,000,000*	*+$20,000,000*
	• Create transmission/distribution planning tool • Create DER network planning tool • Expand climate change natural threat modeling to include climate change awareness impact to the grid	• Development costs for NAERM in FY 2021 were funded in the Transmission Reliability and Resilience program
Synchronization, Timing, and Sensors $0	*$5,000,000*	*+$5,000,000*
	• Build CAST to operational readiness to support the Federal assets with precision synchronization and timing to include national labs infrastructure, PMAs, and NAERM • Maintain and integrate SAN into the NAERM platform for the detection of anomalies across the U.S. grid landscape	• Development costs for CAST in FY 2021 were funded within the DarkNet project in the Office of Cybersecurity, Energy Security, and Emergency Response

Resilient Distribution Systems

Overview

Resilient, reliable, and affordable electricity is a cornerstone for equitable economic growth and job creation, a critical platform to address climate change, and a foundation for communities to grow and attract new businesses and meet energy demands. For the most part, the existing electrical distribution system—the infrastructure that takes power from the transmission system and delivers it to individual businesses and homes—was designed and built using engineering principles established over 100 years ago. However, that same distribution system is facing dramatic changes—increased electrification, decarbonization of the electricity supply, and continued energy efficiency and conservation. The growing convergence of the entire electricity delivery system requires new architectural, control, and operational approaches. While these changes provide new benefits and new opportunities, they also present significant operational challenges. As the electricity distribution system continues to evolve and its complexity increases, new technologies are needed that enable changes to the way the electric grid is planned and operated. For utilities to maintain reliable and resilient operations, they require tools and capabilities to enhance observability, control, and dynamic protection across all distribution system assets.

The Resilient Distribution Systems (RDS) program focuses on addressing challenges facing the electric power grid by developing transformative technologies, tools, and techniques to enable industry to modernize the distribution portion of the electric delivery system. RDS pursues strategic investments in innovative technologies and practices that improve reliability, increase resilience, support vehicle electrification, integrate clean distributed energy resources (DER), and provide consumers with more choices for managing their energy consumption. The program builds upon grid modernization efforts including the Grid Modernization Laboratory Consortium (GMLC).

Microgrid research & development (R&D) focuses on developing and validating new technologies and methods to improve grid reliability and resilience under both normal and disruptive conditions, while enabling DER integration, enhancing consumer participation and choice, and driving grid technology innovation. Microgrid investments have successfully enhanced reliability, resilience, and efficiency, particularly at the community level, and continue to be an RDS focus area.

New approaches and technologies will also be investigated, including Dynamic Controls R&D to enhance the Nation's electric distribution grid to harness flexibility across all distribution assets. This includes expanded sensor research to increase situational awareness at the distribution level, which provides the ability to withstand and recover from disruptions caused by extreme weather events and man-made events, as well as supporting normal operations. In addition, Dynamic Controls will explore the local, regional, and structural implications of transportation electrification.

Results from the RDS research in Microgrids and Dynamic Controls will enable industry to strengthen the reliability and resilience of electrical infrastructure and support the ongoing evolution of the electric grid in a manner that supports a just transition to a decarbonized economy.

The integrated planning component of the program will develop methods, tools, and guidelines through collaborative efforts with the electric utility industry, including regulators and consumer advocates, that enable the formulation of staged strategies for transitioning to an advanced, decarbonized, and resilient electric grid. These strategies will address technological and institutional issues associated with the implementation of advanced grid capabilities by the industry. They will also include the advancement of integrated planning practices to ensure the formulation of coherent grid investment strategies that apply advanced technologies for meeting reliability, resilience, decarbonization, efficiency, equity, and flexibility objectives.

Highlights of the FY 2023 Budget Request

Microgrid activities in FY 2023 support R&D in several areas:

- Development of microgrid building blocks (MBBs) as fundamental units for microgrids to reduce the cost and time for microgrid deployment will continue. In FY 2023, this development, led by multiple national laboratories and universities, will complete the design and prototype of MBB hardware and software that integrates the power conversion, switching, communication, and microgrid controller functions into one single unit. The resultant MBB prototype will feature functions for a wide range of microgrids, and provide modular and standard interfaces to generation, load, control facilities, and the utility system. Modeling and simulation to validate the MBB prototype

performance design and performance is planned to be complete in FY 2024, followed by field demonstrations. The low-cost standard approach for MBBs is key to achieving affordability for widespread equitable deployment of microgrids.

- Developing modeling and simulation capabilities for optimal system design and operations of networked microgrids continues. Networking two or more microgrids that share loads and complementary power resources can increase their combined resilience during power outages, while lowering capital and operational costs for normal operations. Work in FY 2023 will examine various control schemes for mixes of generation assets, and include, but not be limited to, decentralized load control, centralized voltage control, and adaptive controls, to support a range of resiliency and decarbonization operations at U.S. ports.
- Another activity in networked microgrids will focus on enabling dynamic formation of microgrid boundaries for optimized operations under both normal and emergency conditions. This DynaGrid approach, built on the Resilient Operations of Networked Microgrids (RONM) activity that was completed in FY 2022, will lay the foundation for a future grid that is composed of dynamically formed microgrids in a repetitive pattern (a fractal grid). Key tasks in FY 2023, led by multiple national laboratories, include developing realistic use cases and developing and evaluating algorithms for optimization-based dynamic reconfiguration on the use cases. Evaluation will be done in lab environments in FY 2023 to assess the effect on equity, energy justice, and outcomes for different groups of customers, followed by field validation testing and demonstration planned in FY 2024. Dynamic microgrids through this activity are expected to accommodate larger-scale integration of DERs and electrification envisioned for the future grid.
- The Net-Zero Microgrids (NZMs) activity will implement its technology roadmap developed in FY 2022. The roadmap defines cross-cutting research needed to support the accelerated removal of carbon-emitting generation from microgrids. FY 2023 tasks include modeling and simulation of a microgrid design with a small modular reactor (SMR) integrated as part of its generation mix to investigate power system engineering issues involving microgrid operations and its integrated operations with the grid to provide grid services. A net-zero techno-economic analysis platform to model and evaluate NZMs will be developed. The platform will be applied for infrastructure electrification, with the first application centering on microgrid fast charging station designs for electric vehicles.
- Development of protection schemes for microgrids with high penetration of inverter-based resources and development of new microgrid fault location algorithms using real-time sensor data and analytics will continue for both singular and networked microgrids. Protection research for secondary networks involving DERs and microgrids also continues. In FY 2023, this work will complete development of a potential replacement technique for reverse power relaying protection for secondary network. Currently, heavy reliance on reverse power flow for protection poses a fundamental challenge to placing DERs in secondary systems. The research outcome will be applicable for future meshed distribution systems, networked microgrids, and transmission protection.

Dynamic Controls R&D activities will support priorities on grid resiliency and dynamically sourced grid support services to transform distribution grid infrastructure. Activities will be supported in the following areas:

- Dynamic Controls: These activities will develop the theoretical basis for methods and tools to evolve from centralized command and control to a more decentralized but coordinated system. Economic-control theory hybrid work will see continued simulation, development, and demonstration. A new effort in this area will explore data efficiency, maximizing the utilization of high volumes of data while minimizing computing and communications resources. Blockchain and other digital-ledger technology concepts will be explored through public private partnerships in academia and industry for the purposes of secure peer-to-peer transactions, high integrity distributed data stores, and secure computing platforms in untrusted environments.
- Grid Data Science: R&D activities will develop highly resilient distribution designs capable of accommodating evolving electricity supply and adapting to extreme events and disruptions. Data flow across ownership boundaries creates the need for new data integrity methods, data sharing agreements, and coordination frameworks. The effort will also extend the linkage between secure distributed compute environments and their associated impacts on data transport architectures within the utility environment.
- Transport Electrification: Increasing the intensity of the linkage between the electric and transportation sectors creates interdependencies that can have both positive and negative effects. Dynamic Controls will launch two efforts examining vehicle electrification. A Sector Coupling Analysis will look at structural and architectural aspects, seeking to establish a converged perspective on reliability, sustainability, and resilience across both transportation and electricity. In parallel, control and coordination approaches that address vehicle grid integration issues through both nodal and network solution paths, encompassing all grid and DER assets and their incentive mechanisms.

Sensors: R&D activities will support the development and integration of high-fidelity, fast-acting sensor technologies and advanced data analytics into the power grid. The program will also revolutionize the use of these technologies in electricity operations and delivery—from transmission to distribution to end-use load (including behind-the-meter DER)—for improved diagnostics and prediction of system variables and assets during normal and extreme-event conditions. Advances in sensing on the distribution system will facilitate better two-way power flow across the transmission and distribution system. It will also enable better understanding and tracking of energy equity and enable the development of more effective strategies to address energy justice. Developing tools for sensor management and data analytics enable utilities to better forecast and react to changes in generation from DERs and load to maintain reliability and reduce costs. This could include advanced contingency analysis and improved simulations of dynamic behavior, such as those related to inverter-based resources in the distribution system. Distribution system visibility is behind the visibility of the transmission level, and reducing this asymmetry is important for the full participation of distribution in markets and system planning. Distribution sensors, and their associated tools and analytics, provide the foundation for enhanced observability, predictability, and flexibility—from advanced distribution management systems to microgrid controllers to distributed controls.

