## 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, **[**$350,000,000**]** *$297,475,000,* to remain available until expended: Provided, That of such amount, **[**$23,000,000**]** *$18,675,000* shall be available until September 30, **[**2024**]** *2025*, for program direction. *(Energy and Water Development and Related Agencies Appropriations Act, 2023)*

**[**For an additional amount for the "Electricity", $1,000,000,000, to remain available until expended, to carry out activities to improve the resilience of the Puerto Rican electric grid, including grants for low income households and households that include Individuals with disabilities for the purchase and installation of renewable energy, energy storage, and other grid technologies: Provided, That the Department of Energy shall coordinate with the Federal Emergency Management Agency and the Department of Housing and Urban Development on these activities.**]** *(Disaster Relief Supplemental Appropriations Act, 2023)*

### Explanation of Changes

The Energy and Water Development and Related Agencies Appropriation Act, 2023, appropriations for the Electricity account supports both the Office of Electricity and the Grid Deployment Office. Of the $350,000,000 appropriated in FY 2023 in the Electricity account, $285,293,000 supports the Office of Electricity and $64,707,000 supports the Grid Deployment Office. Within those amounts, of the $23,000,000 provided for program direction, $17,793,000 supports Office of Electricity program direction and $5,207,000 supports Grid Deployment Office program direction. The FY 2024 Request in the Electricity account supports only the Office of Electricity, with Grid Deployment Office activities requested under the Grid Deployment appropriations account.

The Disaster Relief Supplemental Appropriations Act, 2023, appropriations in the Electricity account were designated as an emergency requirement under Section 21104 of the Act and are one-time funding exclusively supporting Grid Deployment Office activities.

### 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"

**Electricity / Office of Electricity**
**($K)**

| FY 2022 Enacted | FY 2022 Enacted (Comparable)[a] | FY 2023 Enacted | FY 2023 Enacted (Comparable)[a] | FY 2024 Request |
|---|---|---|---|---|
| 277,000 | 266,000 | 350,000 | 285,293 | 297,475 |

**Overview**

The ability to move abundant clean electricity from where it is produced to where and when it is needed is the cornerstone of a reliable electric grid. The electricity delivery system must be capable of supporting all types of generation resources and loads, and ensure reliable, resilient grid operations under all conditions. The Office of Electricity (OE) leads the Department's efforts in developing new technologies to strengthen, transform, and improve electricity delivery infrastructure so new generation and loads can be fully integrated into the energy ecosystem and consumers have access to resilient, secure, and clean sources of electricity. OE provides solutions to technical, market, institutional, and operational challenges that go beyond any one utility's ability to solve.[b] To accomplish this critical mission, OE engages stakeholders throughout the sector on a variety of innovative technology solutions to modernize the electric grid.

A dramatic structural transformation of the electricity delivery system is underway to ensure that reliability is maintained during the rapid integration of renewable generation and customer-based technologies, including distributed generation and the electrification of transportation and building infrastructures. America's grid is transforming into a more dynamic and structurally complex system, with bidirectional power flows. Managing this transition will require significant reengineering and 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 for American workers, as well as to ensure benefits accrue to marginalized and overburdened communities while addressing four critical challenges:

- Increasing threats and risks to the reliability and 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 that 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 improve and enhance the following key characteristics of the U.S. electric transmission and distribution systems:

- Reliability—consistent and dependable delivery of high-quality power
- 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
- Flexibility—the ability to accommodate changing supply and demand patterns and new technologies
- Affordability—more optimal deployment of assets to meet system needs and minimize costs
- Efficiency—low energy losses in electricity delivery and more optimal use of system assets

[a] The FY 2024 Budget Request to Congress proposes to split the Electricity appropriation account into two accounts: Electricity and Grid Deployment. To allow an apples-to-apples comparison with FY 2024, the FY 2022 and FY 2023 comparable amounts for OE exclude funding for GDO activities, equivalent to what would have been in the Grid Deployment account had the proposed structure been in place since FY 2022. Detailed adjustments are shown below in the Comparability Matrices section.

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

- Energy Justice—achieving equity in both the social and economic participation in the energy system, while also considering and mitigating detrimental effects on disadvantaged and energy-burdened communities

Within the Request, OE funds:

- Research, Development and Demonstration (RD&D)—pursuing and executing R&D programs and pilot demonstrations for technologies that improve grid reliability, resilience, efficiency, flexibility, and functionality.
- Power Grid Modeling and Analytics—developing and validating core analytic, assessment, and engineering capabilities that characterize the reliability and performance of the electricity system. These analyses will explore complex interdependencies among infrastructure systems across a rapidly evolving operational/threat environment.
- Cyber Resilience—designing next-generation grid-communications systems that are built from inception through final implementation to automatically detect, reject, and withstand cyber incidents. These efforts will include designing, building, and executing hardware-in-the-loop testing and model-based systems analyses capable of identifying shortfalls in grid communications, technology development priorities, and mitigation strategies.
- Market Design and Distribution Planning—conducting research on electricity market designs and distribution planning processes, particularly at state and community levels, that increase the reliability, social equity, and efficiency related to the electricity delivery system.

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

- Grid Flexibility through Megawatt-Scale Grid Storage—pursuing megawatt-scale storage capability(s) that support voltage and frequency regulation, ramping, and energy management for bulk and distribution power systems.
- Improving Observability and Deep Learning via Sensing Technology Utilization—driving integration of high-fidelity sensing technology (and associated data analytics) to support the integration of distributed energy resources (DERs) and reliable operations under normal and extreme conditions.
- Driving Modeling Advancements to Elucidate Uncertainty—leading research to better understand the structural, operational, and contextual issues affecting the current and future electric grid, and to enable development of robust toolsets for operators and planners to assess emerging risks to reliability and system performance.
- Building in Cybersecurity—accelerating and expanding cybersecurity and resilient communications for electricity infrastructure and mitigating vulnerabilities.
- Expanding Functionality of Grid Components—accelerating development and use of advanced grid technologies and national technology testing facilities to demonstrate technologies in a controlled environment supporting the adoption of modular designs and standards to facilitate manufacturing supply chain and rapid replacement.
- Integrated Grid Planning to Ensure Coherence—formulating coherent grid strategies and pathways that apply advanced technologies for meeting reliability, resilience, decarbonization, efficiency, equity, and flexibility objectives through the advancement of integrated planning practices in concert with states and the electric industry.

OE's Budget Request will extend the impact of our RD&D funding by leveraging creative funding mechanisms—such as prizes, competitions, and coordination, collaboration, and partnerships with other DOE programs and Federal agencies—to maximize scope and reach. The objective is to enable the commercialization of clean energy innovations that 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 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. The GMI portfolio features multiple Grid Modernization Lab Calls to ensure comprehensive grid research efforts across 14 national laboratories that are coordinated through the Grid Modernization Laboratory Consortium (GMLC).[a]

**Highlights and Major Changes in the FY 2024 Budget Request**

**Transmission Reliability and Resilience (TRR)** ($42,500,000; +$10,913,000) is focused on ensuring the reliability and resilience of the U.S. electric grid through R&D on system observability and control capabilities. TRR also develops and validates models to characterize evolving system needs, identifies pathways to achieve an equitable transition to decarbonization and electrification, addresses ongoing industry challenges related to relay misoperations and identification and isolation of faults, and mitigates risks across integrated energy systems through data fusion and tool development. The Request supports modernizing transmission system tools through human factor and cognitive science research for system operations, increasing net power flowing through transmission lines, developing analytical methods to manage uncertainties of bulk power system grid reliability impacts associated with increased deployment of renewables, developing new models and tools to help the electric industry understand and maintain reliability as supply and load change to meet the decarbonization and electrification targets, and increasing the level of understanding and industry awareness related to energy justice.

**Energy Delivery Grid Operations Technology (EDGOT)** ($30,000,000; -$614,000) 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), 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 will provide for enhanced planning and analysis capabilities that can be leveraged to facilitate grid investments to address these threats. The Request focuses on developing and enhancing the portfolio of tools that are needed to address grid reliability in a system with pervasive and evolving threats and challenges. NAERM will improve capability limitations and transition the underlying capabilities to a robust, secure operational state that prioritizes “what if” scenarios affecting reliability, which is essential for maintaining OE’s ability to identify and advance solutions for America’s grid.

**Resilient Distribution Systems (RDS)** ($47,300,000; -$6,248,000) develops transformative technologies, tools, and techniques that enable industry to keep pace with emerging and evolving conditions that necessitate modernization of the distribution network to ensure continued reliability and resilience. RDS pursues strategic investments in innovative technologies and practices that improve reliability, increase resilience, support vehicle electrification, integrate clean DERs, and provide consumers with more choices for managing their energy consumption. The Request expands microgrid building block development to advance virtual prototype design performance and sector coupling analysis to look at structural and architectural aspects as well as control and coordination approaches addressing vehicle–grid integration issues.

**Cyber Resilient and Secure Utility Communications Networks (SecureNet)** ($15,000,000; +$409,000) develops solutions to strengthen the security and resilience of the electricity delivery system against cyber-related threats to operational data, communications networks, and control systems. Our Nation’s energy system is heavily dependent on data communications and cyber-physical controls for operational reliability and resilience. More integration of distributed assets on the grid increases this dependency and presents a broader attack surface for increasingly sophisticated adversaries to exploit. Funding this R&D effort to design security into the future grid is essential to extend the Department’s focus beyond today’s challenges and ensure the efficient, reliable, and resilient operation of the electric power system in tomorrow’s even more complex and dynamic risk landscape. The Request’s core focus supports research on secure and resilient utility communications networks, including the development of an architectural framework for communications infrastructure, an associated technology roadmap for communications infrastructure that meets utility systems’ functional and performance requirements, and key technologies such as synchronization, timing, and blockchain. The Request also supports modeling cyber aspects of future grid scenarios, researching cyber-hardening new grid technologies, and providing cyber design inputs, testing capabilities, and cyber vulnerability assessments to other OE programs.

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

**Energy Storage** ($78,600,000; -$10,365,000) accelerates bi-directional electrical energy storage technologies as a key component of a reliable, resilient, and affordable future-ready grid. OE Storage research, development, demonstration, and deployment efforts accelerate the development of long duration grid storage technologies through increasing amounts of stored energy and operational durations, reducing technology costs, de-risking technologies to ensure safe long-term reliability, developing analytic models to uncover technical and economic benefits, and demonstrating how storage can provide clean and equitable energy access for consumers and communities. The Request launches a new cohort for the Energy Storage for Social Equity Technical Assistance and Pilot Program, supporting an additional 5–10 communities in the technical assistance phase with 2–4 of those communities continuing to the pilot demonstration phase, and expands the Rapid Operational Validation Initiative to improve the performance projection methodologies of 2–3 new non-lithium electrochemistries. To respond to the rapidly growing number of energy storage installations, the Request also expands outreach to key deployment stakeholders, including fire safety, codes and standards, and other groups.

**Transformer Resilience and Advanced Components (TRAC)** ($21,700,000; -$4,915,000) develops innovations to carry, control, convert, and condition electricity, equipping the future-ready grid to achieve decarbonization goals while enhancing its reliability and resilience. The TRAC scope encompasses materials research, exploratory concepts, 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. The Request accelerates addressing high voltage direct current (HVDC) hardware technical challenges to perform a field validation of the Smart Universal Power Electronics Regulators device and expands the development of modular and scalable transformers.

**Applied Grid Transformation Solutions (AGTS)** ($29,700,000; +$19,827,000) addresses the pressing need for rapidly assessing new grid systems and subsystems (including energy storage, transmission, distribution, and power control and conversion hardware and associated software) by testing integrated technology suites in pilot environments prior to the hardware and software being deployed by industry in operational environments. These assessments provide utilities with the information they need to quantify and validate functionality, performance, and economic benefits before deploying new technologies. The results of pilot demonstrations will validate the techno-socio-economic performance of the systems and accelerate the adoption of new technology by the industry. The Request supports at least two new pilots to validate technological maturity and show how new technologies achieve desired environmental, societal, policy, and market outcomes and will be targeted to provide regional diversity.

**Electricity Innovation and Transition (EIT)** ($14,000,000; +$2,293,000) is a new program in FY 2024 consolidating all OE funding for Small Business Innovation Research (SBIR), Technology Commercialization Fund (TCF), and workforce development activities. The reorganization of these efforts provides a more flexible, streamlined, and transparent approach for OE to support innovators, small businesses, and researchers moving grid technologies forward.

**FY 2022 Key Accomplishments**

**Flexible Transformer Validation:** OE, GE, and Cooperative Energy have completed field validation of the world's first flexible transformer that adapts to a range of voltage ratios and impedance levels. Results include over 99.5% efficiency with size and weight within 120% of comparable conventional large power transformers (LPTs). Flexible transformers have enhanced capabilities, reduce the need for custom-designed transformers, and will lead to significantly reduced manufacturing costs and timeframes relative to 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.

- **Cost Competitive and Long Duration Storage technologies:**
  - Achieved OE's FY 2022 Energy Storage milestone to demonstrate an enhanced novel aqueous soluble organic flow battery with a projected system cost of less than $175 per kWh for a projected 1MW/4MWh system.
  - Developed new materials and processes to advance sodium-based technologies—from novel sodium conducting membranes to sodium-based flow battery catholytes.
  - Developed novel freeze-thaw technology enabling batteries to potentially operate as seasonal storage assets.
  - Received R&D 100 award for developing the world's first iron nitride soft magnetic cores for power converters.
- **Learning to Adapt and Control for Complex Power Systems (LACC):** A framework for controlling utility-scale renewable assets was developed under this OE-supported project to adaptively ride through system disturbances and increase the security and reliability of modern power grids. Compared to traditional controllers, LACC is faster, more reliable, and

less expensive, while reducing impacts of current introduced by outages during a severe fault by more than 40%. Ultimately, the LACC controller will allow more renewable resources to connect to the grid.

- **Chronological AC Power Flow Automated Generation (C-PAGE):** The C-PAGE tool advances renewable integration efficiency by automatically creating realistic, reliable, and economic planning models for long-term planning studies of renewable integrations and reducing the model preparation time from months to minutes. This OE-supported tool has been recognized by industry, was used by Western Electric Coordinating Council to develop 2032 renewable planning base cases, and has been selected by the Power Company of New Mexico to support transmission planning studies.
- **Validated resilient operations of networked microgrids software capabilities:** The resilience benefit from the software solution for networking microgrids was clearly quantified during a simulated outage event on a distribution utility feeder circuit serving a remote community, which showed that close to two-thirds of the load can be supported. This is a significant increase, as only about 22% of the load could be supported with the same microgrids operating in isolation. The software has been deployed on an industry-sponsored platform to transition its use by utilities in rapid recovery during extreme weather events.
- **Holistic platform to plan for and manage behind-the-meter DERs to support grid services:** A platform for distribution utilities demonstration of aggregated DER use cases for peak load reduction, load shaping, distribution network management, and ancillary services showed the platform can provide utilities with a visibility and management tool for DERs to relieve congestion while also delivering grid services to markets. This promising platform was acquired by a commercial entity, anticipating that a greater industry impact will result.
- **Grid Deployments and Field Validations:**
  - OE-supported staff co-led IEEE 1547.9, the first standard for grid interconnection of energy storage systems.
  - Published the first comprehensive review paper on cyber-physical security of energy storage systems.[a]
  - Commissioned a microgrid with new zinc-manganese dioxide batteries in the Navajo Nation (in collaboration with the Navajo Tribal Utility Authority).
  - Developed a dispatchable working prototype of a power electronic system to support multiple secondary use energy storage technologies.
- **U.S.-India Collaborative for Smart Distribution System with Storage (UI-ASSIST):** OE is supporting Washington State University and their 15 U.S. university and industry partners in a joint research project with India to advance the development of the electric distribution systems in both the United States and India. UI-ASSIST focuses on providing affordable, clean energy while maintaining grid reliability and resiliency, and is promoting grid innovations that will promote economic growth and energy security in both countries.
- **Advanced Conductors SBIR Projects:** OE and the Advanced Manufacturing Office co-funded several SBIR projects under the Conductivity-enhanced materials for Affordable Breakthrough Leapfrog Electric and thermal applications initiative. Two OE-led projects under the Electricity Delivery System SBIR subtopic were successfully completed: QuesTek Innovations, developing advanced aluminum conductors for overhead transmission applications, and Mainstream Engineering, developing advanced copper conductors for underground and undersea applications.
- **SBIR Phase III Wildfire Mitigation:** In May 2022, OE awarded a Phase III SBIR cooperative agreement to Brains4Drones (Plano, TX) to apply their AI technology on drones to mitigate against wildfires. The Brains4Drones project focused on adapting drone-based solutions to mitigate fire risks at distribution lines in hard-to-access terrain by performing powerlines, equipment, and vegetation inspections. Brains4Drones developed AI algorithms, integrated the necessary sensors for defect detection and developed prototypes that specifically gathered and curated real-time information on potential hazards. The technology was adapted to utility needs and was field demonstrated in September 2022 by Consumers Power, an electric cooperative utility in Oregon.