RDS is working closely with industry stakeholders, including regulators, utilities, states, and communities, through the integrated planning component of the program to address both technological and institutional issues and develop strategies to enable a just transition to a modern electricity delivery system. This aspect of the program is focused on the formulation and implementation of coherent strategies for deploying needed functional and structural features of the electric grid through the application of grid architecture and the advancement of integrated grid planning practices. Efforts include:

- Working collaboratively with various associations (NARUC, NASEO, NRECA, APPA, NGA, and NCSL) through formal arrangements to engage their respective stakeholders to:
  - Advance methods for incorporating resilience, decarbonization, and energy justice into utility planning practices;
  - Undertake demonstration projects that apply renewable and advanced grid technologies within underserved communities;
  - Address interjurisdictional oversight issues related to grid and market operations that cross transmission, distribution, and behind-the-meter domains; and
  - Institute practical grid modernization strategies, including the provision of training to inform state officials of best practices.
- Developing an architecture for the distribution system that can accommodate many forms of distributed (inverter-based) energy resources, ownership models, and market structures, and ensuring an effective transfer of know-how to the industry.
- Producing “Voluntary Model Pathways” (per Section 8008 of the Energy Act of 2020) in concert with the industry to identify technological and institutional barriers to the attainment of a resilient, decarbonized, and equitable electricity delivery system, and developing transitional, coordinated strategies for addressing them.
- A demonstrated multi-objective decision framework incorporating decarbonization, resilience, flexibility, and energy justice with traditional planning objectives that can then guide the formulation of holistic and equitable grid modernization strategies and technology investment plans by regulators, utilities, and planners at the regional system level.
- A set of practical design guidelines that address operational coordination requirements to enable evolving industry, business, and market structures at the grid edge (such as community microgrids, virtual power plants, and electric vehicle infrastructure) to interface with the electric grid, as well as share services across the transmission and distribution system domains.

Technology, tools, and applications developed under RDS will be evaluated for security risks including cybersecurity. Testing and evaluations will be conducted to ensure that security is built-in and new security risks are not being introduced into the electric sector.

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

In FY 2022, RDS and EERE will also jointly fund competitively selected projects to engage with regional and local partners, especially in underserved communities, to develop and demonstrate innovative technologies (including distributed solar, energy storage, EVs, and other DERs) and planning practices to enhance community resilience to physical hazards and to support decarbonization goals.

Resilient Distribution Systems
Funding ($K)

	FY 2021 Enacted	FY 2022 Enacted Annualized CR[a]	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
Resilient Distribution Systems					
Microgrids	9,800	–	14,000	+4,200	+42.9%
Dynamic Controls & Communications	12,218	–	20,000	+7,782	+63.7%
Sensors	3,800	–	7,000	+3,200	+84.2%
Electricity Delivery Systems	9,182	–	9,000	-182	-2.0%
Demonstration Sensors	5,000	–	0	-5,000	-100.0%
COMMANDER National Testbed Laboratory	10,000	–	0	-10,000	-100.0%
Total, Resilient Distribution Systems	**50,000**	**50,000**	**50,000**	**0**	**0.0%**

SBIR/STTR:

- FY 2021 Enacted: SBIR/STTR: $1,265
- FY 2023 Request: SBIR/STTR: $1,315

Resilient Distribution Systems
Explanation of Major Changes ($K)

	FY 2023 Request vs FY 2021 Enacted
• Microgrids: The increase supports microgrid building block development, advancing the design and production of the prototype unit. It also supports the multi-laboratory DynaGrid approach with development of use cases to assess the effect on equity, energy justice, and outcomes for different groups of customers.	+4,200
• Dynamic Controls & Communications: The increase supports a sector coupling analysis looking at structural and architectural aspects as well as control and coordination approaches addressing vehicle grid integration issues through both nodal and network solution paths encompassing all grid and DER assets and their incentive mechanisms. The increase also supports research related to data flow across ownership boundaries, such as the need for new data integrity methods, data sharing agreements, and coordination frameworks.	+7,782
• Sensors: The increase supports the development and integration of high-fidelity, fast-acting sensor technologies and advanced data analytics into the electricity delivery system.	+3,200

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

	FY 2023 Request vs FY 2021 Enacted
• Electricity Delivery Systems: Work continues as planned with a slight reduction of effort in activities with States	-182
• Demonstration Sensors: Planned activities for this Congressionally directed activity are completed with funding provided in FY 2021.	-5,000
• COMMANDER National Testbed Laboratory: Planned activities for this Congressionally directed activity are completed with funding provided in FY 2021.	-10,000
Total, Resilient Distribution Systems	**0**

Resilient Distribution Systems

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Resilient Distribution Systems $50,000,000	**$50,000,000**	**$0**
Microgrids $9,800,000	*$14,000,000*	*+$4,200,000*
• Continue software development for resilient operations of networked microgrids (RONM) and Version 1 testing at utility hardware-in-loop (HIL) • Advance standard-based microgrid-to-microgrid communication and control that involves self-assembly of microgrids and collaborative autonomy operations • Continue development and application of consequence-based, quantitative models for system resilience applied to microgrids • Provide technical assistance on resilient microgrid implementation to critical defense facilities in meeting their mission-critical needs utilizing national laboratory expertise • Continue development of a key, standardized building-blocks with combined capabilities for power conversion and microgrid control functions	• Conduct R&D on the DynaGrid concept to enable dynamic formation of microgrid boundaries for optimized operations of networked microgrids, building on the RONM capabilities developed for static-boundary applications • Develop modeling and simulation capabilities for optimal system design and operations of networked microgrids for decarbonization and resilience of critical infrastructure with a focus of the use case on ports • Complete the design and prototype of MBB hardware and software that integrates the power conversion, switching, communication, and microgrid controller functions into one single unit • Develop modeling and simulation of a small-modular-reactor-integrated microgrid design to examine power system engineering issues and operational challenges for providing grid services	• Increase support of the multi-lab MBB development to advance the design and produce the prototype unit • Increase support of the multi-lab DynaGrid approach with development of use cases to assess the effect on equity, energy justice, and outcomes for different groups of customers • Support implementation of the technology roadmap for the Net-Zero Microgrids (NZMs) activity, including development of modeling/ simulation capabilities and a techno-economic analysis platform

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
• Develop protection schemes for microgrids with high penetration of inverter-based resources and develop new microgrid fault location algorithms using real-time sensor data and analytics • Conduct funding opportunity on highly resilient adaptive networks leveraging analysis and laboratory activities accomplished in FY 2020	• Develop a net-zero techno-economic analysis platform and apply it to evaluate microgrid fast charging station designs for electric vehicles • Develop protection schemes for microgrids (singular and networked) with high penetration of inverter-based resources and for secondary networks with DERs and microgrids • Complete development of a potential replacement technique for reverse power relaying protection of secondary network	
Dynamic Controls & Communications $12,218,000	*$20,000,000*	*+$7,782,000*
• Initiate the development of a comprehensive communications planning toolkit • Demonstrate the feasibility and benefits of resilience services utilizing Dynamic Control Source	• Develop data efficient operations approach with increased reliance on combinations of distributed control and incentivization of flexible DER for reliability and resilience • Develop FERC Order 2222 implementation paths that emphasize transmission and distribution coordination and increased storage utilization • Develop a broad framework for data sharing across ownership and responsibility boundaries that assures data security, integrity, and privacy while ensuring operational objectives of all stakeholders are attained • Extend Sector Coupling Analysis of the Transport and Electricity Sectors including structural and architectural aspects, seeking to establish a converged perspective on reliability, sustainability, and resilience across both transportation and electricity	• Increase support for the deployment mission through enhanced emphasis on implementation strategies • Expand data science approaches in the rapidly expanding grid-edge, collaborative control frontier, strengthening coordination capabilities and enabling decarbonized and resilient systems • Anticipate the substantial impact of transportation electrification through increased research on interdependency, adaptation of distribution systems, and coordination of optimizations across new and legacy participants in the electric system

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
	• Develop control and coordination approaches that address vehicle grid integration issues through nodal and network solution paths, encompassing all grid and DER assets and their incentive mechanisms. • Develop digital ledger technology use cases that further enable DER integration and data integrity in distributed control and distributed compute environments	
Sensors $3,800,000	*$7,000,000*	*+$3,200,000*
• Operation, maintenance, and expansion of the SAN	• Develop approaches and tools that will accurately detect, characterize, and forecast DER behavior and its impacts on distribution systems • Develop new analytical algorithms that utilize real-time sensor data from transmission and distribution systems to diagnose asset health and predict imminent failures • Demonstrate grid models and tools that optimize sensor placement in terms of monitoring effectiveness and cost • Fund a prize program for AI/ML tool development utilizing open distribution system data sets, to catalyze independent academic research into equity and integration of DERs	• Develop and integrate high-fidelity, fast-acting sensor technologies and advanced data analytics into the electricity delivery system
Electricity Delivery Systems $9,182,000	*$9,000,000*	*-$182,000*
• Establish formal relationships with NARUC, NASEO, NGA, NCSL, NRECA, and APPA to address institutional barriers related to advancing grid capabilities	• Develop formal methods for incorporating resilience, energy justice, and decarbonization, as well as for balancing priorities among multiple objectives, into integrated planning processes	• Work continues as planned with a slight reduction of effort in activities with States