[a] https://ieeexplore.ieee.org/document/9787060

**Electricity**
**Funding by Congressional Control ($K)**

| | FY 2022 Enacted | FY 2022 Enacted (Comparable)[a] | FY 2023 Enacted | FY 2023 Enacted (Comparable)[a] | FY 2024 Request | FY 2024 vs FY 2023 Enacted (Comp) ($) | FY 2024 vs FY 2023 Enacted (Comp) (%) |
|---|---|---|---|---|---|---|---|
| Grid Controls and Communications | | | | | | | |
| Transmission Reliability and Resilience | 26,000 | 24,941 | 34,000 | 31,587 | 42,500 | +10,913 | +34.5% |
| Energy Delivery Grid Operations Technology | 23,000 | 12,791 | 31,000 | 30,614 | 30,000 | -614 | -2.0% |
| Resilient Distribution Systems | 55,000 | 53,500 | 55,000 | 53,548 | 47,300 | -6,248 | -11.7% |
| Cyber Resilient and Secure Utility Communications Networks (SecureNet) | 11,150 | 20,372 | 15,000 | 14,591 | 15,000 | +409 | +2.8% |
| Total, Grid Controls and Communications | 115,150 | 111,604 | 135,000 | 130,340 | 134,800 | +4,460 | +3.4% |
| Grid Hardware, Components, and Systems | | | | | | | |
| Energy Storage | | | | | | | |
| Research | 73,000 | 70,684 | 95,000 | 88,965 | 78,600 | -10,365 | -11.7% |
| Construction: 20-OE-100 Grid Storage Launchpad | 47,000 | 47,000 | 0 | 0 | 0 | 0 | N/A |
| Total, Energy Storage | 120,000 | 117,684 | 95,000 | 88,965 | 78,600 | -10,365 | -11.7% |
| Transformer Resilience and Advanced Components | 11,000 | 10,636 | 27,500 | 26,615 | 21,700 | -4,915 | -18.5% |
| Applied Grid Transformation Solutions | 0 | 0 | 10,000 | 9,873 | 29,700 | +19,827 | +200.8% |
| Total, Grid Hardware, Components, and Systems | 131,000 | 128,320 | 132,500 | 125,453 | 130,000 | +4,547 | +3.6% |
| Electricity Innovation and Transition | 0 | 6,226 | 0 | 11,707 | 14,000 | +2,293 | +19.6% |
| Transmission Permitting and Technical Assistance (TPTA) | 8,000 | 0 | 0 | 0 | 0 | 0 | N/A |
| Grid Deployment Office (GDO) | 0 | 0 | 59,500 | 0 | 0 | 0 | N/A |
| Congressionally Directed Spending | 2,850 | 2,850 | 0 | 0 | 0 | 0 | N/A |
| Program Direction (PD) | 20,000 | 17,000 | 23,000 | 17,793 | 18,675 | +882 | +5.0% |
| **Total, Electricity** | **277,000** | **266,000** | **350,000** | **285,293** | **297,475** | **+12,182** | **+4.3%** |
| | | | | | | | |
| **Federal Full Time Equivalent Employees (FTEs)** | **70** | **63** | **82** | **63** | **64** | **+1** | **+1.6%** |
| Additional FECM FTEs at NETL supporting OE[b] | 12 | 11 | 13 | 10 | 10 | 0 | 0.0% |
| Total OE-funded FTEs | 82 | 74 | 95 | 73 | 74 | +1 | +1.4% |

SBIR/STTR:
FY 2022 Enacted: SBIR: $4,581
FY 2023 Request: SBIR: $5,589
FY 2024 Request: SBIR: $6,407

---

[a] The FY 2024 Request proposes to split the Electricity appropriation account into two accounts: Electricity and Grid Deployment. To allow an apples-to-apples comparison with FY 2024, the comparable amounts for Electricity in FY 2022 and FY 2023 exclude all funding for GDO activities that would have been in the Grid Deployment account under the proposed structure. Within OE, the Request proposes to consolidate all SBIR, TCF, and workforce development activities under EIT. The FY 2023 enacted appropriation moved DarkNet funding within OE from EDGOT to SecureNet. FY 2022 and FY 2023 are also shown as if these changes had been in place since FY 2022. Detailed adjustments are shown below in the Comparability Matrices section.

[b] OE funds FTEs at the Office of Fossil Energy and Carbon Management's (FECM's) National Energy Technology Laboratory that are FECM employees, but support OE activities. The FTEs are included in FECM's FTE totals and not in the OE FTE totals shown on the "Federal Full Time Equivalent Employees (FTEs)" line.

**Comparability Matrices**

The FY 2024 Request proposes to split the Electricity appropriation account into two accounts: Electricity and GDO. The Request also proposes an internal shift within OE to consolidate all funding for SBIR, TCF, and workforce development activities into a new Electricity Innovation and Transition (EIT) program. The FY 2023 appropriation also moved Darknet funding from Energy Delivery Grid Operations Technology to SecureNet.

The tables below show the how funding would move between the original budget structure (the table rows) and the proposed budget structure (the table columns) in FY 2022 and FY 2023 if the proposed FY 2024 budget structure had been in place since FY 2022. More detailed comparability matrices are shown after each program budget narrative.

FY 2022 Enacted Appropriation Comparability Matrix

| | **Proposed Budget Structure ($K)** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | OE | | | | | | GDO | Total |
| | EDGOT | SecureNet | EIT | PD | Other OE | Total | | |
| **Original Budget Structure** | | | | | | | | |
| TRR | 0 | 0 | 1,059 | 0 | 24,941 | 26,000 | 0 | 26,000 |
| EDGOT | 12,791 | 9,672 | 537 | 0 | 0 | 23,000 | 0 | 23,000 |
| RDS | 0 | 0 | 1,500 | 0 | 53,500 | 55,000 | 0 | 55,000 |
| SecureNet | 0 | 10,700 | 450 | 0 | 0 | 11,150 | 0 | 11,150 |
| Energy Storage | 0 | 0 | 2,316 | 0 | 117,684 | 120,000 | 0 | 120,000 |
| TRAC | 0 | 0 | 364 | 0 | 10,636 | 11,000 | 0 | 11,000 |
| TPTA | 0 | 0 | 0 | 0 | 0 | 0 | 8,000 | 8,000 |
| Congressionally Directed Spending | 0 | 0 | 0 | 0 | 2,850 | 2,850 | 0 | 2,850 |
| PD | 0 | 0 | 0 | 17,000 | 0 | 17,000 | 3,000 | 20,000 |
| **Total** | **12,971** | **20,372** | **6,226** | **17,000** | **209,611** | **266,000** | **11,000** | **277,000** |

FY 2023 Enacted Appropriation Comparability Matrix

| | **Proposed Budget Structure ($K)** | | | | | |
|---|---|---|---|---|---|---|
| | OE | | | | GDO | Total |
| | EIT | PD | Other OE | Total | | |
| **Original Budget Structure** | | | | | | |
| TRR | 2,413 | 0 | 31,587 | 34,000 | 0 | 34,000 |
| EDGOT | 386 | 0 | 30,614 | 31,000 | 0 | 31,000 |
| RDS | 1,452 | 0 | 53,548 | 55,000 | 0 | 55,000 |
| SecureNet | 409 | 0 | 14,591 | 15,000 | 0 | 15,000 |
| Energy Storage | 6,035 | 0 | 88,965 | 95,000 | 0 | 95,000 |
| TRAC | 885 | 0 | 26,615 | 27,500 | 0 | 27,500 |
| AGTS | 127 | 0 | 9,873 | 10,000 | 0 | 10,000 |
| GDO | 0 | 0 | 0 | 0 | 59,500 | 59,500 |
| Program Direction | 0 | 17,793 | 0 | 17,793 | 5,207 | 23,000 |
| **Total** | **11,707** | **17,793** | **255,793** | **285,293** | **64,707** | **350,000** |

**Future Years Energy Program**
**($k)**

| | FY 2024 | FY 2025 | FY 2026 | FY 2027 | FY 2028 |
|---|---|---|---|---|---|
| Electricity | 297,475 | 304,000 | 311,000 | 318,000 | 325,000 |

This future years energy program shows outyear funding for FY 2025–2028. Actual future budget request levels will be determined as part of the annual budget process.

OE priorities in the outyears include the following activities aimed at maintaining the reliability, resilience, security, and affordability of America's electricity delivery system:

- Developing data and analytical tools necessary to assess the reliability and performance of the electricity system
- Accelerating development of modular and flexible next-generation technologies, such as HVDC, solid state power substations (SSPS), and power electronics, to enable advanced grid capabilities and more fully unlock the value of storage and renewables
- Developing 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
- Architecting next-generation grid-communications systems that are built from inception to mitigate communication failures and automatically detect, reject, and withstand cyber incidents
- Conducting research on electricity market designs and distribution planning processes that increase the reliability, social equity, and efficiency of the electricity delivery system

## Transmission Reliability and Resilience

**Overview**

The Transmission Reliability and Resilience (TRR) program collaborates with the electric industry to research and develop system monitoring, data analytics, and control technologies that are critically needed to assess the reliability and performance of the electricity system, to mitigate large-scale blackouts and respond to natural disasters, and to adapt to evolving system needs and interdependencies. TRR focuses on:

- Ensuring the reliability and resilience of the U.S. electric grid through research and development (R&D) on system observability and control capabilities
- Developing and validating models to characterize evolving system needs and the emerging operational landscape, and identifying pathways for achieving an equitable transition towards decarbonization and electrification
- Addressing ongoing industry challenges related to relay misoperations and identification and isolation of faults
- Mitigating risks across integrated energy systems through data fusion and tool development

TRR brings together energy stakeholders from government, industry, and academia to generate ideas and develop solutions to address the Nation's energy infrastructure challenges, including both natural and man-made hazards.

Transmission Reliability and Renewable Integration (TRRI) develops transmission system operations tools and data analytics to inform decisions that maintain and improve system reliability while accelerating the integration of renewable energy. Data analytics and visualization advancements ensure utilities obtain full value from new and existing sensor capabilities 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 develops tools that help system operators understand and respond to reliability events like wildfires, heatwaves, and cold snaps, all while adapting to growth in clean power generation, decarbonization, distributed energy resources, and increased electrification. The program works to modernize 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 improve the speed, accuracy, and precision of power system state determinations 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 electricity sector capacity and capability 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. AGM leads research activities to better understand issues surrounding the current and future electric power grid and develop robust model-based solutions, resulting in new software and analytical toolsets for operators and planners. Successful research enables grid operators and planners to optimize 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 to quickly identify and isolate faults so the remaining system will continue to operate under normal conditions. This prevents or reduces equipment damage and potential injury to utility personnel and the public. Protective relaying is increasingly integrated with normal grid operations such as stabilizing voltage and frequency. The Protective Relaying subprogram addresses ongoing industry issues, such as relay misoperations, while advancing state-of-the-art technology related to bi-directional power flow, faster response times, and enhanced detection methods. The subprogram also develops 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 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, continues work to develop research datasets and data platforms that reduce utility burden from data requests and facilitate tool development with real data. This sets 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) further develops 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 2024 Budget Request**
The TRR program continuously investigates ways to make the present and future grid resilient, reliable, efficient, and secure. In FY 2024, TRR 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 robust decision making and training for system operators
- Advancing protective relaying methods to improve the functional integrity and effectiveness of corrective actions to prevent misoperations and mitigate power outages
- Continuing research on the impact of grid changes with a concentration on transmission planning to accommodate large renewable deployments to facilitate decarbonization
- Identifying and mitigating risk resulting from supply and demand changes and integration of large numbers of inverter-based resources (IBRs) across the integrated energy system
- Developing models and tools to help the electric industry understand and maintain reliability as the supply and load change to meet decarbonization and electrification targets
- Increasing collaboration between OE and other public and private entities
- Continuing the partnership with the National Science Foundation (NSF) on the Algorithms for Modern Power Systems (AMPS) program targeting university-based research to improve grid reliability, resilience, and security
- 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 plans to enable the operation of degraded or damaged electricity systems while sustaining critical functionality
- Advancing tools for transmission and distribution systems operations and control to rapidly mitigate reliability events and for developing training simulators for operators to improve reliability outcomes

Technology, tools, and applications developed under TRR will be evaluated for security risks including cybersecurity. Testing and evaluations will be conducted in coordination with OE's SecureNet program to ensure that security is built into these technologies and new security risks are not being introduced into the electric sector.

Support of R&D activities through the Grid Modernization Initiative, including 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 ERC, 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 2022 Enacted (comparable)[a] | FY 2023 Enacted (comparable)[a] | FY 2024 Request | FY 2024 Request vs FY 2023 Enacted ($) | FY 2024 Request vs FY 2023 Enacted (%) |
|---|---|---|---|---|---|
| **Transmission Reliability and Resilience** | | | | | |
| Transmission Reliability and Renewable Integration | 4,686 | 8,815 | 13,500 | +4,685 | +53.1% |
| Advanced Modeling Grid Research | 15,613 | 18,925 | 24,000 | +5,075 | +26.8% |
| Protective Relaying | 3,655 | 3,847 | 5,000 | +1,153 | +30.0% |
| Transmission Sensors | 987 | 0 | 0 | 0 | N/A |
| **Total, Transmission Reliability and Resilience** | **24,941** | **31,587** | **42,500** | **+10,913** | **+34.5%** |

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

| | FY 2024 Request vs FY 2023 Enacted |
|---|---|
| • **Transmission Reliability and Renewable Integration**: 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 | +4,685 |
| • **Advanced Modeling Grid Research**: Supports R&D to increase the net power flowing through transmission lines, develop analytical methods to manage the impact of uncertainty associated with increased renewable sources on the bulk power system to maintain the reliability of the grid, develop new models and tools that can help the electric industry understand and maintain reliability as supply and load change to meet decarbonization and electrification targets, and increase the level of understanding and industry awareness related to energy justice | +5,075 |
| • **Protective Relaying**: Supports understanding and better management of misoperations of relays while advancing state-of-the-art technology related to bi-directional power flow, faster response times, and enhanced detection methods | +1,153 |
| **Total, Transmission Reliability and Resilience** | **+10,913** |

[a] The FY 2024 Request proposes to consolidate all Small Business Innovation Research, Technology Commercialization Fund, and workforce development activities under the new Electricity Innovation and Transition (EIT) program. To allow an apples-to-apples comparison, FY 2022 and FY 2023 are shown as if this approach had been in place since FY 2022, moving $1,059,000 in FY 2022 and $2,413,000 in FY 2023 from TRR to EIT. Details of these adjustments are shown in the Comparability Matrix section below.