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
• Establish a Steering Committee (EAC, FERC, and national laboratories) to begin the process to develop pathways for addressing barriers to grid transformation	• Develop architecture-based guidelines to enable the formulation of frameworks to support the coordination of distributed energy resources within grid and market operations across the transmission, distribution, and behind-the-meter domains • Develop draft architecture specifications for a distribution grid, including structural views (physical and cyber) that can accommodate all forms of DERs, ownership models, and market structures • Establish and use formal working groups with NARUC, NASEO, NRECA, and APPA to vet and disseminate advanced planning practices and guidelines for operational coordination, as well as to provide technical assistance in these areas	
Demonstration Sensors $5,000,000	*$0*	*-$5,000,000*
• Utilize sensor data and data analytics from distribution utilities that have deployed advanced metering infrastructure to improve electrical system performance		• Planned activities for this Congressionally directed activity are completed with funding provided in FY 2021
COMMANDER National Testbed Laboratory $10,000,000	*$0*	*-$10,000,000*
• Multiple lab activities were conducted at ORNL • Activities included testing new technologies, examining the use of microgrids, and developing new analytics that will unlock the power of the smart grid data to improve operations		• Planned activities for this Congressionally directed activity are completed with funding provided in FY 2021

Cyber Resilient and Secure Utility Communications Networks[a]

Overview

The increasingly sophisticated cybersecurity exploit capabilities of our adversaries, coupled with increased reliance on the data communications and cyber-physical control of our Nation's energy systems, have made it extremely challenging for the energy sector to stay ahead of a quickly evolving risk landscape. The Department has prioritized investment in secure communications and cybersecurity to identify solutions to reduce risk for the energy sector.

The Cyber Resilient and Secure Utility Communications Networks (SecureNet) program develops solutions to strengthen electricity infrastructure against cyber-related threats and to mitigate vulnerabilities through support of game-changing R&D. The program focuses on enhancing the inherent resilience (the ability to withstand and quickly recover from disruptions and maintain critical function) and security (the ability to reduce risks in the protection system assets and critical functions from unauthorized access and actions) of the electricity delivery system. SecureNet ensures a security-by-design approach based on data and physics to address vulnerabilities of the grid and critical operational data, communications, and control systems that expose the electricity system to cyber threats.

The SecureNet program is designing next-generation cyber and grid-communications systems that are built from inception to automatically detect, reject, and withstand cyber incidents, regardless of the threat. The evolving electric grid—with its rapidly growing number of cyber-enabled, highly-distributed components—is increasingly reliant on data communications and cyber-physical control for reliable operation. This requires new approaches to prevent or mitigate the impact of potential cyber-related risks. To accomplish this goal, the increasing focus is on data and physics to redesign the current grid cyber, data, communications, and control architecture that exposes the electricity system to cyber threats. Proactive assessment of technology, design modifications, or operational considerations early in the R&D process will position the grid solutions to more effectively and economically mitigate physical consequences from a cyber-attack. This ensures that all relevant OE R&D activities have an embedded security-by-design philosophy that directly complements ongoing OE research to understand, characterize, and model the electricity system.

Complementing its strategic R&D approach, SecureNet also pursues coordinated engagement with the Department's cyber-related operational activities, including that of the Office of Cybersecurity, Energy Security, and Emergency Response (CESER) and the Office of Intelligence and Counterintelligence. Through these partnerships, the SecureNet program will develop unmatched scientific and technical expertise in support of the Department's national security mission; strengthen public-private sector outreach, information sharing, training, and technical assistance; and enhance emergency preparedness, response, and recovery of U.S. infrastructure from all threats and hazards.

Highlights of the FY 2023 Budget Request

The FY 2023 Budget request provides support to research and develop advanced solutions that focus on a security-by-design approach based on data and physics to address vulnerabilities of the grid and critical operational data acquisition, processing, communications, and control systems that are specific to the electricity delivery system, both transmission and distribution. It also addresses OE's responsibility for catalyzing energy sector cybersecurity associated with electricity delivery systems, providing an opportunity to strengthen the relationship with other OE research for accelerated results. CESER retains lead responsibility for crosscutting cybersecurity issues that span beyond electricity delivery systems, as well as for coordinating energy sector cybersecurity activities across the Department.

The SecureNet program will develop technical solutions enabling accelerated and expanded efforts to strengthen electricity infrastructure against cyber threats while mitigating vulnerabilities. Working closely with the energy sector and our government partners, the request focuses on accelerating game-changing R&D to mitigate cyber incidents in today's systems and to develop next-generation resilient electricity delivery systems. The resilient electricity delivery systems (including synergistic communications networks) will be designed, installed, operated, and maintained to survive a cyber incident while sustaining critical functions. For instance, research could accelerate development of technical solutions based on artificial intelligence (AI) techniques for critical electricity delivery infrastructure, such as machine learning using data generated by the underlying physical process of electricity delivery as well as data generated by the cyber-systems that

[a] The Cyber Resilient and Secure Utility Communications Network program was called Cybersecurity Research and Development in the FY 2022 Request to Congress.

control that physical process, to provide for an automatic response to cyber-attack. Such AI techniques could allow for electricity delivery systems or components to automatically adapt operations and survive a cyber-attack that would otherwise disrupt energy delivery. This effort may leverage advancements in grid modeling and data analytics from other OE programs, such as Transmission Reliability and Resilience, Resilient Distribution Systems, and Energy Delivery Grid Operations Technology.

The request continues to support university collaborations focused on advanced energy sector cybersecurity R&D. Project activities will integrate rigorous academic approaches with real-world expertise. Academic R&D is an important aspect of the SecureNet portfolio because it involves technology-focused activities that, when combined with industry guidance, results in real-world, impactful solutions, as well as helping to train and develop the next generation of cybersecurity specialists.

SecureNet will support R&D activities through the Grid Modernization Laboratory Consortium (GMLC).

Cyber Resilient and Secure Utility Communications Networks (SecureNet)
Funding ($K)

	FY 2021 Enacted	FY 2022 Enacted Annualized CR[a]	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
Cyber Resilient and Secure Utility Communications Networks (SecureNet)					
University Research	0	–	2,000	+2,000	N/A
Industry Research	0	–	10,000	+10,000	N/A
Cyber Assessments and Technology	0	–	8,000	+8,000	N/A
Total, Cyber Resilient and Secure Utility Communications Networks (SecureNet)	**0**	**0**	**20,000**	**+20,000**	**N/A**

SBIR/STTR:

- FY 2021 Enacted: SBIR/STTR: $0
- FY 2023 Request: SBIR/STTR: $412

Cyber Resilient and Secure Utility Communications Networks (SecureNet)
Explanation of Major Changes ($K)

	FY 2023 Request vs FY 2021 Enacted
• University Research: Supports cyber research partnerships with universities on electricity delivery system technologies (such as energy storage and microgrids) and related NSF partnerships	+2,000
• Industry Research: Improves cybersecurity practice and technology development related to the electricity delivery system, with particular focus on cyber-enabled, highly distributed components	+10,000
• Cyber Assessments and Technology: Conducts cyber maturity reviews and assessment of existing OE research, development and demonstration programs	+8,000
Total, Cyber Resilient and Secure Utility Communications Networks (SecureNet)	**+20,000**

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

Cyber Resilient and Secure Utility Communications Networks (SecureNet)

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Cyber Resilient and Secure Utility Communications Networks (SecureNet) $0	**$20,000,000**	**+$20,000,000**
University Research $0	*$2,000,000*	*+$2,000,000*
	• Create cyber research partnerships with universities on electricity delivery system technologies (such as energy storage and microgrids) and support related NSF partnerships	• FY 2022 is the first year of funding for this program
Industry Research $0	*$10,000,000*	*+$10,000,000*
	• Improve cybersecurity practice and technology development related to the electricity delivery system, with particular focus on cyber-enabled, highly distributed components	• FY 2022 is the first year of funding for this program
Cyber Assessments and Integrity $0	*$8,000,000*	*+$8,000,000*
	• Conduct cyber maturity reviews and assessment of existing OE research, development and demonstration programs	• FY 2022 is the first year of funding for this program

Energy Storage

Overview

The Energy Storage program leads a national effort to ensure a more flexible, resilient, and equitable North American power grid through increased deployment of bi-directional electrical energy storage. Executive Order 14008 establishes a goal to reach 100% carbon pollution-free electricity by 2035 and a net-zero emissions economy by no later than 2050. Maintaining grid reliability and resource adequacy with increased levels of variable renewable energy technologies will require cost-effective methods of storing and discharging energy. Energy storage is the key enabling element for this transition as it is a bi-directional flexible resource capable of providing a suite of grid services while improving the inherent resiliency of the grid. Executive Order 14008 created the Justice40 Initiative, a plan to deliver 40% of the overall benefits of climate investments to disadvantaged communities. Energy storage provides new tools to improve grid resiliency in underserved communities and, when paired with renewable generation or offsetting the use of fossil-based resources, can help alleviate environmental issues in these communities.