**Activities and Explanation of Changes**

| FY 2023 Enacted (comparable) | FY 2024 Request | Explanation of Changes<br>FY 2024 Request vs FY 2023 Enacted |
|---|---|---|
| **Transmission Reliability and Resilience $31,587,000** | **$42,500,000** | **+$10,913,000** |
| *Transmission Reliability and Renewable Integration $8,815,000* | *$13,500,000* | *+$4,685,000* |
| • Continue technical support for NASPI to conduct competitions, information sharing and joint problem solving among utilities, vendors, universities, and the Federal Government<br>• 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<br>• 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<br>• Develop transmission system data modernization of for wide area situational awareness, to prevent cascading power outages, through prizes, data set creation, and artificial intelligence (AI)/machine learning (ML) research<br>• 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 | • Advance the application of cognitive science and human factors to identify and develop tools needed for decision making and training. Use this to develop training simulators for operators to improve reliability outcomes<br>• Continue technical support for NASPI to conduct competitions, information sharing and joint problem solving among utilities, vendors, universities, and the Federal Government<br>• Support operating strategies, decision analysis, contingency analysis, and control approaches that recognize and incorporate the control capabilities offered by, and attributes of, wind and solar generation<br>• 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<br>• 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 | • Increase in work related to mitigation of pressing challenges to the power system, including heat waves, wildfires, and rapid decarbonization<br>• Additional industry engagement and tool demonstrations for system operators to fully utilize new energy resources while responding and preventing reliability events<br>• Increase development of operational strategies that increase transmission infrastructure utilization and reliability through advances in power flow and topology control strategies<br>• Increase industry demonstrations and research for new dashboards and decision processes for reliability events |

| FY 2023 Enacted (comparable) | FY 2024 Request | Explanation of Changes<br>FY 2024 Request vs FY 2023 Enacted |
|---|---|---|
| *Advanced Modeling Grid Research $18,925,000* | *$24,000,000* | *+$5,075,000* |
| • Continue mathematical and computational research to manage uncertainty, associated with data, modeling, and model validation<br>• 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<br>• Continue studying of the impact of grid changes with a limited concentration on transmission planning to accommodate deployment of limited level of renewables to facilitate decarbonization<br>• Increase the level of understanding and awareness in National Laboratories related to energy justice while exploring a limited level of mitigation through R&D<br>• Identify grid risk to accommodate increasing levels of renewables and explore a limited level of mitigation to facilitate decarbonization while ensuring grid reliability, resiliency, security, and efficiency | • Identify and mitigate risk from changes in supply and demand and integration of large number of IBRs across the integrated energy system<br>• Develop models and tools to help the electric industry understand and maintain reliability as the supply and load change to meet decarbonization and electrification targets<br>• Advance tools for transmission and distribution systems operations and control to rapidly mitigate reliability events<br>• Develop new models and tools that can help the electric industry understand and maintain reliability by managing the system as supply and load change to meet the decarbonization and electrification targets<br>• Continue mathematical and computational research to manage uncertainty, associated with data, modeling, and model validation<br>• 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<br>• Continue exploring alternative methods for transmission planning to increase the amount of energy delivered using existing rights of way<br>• 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 stakeholder engagement on IBRs to better understand issues and explore mitigating actions, as the integration of more renewables makes the system more complex where existing control strategies may not be adequate to ensure the reliability of the system<br>• Support R&D to understand the changes and develop mitigating actions to ensure the reliable operation of the grid |

| FY 2023 Enacted (comparable) | FY 2024 Request | Explanation of Changes<br>FY 2024 Request vs FY 2023 Enacted |
|---|---|---|
| | • Identify and mitigate grid risk to accommodate increasing levels of renewables to facilitate decarbonization while ensuring grid reliability, resiliency, security, and efficiency | |
| *Protective Relaying $3,847,000* | *$5,000,000* | *+$1,153,000* |
| • Develop mitigations that reduce misoperations at transmission levels<br>• Develop solutions to distinguish between momentary and permanent faults for reclosers at the distribution level at the test level<br>• Develop cybersecurity solutions for protective relaying at the transmission levels<br>• Continue research on adaptive relay settings that address bi-directional power flow<br>• Address best practices and toolsets that will support the protective relaying workforce in an evolving grid environment | • Develop solutions for a faster response time and enhanced detection method for relay operation<br>• Advance protective relaying methods to improve the functional integrity and effectiveness at preventing and mitigating power outages<br>• Develop mitigations that reduce misoperations at both transmission and distribution levels<br>• Develop solutions to distinguish between momentary and permanent faults for reclosers at the distribution level<br>• Develop cybersecurity solutions for protective relaying at both the transmission and distribution levels<br>• Continue research on adaptive relay settings that address bi-directional power flow<br>• Address best practices and toolsets that will support the protective relaying workforce in an evolving grid environment | • Continue advancing protective relaying to avoid cascading outages and system blackouts<br>• Expand the work done at the transmission level to the distribution system |

**Comparability Matrix**

The table below shows the Small Business Innovation Research (SBIR), Technology Commercialization Fund (TCF), and workforce development funding associated with TRR in FY 2022 and FY 2023 under both the prior budget structure, where these activities were funded within TRR, and the proposed budget structure, where these activities are consolidated across OE under the new Electricity Innovation and Transition (EIT) program.

| | FY 2024 Proposed Budget Structure ($K) | | | | | |
|---|---|---|---|---|---|---|
| | FY 2022 Enacted | | | FY 2023 Enacted | | |
| | TRR | EIT | Total | TRR | EIT | Total |
| **FY 2022 and FY 2023 Budget Structure** | | | | | | |
| Transmission Reliability & Resilience | | | | | | |
| Transmission Reliability & Renewable Integration | | | | | | |
| SBIR | 0 | 160 | 160 | 0 | 302 | 302 |
| TCF | 0 | 44 | 44 | 0 | 83 | 83 |
| Other TRRI | 4,686 | 0 | 4,686 | 8,815 | 0 | 8,815 |
| Total, TRRI | 4,686 | 204 | 4,890 | 8,815 | 385 | 9,200 |
| Advanced Modeling Grid Research | | | | | | |
| SBIR | 0 | 565 | 565 | 0 | 707 | 707 |
| TCF | 0 | 132 | 132 | 0 | 168 | 168 |
| Workforce Development | 0 | 0 | 0 | 0 | 1,000 | 1,000 |
| Other AMGR | 15,613 | 0 | 15,613 | 18,925 | 0 | 18,925 |
| Total, AMGR | 15,613 | 697 | 16,310 | 18,925 | 1,875 | 20,800 |
| Protective Relaying | | | | | | |
| SBIR | 0 | 111 | 111 | 0 | 117 | 117 |
| TCF | 0 | 34 | 34 | 0 | 36 | 36 |
| Other Protective Relaying | 3,655 | 0 | 3,655 | 3,847 | 0 | 3,847 |
| Total, Protective Relaying | 3,655 | 145 | 3,800 | 3,847 | 153 | 4,000 |
| Transmission Sensors | | | | | | |
| SBIR | 0 | 4 | 4 | 0 | 0 | 0 |
| TCF | 0 | 9 | 9 | 0 | 0 | 0 |
| Other Transmission Sensors | 987 | 0 | 987 | 0 | 0 | 0 |
| Total, Transmission Sensors | 987 | 13 | 1,000 | 0 | 0 | 0 |

| | FY 2024 Proposed Budget Structure ($K) | | | | | |
|---|---|---|---|---|---|---|
| | FY 2022 Enacted | | | FY 2023 Enacted | | |
| | TRR | EIT | Total | TRR | EIT | Total |
| Total, TRR | 24,941 | 1,059 | 26,000 | 31,587 | 2,413 | 34,000 |
| *SBIR Recap* | *0* | *840* | *840* | *0* | *1,126* | *1,126* |
| *TCF Recap* | *0* | *219* | *219* | *0* | *287* | *287* |
| *Workforce Development Recap* | *0* | *0* | *0* | *0* | *1,000* | *1,000* |
| *Other TRR Recap* | *24,941* | *0* | *24,941* | *31,587* | *0* | *31,587* |

## Energy Delivery Grid Operations Technology

**Overview**

The Nation's energy resilience strategy would benefit from advancements in national-scale energy analytics, including short-term (operational) and long-term (infrastructure) planning 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 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 to address these threats.

The NAERM activities focus on developing and enhancing the portfolio of tools that are needed to address grid reliability in a system with pervasive and evolving threats and challenges. NAERM will improve capability limitations and transition the underlying capabilities to a robust, secure operational state and prioritizes "what if" scenarios affecting reliability, which is essential for maintaining OE's ability to identify and advance solutions for America's grid. EDGOT's tools will support private and public efforts by:

- 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

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.

**Highlights of the FY 2024 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 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 near-real-time data feeds into the NAERM platform

- 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 and updating the 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
- Formalizing procedures and establish partnerships for sharing data with industry stakeholders
- Engaging with industry stakeholders 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 other government offices and agencies, including the Grid Deployment Office, to assess structural, operational, and contextual changes on the power grid on a regional and national level as well as identifying mitigation approaches to potential reliability concerns
- Supporting short- and long-term planning activities necessary to achieve a significant and early decarbonization of the power sector on a pathway to a net-zero carbon economy while addressing emerging threats. Activities could include 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 in coordination with OE's SecureNet program to ensure that security is embedded within these technologies.

**Energy Delivery Grid Operations Technology**
**Funding ($K)**

| | FY 2022 Enacted (comparable)[a] | FY 2023 Enacted (comparable)[a] | FY 2024 Request | FY 2024 Request vs FY 2023 Enacted ($) | FY 2024 Request vs FY 2023 Enacted (%) |
|---|---|---|---|---|---|
| **Energy Delivery Grid Operations Technology** | | | | | |
| North American Energy Resilience Model (NAERM) | | | | | |
| NAERM Operations | 8,000 | 14,000 | 14,000 | 0 | 0.0% |
| NAERM Upgrades | 0 | 16,614 | 16,000 | -614 | -3.7% |
| Total, NAERM | 8,000 | 30,614 | 30,000 | -614 | -2.0% |
| Silicon Carbide Semiconductors | 4,791 | 0 | 0 | 0 | N/A |
| **Total, Energy Delivery Grid Operations Technology** | **12,791** | **30,614** | **30,000** | **-614** | **-2.0%** |

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

| | FY 2024 Request vs FY 2023 Enacted |
|---|---|
| • NAERM Upgrades: The reduction results from the completion of data access and system architecture efforts using FY 2023 funding, allowing prioritization in FY 2024 on the development of "what if" scenarios affecting reliability | -614 |

[a] The FY 2024 Request proposes to consolidate all Small Business Innovation Research, Technology Commercialization Fund, and workforce development activities under the new Electricity Innovation and Transition (EIT) program. To allow an apples-to-apples comparison, FY 2022 and FY 2023 are shown as if this approach had been in place since FY 2022, moving $537,000 in FY 2022 and $386,000 in FY 2023 from EDGOT to EIT. Details are shown under the Comparability Matrix section below.

**Activities and Explanation of Changes**

| FY 2023 Enacted (comparable) | FY 2024 Request | Explanation of Changes<br>FY 2024 Request vs FY 2023 Enacted |
|---|---|---|
| **Energy Delivery Grid Operations Technology<br>$30,614,000** | **$30,000,000** | **-$614,000** |
| *NAERM Operations $14,000,000* | *$14,000,000* | *$0* |
| • NAERM begins operations in FY 2023 | • Expand the users of NAERM to include industry stakeholders<br>• Shift NAERM concentration from real-time situational awareness to the short- and long-term planning time frame | • Expand the user group beyond National Laboratories and government agencies to include industry stakeholders such as NERC |
| *NAERM Upgrades $16,614,000* | *$16,000,000* | *-$614,000* |
| • Create transmission/distribution planning tool<br>• Create DER network planning tool<br>• Expand climate change natural threat modeling to include climate change awareness impact to the grid | • Enhance the already-developed tools to support short- and long-term planning activities necessary to significantly accelerate decarbonization of the power sector in the context of emerging threats | • A number of models and tools developed for NAERM are fully developed and integrated into NAERM such as a static gas model and a static gas-electricity simulation tool<br>• Data access and system architecture that enables additional tools to be easily integrated into NAERM will be completed with FY 2023 funding |

**Comparability Matrix**

The table below shows the Small Business Innovation Research (SBIR) and Technology Commercialization Fund (TCF) funding associated with EDGOT in FY 2022 and FY 2023 under both the prior budget structure, where these activities were funded within EDGOT, and the proposed budget structure, where these activities are consolidated across OE under the new Electricity Innovation and Transition (EIT) program. It also shows a comparability adjustment from the FY 2022 structure to the FY 2023 structure, to reflect Congress moving the DarkNet activity from EDGOT in the FY 2022 enacted appropriation to SecureNet in the FY 2023 enacted appropriation.

| | **FY 2024 Proposed Budget Structure ($K)** | | | | | | |
|---|---|---|---|---|---|---|---|
| | FY 2022 Enacted | | | | FY 2023 Enacted | | |
| | EDGOT | SecureNet | EIT | Total | EDGOT | EIT | Total |
| **FY 2022 and FY 2023 Budget Structure** | | | | | | | |
| Energy Delivery Grid Operations Technology | | | | | | | |
| NAERM Operations | 8,000 | 0 | 0 | 8,000 | 14,000 | 0 | 14,000 |
| NAERM Upgrades | | | | | | | |
| SBIR | 0 | 0 | 0 | 0 | 0 | 248 | 248 |
| TCF | 0 | 0 | 0 | 0 | 0 | 138 | 138 |
| Other NAERM Upgrades | 0 | 0 | 0 | 0 | 16,614 | 0 | 16,614 |
| Total, NAERM Upgrades | 0 | 0 | 0 | 0 | 16,614 | 386 | 17,000 |
| Darknet | | | | | | | |
| SBIR | 0 | 0 | 238 | 238 | 0 | 0 | 0 |
| TCF | 0 | 0 | 90 | 90 | 0 | 0 | 0 |
| Other Darknet | 0 | 9,672 | 0 | 9,672 | 0 | 0 | 0 |
| Total, Darknet | 0 | 9,672 | 328 | 10,000 | 0 | 0 | 0 |
| Silicon Carbide Semiconductors | | | | | | | |
| SBIR | 0 | 0 | 164 | 164 | 0 | 0 | 0 |
| TCF | 0 | 0 | 45 | 45 | 0 | 0 | 0 |
| Other SiC Semiconductors | 4,791 | 0 | 0 | 4,791 | 0 | 0 | 0 |
| Total, SiC Semiconductors | 4,791 | 0 | 209 | 5,000 | 0 | 0 | 0 |
| Total | 12,791 | 9,672 | 537 | 23,000 | 30,614 | 386 | 31,000 |
| *SBIR Recap* | *0* | *0* | *402* | *402* | *0* | *248* | *248* |
| *TCF Recap* | *0* | *0* | *135* | *135* | *0* | *138* | *138* |
| *Other Activities Recap* | *12,791* | *9,672* | *0* | *22,463* | *30,614* | *0* | *30,614* |

## 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. Much of the electrical distribution system—infrastructure delivering power from the transmission system to individual businesses and homes—was designed and built using engineering principles established over 100 years ago. Yet this same distribution system is facing dramatic changes: accelerated distribution of energy supply, increased electrification, growing consumer participation, and continued energy efficiency and conservation. The growing convergence of transmission and distribution (T&D) systems requires new architectural, control, and operational approaches. Along with significant benefits and opportunities, these changes 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 collaborate with an increasingly capable grid edge and 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 electric grid challenges by developing transformative technologies, tools, and techniques to enable industry to keep pace with emerging and evolving conditions that necessitate modernization of the distribution network to ensure continued reliability and resilience. It also coordinates the planning, design, and operations with transmission and distributed energy resources (DERs). RDS activities assist in increasing electrification of the economy and integrating multiple grid edge resources that improve the reliability and resilience of the system. RDS pursues strategic investments in innovative technologies and practices that improve reliability, increase resilience, support vehicle electrification, integrate clean DERs, and provide consumers with more choices for managing their energy consumption.