Compared to the U.S. electric grid's installed electricity generation summer capacity of just over 1 terawatt (TW) (1,000 GW), the grid has roughly 23 GW of energy storage, of which 22 GW is provided by large pumped storage hydropower (PSH) energy storage plants and the remainder provided mostly by lithium-ion batteries. Achieving grid and full economy-wide decarbonization could require 300–1,000 GW or more of new storage power capacity, along with thousands of terawatt-hours (TWh) in storage energy duration. While existing storage technologies have the potential for significant growth, they face certain limitations. Underlying materials costs will limit the ability of lithium batteries to cost-effectively provide long-duration storage, and there are not enough PSH sites to achieve the hundreds of gigawatts required for daily and seasonal energy supply and demand imbalances. Ongoing research, development, demonstration, and deployment (RDD&D) efforts are focused on increasing storage durations, reducing technology costs, and deploying next generation energy storage solutions around the country. Further research is also needed in the safety and long-term reliability of utility-scale energy storage systems. In addition, further research is needed in developing analytic models that can facilitate not only greater understanding of technical and economic benefits energy storage can provide to utilities and grid operators, but also the role storage plays in providing equitable power for consumers and communities and the impact of long-duration storage on deep decarbonization of the power sector.

The Energy Storage program is designed to foster new and advanced energy storage technologies that will ensure a reliable and resilient electricity infrastructure, equitably delivered to all stakeholders. The R&D program focuses on:

- Cost-Competitive and Long-Duration Energy Storage Technology Development
  - Performing advanced research on the development of novel materials and system components to resolve key cost and performance challenges with respect to novel flow, lithium, sodium, zinc manganese dioxide, and lead-based batteries, electrode materials, membranes, electrolytes, interconnects, and supporting power electronics and power conversion systems. These advanced battery and device technologies will lead to significant improvements in the cost and performance of energy storage systems, in line with the Long Duration Storage Shot, enabling widespread deployment of longer-duration storage solutions and supporting increased domestic manufacturing.
  - Supporting a competitive funding opportunity announcement (FOA) to target innovative, longer-duration energy storage technologies that have require preliminary early-stage validation. The FOA will provide a pathway for demonstration and deployment of new flow or other innovative battery chemistries that can ultimately achieve the Long Duration Energy Storage EarthShot target of 5¢/kWh on a levelized cost basis.
  - Initiating a new Fellowship program for the Grid Storage Launchpad (GSL) to leverage the new capabilities being developed at the upcoming GSL facility.
- Validated Reliability and Safety
  - Developing a scientifically derived knowledge base to improve the understanding and predictability of energy storage systems and components under realistic grid use cases, inspiring greater confidence in the safety and reliability of energy storage systems.
  - Improving the safety and reliability of energy storage technologies and their installation in close collaboration with fire departments, building managers, and other approval authorities.
- Energy Storage Analytics for an Equitable Regulatory and Social Environment
  - Developing open-source analytic tools for small and large utility customers and regulatory agencies to facilitate planning and implementation of energy storage in transmission and distribution infrastructure.

- Quantifying the environmental and social impacts storage impacts to decarbonizing the power sector and enabling consistent and reliable power to underserved communities.
- Supporting the development of open-source tools for optimal sizing, placement, and valuation of energy storage and develop performance protocols for rapid adaption of energy storage.
- Designing and testing advanced control systems to optimize fleets of diverse energy storage systems to supply existing and emerging grid services.
- Developing new analytical tools that help quantify the societal and environmental impacts that storage provides to communities with poor electrical reliability.
- Additional funding support new cohort of communities and projects in recently launched Energy Storage for Social Equity Technical Assistance Program, designed to provide a range of defined, community-centered energy storage analyses including valuation, grid services, system resilience, and equity to measure the relationship between storage investments and community benefit outcomes.

- Storage Grid and Field Validation
  - Develop the Rapid Operational Validation Initiative (ROVI), a cross-cutting analytical framework that can support faster validation and industry acceptance of new storage technologies. ROVI aims to provide at least a 15-year technology life and performance prediction using 1-year or less of data.

Highlights of FY 2023 Budget Request

Grid energy storage is one of the key components for the development of a flexible and resilient electric grid infrastructure. The Request continues support for the program's core R&D agenda including materials research on the next generation of long-duration energy storage technologies, development of new materials and devices for efficient power conversion, improved safety and reliability of storage systems, development of optimal design and control architectures for energy storage integration, and development of open-source models and software tools for system level energy storage planning and evaluation. The request also continues the program's outreach and support to the energy storage industry through workshops with public utility commissions (PUCs), educational programs and materials for code officials and first responders, and technical conferences for industry.

The research builds on a long history of successful research, development, and deployment (RD&D) by the OE Energy Storage program.

- Advanced materials R&D is focused primarily on improving the cost and performance of earth-abundant, domestically available storage technologies with an emphasis on longer-duration (8–12 hour) technologies such as flow batteries and new systems based on advanced sodium and zinc chemistries).
- Materials research is aimed at improving the operational lifetime and performance of the chemistries and all critical cell components and moving these technologies toward practical prototypes that can potentially achieve cost-competitive long-range cost targets of 5¢ per kWh levelized cost of storage (LCOS), consistent with the recently announced Long Duration Energy Storage Earthshot.
- Targeted R&D efforts for low-cost, earth-abundant systems (e.g., sodium, zinc manganese dioxide, and lead-based systems) that are coordinated in national programs that engage a cross-section of national laboratories, universities, and industry partners to meet ultimate performance objectives.

In FY 2023, materials and device R&D efforts will progress to validation of novel storage technologies that can cost-effectively provide longer discharge durations (10+ hours continuously), and storage systems that may enable seasonal shifting of electrical energy usage.

The Request also supports a competitive funding opportunity announcement (FOA) that targets innovative, longer-duration energy storage technologies that have require preliminary early-stage validation. The FOA will provide a pathway for demonstration and deployment of new flow or other innovative battery chemistries that can ultimately achieve the Long Duration Energy Storage EarthShot target of 5¢/kWh on a levelized cost basis. This FOA would leverage prior work performed within the OE storage program and the recent EERE-AMO Redox Flow Battery Manufacturing call, and directly supports both the Energy Storage Grand Challenge (ESGC) and the Long Duration Energy Storage Earthshot. This FOA will prepare technologies for scaled demonstrations that would be subsequently supported by the Energy Storage

Demonstration Projects and the Long Duration Demonstration Initiatives created by 42 USC § 17232 (c) and (d), respectively.[a]

Power electronics and power conversion systems can represent up to 30% of an installed storage system's cost. The program's leadership in advanced power electronics will continue with anticipated improvements in new wide-bandgap materials for power electronics and advanced dielectric materials for high voltage capacitors. R&D activities investigating new topologies for optimal control and safety of power electronics will continue, as well as the development of advanced power electronic architectures to address stranded energy, improve battery failure diagnostics, and integrate highly accurate state-of-charge and state-of-health monitoring of energy storage systems.

Safety and reliability of energy storage systems are critical for large-scale deployment of storage technologies into grid infrastructure and will continue to be an active R&D area in the program. The OE Energy Storage program continues to be the primary conduit between research and industry for energy storage safety and is supporting industry-led effort to establish strong safety standards. The program continues working closely with fire departments, building managers, and other approval authorities to understand the critical R&D needs of the end users, and providing fundamental research information for use by standards development organizations such as the Institute of Electrical and Electronics Engineers (IEEE), National Fire Protection Association (NFPA), and UL. The Program will continue to engage with national and international safety organizations to understand the root cause of known failures and facilitate uniformity of safety codes and standards. Establishing a validated and referenceable database of energy storage degradation and expected lifetimes, in collaboration with industry, will continue to be a significant program priority as new storage technologies are introduced into the marketplace. The Grid Storage Launchpad will make critical testing and validation capabilities (up to 100kW) available to industry and academia aimed at long-term and accelerated testing methodologies to determine the expected lifetime of storage technologies when operated under grid duty cycles.

Uncertainty on the economic performance of energy storage technologies continues to impede the wider-scale adoption of grid energy storage. The program's energy storage analytics focus has an established track record for providing analysis on performance of energy storage systems for a full range of grid application. The program will continue to support the development of open-source analytic tools for the North American electric utility industry to ensure availability of tools required for greater adoption of flexible energy storage assets. In addition to quantifying the economic benefits of storage technologies, these new models must also capture the societal and environmental benefits storage can provide to consumers through improved power quality and environmental mitigation. The impact of improving electrical reliability in underserved communities and improvements in air-quality through reduction of fossil generation are examples of benefits that are not currently captured in analytical models but are critical to achieve social equity. Developmental tools that accurately capture the complete economic and societal value proposition for storage in both well-defined markets and non-market conditions will continue to be a priority. The program will also continue to support the development of robust user tools for storage planning, operation, and evaluation. This entails open-source software development for optimal sizing and placement, optimal control and coordination, cyber-threat analysis and protection, and techno-economic assessment.

Real-world validation of storage tools and models can greatly lower the barrier for acceptance by stakeholders by enabling them to fully understand how integrating storage into the grid can lower energy prices, secure their electrical supply, and solve a variety of reliability and equity challenges faced by specific localities across the United States. Providing technical assistance to states and regional stakeholders in the use of these analytical tools and how to safely install, integrate, and operate deployed energy storage systems will continue to be a vital element of the program. The program's support of energy storage installations to enhance resilience will continue through joint projects with local and rural utilities responsible for supplying electricity to critical infrastructures. The data and experience from these projects will be used to support the North American Energy Resiliency Model (NAERM) by advancing the Nation's understanding of the strategic use and placement of energy storage systems, including batteries, within the energy sector.