Microgrid research and 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 distributed energy resource (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. As microgrid technology evolves to further improve grid performance, microgrids are envisioned to be essential building blocks of the future electric grid.

Dynamic Controls R&D investigates new approaches and technologies to enhance the electric distribution grid's ability 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 explores the local, regional, and structural implications of transportation electrification, among other transformative grid edge influences.

The integrated planning component of the program develops transformative 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 advancing integrated planning practices leading to coherent grid investment strategies that apply advanced technologies to meet reliability, resilience, decarbonization, efficiency, equity, and flexibility objectives.

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

### Highlights of the FY 2024 Budget Request

<u>Microgrids</u>

- Microgrid Building Blocks (MBBs): This subprogram will continue development of MBBs as the fundamental base to reduce microgrid deployment costs and time. Going beyond current microgrid functionalities, such as supporting local resilience and integrating distributed generation, the virtual MBB prototype designs developed in FY 2023 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 activities will validate the performance of the virtual MBB prototype performance designs in FY 2024.

- Networked 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. FY 2024 work will apply advanced modeling and simulation capabilities developed in FY 2023 in the use case to support a range of resiliency and decarbonization operations at U.S. ports. Networked microgrid R&D will focus on enabling DynaGrid, a concept to enable dynamic formation of microgrid boundaries for optimized operations under both normal and emergency conditions, laying the foundation for a future fractal grid composed of dynamically formed microgrids in a repetitive pattern. Realistic use cases developed in FY 2023 will be evaluated and demonstrated in FY 2024. This activity is expected to accommodate larger-scale integration of DERs and electrification envisioned for the future grid.
- Development of protection schemes for microgrids with high penetration of inverter-based resources (IBRs) 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 will also continue.
- Net-Zero Microgrids (NZMs): NZM activity will follow its Technical Studies Guidance report published in 2021. Work will continue on modeling and simulation of a microgrid design with integrated small modular reactors as part of the generation mix to investigate power system engineering issues involving microgrid operations and integrated operations with the grid to provide grid services.

Dynamic Controls

Dynamic Controls R&D activities will support priorities on grid resilience and dynamically sourced grid support services to transform distribution grid infrastructure. FY 2024 activities will be supported in the following areas:

- Dynamic Controls: Research will expand on grid service guarantees matching the level of certainty for centralized single-owner control systems. 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 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: The increased linkage between the electric and transportation sectors creates interdependencies that can have both positive and negative effects. 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, the subprogram will develop 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

Sensors activities will support the development of increasingly diverse information-gathering devices and systems, advanced data analytics, and their integration into the power grid.

The Sensors subprogram seeks to 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. Distribution system visibility is lagging transmission-level visibility, and reducing this asymmetry is important for the full participation of distribution in markets and system planning. Distribution system sensing advancements will facilitate better two-way power flow across the T&D system. Tools developed for sensor management and data analytics will 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 IBRs in the distribution system. 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.

Electricity Delivery Systems

RDS works 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 of coherent strategies for achieving 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 reference design architectures for the distribution system that can accommodate many forms of distributed IBRs, ownership models, and market structures, and ensuring an effective transfer of know-how to the industry, including regulators.
- 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.
- Evolving integrated distribution system planning practices with regulators and utilities that begin to address myriad issues associated with the integration and utilization of DERs, as well as how to develop rational, staged technology investment strategies that incorporate multiple objectives, including decarbonization, resilience, flexibility, and energy justice with traditional planning objectives, in a balanced, holistic manner.
- A set of practical design guidelines that address operational coordination requirements to enable evolving industry, business, and market structures at the grid edge (e.g., community microgrids, virtual power plants, and electric vehicle infrastructure) to interface with the electric grid, as well as share services across T&D system domains.

Technology, tools, and applications developed under RDS will be evaluated, in conjunction with SecureNet testbed capabilities, for security risks including cybersecurity. Testing and evaluations will be conducted to ensure that security is built into these technologies 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.

**Resilient Distribution Systems**
**Funding ($K)**

| | FY 2022 Enacted (comparable)[a] | FY 2023 Enacted (comparable)[a] | FY 2024 Request | FY 2024 Request vs FY 2023 Enacted ($) | FY 2024 Request vs FY 2023 Enacted (%) |
|---|---|---|---|---|---|
| **Resilient Distribution Systems** | | | | | |
| Microgrids | 7,711 | 5,782 | 14,000 | +8,218 | +142.1% |
| Dynamic Controls & Communications | 11,539 | 8,652 | 20,000 | +11,348 | +131.2% |
| Sensors | 9,910 | 0 | 6,800 | +6,800 | N/A |
| Electricity Delivery Systems | 4,812 | 4,877 | 6,500 | +1,623 | +33.3% |
| Modeling Distributed Energy Resources | 0 | 4,836 | 0 | -4,836 | -100.0% |
| Sensors Demonstration | 0 | 14,701 | 0 | -14,701 | -100.0% |
| COMMANDER National Testbed Laboratory | 9,654 | 4,827 | 0 | -4,827 | -100.0% |
| Underserved & Indigenous Community Microgrids | 9,874 | 9,873 | 0 | -9,873 | -100.0% |
| **Total, Resilient Distribution Systems** | **53,500** | **53,548** | **47,300** | **-6,248** | **-11.7%** |

**Resilient Distribution Systems**
**Explanation of Major Changes ($K)**

| | FY 2024 Request vs FY 2023 Enacted |
|---|---|
| • Microgrids: The increase supports MBB development, advancing the performance of the virtual prototype designs | +8,218 |
| • Dynamic Controls & Communications: The increase expands sector coupling analysis to look 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, addressing the need for new data integrity methods, data sharing agreements, and coordination frameworks | +11,348 |
| • Sensors: The increase supports the development and integration of increasingly diverse information-gathering devices and systems and advanced data analytics into the electricity delivery system | +6,800 |

[a] The FY 2024 Request proposes to consolidate all Small Business Innovation Research, Technology Commercialization Fund, and workforce development activities under the new Electricity Innovation and Transition (EIT) program. To allow an apples-to-apples comparison, FY 2022 and FY 2023 are shown as if this approach had been in place since FY 2022, moving $1,500,000 in FY 2022 and $1,452,000 in FY 2023 from RDS to EIT.

| | FY 2024 Request vs FY 2023 Enacted |
|---|---|
| • Electricity Delivery Systems: Supports more robust stakeholder engagement to vet and share guidelines around integrated distribution system planning (IDSP), operational coordination and distribution system reference designs | +1,623 |
| • Modeling Distributed Energy Resources: Planned activities for this congressionally directed activity are completed with funding provided in FY 2023 | -4,836 |
| • Sensors Demonstration: Planned activities for this congressionally directed activity are completed with funding provided in FY 2023 | -14,701 |
| • COMMANDER National Testbed Laboratory: Planned activities for this congressionally directed activity are completed with funding provided in FY 2023 | -4,827 |
| • Underserved & Indigenous Community Microgrids: Planned activities for this congressionally directed activity are completed with funding provided in FY 2023 | -9,873 |
| **Total, Resilient Distribution Systems** | **-6,248** |

**Resilient Distribution Systems**

**Activities and Explanation of Changes**

| FY 2023 Enacted (Comparable) | FY 2024 Request | Explanation of Changes FY 2024 Request vs FY 2023 Enacted |
|---|---|---|
| **Resilient Distribution Systems $53,548,000** | **$47,300,000** | **-$6,248,000** |
| *Microgrids $5,782,000* | *$14,000,000* | *+8,218,000* |
| • 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<br>• Develop modeling and simulation capabilities for optimal system design and operation of networked microgrids for decarbonization and resilience of critical infrastructure with a focus of the use case on ports<br>• Complete the design of virtual MBB prototypes for microgrid communications and control | • 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<br>• Apply modeling and simulation capabilities for optimal system design and operations of networked microgrids for decarbonization and resilience of critical infrastructure in a use case on ports<br>• Conduct modeling and simulation to validate the performance of the virtual MBB designs and performance | • Increase support of the multi-lab MBB development to advance the performance of the virtual prototype designs |

| FY 2023 Enacted (Comparable) | FY 2024 Request | Explanation of Changes<br>FY 2024 Request vs FY 2023 Enacted |
|---|---|---|
| • 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<br>• Develop protection schemes for microgrids (singular and networked) with high penetration of IBRs and for secondary networks with DERs and microgrids | • 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<br>• Develop protection schemes for microgrids (singular and networked) with high penetration of IBRs and for secondary networks with DERs and microgrids | |
| *Dynamic Controls & Communications $8,652,000* | *$20,000,000* | *+$11,348,000* |
| • Develop data efficient operations approach with increased reliance on combinations of distributed control and incentivization of flexible DER for reliability and resilience<br>• 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<br>• Extend Sector Coupling Analysis of the transportation and electricity sectors including structural and architectural aspects, seeking to establish a converged perspective on reliability, sustainability, and resilience across both transportation and electricity<br>• 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 | • Publish a data efficient operations methodology with increased reliance on combinations of distributed control and incentivization of flexible DER for reliability and resilience<br>• Overcome value stacking barriers associated with current T&D operational and market structures to maximize utilization of grid edge resources<br>• Drive industry consensus on complex data sharing challenges across ownership and responsibility boundaries that assures data security, integrity, and privacy while ensuring operational objectives of all stakeholders are attained<br>• Apply the Sector Coupling Analysis of the transportation and electricity sectors to propose new reliability index targets for existing metrics and construct new metrics where these newly interdependent systems require them<br>• Develop coordinated control options that reduce distributions system upgrade capital requirements by 25%, utilizing grid and DER asset combinations and their incentive mechanisms<br>• Engage digital ledger technology (DLT) industry in generating testable pilots applying DLT to operational challenges | • The combination of electrification and decarbonization requires transformative control approaches to keep electricity affordable, reliable, and resilient; more aggressive efforts are required in both R&D and demonstration<br>• Expand data science approaches in the rapidly expanding grid-edge, collaborative control frontier, strengthening coordination capabilities and enabling decarbonized and resilient systems<br>• 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 2023 Enacted (Comparable) | FY 2024 Request | Explanation of Changes<br>FY 2024 Request vs FY 2023 Enacted |
|---|---|---|
| *Sensors $0* | *$6,800,000* | *+$6,800,000* |
| | • Develop approaches and tools that will accurately detect, characterize, and forecast DER behavior and its impacts on electric power systems at high penetration levels<br>• Expand sensor research related to enhanced power system resilience, enabling better prediction of, response to, and recovery from critical events<br>• Investigate, develop, and demonstrate sensor technologies applicable to real-time monitoring of critical infrastructure interdependencies, including development and promotion of methodologies for improved sensor selection, valuation assessment, and cost/benefit allocation<br>• Support a prize program for data analytics tool development utilizing utility data sets, to catalyze independent and 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 $4,877,000* | *$6,500,000* | *+$1,623,000* |
| • Advance ISDP practices with regulators and the industry that enable the formulation of holistic technology investment strategies that address multiple objectives (including resilience, energy justice, and decarbonization) and enable the utilization of DERs<br>• Develop architecture-based guidelines to enable DER coordination to support grid and market operations across the transmission, distribution, and behind-the-meter domains | • Continue development of IDSP practices with the development of guidelines, vetted through stakeholder processes with regulators and utilities, in several key areas including cost-effectiveness frameworks, resilience planning, and multi-objective prioritization<br>• Continue to work with the national associations to vet and advance this this work for practical applications by States | • Supports more robust stakeholder engagement to vet and share guidelines around IDSP, operational coordination and distribution system reference designs, and additional efforts to work directly with states through direct technical assistance, education, and training activities to advance these emerging, leading practices |

| FY 2023 Enacted (Comparable) | FY 2024 Request | Explanation of Changes<br>FY 2024 Request vs FY 2023 Enacted |
|---|---|---|
| • Apply key grid architecture principles to develop reference designs for a distribution system to address the application of DERs in T&D markets, reliability, and resilience through the use of microgrids and power flow requirements to enable the real-time application of all grid assets<br>  • This begins in FY 2023 and is expected to continue through FY 2025<br>• Establish and use formal working groups with several national associations (NARUC, NASEO, NRECA, NGA, NCSL, and APPA) to vet and disseminate advanced practices and guidelines for integrated distribution system planning and operational coordination, as well as to provide technical assistance in these areas | • Complete reference architectures for use of DERs in T&D markets and for improving reliability and resilience using microgrids and continue work on a reference design for controlling power flow in a highly dynamic grid<br>• Develop staged approaches for deploying these capabilities through focused efforts with the industry<br>• Finalize guidelines for the operational coordination of DERs in T&D markets and develop grid codes to set roles and responsibilities among all participants | |
| *Modeling Distributed Energy Resources $4,836,000* | *$0* | *-$4,836,000* |
| • Explore existing DER modeling and develop standardized approaches to facilitate improvements in resilience and reliability metrics for utilities and regulators to inform short- and long-term planning efforts | | • Planned activities for this congressionally directed activity are completed with funding provided in FY 2023 |
| *Sensors Demonstration $14,701,000* | *$0* | *-$14,701,000* |
| • Demonstrate sensor analytics with industry to allow for better utilization of existing sensors, facilitate data integration from disparate sensors, and inform sensor placement<br>• Demonstrate sensor analytic tools to help accelerate industry utilization of advanced sensor data, improving resilience and operations<br>• Demonstrate grid models and tools to optimize the monitoring effectiveness and cost of sensor placements | | • Planned activities for this congressionally directed activity are completed with funding provided in FY 2023 |

| FY 2023 Enacted (Comparable) | FY 2024 Request | Explanation of Changes<br>FY 2024 Request vs FY 2023 Enacted |
|---|---|---|
| • Continue to fund a prize program for data tool demonstrations in partnership with utilities and their system data sets to catalyze independent academic research into equity and integration of DERs | | |
| *COMMANDER National Testbed Laboratory*<br>*$4,827,000* | *$0* | *-$4,827,000* |
| • Activities include evaluating the current and future role of microgrids and DERs in distribution system operation<br>• Enhancement of testbed resources, data flows and exchanges, and understanding the impacts of ownership boundaries in coordinated operation, system security, and economic optimization | | • Planned activities for this congressionally directed activity are completed with funding provided in FY 2023 |
| *Underserved & Indigenous Community Microgrids Delivery Systems $9,873,000* | *$0* | *-$9,873,000* |
| • Release the Underserved and Indigenous Community Microgrids (UICM) funding opportunity announcement (FOA) to seek projects providing replicable microgrid solutions for underserved and Indigenous communities<br>• Award competitively selected projects under the UICM FOA | | • Planned activities for this congressionally directed activity are completed with funding provided in FY 2023 |

**Comparability Matrix**

The table below shows the Small Business Innovation Research (SBIR) and Technology Commercialization Fund (TCF) funding associated with RDS in FY 2022 and FY 2023 under both the prior budget structure, where these activities were funded within RDS, and the proposed budget structure, where these activities are consolidated across OE under the new Electricity Innovation and Transition (EIT) program.

| | FY 2024 Proposed Budget Structure ($K) | | | | | |
|---|---|---|---|---|---|---|
| | FY 2022 Enacted | | | FY 2023 Enacted | | |
| | RDS | EIT | Total | RDS | EIT | Total |
| **FY 2022 and FY 2023 Budget Structure** | | | | | | |
| Resilient Distribution Systems | | | | | | |
| Microgrids | | | | | | |
| SBIR | 0 | 217 | 217 | 0 | 164 | 164 |
| TCF | 0 | 72 | 72 | 0 | 54 | 54 |
| Other Microgrids | 7,711 | 0 | 7,711 | 5,782 | 0 | 5,782 |
| Total, Microgrids | 7,711 | 289 | 8,000 | 5,782 | 218 | 6,000 |
| Dynamic Controls & Communications | | | | | | |
| SBIR | 0 | 358 | 358 | 0 | 271 | 271 |
| TCF | 0 | 103 | 103 | 0 | 77 | 77 |
| Other DC&C | 11,539 | 0 | 11,539 | 8,652 | 0 | 8,652 |
| Total, DC&C | 11,539 | 461 | 12,000 | 8,652 | 348 | 9,000 |
| Sensors | | | | | | |
| TCF | 0 | 90 | 90 | 0 | 0 | 0 |
| Other Sensors | 9,910 | 0 | 9,910 | 0 | 0 | 0 |
| Total, Sensors | 9,910 | 90 | 10,000 | 0 | 0 | 0 |
| Electricity Delivery Systems | | | | | | |
| SBIR | 0 | 143 | 143 | 0 | 78 | 78 |
| TCF | 0 | 45 | 45 | 0 | 45 | 45 |
| Other EDS | 4,812 | 0 | 4,812 | 4,877 | 0 | 4,877 |
| Total, EDS | 4,812 | 188 | 5,000 | 4,877 | 123 | 5,000 |

| | FY 2024 Proposed Budget Structure ($K) | | | | | |
|---|---|---|---|---|---|---|
| | FY 2022 Enacted | | | FY 2023 Enacted | | |
| | RDS | EIT | Total | RDS | EIT | Total |
| Modeling Distributed Energy Resources | | | | | | |
| SBIR | 0 | 0 | 0 | 0 | 119 | 119 |
| TCF | 0 | 0 | 0 | 0 | 45 | 45 |
| Other MDER | 0 | 0 | 0 | 4,836 | 0 | 4,836 |
| Total, MDER | 0 | 0 | 0 | 4,836 | 164 | 5,000 |
| Demo Sensors | | | | | | |
| SBIR | 0 | 0 | 0 | 0 | 164 | 164 |
| TCF | 0 | 0 | 0 | 0 | 135 | 135 |
| Other Demo Sensors | 0 | 0 | 0 | 14,701 | 0 | 14,701 |
| Total, Demo Sensors | 0 | 0 | 0 | 14,701 | 299 | 15,000 |
| COMMANDER National Testbed Laboratory | | | | | | |
| SBIR | 0 | 256 | 256 | 0 | 128 | 128 |
| TCF | 0 | 90 | 90 | 0 | 45 | 45 |
| Other COMMANDER | 9,654 | 0 | 9,654 | 4,827 | 0 | 4,827 |
| Total, COMMANDER | 9,654 | 346 | 10,000 | 4,827 | 173 | 5,000 |
| Underserved & Indigenous Community Microgrids | | | | | | |
| SBIR | 0 | 36 | 36 | 0 | 37 | 37 |
| TCF | 0 | 90 | 90 | 0 | 90 | 90 |
| Other Underserved & Indigenous Community Microgrids | 9,874 | 0 | 9,874 | 9,873 | 0 | 9,873 |
| Total, Underserved & Indigenous Community Microgrids | 9,874 | 126 | 10,000 | 9,873 | 127 | 10,000 |
| Total, RDS | 53,500 | 1,500 | 55,000 | 53,548 | 1,452 | 55,000 |
| *SBIR Recap* | *0* | *1,010* | *1,010* | *0* | *961* | *961* |
| *TCF Recap* | *0* | *490* | *490* | *0* | *491* | *491* |
| *Other Activities Recap* | *53,500* | *0* | *53,500* | *53,548* | *0* | *53,548* |

## Cyber Resilient and Secure Utility Communications Networks

**Overview**

Our Nation's energy system is heavily dependent on data communications and cyber-physical controls for operational reliability and resilience. The evolution of the electric grid to include more distributed assets increases demands on this infrastructure to enable observability under more dynamic conditions. At the same time, these distributed assets present a broader cyberattack surface for increasingly sophisticated adversaries to exploit. The modernization of communications and control systems—to include integrated cybersecurity—is essential to ensure the efficient, reliable, and resilient operation the electrical power system in a complex and dynamic risk landscape.

The Cyber Resilient and Secure Utility Communications Networks (SecureNet) program develops solutions to strengthen both the security and resilience of the electricity delivery system against cyber-related threats through a security-by-design approach for operational data, communications networks, and control systems.

The program pursues this goal in three ways:

- Supporting next-generation grid communications research and development (R&D) for systems built from inception to mitigate communication failures and detect, reject, and withstand cyber incidents and other disruptions
- Applying a cybersecurity lens to relevant OE R&D activities, ensuring that they have an embedded security-by-design philosophy throughout development and address cybersecurity concerns through design modifications or operational change
- Engaging with the Department's cyber-related operational activities, including those in the Office of Cybersecurity, Energy Security, and Emergency Response (CESER) and the Office of Intelligence and Counterintelligence, to ensure OE's R&D activities are responsive to operational needs, develop a broad base of scientific and technical expertise in grid communications and controls cybersecurity to support of the Department's national security mission, and strengthen public-private sector outreach, information sharing, and training in this area

**Highlights of the FY 2024 Budget Request**

The SecureNet program will develop technical solutions to accelerate and expand efforts to strengthen electricity communications infrastructure against cyber threats. The program's core R&D focus is on cybersecurity and resilience for grid communications and data networks, including enabling components and technologies such as synchronization/timing and blockchain. The program also includes collaboration across the OE R&D portfolio to ensure cybersecurity is considered in those activities and partnership and outreach with other DOE, Federal, and public stakeholders. SecureNet will also be a key element of the Grid Modernization Initiative, including the Grid Modernization Laboratory Consortium (GMLC).

The Request includes two categories of R&D activities:

- Secure Communications Network R&D: the Request supports continued research on secure utility communications, including the development of an architectural framework and technology roadmap for communications infrastructure that meets utility systems' functional and performance requirements. This architecture and roadmap will be informed by utility stakeholder feedback and model-based analysis and will in turn be the foundation for university research, pilot demonstrations with industry, other technology R&D activities, and standards development. This activity also includes information sharing and training to help develop the next generation of secure grid communications specialists.
- Grid Technology Cyber Resilience R&D: the Request includes R&D activities in support of other programs in the OE portfolio to ensure cybersecurity and cyber-resilience are built into new technologies for grid coordination, operation, and control. Activities may include modeling cyber aspects of future grid scenarios, researching cyber-hardening new grid technologies, and providing cyber design inputs, testing capabilities, and cyber vulnerability assessments to other OE R&D programs.

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

| | FY 2022 Enacted (Comparable)[a] | FY 2023 Enacted (Comparable)[a] | FY 2024 Request | FY 2024 Request vs FY 2023 Enacted ($) | FY 2024 Request vs FY 2023 Enacted (%) |
|---|---|---|---|---|---|
| **Cyber Resilient and Secure Utility Communications Networks (SecureNet)** | | | | | |
| Secure Communications Network R&D | 9,000 | 0 | 10,000 | +10,000 | N/A |
| Grid Technology Cyber Resilience R&D | 1,700 | 0 | 5,000 | +5,000 | N/A |
| Darknet | 9,672 | 9,673 | 0 | -9,673 | -100.0% |
| Distribution Communications and Control Technologies | 0 | 4,918 | 0 | -4,918 | -100.0% |
| **Total, Cyber Resilient and Secure Utility Communications Networks (SecureNet)** | **20,372** | **14,591** | **15,000** | **+409** | **+2.8%** |

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

| | FY 2024 Request vs FY 2023 Enacted |
|---|---|
| • Secure Communications Network R&D: Builds on FY 2022 grid communications architecture development, technology R&D, and stakeholder partnership activities | +10,000 |
| • Grid Technology Cyber Resilience R&D: Supports addressing cybersecurity and resilience considerations in existing OE research, development, and demonstration programs, with particular focus on communications-enabled, highly distributed components | +5,000 |
| • Darknet: Planned activities for this congressionally directed activity will be completed with funding provided in FY 2023 | -9,673 |
| • Distribution Communications and Control Technologies: Planned activities for this congressionally directed activity will be completed with funding provided in FY 2023 | -4,918 |
| **Total, Cyber Resilient and Secure Utility Communications Networks (SecureNet)** | **+409** |

[a] The FY 2024 Request proposes to consolidate all Small Business Innovation Research, Technology Commercialization Fund, and workforce development activities under the new Electricity Innovation and Transition (EIT) program. Additionally, FY 2022 activities for University Research and Cyber Assessments and Technology are consolidated in FY 2024 under the Secure Communications Network R&D subprogram and the FY 2023 appropriation moved Darknet activities from Energy Delivery Grid Operations Technology to SecureNet. To allow an apples-to-apples comparison, FY 2022 and FY 2023 are shown as if these structure changes had been in place since FY 2022. Details of these adjustments are shown in the Comparability Matrices section below.

## Cyber Resilient and Secure Utility Communications Networks (SecureNet)

**Activities and Explanation of Changes**

| FY 2023 Enacted (Comparable) | FY 2024 Request | Explanation of Changes<br>FY 2024 Request vs FY 2023 Enacted |
|---|---|---|
| **Cyber Resilient and Secure Utility Communications Networks (SecureNet) $14,591,000** | **$15,000,000** | **+$409,000** |
| *Secure Communications Network R&D $0* | *$10,000,000* | *+$10,000,000* |
| | • Develop an architectural framework and technology roadmap for grid communications infrastructure<br>• Improve communications technology development related to the electricity delivery system through research partnerships<br>• Build knowledge and capacity through stakeholder engagement | • Continue and build on grid communications R&D activities funded in FY 2022 |
| *Grid Technology Cyber Resilience R&D $0* | *$5,000,000* | *+$5,000,000* |
| | • Support cybersecurity research related to existing OE R&D programs, including those featuring communications-enabled, highly distributed components | • Continue and build on cybersecurity and resilience R&D activities funded in FY 2022 |
| *Darknet $9,673,000* | *$0* | *-$9,673,000* |
| • Continue R&D activities to shield the Nation's electricity infrastructure from disruptive cyber penetration, including expansion of the communications network architecture and development of cutting-edge networking technologies | | • Planned activities for this congressionally directed activity will be completed with funding provided in FY 2023 |
| *Distribution Communications and Control Technologies $4,918,000* | *$0* | *-$4,918,000* |
| • Research, evaluate, and commission new distribution communications and control technologies for a secure smart grid | | • Planned activities for this congressionally directed activity will be completed with funding provided in FY 2023 |

**Comparability Matrices**

The tables below show Small Business Innovation Research (SBIR) and Technology Commercialization (TCF) funding associated with SecureNet in FY 2022 and FY 2023 under both the prior budget structure, where these activities were funded within SecureNet, and the proposed budget structure, where these activities are consolidated across OE under the new Electricity Innovation and Transition program. Additionally, they show the reallocation within SecureNet from the subprograms proposed in FY 2022 to the subprograms proposed in FY 2024, and the change in the FY 2023 appropriation to move funding for DarkNet from Energy Delivery Grid Operations Technology (EDGOT) to SecureNet.

FY 2022 Enacted Appropriation Comparability Matrix

| | FY 2024 Proposed Budget Structure ($K) | | | | | | |
|---|---|---|---|---|---|---|---|
| | SecureNet | | | | EDGOT | EIT | Total |
| | Secure Comms. Network R&D | Grid Tech Cyber Resilience R&D | Darknet | Total | | | |
| **FY 2022 Budget Structure** | | | | | | | |
| SecureNet | | | | | | | |
| University Research | | | | | | | |
| SBIR | 0 | 0 | 0 | 0 | 0 | 98 | 98 |
| TCF | 0 | 0 | 0 | 0 | 0 | 26 | 26 |
| Other University Research | 2,339 | 537 | 0 | 2,876 | 0 | 0 | 2,876 |
| Total, University Research | 2,339 | 537 | 0 | 2,876 | 0 | 124 | 3,000 |
| Cyber Assessments and Technology | | | | | | | |
| SBIR | 0 | 0 | 0 | 0 | 0 | 253 | 253 |
| TCF | 0 | 0 | 0 | 0 | 0 | 73 | 73 |
| Other Cyber Assessments and Technology | 6,661 | 1,163 | 0 | 7,824 | 0 | 0 | 7,824 |
| Total, Cyber Assessments and Technology | 6,661 | 1,163 | 0 | 7,824 | 0 | 326 | 8,150 |
| Total, SecureNet | 9,000 | 1,700 | 0 | 10,700 | 0 | 450 | 11,150 |
| *SBIR Recap* | *0* | *0* | *0* | *0* | *0* | *351* | *351* |
| *TCF Recap* | *0* | *0* | *0* | *0* | *0* | *99* | *99* |
| *Other Activities Recap* | *9,000* | *1,700* | *0* | *10,700* | *0* | *0* | *10,700* |

| | FY 2024 Proposed Budget Structure ($K) | | | | | | |
|---|---|---|---|---|---|---|---|
| | SecureNet | | | | EDGOT | EIT | Total |
| | Secure Comms. Network R&D | Grid Tech Cyber Resilience R&D | Darknet | Total | | | |
| Energy Delivery Grid Operations Technology | | | | | | | |
| DarkNet | 0 | 0 | 9,672 | 9,672 | 0 | 0 | 9,672 |
| Other EDGOT | 0 | 0 | 0 | 0 | 12,791 | 0 | 12,791 |
| Total, EDGOT | 0 | 0 | 9,672 | 9,672 | 12,791 | 0 | 22,463 |
| Total, FY 2022 Budget Structure | 9,000 | 1,700 | 9,672 | 20,372 | 12,791 | 450 | 33,613 |

FY 2023 Enacted Appropriation Comparability Matrix

| | FY 2024 Proposed Budget Structure ($K) | | |
|---|---|---|---|
| | SecureNet | EIT | Total |
| **FY 2023 Budget Structure** | | | |
| SecureNet | | | |
| Darknet | | | |
| SBIR | 0 | 237 | 237 |
| TCF | 0 | 90 | 90 |
| Other Darknet | 9,673 | 0 | 9,673 |
| Total, Darknet | 9,673 | 327 | 10,000 |
| Distribution Communications & Control Technology | | | |
| SBIR | 0 | 37 | 37 |
| TCF | 0 | 45 | 45 |
| Other Distribution Comms & Control Tech | 4,918 | 0 | 4,918 |
| Total, Distribution Comms & Control Tech | 4,918 | 82 | 5,000 |
| Total, SecureNet | 14,591 | 409 | 15,000 |
| *SBIR Recap* | *0* | *274* | *274* |
| *TCF Recap* | *0* | *135* | *135* |
| *Other Activities Recap* | *14,591* | *0* | *14,591* |

## Energy Storage

**Overview**

The Energy Storage program accelerates bi-directional electrical energy storage technologies as a key component of a reliable, resilient, and affordable future-ready grid. Energy storage is the major enabler of a 100% carbon pollution-free electricity grid; provides new tools to improve grid resiliency, especially in underserved communities; and creates new options for infrastructure planning, from deferral to rapid expansion.

While pumped-storage hydropower (PSH) and lithium-ion batteries are already common on the grid, new technologies with more flexible siting, more modularity, and lower marginal duration cost attributes will dramatically expand where storage can be beneficially deployed. OE Storage research, development, demonstration, and deployment (RDD&D) efforts accelerate the development of long duration grid storage technologies through increasing amounts of stored energy and operational durations, reducing technology costs, de-risking technologies to ensure safe long-term reliability, developing analytic models to uncover technical and economic benefits, and demonstrating how storage provide clean and equitable energy access for consumers and communities. The program has four primary focus areas:

- Cost-Competitive and Long-Duration Technology Development
  - This focus area resolves key cost and performance challenges for earth-abundant, domestically available storage technologies with an emphasis on longer-duration (10+ hour) technologies.
  - OE supports flow, sodium, zinc manganese dioxide, and lead-based batteries as part of a portfolio of the most promising innovative battery chemistries for cost reduction. Under the Long Duration Energy Storage Earthshot's target to reduce the cost of grid-scale energy storage by 90% for systems that deliver 10+ hours of duration within the decade, OE is seeking to realize a 5¢/kWh levelized cost basis for stationary, 10+ hour duration applications.
  - Within each chemistry, major improvements are anticipated in electrode materials, membranes, and electrolytes. Additional crosscutting research and development (R&D) areas include interconnections, power electronics, and power conversion systems.
- Validated Reliability and Safety
  - This focus area improves the understanding and predictability of energy storage systems and components under realistic grid use cases, fostering greater confidence in the safety and reliability of energy storage systems.
  - Major stakeholders in this focus area include fire departments, building managers, and other approval authorities.
- Analytics for an Equitable Regulatory and Social Environment
  - This focus area assists stakeholders, including small end users, utilities, regulatory agencies, and investors, in understanding optimal storage sizing, placement, operation, and valuation, as well as quantifying environmental and social impacts.
  - These assistance activities are enabled through the development of new analytical and open-source tools, performance protocols, and advanced control systems.
- Grid and Field Validation
  - This focus area helps end users gain confidence in the economic viability of storage through real-world validation of storage tools and models.
  - Similarly, the Rapid Operational Validation Initiative (ROVI), a cross-cutting performance analytical framework, will help users build confidence in the long-term operational reliability of new storage technologies.