Insufficient operational performance data will be a distinct barrier to wide commercial deployments of new storage technologies. Nascent technologies do not have a long-term operational track record, and traditional calendar-life-based validation methods today will not allow sufficient time to develop, validate and install the various energy storage systems required to meet the Administration's 2035 goals for the Nation. The Rapid Operational Validation Initiative (ROVI) aims to provide at least a 15-year technology life and performance prediction using 1-year or less of data. ROVI is envisioned as a

[a] https://www.law.cornell.edu/uscode/text/42/17232

cross-cutting analytical framework that can support faster validation of storage technologies currently being developed. ROVI will use a combination of physical characterization and performance data, data generated from physics-based models and digital twins, and deployment data. The FY 2023 request includes support for the ROVI framework and its initial development for 1–2 emerging electrochemistries.

The FY 2023 Request continues support for the recently launched Energy Storage for Social Equity Technical Assistance and Pilot Program.[a] Communities across the country face significant energy challenges but may not fully understand how energy storage can be a solution. This program is designed to provide a range of defined, community-centered energy storage analyses including valuation, grid services, system resilience, and equity to measure the relationship between storage investments and community benefit outcomes. The program offers assessments on energy storage feasibility, design, application, operations, and maintenance in support of disadvantaged communities.

Support for the OE Grid Storage Launchpad (GSL) construction project, which is aimed at accelerating materials development, testing, and independent evaluation of battery materials and battery systems for grid applications, was fully funded through the completion of construction by FY 2022 appropriations. Beneficial occupancy is planned for late 2023, and start of operations (CD-4) in 2025. GSL will:

- Focus on materials development and prototype battery systems (up to 100 kW, rather than megawatt-scale systems integration and testing), to identify and solve issues before moving to larger-scale systems
- Standardize grid performance testing across the spectrum of battery materials, battery systems, inverters, auxiliary power, and battery management systems under grid use-case conditions
- Provide an objective national resource to report battery testing performance under grid conditions
- Integrate and coordinate researchers from universities and national labs together to rapidly solve crosscutting science and technology challenges
- Develop new capabilities to rapidly scale-up new materials for grid scale storage, deliver dedicated state of the art characterization capabilities that do not exist
- Conduct realistic testing of design options in a laboratory environment

The GSL mission directly supports the ESGC crosscut, the Long Duration Energy Storage Earthshot, and the Rapid Operational Validation Initiative. Project Engineering and Design (PED) funds were used in FY 2020 and FY 2021 to complete the DOE O 413.3B requirements leading up to Critical Decision (CD)–2/3. FY 2021 funding was used to initiate a design-build acquisition strategy in which design and construction services are secured together, including start of construction. The FY 2022 appropriation supports final construction and commissioning of the GSL facility. CD-4 (to approve start of operations) is planned in the last quarter of FY 2025 (including schedule contingency for risk mitigation).

The request includes support to initiate a new GSL Fellowship program. The GSL facility includes space for early-stage entities or early-career innovators to utilize the testing and validation capabilities for storage development. In 2023, this program will be developed and begin initial recruitment. Selections by late 2023 will provide awardees sufficient time to relocate to the GSL in parallel with the anticipated beneficial occupancy date.

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

Energy Storage Grand Challenge: ESGC is a crosscutting effort managed by DOE's Research and Technology Investment Committee (RTIC) and co-chaired by OE and the Office Energy Efficiency and Renewable Energy (EERE). ESGC coordinates R&D across DOE, including complementary R&D investments beyond the applied energy offices, to advance energy storage and technologies that provide similar capabilities. OE's Energy Storage program's request supports grid-related ESGC objectives and other OE R&D efforts are also complementary to ESGC goals. DOE is taking a holistic approach to accelerate the development, commercialization, and utilization of next-generation energy storage technologies. The Department integrated the existing disparate storage efforts from the Grid Modernization Initiative (GMI), Advanced Energy Storage Initiative (AESI), Beyond Batteries (BB), and others into the Energy Storage Grand Challenge, an integrated, comprehensive DOE-wide strategy. The ESGC is deploying the Department's extensive resources and expertise to address technology development, commercialization, manufacturing, valuation, and workforce challenges. The vision for the ESGC is to create

[a] https://www.pnnl.gov/projects/energy-storage-social-equity/technical-assistance-program

and sustain global leadership in energy storage utilization and exports, with a secure domestic manufacturing supply chain that is independent of foreign sources of critical materials, by 2030.

Energy Storage
Funding ($K)

	FY 2021 Enacted	FY 2022 Enacted Annualized CR[a]	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
Energy Storage					
Research					
Cost-Competitive and Long-Duration Energy Storage	19,500	–	35,000	+15,500	+79.5%
Validated Reliability and Safety	14,700	–	16,200	+1,500	+10.2%
Energy Storage Analytics for an Equitable Regulatory and Social Environment	7,500	–	12,400	+4,900	+65.3%
Grid and Field Validation	10,300	–	17,400	+7,100	+68.9%
Resilience Projects	5,000	–	0	-5,000	-100.0%
Total, Research	57,000	57,000	81,000	+24,000	+42.1%
Construction	23,000	23,000[b]	0	-23,000	-100.0%
Total, Energy Storage	**80,000**	**80,000**	**81,000**	**+1,000**	**+1.3%**

SBIR/STTR:

- FY 2021 Enacted: SBIR/STTR: $1,606
- FY 2023 Request: SBIR/STTR: $2,639

Energy Storage
Explanation of Major Changes ($K)

	FY 2023 Request vs FY 2021 Enacted
Research	
• Cost-Competitive and Long-Duration Energy Storage: Initiate new emerging technology FOA focused on ultra-low-cost chemistries and consistent with goals of the Long Duration Energy Storage Earthshot. Initiate new GSL fellowship program.	+15,500
• Validated Reliability and Safety: Expanded training and technical assistance for fire and safety officials.	+1,500

[a] FY 2022 amounts shown reflect the P.L. 117–95 continuing resolution (CR) level annualized to a full year. These amounts are shown only at the "congressional control" level and above; below that level, a dash (–) is shown.
[b] The FY 2022 appropriation provided $47,000,000 for GSL, which represents full funding through the completion of construction.

	FY 2023 Request vs FY 2021 Enacted
• Energy Storage Analytics for an Equitable Regulatory and Social Environment: Additional funding support new cohort of communities and projects in recently launched Energy Storage for Social Equity Technical Assistance Program.	+4,900
• Grid and Field Validation: Development of the Rapid Operational Validation Initiative, to incorporate data and models for 1–2 chemistries or storage technology types.	+7,100
• Resilience Projects: Planned activities for this Congressionally directed activity are completed with funding provided in FY 2021	-5,000
Total, Research	**+24,000**
Construction	
• The FY 2022 appropriation provided $47,000,000 to complete construction funding for the Grid Storage Launchpad (GSL).	-23,000
Total, Energy Storage	**+1,000**

Energy Storage

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Research $57,000,000	**$81,000,000**	**+$24,000,000**
Cost-Competitive and Long-Duration Energy Storage $19,500,000	*$35,000,000*	*+$15,500,000*
• Demonstrate a 5 kW prototype of a novel aqueous soluble organic flow battery technology capable of achieving 400 mA/cm² with a projected 1 MW/4 MWh system cost of less than $200 per kWh • Demonstrate large format (300 Ah) zinc-manganese dioxide batteries with an energy density of 150 Wh/L with projected cell level costs below $50 per kWh when produced in volume	• Initiate new emerging technology FOA focused on ultra-low-cost chemistries and consistent with goals of the Long Duration Energy Storage Earthshot. Multi-year consortium targeting progress toward the 5¢/kWh levelized cost of storage (LCOS) goal with intermediate targets of 30¢/kWh, 20¢/kWh, etc. • Continue focused development programs on other earth-abundant materials systems (sodium, zinc, sulfur, etc.) with potential to meet 2030 LCOS target	• New $15 million emerging technology FOA focused on ultra-low-cost chemistries and consistent with goals of the Long Duration Energy Storage Earthshot. Multi-year consortium targeting progress toward the 5¢/kWh levelized cost of storage (LCOS) goal with intermediate targets of 30¢/kWh, 20¢/kWh, etc. • Initiate new GSL fellowship program