**Highlights of FY 2024 Budget Request**

The Request continues support for the program's core R&D focus areas in Cost-Competitive and Long-Duration Technology Development, Validated Reliability and Safety, Analytics for an Equitable Regulatory and Social Environment, and Grid and Field Validation.

The Request will also launch a new cohort for the Energy Storage for Social Equity (ES4SE) 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,

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

application, operations, and maintenance in support of disadvantaged communities. This Request enables the launch of a new ES4SE cohort with an additional five to ten communities in the technical assistance phase and two to four of those communities continuing to the pilot demonstration phase.

The Request expands ROVI to improve the performance projection methodologies of two to three new non-lithium electrochemistries to deliver performance projections of up to five years. Nascent technologies lack a long-term operational track record, impeding wide commercial deployment. Traditional calendar-life-based validation methods today require longer to develop, validate, and install these systems than the time available to meet the Administration's 2035 decarbonization goals. ROVI aims to provide at least a 15-year technology life and performance prediction using one year or less of data. ROVI enables faster validation of storage technologies through a combination of physical characterization and performance data, data generated from physics-based models and digital twins, and deployments. This Request extends the framework to cover additional technologies that are suitable candidates for long-duration (10+ hour) applications.

To respond to the rapidly growing number of energy storage installations, this Request also expands outreach to key deployment stakeholders (including fire safety, codes and standards, and other groups) as part of the Validated Reliability and Safety subprogram.

Continuing activities under Cost-Competitive and Long-Duration Technology Development include advanced materials R&D and power conversion systems. 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, including systems based on sodium, zinc, and lead chemistries. The program will collaborate with counterpart offices to identify supply chain requirements for these advanced materials. Power electronics and power conversion systems can represent up to 30% of an installed storage system's cost. In contrast to high-voltage power electronics for grid enhancing technologies, storage has specialized requirements for low-voltage, high-current capabilities. The program's leadership in advanced power electronics will continue with anticipated improvements in wide-bandgap materials; advanced dielectric materials for high voltage capacitors; new topologies for optimal control and safety; and architectures that address stranded energy, improve battery failure diagnostics, and integrate highly accurate state-of-charge and state-of-health monitoring.

Continuing activities under Validated Reliability and Safety include testing, data collection, standards development, and outreach. The program continues to facilitate knowledge exchanges between research and industry for energy storage safety, working closely with fire departments, building managers, and other approval authorities to understand the critical R&D needs of end users. Knowledge from safety R&D in turn forms the basis for strong safety standards at organizations such as the Institute of Electrical and Electronics Engineers (IEEE), National Fire Protection Association (NFPA), and UL (formerly Underwriters Laboratories). Examples of activities include root cause failures analysis and facilitating uniformity of safety codes and standards. Establishing a validated and referenceable database of energy storage degradation and expected lifetimes, in collaboration with industry, will help new storage technologies gain market acceptance.

Continuing activities under Analytics include model and tool development as well as outreach. Uncertainty on the economic viability of energy storage technologies can impede adoption of grid energy storage, especially for smaller utilities and end users. 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 identify the societal and environmental benefits of storage, such as improving electrical reliability in underserved communities and improvements in air-quality through reduction of fossil generation. The program will also continue to develop robust open-source user tools for optimal sizing and placement, optimal control and coordination, cyber-threat analysis and protection, and techno-economic assessment. The Request also continues the program's outreach to the energy storage community through workshops with public utility commissions (PUCs), educational programs and materials for code officials and first responders, technical conferences for the industry, and facilitating investment industry familiarity with energy storage through OE's annual workshop series on storage finance.

Continuing activities under Grid and Field Validation include efforts to validate both the business case and operational reliability of storage. 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. 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 projects with local communities and rural utilities.

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 early 2024 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 and 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 Energy Storage Grand Challenge (ESGC) crosscut, the Long Duration Energy Storage Earthshot, and the ROVI. 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 FY 2024 Request includes operational support for activities at the GSL as applicable across the four energy storage program focus areas.

Support of R&D activities through the Grid Modernization Initiative (GMI), including 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 GMI, Advanced Energy Storage Initiative (AESI), Beyond Batteries (BB), and others into the ESGC, 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 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 2022 Enacted (Comparable)[a] | FY 2023 Enacted (Comparable)[a] | FY 2024 Request | FY 2024 Request vs FY 2023 Enacted ($) | FY 2024 Request vs FY 2023 Enacted (%) |
|---|---|---|---|---|---|
| **Energy Storage** | | | | | |
| Research | | | | | |
| Cost-Competitive and Long-Duration Technology Development | 18,575 | 34,493 | 28,000 | -6,493 | -18.8% |
| Validated Reliability and Safety | 13,939 | 11,947 | 15,000 | +3,053 | +25.6% |
| Analytics for an Equitable Regulatory and Social Environment | 7,065 | 8,113 | 11,600 | +3,487 | +43.0% |
| Grid and Field Validation | 6,421 | 9,728 | 24,000 | +14,272 | +146.7% |
| Section 3201 Pilot Demonstration Grants | 19,820 | 19,747 | 0 | -19,747 | -100.0% |
| Resilience Projects | 4,864 | 0 | 0 | 0 | N/A |
| Storage and Microgrid Deployment Assistance | 0 | 4,937 | 0 | -4,937 | -100.0% |
| Total, Research | 70,684 | 88,965 | 78,600 | -10,365 | -11.7% |
| Construction | 47,000 | 0 | 0 | 0 | N/A |
| **Total, Energy Storage** | **117,684** | **88,965** | **78,600** | **-10,365** | **-11.7%** |

**Energy Storage**
**Explanation of Major Changes ($K)**

| | FY 2024 Request vs FY 2023 Enacted |
|---|---|
| • Cost-Competitive and Long-Duration Technology Development: the emerging technology FOA is fully funded in FY 2023 and FY 2024 funding is reallocated to support activities in the Analytics and Field Validation subprograms | -6,493 |
| • Validated Reliability and Safety: increase reflects rising costs of continuing activities and expanded outreach to key stakeholders (including fire safety, codes and standards, and other groups) given the growing number of energy storage installations | +3,053 |

[a] The FY 2024 Request proposes to consolidate all Small Business Innovation Research, Technology Commercialization Fund, and workforce development activities under the new Electricity Innovation and Transition (EIT) program. To allow an apples-to-apples comparison, FY 2022 and FY 2023 are shown as if this approach had been in place since FY 2022, moving $2,316,000 in FY 2022 and $6,035,0000 in FY 2023 from Storage to EIT. Details are shown below under the Comparability Matrix heading.

| | FY 2024 Request vs FY 2023 Enacted |
|---|---|
| • Analytics for an Equitable Regulatory and Social Environment: launch a new ES4SE cohort with five to ten communities in the initial technical assistance phase | +3,487 |
| • Grid and Field Validation: expand ROVI to improve the performance projection methodologies of two to three new non-lithium electrochemistries and launch a new ES4SE cohort with two to four communities reaching the second, pilot phase | +14,272 |
| • Section 3201 Pilot Demonstration Grants: planned activities for this congressionally directed activity are completed with funding provided in FY 2022 and 2023 | -19,747 |
| • Storage and Microgrid Deployment Assistance: planned activities for this congressionally directed activity are completed with funding provided in FY 2023 | -4,937 |
| **Total, Energy Storage** | **-10,365** |

**Energy Storage**

**Activities and Explanation of Changes**

| FY 2023 Enacted (Comparable) | FY 2024 Request | Explanation of Changes FY 2024 Request vs FY 2023 Enacted |
|---|---|---|
| **Research $88,965,000** | **$78,600,000** | **-$10,365,000** |
| *Cost-Competitive and Long-Duration Technology Development $34,493,000* | *$28,000,000* | *-$6,493,000* |
| • 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.<br>• Continue focused development programs on other earth-abundant materials systems (sodium, zinc, sulfur, etc.) with potential to meet the 2030 LCOS target | • Accelerate development programs on other earth-abundant materials (sodium, zinc, sulfur, etc.) with the potential to meet the 2030 LCOS target<br>• Develop and test prototype packs for one to two additional cell chemistries in the 1–5 kW, 5–10 kWh scale<br>• Integrate power electronics and power converter designs into prototype systems capable of operating under simulated grid environments | • The emerging technology FOA is fully funded in FY 2023<br>• FY 2024 funding is reallocated to support activities in the Analytics and Field Validation subprograms |

| FY 2023 Enacted (Comparable) | FY 2024 Request | Explanation of Changes<br>FY 2024 Request vs FY 2023 Enacted |
|---|---|---|
| • 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<br>• 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 $11,947,000* | *$15,000,000* | *+$3,053,000* |
| • Expand training and technical assistance to fire officials and safety code officials for energy storage best practices<br>• 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<br>• 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 | • Continue training and technical assistance to fire officials and safety code officials for energy storage best practices<br>• 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<br>• Continue 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 | • Increase reflects rising costs of continuing activities and expanded outreach to key stakeholders (including fire safety, codes and standards, and other groups) given the growing number of energy storage installations |
| *Analytics for an Equitable Regulatory and Social Environment $8,113,000* | *$11,600,000* | *+3,487,000* |
| • Continue support for execution of projects selected under FY 2022 FOA<br>• Continue engagement with PUC's and States developing energy storage policy and integrated resource planning<br>• Continue Energy Storage for Social Equity Technical Assistance (ES4SE) Program | • Launch a new ES4SE cohort with five to ten communities in the initial technical assistance phase<br>• Continue outreach to end users, utilities, regulators, the financial industry, and other storage decisionmakers | • Expansion of activities under ES4SE |

| FY 2023 Enacted (Comparable) | FY 2024 Request | Explanation of Changes<br>FY 2024 Request vs FY 2023 Enacted |
|---|---|---|
| *Grid and Field Validations $9,728,000* | *$24,000,000* | *+14,272,000* |
| • Develop ROVI, to incorporate data and models for one to two additional chemistries or storage technology types<br>• Continue development of higher fidelity software tools and analytical models for the optimal value and sizing based on storage location<br>• Add additional functionality to tools to quantify environmental (e.g., greenhouse gas reduction) and social benefits storage provides | • Expand ROVI to improve the performance projection methodologies of two to three non-lithium electrochemistries<br>• Launch a new ES4SE cohort with two to four communities reaching the second, pilot phase<br>• Continue development of software tools and analytical models for the optimal value, sizing, and location of storage resources, as well as quantifying environmental and social benefits | • Expansion of activities under ROVI and ES4SE |
| *Section 3201 Pilot Demonstration Grants $19,747,000* | *$0* | *-$19,747,000* |
| • New competitive opportunity to accelerate large scale commercial development and deployment of energy storage technologies, including for long-cycle-life lithium grid-scale batteries | | • Planned activities for this congressionally directed activity are completed with funding provided in FY 2022 and 2023 |
| *Storage and Microgrid Deployment Assistance $4,937,000* | *$0* | *-$4,937,000* |
| • Support electric cooperatives and municipal power utilities in the analysis and deployment of energy storage technologies | | • Planned activities for this congressionally directed activity are completed with funding provided in FY 2023 |

**Construction Projects Summary ($K)**

| | Total Project Cost (TPC) | Prior Years | FY 2022 Enacted | FY 2023 Enacted | FY 2024 Request | FY 2024 Request vs FY 2023 Enacted | Future Years |
|---|---|---|---|---|---|---|---|
| **20-OE-100 Grid Storage Launchpad** | | | | | | | |
| Total Estimated Cost (TEC) | 75,000 | 28,000 | 47,000 | 0 | 0 | 0 | 0 |
| Other Project Costs (OPC) | 2,000[a] | 1,000[a] | 0 | 1,000[a] | 0 | -1,000 | 0 |
| TPC | 77,000 | 29,000 | 47,000 | 1,000 | 0 | -1,000 | 0 |

[a] OPC is funded through laboratory overhead.

**Comparability Matrix**

The table below shows the Small Business Innovation Research (SBIR), Technology Commercialization Fund (TCF), and workforce development funding associated with Energy Storage in FY 2022 and FY 2023 under both the prior budget structure, where these activities were funded within Energy Storage, and the proposed budget structure, where these activities are consolidated across OE under the new Electricity Innovation and Transition (EIT) program.

| | FY 2024 Proposed Budget Structure ($K) | | | | | |
|---|---|---|---|---|---|---|
| | FY 2022 Enacted | | | FY 2023 Enacted | | |
| | Energy Storage | EIT | Total | Energy Storage | EIT | Total |
| **FY 2022 and FY 2023 Budget Structure** | | | | | | |
| Energy Storage | | | | | | |
| Cost-Competitive & Long-Duration Technology Development | | | | | | |
| SBIR | 0 | 703 | 703 | 0 | 1,279 | 1,279 |
| TCF | 0 | 122 | 122 | 0 | 228 | 228 |
| Workforce Development | 0 | 0 | 0 | 0 | 3,000 | 3,000 |
| Other Cost-Competitive & Long-Duration Technology Development | 18,575 | 0 | 18,575 | 34,493 | 0 | 34,493 |
| Total, Cost-Competitive & Long-Duration Technology Development | 18,575 | 825 | 19,400 | 34,493 | 4,507 | 39,000 |
| Validated Reliability & Safety | | | | | | |
| SBIR | 0 | 529 | 529 | 0 | 441 | 441 |
| TCF | 0 | 132 | 132 | 0 | 112 | 112 |
| Other Validated Reliability and Safety | 13,939 | 0 | 13,939 | 11,947 | 0 | 11,947 |
| Total, Validated Reliability & Safety | 13,939 | 661 | 14,600 | 11,947 | 553 | 12,500 |
| Analytics for an Equitable Regulatory & Social Environment | | | | | | |
| SBIR | 0 | 268 | 268 | 0 | 310 | 310 |
| TCF | 0 | 67 | 67 | 0 | 77 | 77 |
| Other Analytics for an Equitable Regulatory & Social Environment | 7,065 | 0 | 7,065 | 8,113 | 0 | 8,113 |
| Total, Analytics for an Equitable Regulatory & Social Environment | 7,065 | 335 | 7,400 | 8,113 | 387 | 8,500 |
| Grid Deployment & Field Validations | | | | | | |
| SBIR | 0 | 120 | 120 | 0 | 182 | 182 |
| TCF | 0 | 59 | 59 | 0 | 90 | 90 |
| Other Grid Deployment & Field Validations | 6,421 | 0 | 6,421 | 9,728 | 0 | 9,728 |
| Total, Grid Deployment & Field Validations | 6,421 | 179 | 6,600 | 9,728 | 272 | 10,000 |

| | FY 2024 Proposed Budget Structure ($K) | | | | | |
|---|---|---|---|---|---|---|
| | FY 2022 Enacted | | | FY 2023 Enacted | | |
| | Energy Storage | EIT | Total | Energy Storage | EIT | Total |
| Section 3201 Pilot Demonstration Grants | | | | | | |
| SBIR | 0 | 0 | 0 | 0 | 73 | 73 |
| TCF | 0 | 180 | 180 | 0 | 180 | 180 |
| Other Section 3201 Pilot Demonstration Grants | 19,820 | 0 | 19,820 | 19,747 | 0 | 19,747 |
| Total, Section 3201 Pilot Demonstration Grants | 19,820 | 180 | 20,000 | 19,747 | 253 | 20,000 |
| Resilience Projects | | | | | | |
| SBIR | 0 | 91 | 91 | 0 | 0 | 0 |
| TCF | 0 | 45 | 45 | 0 | 0 | 0 |
| Other Resilience Projects | 4,864 | 0 | 4,864 | 0 | 0 | 0 |
| Total, Resilience Projects | 4,864 | 136 | 5,000 | 0 | 0 | 0 |
| Storage & Microgrid Deployment Assistance | | | | | | |
| SBIR | 0 | 0 | 0 | 0 | 18 | 18 |
| TCF | 0 | 0 | 0 | 0 | 45 | 45 |
| Other Storage & Microgrid Deployment Assistance | 0 | 0 | 0 | 4,937 | 0 | 4,937 |
| Total, Storage & Microgrid Deployment Assistance | 0 | 0 | 0 | 4,937 | 63 | 5,000 |
| Construction | 47,000 | 0 | 47,000 | 0 | 0 | 0 |
| Total, Energy Storage | 117,684 | 2,316 | 120,000 | 88,965 | 6,035 | 95,000 |
| *SBIR Recap* | *0* | *1,711* | *1,711* | *0* | *2,303* | *2,303* |
| *TCF Recap* | *0* | *605* | *605* | *0* | *732* | *732* |
| *Workforce Development Recap* | *0* | *0* | *0* | *0* | *3,000* | *3,000* |
| *Other Energy Storage Recap* | *117,684* | *0* | *117,684* | *88,965* | *0* | *88,965* |