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
• Demonstrate performance and long-term stability of sodium batteries technologies (sodium-ion and sodium metal halide) in greater than 5 Ah prototypical formats capable of achieving less than $100 per kWh when produced at scale • Continue research and development of new power electronics and power converter topologies for efficient coupling between batteries and power electronics for improved power conversion optimized for aqueous batteries including flow batteries and zinc-based batteries • Expand R&D efforts on lead-acid batteries as potential grid scale energy storage solutions	• Demonstrate prototype pack architectures with capacities greater than 5 kWh based on 300 Ah zinc-manganese dioxide batteries and projected cell level costs below $50 per kWh when produced in volume • Initiate new GSL fellowship program • Migrate new power electronics and power converter topologies from R&D to scalable prototype formats and demonstrate efficient coupling between batteries and power electronics	
Validated Reliability and Safety $14,700,000	*$16,200,000*	*+$1,500,000*
• Migrate novel control strategies and architectures for distributed control of energy storage from R&D to industry for improved grid stability, economic dispatch, and system reliability and safety • Expand reliability testing of new battery chemistry under defined grid use cases and develop comprehensive reliability metric for grid scale storage systems	• Expand training and technical assistance to fire officials and safety code officials for energy storage best practices. • Continue development and validation of novel control strategies and architectures with industry for distributed control of energy storage for improved grid stability, economic dispatch, and system reliability and safety • Expand reliability testing of new battery chemistry under defined grid use cases and develop comprehensive grid scale storage system reliability metrics with industry for use at GSL	• Expand training and technical assistance to fire and safety officials
Equitable Regulatory and Social Environment $7,500,000	*$12,400,000*	*+$4,900,000*
• Disseminate open-source software tools and validated analytical models for optimal sizing, location, and operation of grid scale energy storage	• Continues support for execution of projects selected under FY 2022 FOA • Continues engagement with PUC's and States developing energy storage policy and integrated resource planning	• Additional funding supports a new cohort of communities and projects in the recently launched Energy Storage for Social Equity Technical Assistance Program

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
	• Continues Energy Storage for Social Equity Technical Assistance Program	
Grid Deployment and Field Validations $10,300,000	*$17,400,000*	*+$7,100,000*
• Support installation, integration, and validation of at least 3 new electrical energy storage projects that highlight longer term (6+ hour) storage applications for defense critical infrastructures • Support installation, integration, and validation of at least 2 new electrical energy storage projects aimed at improving resiliency and operational efficiency of rural co-operatives	• Continues development of higher fidelity software tools and analytical models for the optimal value, sizing based on storage location • Adds additional functionality to tools to quantify environmental (e.g., greenhouse gas reductions) and social benefits storage provides • Development of the Rapid Operational Validation Initiative (ROVI), to incorporate data and models for 1–2 additional chemistries or storage technology types	• Incorporate data and models for 1–2 additional chemistries or storage technology types to populate ROVI
Construction $23,000,000	**$0**	**-$23,000,000**
• Complete funding for construction and commissioning of the Grid Storage Launchpad facility		• No funding is required in FY 2023; full funding for the remainder of construction is provided in FY 2022

Construction Projects Summary ($K)

	Total Project Cost (TPC)	Prior Years	FY 2021 Enacted	FY 2022 Enacted	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted	Future Years
20-OE-100 Grid Storage Launchpad							
Total Estimated Cost (TEC)	75,000	5,000	23,000	47,000	0	-23,000	0
Other Project Costs (OPC)	2,000[a]	1,000[a]	0	0	1,000[a]	+1,000	0
TPC	77,000	6,000	23,000	47,000	1,000	-22,000	0

[a] OPC is funded through laboratory overhead.

Transformer Resilience and Advanced Components

Overview

The Transformer Resilience and Advanced Components (TRAC) program develops innovations for grid hardware to carry, control, and convert electricity. These technologies help the electric grid achieve decarbonization goals, ensure reliability and resilience of electric infrastructure, and adapt the electricity delivery system to the evolution of the electric power grid. TRAC addresses the unique challenges facing transformers, critical components, and other grid hardware technologies responsible for delivering electricity from where it is available to where it is needed. As the electric power system evolves, legacy grid components will need to overcome historic performance limits. Research in advanced power electronics, materials, and sensors will provide the enhancements in next-generation grid hardware required to accommodate the rapidly changing power system. Program activities will ultimately address the need for real and reactive power flow control, facilitate the integration of grid-scale energy storage and new centralized and distributed energy resources (DERs), develop new system components, and increase system efficiency, stability, and resilience.

Decarbonization of the electric grid will require modernization of the transmission and distribution (T&D) systems and application of new components to support the changing mix and characteristics and types of electricity generation. In addition, T&D equipment such as transformers, power lines, and substation equipment are often exposed to the elements and are vulnerable to adverse conditions, which are occurring increasingly often. To support the transition to a decarbonized grid and enhance the security, reliability, and resilience of the electric power system, the next generation of these grid hardware technologies will need to support the requirements of an evolving grid and be built to withstand and rapidly recover from the impact of extreme terrestrial or space weather events, electrical disturbances, equipment failures, accidents, deliberate attacks, and other unknowns. Other important characteristics include flexibility and adaptability to address the wide range of designs and specifications across these critical assets, facilitating modularity, and sharing in emergency situations as highlighted in the 2021 National Academies Report, *The Future of Electric Power in the United States*.[a]

TRAC focuses on innovative designs, materials research, exploratory concepts (such as a high-voltage direct current (HVDC) backbone), and modeling and analysis to address the range of challenges associated with transformers and other grid components. Program activities, developed in close coordination with industry, aim to fill fundamental R&D gaps and encourage the adoption of new technologies and approaches. Next-generation solutions are urgently needed; many existing components cannot support evolving grid demands, while the age of existing grid assets degrades their ability to withstand physical stresses and may result in higher failure rates that could lead to widespread outages and long restoration times. For example, a large power transformer (LPT) failure could disrupt power to a half million homes and take over 12 months to procure, transport, and install a replacement. A significant percentage of grid infrastructure assets are reaching or past replacement age, and results of the TRAC program will help lay the foundation for the grid of the future by catalyzing advances in the underlying physical infrastructure. TRAC supports projects that spur innovative LPT designs that are more flexible and adaptable, increasing the resilience of the Nation's power grid, and providing the foundation to reinvigorate domestic LPT manufacturing.

Highlights of the FY 2023 Budget Request

To enable the Administration’s decarbonization goals, TRAC will accelerate work to address the unique challenges facing LPTs and other critical components, such as advanced conductors and cables, power flow controllers, high voltage direct current (HVDC) equipment, and related grid hardware. The FY 2023 budget request supports testing and field validation of Grid Enhancing Technologies (GETs) by conducting a full scale, multi-faceted field exercise fostering public–private partnerships to accelerate the deployment of GETs for optimal transmission asset utilization and facilitate renewable energy and carbon neutral technology system integration. GETs, such as dynamic line rating and power flow controls, have been shown to improve the energy transfer capabilities of existing transmission paths and are able to be deployed more quickly than building new lines at costs significantly below traditional upgrades.

The FY 2023 budget request also supports the development of characterization methods and tools to evaluate reliability, transient stability, and economics of large-scale direct current (DC) architectures in alternating current (AC) grids. HVDC systems can be an important technology to integrate renewables to load centers in the existing AC transmission systems in

[a] https://nap.nationalacademies.org/catalog/25968/the-future-of-electric-power-in-the-united-states

United States. Some studies have shown that HVDC systems can improve the transient stability, reliability, and economics of operating grids.

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

Technology, tools, and applications developed under TRAC will be evaluated for security risks including cybersecurity, electromagnetic pulses, and geomagnetic disturbances. Testing and evaluations will be conducted to ensure that security is built-in and new security risks are not being introduced into the electric sector.

TRAC will also expand activities in technology solutions that can provide continued grid reliability under an increased frequency of extreme weather events. Such solutions include fire-resistant distribution infrastructure and improved cost and performance of undergrounded power lines to improve, or harden, the current infrastructure.

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

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

Transformer Resilience and Advanced Components
Funding ($K)

	FY 2021 Enacted	FY 2022 Enacted Annualized CR[a]	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
Transformer Resilience and Advanced Components					
Market and System Impact Analysis	520	–	5,000	+4,480	+861.5%
Component Design and Development	6,670	–	14,500	+7,830	+117.4%
Applied Material R&D	310	–	3,000	+2,690	+867.7%
Total, TRAC	**7,500**	**7,500**	**22,500**	**+15,000**	**+200.0%**

SBIR/STTR:
- FY 2021 Enacted: SBIR/STTR: $247
- FY 2023 Request: SBIR/STTR: $557

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

	FY 2023 Request vs FY 2021 Enacted
• Market and System Impact Analysis: methods and tools to evaluate reliability, transient stability, and economics of large-scale DC architectures	+4,480
• Component Design and Development: increased development of critical power conversion and control technologies; full scale testing and field validation of Grid Enhancing Technologies (GETs)	+7,830
• Applied Materials R&D: advanced materials, embedded intelligence for equipment monitoring, validation of prototype converter building blocks, and medium voltage converter building block development	+2,690
Total, TRAC	**+15,000**

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

Transformer Resilience and Advanced Components

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Transformer Resilience and Advanced Components **$7,500,000**	**$22,500,000**	**+$15,000,000**
Market and System Impact Analysis $520,000	*$5,000,000*	*+$4,480,000*
• Establish modeling and testing capabilities to evaluate the performance and interoperability of SSPS building blocks	• Develop the Smart Universal Power Electronics Regulators (SUPER) library, the SSPS controller for the consumer end node and validate the use case • Develop characterization methods and tools to evaluate reliability, transient stability, and economics of large-scale DC architectures in AC grids	• Increased efforts to develop the Smart Universal Power Electronics Regulators (SUPER) library, and characterization methods and tools for large-scale DC architectures
Component Design and Development $6,670,000	*$14,500,000*	*+$7,830,000*
• Continue applied research on converter components • Establish a consortium of diverse stakeholders around the SSPS vision to help guide technology development and maturation	• Develop reliable medium voltage power stages with advanced features for SSPS • Develop advanced medium voltage to high voltage semiconductor modules • Develop advanced gate driver technologies to support advanced semiconductor switches • Develop high voltage auxiliary power supply stages • Develop subsystems to support EMI mitigation and thermal limitations • Develop advanced features for diagnostics and prognostics of future grid interfaces • Test and validate Grid Enhancing Technologies (GETs) by conducting a full scale, multi-faceted field exercise	• Increased development of critical power conversion and control technologies, including medium voltage power stages with advanced features for SSPS, advanced medium voltage to high voltage semiconductor modules, advanced gate driver technologies, high voltage auxiliary power supply stages, subsystems to support EMI mitigation and thermal limitations, and advanced features for diagnostics and prognostics of future grid interfaces • New field testing and validation of GETs