## Transformer Resilience and Advanced Components

**Overview**

The Transformer Resilience and Advanced Components (TRAC) program identifies and addresses issues facing the electric transmission system due to the rapid changes challenging the system. The TRAC program develops innovations to carry, control, convert, and condition electricity to ensure the system is future ready. These innovations equip the future-ready grid to achieve decarbonization goals while enhancing its reliability and resilience. As every aspect of daily life increasingly depends on the grid, legacy approaches to power conversion and delivery will no longer be sufficient. TRAC principles—to incorporate flexible, modular, and data-driven approaches—will ensure that every component of the grid will be ready to serve the clean energy future.

Flexibility will be a major advantage of new critical grid components. For example, a large power transformer (LPT) failure could disrupt power to a half million homes. Even prior to recent supply chain disruptions, a replacement could take over 12 months to procure, transport, and install in large part because LPTs are nearly always custom-made. TRAC supports innovative transformer designs that are more flexible and adaptable, enabling fewer standardized designs to be used in more locations, which decreases manufacturing lead times while increasing the applicability of spare inventory. The program covers full range of electric power transformers from LPTs to distribution service transformers.

Modularity will be an essential part of grid infrastructure planning. Trends such as the increasing adoption of rooftop solar and electric vehicles will introduce new uncertainties in load growth projections. Consumer behaviors and technological improvements could require new grid capacity in increasingly unpredictable ways. Legacy grid expansion approaches, with long lead times and large, lumpy installations, are insufficient in this new environment. TRAC supports innovative grid-enhancing technologies (GETs), High Voltage Direct Current (HVDC) technologies, and solid-state power substations (SSPS) to enable faster capacity additions at a smaller, granular scale. In the near term, HVDC technologies and GETs, including dynamic line ratings and power flow controllers, will help unlock more capacity from existing and future infrastructure. In the medium to long term, the SSPS building block concept will allow for nearly on-demand capacity additions or reallocations. These modular and scalable designs enable greater standardization and allow for more cost-effective capacity expansion. Additional benefits include smaller module sizes for ease of transport and lower power ratings to reduce criticality.

Data-driven approaches will be necessary for a resilient and efficient grid. For example, transmission and distribution (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. The next generation of these grid hardware technologies will need to anticipate, withstand, and rapidly recover from the impact of extreme events, including from terrestrial and space weather events, other electrical disturbances, equipment failures, accidents, deliberate attacks, and other unknowns. Local intelligence with embedded sensors, data processing, and communications would enable real-time health monitoring, reducing maintenance costs and enhancing system reliability. Leveraging results from other OE activities, including phasor measurement units (PMUs) and other sensors, and incorporating emerging technologies, including unmanned aerial vehicles (UAVs), TRAC technologies will proactively respond to a changing threat landscape to enhance the security, reliability, and resilience of the electric power system.

The TRAC scope encompasses materials research, exploratory concepts, and modeling and analysis to address the range of challenges associated with transformers and other grid components. Specific technologies include transformers, cables and conductors, power flow and voltage controllers, protection equipment and switchgear, and equipment sensors. Program activities, developed in close coordination with industry, aim to fill fundamental research and development (R&D) gaps and encourage the adoption of new technologies and approaches.

Applied Material R&D targets the use of advanced materials for improvements in magnetics, packaging, and insulation to increase voltage and power capability while withstanding more rigorous environments, including for use in HVDC technologies. Component Design and Development addresses critical GET and SSPS research needs with an emphasis on embedded intelligence for equipment monitoring, validation of prototype converter building blocks, and medium voltage

converter building block development.[a] Market and System Impact Analysis supports high-fidelity modeling and simulation to help the grid community understand the value and impact of these improved grid component capabilities.

**Highlights of the FY 2024 Budget Request**
The Request continues materials, component, and system development to enable next-generation transformers and converters. Major technology focus areas in FY 2024 include:

- Market and System Impact Analysis: The Request supports developing a framework for a distribution-scale pilot for advanced power electronic systems, and the continued 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. The Request also supports the development of a next-generation transformer technology roadmap structured to provide the context, rationale, and potential benefits of utilizing the next-generation of transformers and articulates a research, development, and demonstration pathway to accelerate maturation. It aims to capture the state of the art in critical enabling technologies, highlight research gaps and opportunities, and align disparate activities across stakeholder communities to realize the next-generation transformer vision.
- Component Design and Development: The Request supports continued device and operational improvements for SSPS technologies as identified in the 2020 SSPS roadmap. The high-voltage, high-power, and high-reliability requirements of grid applications present unique challenges for SSPS 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 flexibility, reliability, and resilience. The Request advances modular, scalable, and flexible transformers from early concept prototypes systems to larger systems suitable for field validation, enabling standardized designs to increase grid resilience. The Request also supports the development of HVDC and medium voltage DC (MVDC) hardware components, controls, testbeds, and advanced concepts to address technical challenges of HVDC deployment.
- Applied Material R&D: The Request supports continued improvements in magnetics, conductors, packaging, and insulation, targeting increases in heat dissipation, electrical and thermal conductivity, mechanical strength, voltage limits, and operational durability.
- Equipment and system condition monitoring: The Request supports the continued development of technologies to improve situational awareness of the condition of the power grid systems, subsystems, and components. This will include the development and application of sensing technologies and the utilization of emerging platforms such as robotics and UAVs.
- 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.

Support of R&D activities through the Grid Modernization Initiative, including 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 2022 Enacted (Comparable)[a] | FY 2023 Enacted (Comparable)[a] | FY 2024 Request | FY 2024 Request vs FY 2023 Enacted ($) | FY 2024 Request vs FY 2023 Enacted (%) |
|---|---|---|---|---|---|
| **Transformer Resilience and Advanced Components** | | | | | |
| Market and System Impact Analysis | 1,435 | 4,773 | 3,000 | -1,773 | -37.1% |
| Component Design and Development | 2,442 | 14,591 | 15,800 | +1,209 | +8.3% |
| Applied Material R&D | 959 | 2,424 | 2,900 | +476 | +19.6% |
| Grid Research Integration & Design Center | 4,827 | 4,827 | 0 | -4,827 | -100.0% |
| Composite Utility Pole Assessment | 973 | 0 | 0 | 0 | N/A |
| **Total, TRAC** | **10,636** | **26,615** | **21,700** | **-4,915** | **-18.5%** |

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

| | FY 2024 Request vs FY 2023 Enacted |
|---|---|
| • Market and System Impact Analysis: reduction reflects tapering of market and system analysis phase of Smart Universal Power Electronics Regulators (SUPER) and SSPS development | -1,773 |
| • Component Design and Development: increases to accelerate addressing HVDC hardware technical challenges, to perform a field validation of the SUPER device, and to further expand the development of modular and scalable transformers | +1,209 |
| • Applied Material R&D: advanced materials, embedded intelligence for equipment monitoring, validation of prototype converter building blocks, and medium voltage converter building block development | +476 |
| • Grid Research Integration & Design Center: planned activities for this congressionally directed activity are completed with funding provided in FY 2023 | -4,827 |
| **Total, TRAC** | **-4,915** |

[a] The FY 2024 Request proposes to consolidate all Small Business Innovation Research, Technology Commercialization Fund, and workforce development activities under the new Electricity Innovation and Transition (EIT) program. To allow an apples-to-apples comparison, FY 2022 and FY 2023 are shown as if this approach had been in place since in FY 2022, moving $364,000 in FY 2022 and $885,000 in FY 2023 from TRAC to EIT.

**Activities and Explanation of Changes**

| FY 2023 Enacted (Comparable) | FY 2024 Request | Explanation of Changes<br>FY 2024 Request vs FY 2023 Enacted |
|---|---|---|
| **Transformer Resilience and Advanced Components**<br>**$26,615,000** | **$21,700,000** | **-$4,915,000** |
| *Market and System Impact Analysis $4,773,000* | *$3,000,000* | *-$1,773,000* |
| • Develop the Smart Universal Power Electronics Regulators (SUPER) library, the SSPS controller for the consumer end node and validate the use case<br>• Develop characterization methods and tools to evaluate reliability, transient stability, and economics of large-scale DC architectures in AC grids | • Develop a framework and analysis to evaluate the future architecture impact of advanced power flow controllers and distribution scale components<br>• Develop a framework for a distribution scale architecture pilot for advanced power electronic systems<br>• Develop the next-generation transformer technology roadmap structured to provide the context, rationale, and potential benefits of utilizing the next-generation of transformers | • Tapers off market and system analysis phase of SUPER and SSPS development |
| *Component Design and Development $14,591,000* | *$15,800,000* | *+$1,209,000* |
| • Develop reliable medium voltage power stages with advanced features for SSPS<br>• Develop advanced medium voltage to high voltage semiconductor modules<br>• Develop advanced gate driver technologies to support advanced semiconductor switches<br>• Develop high voltage auxiliary power supply stages<br>• Develop subsystems to support electromagnetic interference (EMI) mitigation and thermal limitations<br>• Develop advanced features for diagnostics and prognostics of future grid interfaces | • Develop a prototype to initiate a field demonstration activity of new modular power conversion devices such as the SUPER device at the low-voltage levels<br>• Develop HVDC and MVDC hardware components, controls, testbeds, and advanced concepts to address technical challenges of HVDC deployment<br>• Continue the development of reliable medium-voltage SUPERs with advanced features for SSPS, including advanced features for diagnostics and prognostics | • Accelerates addressing HVDC hardware technical challenges to perform a field validation of the SUPER device and to further expand the development of modular, flexible, and scalable transformers |

| FY 2023 Enacted (Comparable) | FY 2024 Request | Explanation of Changes<br>FY 2024 Request vs FY 2023 Enacted |
|---|---|---|
| • Test and validate Grid Enhancing Technologies (GETs) by conducting a full scale, multi-faceted field exercise | • Develop and expand modular, scalable, and flexible transformers from early-concept prototypes systems to larger systems suitable for field validation | |
| *Applied Material R&D $2,424,000* | *$2,900,000* | *+$476,000* |
| • Develop magnetics and passives to advance basic insulation level and high-frequency requirements for power electronic systems and future grid infrastructure<br>• Develop high voltage and high current interconnects to support the integration of subsystems for large-scale power electronic systems<br>• Research to address critical needs in packaging for the high voltage, high current, and high-temperature environments associated with power electronic systems, transmission, distribution<br>• Address insulation issues associated with transmission, sub-transmission, and distribution voltage grid systems<br>• Fund a prize program to demonstrate Power Electronic Systems (PES) developed using recycled/refurbished parts | • Develop soft magnetics to fill a gap in commercially available core materials for power conversion applications<br>  • Improvements in core materials are needed to achieve the efficiencies, power densities, and reliabilities required for emerging power conversion applications<br>• Continue the development of advanced materials with improved performance for overhead transmission cables<br>• Develop packaging solutions to enable high voltage, high power wide bandgap modules<br>• Develop and demonstrate mechanical bushing isolator solutions to address seismic vulnerabilities and reduce outage risk from LPT failure | • Addresses LPT seismic vulnerabilities and further develops packaging solutions |
| *Grid Research Integration & Demo Center $4,827,000* | *$0* | *-$4,827,000* |
| • Validate a 480 V SSPS 1.0 node which aggregates multiple downstream SUPERs connected to assets/loads<br>• Develop and demonstrate the SSPS controller capable of coordinating the downstream resources (nodes or hubs) using a Controller-Hardware-in-the-Loop (CHIL) test bed in GRID-C | | • Planned activities for this congressionally directed activity are completed with funding provided in FY 2023 |

| FY 2023 Enacted (Comparable) | FY 2024 Request | Explanation of Changes<br>FY 2024 Request vs FY 2023 Enacted |
|---|---|---|
| • Develop a baseline IPS using 3.3 kV semiconductor devices for medium voltage (MV) DC–DC applications, and validate at GRID-C<br>• Continue the development of the GRID-C facility by providing support on the operation, purchase, and maintenance of infrastructure and equipment. | | |

**Comparability Matrix**

The table below shows the Small Business Innovation Research (SBIR) and Technology Commercialization Fund (TCF) funding associated with TRAC in FY 2022 and FY 2023 under both the prior budget structure, where these activities were funded within TRAC, and the proposed budget structure, where these activities are consolidated across OE under the new Electricity Innovation and Transition (EIT) program.

| | FY 2024 Proposed Budget Structure ($K) | | | | | |
|---|---|---|---|---|---|---|
| | FY 2022 Enacted | | | FY 2023 Enacted | | |
| | TRAC | EIT | Total | TRAC | EIT | Total |
| **FY 2022 and FY 2023 Budget Structure** | | | | | | |
| Transformer Resilience & Advanced Components | | | | | | |
| Market and System Impact Analysis | | | | | | |
| SBIR | 0 | 52 | 52 | 0 | 182 | 182 |
| TCF | 0 | 13 | 13 | 0 | 45 | 45 |
| Other Market and System Impact Analysis | 1,435 | 0 | 1,435 | 4,773 | 0 | 4,773 |
| Total, Market and System Impact Analysis | 1,435 | 65 | 1,500 | 4,773 | 227 | 5,000 |
| Component Design and Development | | | | | | |
| SBIR | 0 | 35 | 35 | 0 | 274 | 274 |
| TCF | 0 | 23 | 23 | 0 | 135 | 135 |
| Other Component Design and Development | 2,442 | 0 | 2,442 | 14,591 | 0 | 14,591 |
| Total, Component Design and Development | 2,442 | 58 | 2,500 | 14,591 | 409 | 15,000 |

| | FY 2024 Proposed Budget Structure ($K) | | | | | |
|---|---|---|---|---|---|---|
| | FY 2022 Enacted | | | FY 2023 Enacted | | |
| | TRAC | EIT | Total | TRAC | EIT | Total |
| Applied Material R&D | | | | | | |
| SBIR | 0 | 34 | 34 | 0 | 56 | 56 |
| TCF | 0 | 7 | 7 | 0 | 20 | 20 |
| Other Applied Material R&D | 959 | 0 | 959 | 2,424 | 0 | 2,424 |
| Total, Applied Material R&D | 959 | 41 | 1,000 | 2,424 | 76 | 2,500 |
| Grid Research Integration & Design Center | | | | | | |
| SBIR | 0 | 128 | 128 | 0 | 128 | 128 |
| TCF | 0 | 45 | 45 | 0 | 45 | 45 |
| Other Grid Research Integration & Design Center | 4,827 | 0 | 4,827 | 4,827 | 0 | 4,827 |
| Total, Grid Research Integration & Design Center | 4,827 | 173 | 5,000 | 4,827 | 173 | 5,000 |
| Composite Utility Pole Assessment | | | | | | |
| SBIR | 0 | 18 | 18 | 0 | 0 | 0 |
| TCF | 0 | 9 | 9 | 0 | 0 | 0 |
| Other Composite Utility Pole Assessment | 973 | 0 | 973 | 0 | 0 | 0 |
| Total, Composite Utility Pole Assessment | 973 | 27 | 1,000 | 0 | 0 | 0 |
| Total, TRAC | 10,636 | 364 | 11,000 | 26,615 | 885 | 27,500 |
| *SBIR Recap* | *0* | *267* | *267* | *0* | *640* | *640* |
| *TCF Recap* | *0* | *97* | *97* | *0* | *245* | *245* |
| *Other TRAC Recap* | *10,636* | *0* | *10,636* | *26,615* | *0* | *26,615* |

## Applied Grid Transformation Solutions

**Overview**

America's grid is transforming into a more dynamic and structurally complex system. This complexity includes bidirectional power flows, increasing sources of renewable energy, and the electrification of the transportation and building sector, all while contending with varied threat challenges. Managing this transition will require significant reengineering and advancements in grid technology and system architectures. Innovative technological advances are needed to accomplish these changes while still meeting the strict performance requirements of a safety- and reliability-focused industry that requires high confidence to consider new solutions. The performance and benefits of these innovative grid technologies, systems, and subsystems must be assessed and validated for their ability to meet evolving demands, their integrability into an increasingly complex legacy system, and their compatibility with very diverse operational, institutional, and regulatory contexts.