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Applied Material R&D $310,000	*$3,000,000*	*+$2,690,000*
• Applied materials research with an emphasis on packaging and embedded intelligence	• Develop magnetics and passives to advance basic insulation level (BIL) and high frequency requirements for power electronic systems and future grid infrastructure • Develop high voltage and high current interconnects to support the integration of subsystems for large scale power electronic systems • Research to address critical needs in packaging for the high voltage, high current, and high temperature environments associated power electronic systems, transmission, distribution • Address insulation issues associated with transmission, sub-transmission, and distribution voltage grid systems • Fund a prize program to demonstrate Power Electronic Systems (PES) developed using recycled/refurbished parts	• Increased efforts to develop advanced materials, embedded intelligence for equipment monitoring, validation of prototype converter building blocks, and medium voltage converter building block development

Applied Grid Transformation Solutions

Overview

A dramatic transformation of the electric power sector is needed to reach 100% carbon pollution-free electricity by 2035 and net-zero emissions by 2050.[a] This change must take the existing complexity of the system into account through solutions that crosscut nationally across technological innovations, regulatory layers, and a safety- and reliability-focused industry that requires high confidence to consider new solutions. Technologies such as energy storage, electricity delivery hardware, power electronics, grid modeling software, and protection systems each have the potential to provide value to the system when considered in isolation. However, to achieve the drastic system transformation that customers and evolving threats will require to keep the grid reliable and clean, these systems must be developed for integrability, validated, and rapidly incorporated into an increasingly complex existing system in order to meet this evolving need.

The Applied Grid Transformation Solutions (AGTS) program will address the pressing need for rapidly validating and deploying new systems by integrating technology suites in pilot environments to drive new technology adoption. Applied, integrated pilots are needed to validate how new technologies for transmission and distribution will achieve community, state, and national objectives. Today, the benefits of new grid technologies are difficult to extrapolate when tested in isolation, and difficult to quantify when measuring some benefits like resilience or equity. Risk-averse utilities need the ability to quantify and validate benefits before deploying new technologies.

AGTS will integrate technology suites in pilot environments to complete specialized development and broadcast benefits across stakeholders to accelerate adoption. AGTS will optimize technology portfolio operations, reduce technical risk in deployment, directly connect performance results to stakeholder use cases, and build on previous Grid Modernization Laboratory Consortium (GMLC) device and integrated system projects.

AGTS results will enable decisionmakers to drive new technology adoption. The hardware-in-the-loop results will connect to the needs of decisionmakers such as planners, operators, manufacturers, investors, regulators, and ratepayers. After demonstration, AGTS will encapsulate results to enable decisionmakers to evaluate new T&D approaches alongside legacy solutions. The results can also help technology vendors address emerging market opportunities.

Through integrated pilots, AGTS will enable the availability a validated suite of technology solutions to planners and decision-makers. By working with stakeholders to understand the needs and rapidly evolving demands of the grid, and showing how integrated pilot technologies meet that evolution, the power sector will be better positioned to meet the aggressive goals, address the customer demands, and protect against extreme conditions of the future system.

Highlights of the FY 2023 Budget Request

AGTS is a new program in FY 2023 that will initiate 2–3 integrated pilots to show how new technologies can help achieve stakeholder objectives. For each applied demonstration area, AGTS will consult stakeholders ensure that the project scope and outputs will be immediately useful to targeted decisionmakers. AGTS will identify the most suitable test bed to conduct the demonstration, and then select a suite of technologies that can be used to achieve the desired functionality. These technologies could include:

- High voltage direct current (HVDC)
- Modular large power transformers (LPTs)
- Dynamic line rating and dynamic transformer rating
- Power flow controllers (PFCs)
- Sensors and visibility
- Topology control algorithms
- Energy storage
- Power electronics

These technologies will be integrated onto the test bed and operated to validate the operational capabilities of the new technologies. AGTS will connect hardware-in-the-loop demonstration results to the informational needs of decisionmakers

[a] https://www.whitehouse.gov/briefing-room/presidential-actions/2021/01/27/executive-order-on-tackling-the-climate-crisis-at-home-and-abroad/

(planners, operators, manufacturers, investors, regulators, ratepayers) and explore benefits such as cost, ratepayer impact, emissions, access, and enhanced reliability. Coordinating with stakeholders to quantify and disseminate the measured benefits is essential to a successful demonstration, as is understanding the alignment of benefits and incentives as it relates to these new technologies. At the conclusion of the project, decisionmakers should have sufficient information to evaluate new T&D approaches alongside legacy solutions. Project results can also inform manufacturers of these new technologies in addressing new or emerging market opportunities.

In 2023, AGTS will:

- Scope and solicit an initial cohort of potential projects, potentially through a phased down-select process.
- Develop test beds and initiate 2–3 pilots to validate operational capabilities of advanced grid technologies.
- Conduct stakeholder-focused Grid Transformation Summits to show how new technologies enable community, state, and regional goals.
- Provide technical assistance through modeling, analysis, and use case validation by leveraging existing AGR&D and GMI tools and utilizing pilot projects to test stakeholder-focused hardware-in-the-loop use cases.

AGTS will include coordination with the GMLC on shared technology development objectives.

Applied Grid Transformation Solutions
Funding ($K)

	FY 2021 Enacted	FY 2022 Enacted Annualized CR[a]	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
Applied Grid Transformation Solutions					
Scoping, Design, and Stakeholder Collaboration	0	–	10,000	+10,000	N/A
Demonstrations	0	–	20,000	+20,000	N/A
Total, AGTS	**0**	**0**	**30,000**	**+30,000**	**N/A**

SBIR/STTR:

- FY 2021 Enacted: SBIR/STTR: $0
- FY 2023 Request: SBIR/STTR: $73

Applied Grid Transformation Solutions
Explanation of Major Changes ($K)

	FY 2023 Request vs FY 2021 Enacted
• Scoping, Design, and Stakeholder Collaboration: Conduct stakeholder-focused Grid Transformation Summits and provide technical assistance through modeling, analysis, and validation by leveraging existing OE R&D and GMI tools, and utilizing pilot projects to test stakeholder-focused hardware-in-the-loop use cases	+10,000
• Demonstrations: Develop test beds; solicit and initiate 2–3 pilots to validate operational capabilities of advanced grid technologies.	+20,000
Total, AGTS	**+30,000**

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

Applied Grid Transformation Solutions

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Applied Grid Transformation Solutions $0	**$30,000,000**	**+$30,000,000**
Scoping, Design, and Stakeholder Collaboration $0	*$10,000,000*	*+$10,000,000*
	• Conduct stakeholder-focused Grid Transformation Summits • Technical assistance through modeling, analysis, and use case validation	• This is a new activity in FY 2023
Demonstrations $0	*$20,000,000*	*+$20,000,000*
	• Develop test beds • Initiate 2–3 demonstrations	• This is a new activity in FY 2023

Defense Critical Electric Infrastructure Energy Mission Assurance

Overview

The Defense Critical Electric Infrastructure (DCEI) Energy Mission Assurance program was established in FY 2021 to identify, evaluate, prioritize, and assist in developing executable strategies to ensure that critical national defense and security missions have reliable access to power as energy supply disruptions threaten the civilian grid due to intensifying cybersecurity threats and other hazards. This effort directly supports Secretary of Energy's authority to designate Critical Defense Facilities (CDFs) and identify their associated DCEI under Sec. 215A of the Federal Power Act (FPA) as amended by the Fixing America's Surface Transportation (FAST) Act in 2015. This effort complements additional DOE authorities including emergency grid orders under Sec. 202(c) of the FPA, the protection of critical infrastructure in the energy sector under Presidential Policy Directive 21, improving critical infrastructure cybersecurity under Executive Order 13636, strengthening the cybersecurity of Federal networks and critical infrastructure under Executive Order 13800, and other Departmental authorities and capabilities.

In FY 2022, DOE proposed a realignment of activities, and as part of that realignment, the functions of the DCEI Energy Mission Assurance program were moved to the Office of Cybersecurity, Energy Security, and Emergency Response (CESER) to be integrated with CESER's suite of activities partnering with, supporting, and sharing information with the electric utility industry to enhance energy resilience through its energy assurance planning efforts.

Highlights of the FY 2023 Budget Request

No funding is requested in OE in FY 2023 for DCEI Energy Mission Assurance.

DCEI Energy Mission Assurance
Funding ($K)

	FY 2021 Enacted	FY 2022 Enacted Annualized CR[a]	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
DCEI Energy Mission Assurance	**1,000**	**1,000**	**0**	**-1,000**	**-100.0%**

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

	FY 2023 Request vs FY 2021 Enacted
• Responsibility for the activities formerly funded in the DCEI Energy Mission Assurance program has been transferred to CESER	-1,000

DCEI Energy Mission Assurance

Activities and Explanation of Changes

FY 2021 Enacted	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
DCEI Energy Mission Assurance $1,000,000	**$0**	**-$1,000,000**
• Develop electric power resiliency requirements and metrics for essential critical infrastructure nodes • Develop electric power resiliency strategies and evaluation methodologies for Critical Defense Facilities • Identify and select at least one site for execution of a suite of site-specific strategies	• Responsibility for the activities formerly funded in the DCEI Energy Mission Assurance program has been transferred to CESER	• No funding is requested in OE in FY 2023 for DCEI Energy Mission Assurance

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

Program Direction

Overview

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

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

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

Support Services includes contractor support directed by the Federal staff to perform administrative tasks and provide analyses to management. These efforts include issue-oriented support on science, engineering, environment, and economics that benefit strategic planning; technology and market analysis to improve strategic and annual goals; development of management tools and analyses to improve overall office efficiency; assistance with communications and outreach to enhance OE's external communication and responsiveness to public needs; development of program-specific information tools that consolidate corporate knowledge, performance tracking and inventory data, improve accessibility to this information, and facilitate its use by the entire staff.

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

Highlights of the FY 2023 Budget Request

The FY 2023 Program Direction Request reflects a small increase in the Headquarters staffing pay due to planned staffing levels that support OE's proposed growing portfolio of activities in OE's programs. The increases also address within grade promotions and step increases in some program areas. With the heightened attention and priority of OE's mission to accelerate the transformation of our Nation's power grid, proper staffing levels are crucial to expeditiously meet our goals and objectives. This Request allows for staffing that the programs to address skill gaps and succession planning.

Program Direction
Funding ($K)

	FY 2021 Enacted	FY 2021 Enacted (Comparable)[a]	FY 2022 Enacted Annualized CR[b]	FY 2022 CR (Comparable)[ab]	FY 2023 Request	FY 2023 Request vs FY 2021 Comp. ($)	FY 2023 Request vs FY 2021 Comp. (%)
Program Direction Summary							
Washington Headquarters							
Salaries and Benefits	9,873	7,913	–	–	10,182	+2,269	+28.7%
Travel	300	250	–	–	310	+60	+24.0%
Support Services	1,440	1,077	–	–	1,098	+21	+1.9%
Other Related Expenses	2,965	2,668	–	–	2,861	+193	+7.2%
Total, Washington Headquarters	**14,578**	**11,908**	–	–	**14,451**	**+2,543**	**+21.4%**
National Energy Technology Laboratory							
Salaries and Benefits	1,700	1,468	–	–	1,511	+43	+2.9%
Travel	130	100	–	–	45	-55	-55%
Support Services	371	320	–	–	324	+4	+1.3%
Other Related Expenses	1,221	1,204	–	–	1,255	+51	+4.2%
Total, National Energy Technology Laboratory	**3,422**	**3,092**	–	–	**3,135**	**+43**	**+1.4%**
Total Program Direction							
Salaries and Benefits	11,573	9,381	–	–	11,693	+2,312	+24.6%
Travel	430	350	–	–	355	+5	+1.4%
Support Services	1,811	1,397	–	–	1,422	+25	+1.8%
Other Related Expenses	4,186	3,872	–	–	4,116	+244	+6.3%
Total, Program Direction	**18,000**	**15,000**	**18,000**	**15,000**	**17,586**	**+2,586**	**+17.2%**

[a] The FY 2023 Budget Request to Congress proposes to split the Electricity appropriation account into two accounts: Electricity and Grid Deployment Office. To allow an apples-to-apples comparison with the FY 2023 Request, the comparable amounts for FY 2021 and FY 2022 exclude a portion of Program Direction funding equivalent to what would have been in the Grid Deployment Office had the proposed structure been in place in FY 2021 and FY 2022.

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

	FY 2021 Enacted	FY 2021 Enacted (Comparable)[a]	FY 2022 Enacted Annualized CR[b]	FY 2022 CR (Comparable)[ab]	FY 2023 Request	FY 2023 Request vs FY 2021 Comp. ($)	FY 2023 Request vs FY 2021 Comp. (%)
Federal FTEs	**63**	**56**	–	–	**63**	**+7**	**+12.5%**
Additional FE FTEs at NETL supporting OE[a]	11	10	–	–	10	0	0.0%
Total OE-funded FTEs	74	66	–	–	73	+7	+10.6%
Support Services and Other Related Expenses							
Support Services							
Technical Support	964	744	–	–	757	+13	+1.7%
Management Support	847	653	–	–	665	+12	+1.8%
Total, Support Services	**1,811**	**1,397**	–	–	**1,422**	**+25**	**+1.8%**
Other Related Expenses							
Other Services	1,250	1,234	–	–	1,451	+217	+17.6%
EITS Desktop Services	392	330	–	–	593	+263	+79.7%
WCF	2,544	2,308	–	–	2,072	-236	-10.2%
Total, Other Related Expenses	**4,186**	**3,872**	–	–	**4,116**	**+244**	**+6.3%**

Program Direction

Activities and Explanation of Changes

FY 2021 Enacted (Comparable)	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
Program Direction $15,000,000	**$17,586,000**	**+$2,586,000**
Salaries and Benefits $9,381,000	*$11,693,000*	*+$2,312,000*
• Salaries and Benefits support 66 FTEs at HQ and NETL that provide executive management, programmatic oversight, and analysis for the effective implementation of the OE program	• Salaries and Benefits support 73 FTEs at HQ and NETL that provide executive management, programmatic oversight, and analysis for the effective implementation of the OE program	• Supports 7 additional FTEs and the 2023 Federal pay increase

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

FY 2021 Enacted (Comparable)	FY 2023 Request	Explanation of Changes FY 2023 Request vs FY 2021 Enacted
• An additional 4 OE FTEs at HQ are reimbursed by FEMA through an interagency agreement for place-based long-term recovery and power system resilience planning	• An additional 4 OE FTEs at HQ are reimbursed by FEMA through an interagency agreement for place-based long-term recovery and power system resilience planning	
Travel $350,000	*$355,000*	*+$5,000*
• Travel includes transportation, subsistence, and incidental expenses that allow OE to effectively facilitate its mission	• Travel includes transportation, subsistence, and incidental expenses that allow OE to effectively facilitate its mission	• Increase due to the rising cost of air fares, baggage fees, and per diem
Support Services $1,397,000	*$1,422,000*	*+$25,000*
• Support Services includes contractor support directed by the Federal staff to perform administrative tasks and provide analysis to management. Support Services may include support for post-doctoral fellows and IPA assignments	• Support Services includes contractor support directed by the Federal staff to perform administrative tasks and provide analysis to management. Support Services may include support for post-doctoral fellows and IPA assignments	• Increase in support services to support NAERM, Cyber R&D, and increasing IT Governance requirements
Other Related Expenses $3,872,000	*$4,116,000*	*+$244,000*
Other Related Expenses includes EITS desktop services and WCF expense, such as rent, supplies, copying, graphics, mail, printing, and telephones. It also includes equipment upgrades and replacements, commercial credit card purchases using the simplified acquisition procedures to the maximum extent possible, security clearance expenses and other needs	• Other Related Expenses includes EITS desktop services and WCF expense, such as rent, supplies, copying, graphics, mail, printing, and telephones. It also includes equipment upgrades and replacements, commercial credit card purchases using the simplified acquisition procedures to the maximum extent possible, security clearance expenses and other needs	• Other Related Expenses increases due to additional IT equipment, cellular services, and other IT related expenses with offsetting WCF decreases for transit subsidies and supply store purchases

Electricity

Research and Development ($K)[a]

	FY 2021 Enacted	FY 2022 Enacted Annualized CR[b]	FY 2023 Request	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
Basic	14,146	–	15,185	+1,039	+7.3%
Applied	56,453	–	86,119	+29,666	+52.5%
Development	75,587	–	84,588	+9,001	+11.9%
Total, R&D	146,186	–	185,892	+39,706	+27.2%
R&D-related construction	25,137	–	0	-25,137	-100.0%
Total, R&D and related facilities	171,323	–	185,892	+14,569	+8.5%

Electricity

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

	FY 2021 Enacted Transfer	FY 2022 Annualized CR Projected Transfer	FY 2023 Request Projected Transfer	FY 2023 Request vs FY 2021 Enacted ($)	FY 2023 Request vs FY 2021 Enacted (%)
Transmission Reliability and Resilience	1,527	–	1,155	-372	-24.4%
Resilient Distribution Systems	1,265	–	1,315	+50	+4.0%
Cyber Resilient and Secure Utility Communication Networks	0	–	412	+412	N/A
Energy Storage	1,607	–	2,639	+1,032	+64.2%
Transformer Resilience and Advanced Components	247	–	557	+310	+125.5%
Applied Grid Transformation Solutions	0	–	73	+73	N/A
Total, SBIR/STTR	4,646	–	6,151	+1,505	+32.4%

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

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