The Applied Grid Transformation Solutions (AGTS) program addresses the pressing need for rapidly assessing new grid systems and subsystems (including energy storage, transmission, distribution, and power control and conversion hardware and associated software) by testing the integrated technology suites in pilot environments prior to the hardware and software being deployed by industry in operational environments. These assessments provide utilities with the information they need to quantify and validate functionality, performance, and economic benefits before deploying new technologies. Today, the benefits of new grid technologies are difficult to extrapolate when tested in isolation and difficult to quantify when measuring some socio-economic benefits such as resilience. AGTS pilot integrations will yield the actionable information desired by utilities and regulators to drive new technology adoption, including performance under various conditions and specific validated data on technology costs, uses, and capabilities; investment value and feasibility; cost recovery during changing times; and requirements for integration with other systems. The results of the pilot demonstration will validate the techno-socio-economic performance of the systems and will help to accelerate the adoption of new technology by industry.

AGTS will work with national laboratories, private industry, and academia to develop national electrical grid advanced testing capabilities. To meet the Administration's goals of 100% carbon pollution-free electricity by 2035 and net zero-emissions by 2050, advanced grid hardware and software will be needed and test beds where these new technologies can be safely tested are a key to providing industry confidence and enabling industry adoption.

AGTS will coordinate with other R&D programs and build on previous Grid Modernization Laboratory Consortium (GMLC) devices and integrated system projects.

**Highlights of the FY 2024 Budget Request**

Initiated in FY 2023, AGTS assesses how new grid 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 decision makers. AGTS will identify the most suitable pilot environments to conduct testing and 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) systems
- Advanced conductors
- Advanced transformers including flexible and modular large power transformers (LPTs), hybrid and solid-state transformers, and distribution service transformers
- Dynamic line rating, dynamic transformer rating systems
- Power flow controllers (PFCs)
- Sensors and system and equipment condition monitoring solutions
- Dynamic topology configuration solutions
- Energy storage systems
- Advanced alternating current (AC) and direct current (DC) microgrids
- Power-electronics-based systems
- Other hardware and associated software and controls and communications technologies

The technologies will be integrated into the pilot environments and operated to validate the performance and operational capabilities of the new technologies for a variety of use cases. Results from the AGTS hardware-in-the-loop and other types of demonstrations will be shared with broader decision makers, such as planners, operators, manufacturers, investors, regulators, and ratepayers. 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, decision makers should have sufficient information to evaluate new transmission and distribution approaches alongside legacy solutions. Project results can also inform manufacturers in addressing new or emerging market opportunities.

In FY 2024, AGTS will:

- Continue stakeholder-focused Grid Transformation Summits to show how new technologies enable community, state, and regional goals
- Continue technical assistance through modeling, analysis, and use case validation by leveraging existing OE and Grid Modernization Initiative (GMI) tools and utilizing pilot projects to test stakeholder-focused hardware-in-the-loop use cases
- Support at least two new pilots to validate technological maturity and show how new technologies achieve desired environmental, societal, policy, and market outcomes, and will be targeted to provide regional diversity
- Develop national electrical grid advanced testing capabilities in collaboration with national laboratories, private industry, and academia
- Continue working groups for industry outreach to gather feedback and target new grid technology demonstration needs
- Create workshops for information sharing, education, and support adoption
- Create demonstration and deployment pathways for multiple advanced grid technologies, to build a shared DOE-and-industry perspective on requirements to achieve private sector lift-off for key grid technology areas

AGTS will include coordination with the GMLC on shared technology development objectives. FY 2024 integrated pilots will showcase resiliency and renewable integration objectives aligned with the GMI and other DOE crosscutting efforts.

**Applied Grid Transformation Solutions**
**Funding ($K)**

| | FY 2022 Enacted | FY 2023 Enacted (Comparable)[a] | FY 2024 Request | FY 2024 Request vs FY 2023 Enacted | FY 2024 Request vs FY 2023 Enacted (%) |
|---|---|---|---|---|---|
| **Applied Grid Transformation Solutions** | | | | | |
| Scoping, Design, and Stakeholder Collaboration | 0 | 1,945 | 9,880 | +7,935 | +408.0% |
| Demonstrations | 0 | 7,928 | 19,820 | +11,892 | +150.0% |
| **Total, AGTS** | **0** | **9,873** | **29,700** | **+19,827** | **+200.8%** |

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

| | FY 2024 Request vs FY 2023 Enacted |
|---|---|
| • Scoping, Design, and Stakeholder Collaboration: Create workshops for information sharing, education, and supporting adoption of new technologies; scope an electrical grid national test bed in collaboration with national laboratories, academia, and private industry; and create demonstration and deployment pathways for multiple advanced grid technologies | +7,935 |
| • Demonstrations: Develop electrical grid national test beds to support advance grid technology validation | +11,892 |
| **Total, AGTS** | **+19,827** |

[a] The FY 2024 Request proposed to consolidate all Small Business Innovation Research, Technology Commercialization Fund, and workforce development activities under the new Electricity Innovation and Transition (EIT) program. To allow an apples-to-apples comparison, FY 2023 is shown as if this approach had been in place, moving $127,000 in FY 2023 from AGTS to EIT. Detailed adjustments are shown in the Comparability Matrix section below.

## Applied Grid Transformation Solutions

**Activities and Explanation of Changes**

| FY 2023 Enacted (Comparable) | FY 2024 Request | Explanation of Changes<br>FY 2024 Request vs FY 2023 Enacted |
|---|---|---|
| **Applied Grid Transformation Solutions $9,873,000** | **$29,700,000** | **+$19,827,000** |
| *Scoping, Design, and Stakeholder Collaboration*<br>*$1,945,000* | *$9,880,000* | *+$7,935,000* |
| • Conduct stakeholder-focused grid transformation working groups<br>• Provide technical assistance to State and local governmental entities, Tribal nations, and others through modeling, analysis, and use case validation | • Continue stakeholder-focused grid transformation working groups<br>• Continue technical assistance to State and local governmental entities, tribal nations, and others through modeling, analysis, and use case validation<br>• Scope an electrical grid national test bed in collaboration with national laboratories, academia, and private industry and in coordination with GMLC and DOE offices/programs<br>• Create workshops with industry to support information sharing and adoption, each working group will be a case-by-case activity<br>• Create demonstration and deployment pathways for multiple advanced grid technologies, to build a shared DOE-and-industry perspective on requirements to achieve private sector lift-off for key grid technology areas | • Create workshops for information sharing, education, and supporting adoption<br>• Scope an electrical grid national test bed in collaboration with national laboratories, academia, and private industry<br>• Create demonstration and deployment pathways for multiple advanced grid technologies |

| FY 2023 Enacted (Comparable) | FY 2024 Request | Explanation of Changes<br>FY 2024 Request vs FY 2023 Enacted |
|---|---|---|
| *Demonstrations $7,928,000* | *$19,820,000* | *+$11,892,000* |
| • Support an advanced conductor/cable pilot for reconducting existing power lines with double capacity conductor/cable, without the need to rebuild existing infrastructure, to increase grid efficiency and allow for more renewable connections to the grid<br>• Support a grid enhancing technology pilot for increased capacity, resiliency, and reliability using existing energy delivery pathways<br>• Support an advanced modular/flexible transformer pilot to reduce long transformer lead times, provide system flexibility, and help move the industry to a smarter grid | • Support at least 2 large-scale demonstrations and validations with an emphasis on regional diversity<br>• Provide demonstration and validation of new grid technologies building on FY 2023 pilots<br>• Based on the results of scoping, design, and stakeholder collaboration, develop test beds in collaboration with national laboratories, academia, and private industry to support advanced grid components | • Develop national electrical grid test beds to support advanced grid technology validation<br>• Support large-scale demonstration and validation activities with regional diversity |

**Comparability Matrix**

The table below shows the Small Business Innovation Research (SBIR) and Technology Commercialization Fund (TCF) funding associated with AGTS in FY 2023 under both the prior budget structure, where these activities were funded within AGTS, and the proposed budget structure, where these activities are consolidated across OE under the new Electricity Innovation and Transition (EIT) program.

| | FY 2024 Proposed Budget Structure ($K) | | |
|---|---|---|---|
| | FY 2023 Enacted | | |
| | AGTS | EIT | Total |
| **FY 2023 Budget Structure** | | | |
| Applied Grid Transformation Solutions | | | |
| Scoping, Design, and Stakeholder Collaboration | | | |
| SBIR | 0 | 37 | 37 |
| TCF | 0 | 18 | 18 |
| Other Scoping, Design, and Stakeholder Collaboration | 1,945 | 0 | 1,945 |
| Total, Scoping, Design, and Stakeholder Collaboration | 1,945 | 55 | 2,000 |

| | FY 2024 Proposed Budget Structure ($K) | | |
|---|---|---|---|
| | FY 2023 Enacted | | |
| | AGTS | EIT | Total |
| Demonstrations | | | |
| TCF | 0 | 72 | 72 |
| Other Demonstrations | 7,928 | 0 | 7,928 |
| Total, Demonstrations | 7,928 | 72 | 8,000 |
| Total, AGTS | 9,873 | 127 | 10,000 |
| *SBIR Recap* | *0* | *37* | *37* |
| *TCF Recap* | *0* | *90* | *90* |
| *Other AGTS Recap* | *9,873* | *0* | *9,873* |

## Electricity Innovation and Transition

### Overview

The global electricity sector is undergoing a profound transformation. The nation that leads the transformation will be a leader in the global economy and create economic prosperity for its citizens. The Electricity Innovation and Transition (EIT) program integrates a broader cross-section of the U.S. workforce into America's electricity innovation through its strategy to bring new talent and organizations into the electricity innovation sector in areas relevant to OE's mission. EIT provides competitive opportunities for researchers, students, small businesses, and other innovators and supports partnerships to promote workforce development and higher education within the OE's mission. This program seeks to ensure that access to these opportunities and benefits are equitably provided, specifically seeking ways to include communities that have historically faced limits in access to such capabilities, such as students and faculty at minority-serving institutions (MSIs).

The EIT program will be implemented by consolidating OE funding for Small Business Innovation Research (SBIR) and Technology Commercialization Fund (TCF) activities as well as workforce development activities: the Grid Storage Launchpad (GSL) Fellowship Program and workforce development through strategic partnerships with the National Science Foundation (NSF).

SBIR and TCF were previously funded within each of OE's other research and development (R&D) programs. The GSL Fellowship Program was previously funded within the Energy Storage program. Strategic partnerships with NSF were previously funded within Transmission Reliability and Resilience.

The reorganization of these efforts into a new program in FY 2024 provides a more flexible, streamlined, and transparent approach for OE to support innovators, small businesses, and researchers moving grid technologies forward and advancing workforce outcomes.

Under the Small Business Innovation Development Act of 1982, as amended, at least 3.2% of the Department's extramural basic research, applied research, and development funding each year is set aside for competitive SBIR awards. Under the Small Business Technology Transfer Act of 1992, as amended, at least a further 0.45% of this funding is also set aside for competitive Small Business Technology Transfer (STTR) awards, for a total set aside of at least 3.65%. Within DOE, smaller research programs such as OE provide all 3.65% to support SBIR awards, while other offices support a larger share of STTR awards to ensure DOE meets the agency-wide 3.2% SBIR and 0.45% STTR requirements.

### Highlights of the FY 2024 Budget Request

The Request includes support to continue the GSL Fellowship program, initiated in FY 2023. The GSL Fellowship promotes stakeholder and energy community familiarity with storage technologies and operations by leveraging the hands-on space and realistic simulation capabilities at DOE's GSL facility. Initial program design and recruitment have begun in FY 2023. FY 2024 funding will provide for ongoing support of the first cohorts as well as preparations for subsequent cohorts in FY 2024 or later.

This Request also includes support for the OE partnership with the NSF Division of Engineering Education and Centers (EEC) to invest in undergraduates through the Research Experiences for Undergraduates (REU) Program, as well as supporting non-academic graduate student internships for power systems through the NSF's INTERN Program to support workforce development in power systems to support the reliability, resilience, security, and efficiency of the electric power grid. REU programs helps facilitate undergraduate exposure to advanced topics, and this partnership will provide experiences to foster student interest in applying their interdisciplinary skills towards power sector applications. The INTERN program fosters long term partnerships between academic insutitions and industry, and will benefit the power sector by faciliating the application of research funded by NSF to the power system.

**Electricity Innovation and Transition**
**Funding ($K)**

| | FY 2022 Enacted (Comparable)[a] | FY 2023 Enacted (Comparable)[a] | FY 2024 Request | FY 2024 Request vs FY 2023 Enacted ($) | FY 2024 Request vs FY 2023 Enacted (%) |
|---|---|---|---|---|---|
| **Electricity Innovation and Transition** | | | | | |
| Small Business Innovation Research | 4,581 | 5,589 | 6,407 | +818 | +14.6% |
| Technology Commercialization Fund | 1,645 | 2,118 | 2,190 | +72 | +3.4% |
| Workforce Development | 0 | 4,000 | 5,403 | +1,403 | +35.1% |
| **Total, Electricity Innovation and Transition** | **6,226** | **11,707** | **14,000** | **+2,293** | **+19.6%** |

SBIR/STTR:

- FY 2022 Enacted: SBIR: $4,581
- FY 2023 Enacted: SBIR: $5,589
- FY 2024 Request: SBIR: $6,407

**Electricity Innovation and Transition**
**Explanation of Major Changes ($K)**

| | FY 2024 Request vs FY 2023 Enacted |
|---|---|
| • Small Business Innovation Research: A minimum of 3.65% of extramural basic, applied, and development R&D across OE is assessed for SBIR, and the increase over FY 2023 reflects changes in the overall OE request | +818 |
| • Technology Commercialization Fund: A minimum 0.9% of applied, development, and demonstration activities across OE is assessed for TCF and the increase over FY 2023 reflects changes in the overall OE request | +72 |
| • Workforce Development: Funding for GSL Fellowship program increases in FY 2024, and for a new workforce development effort for non-academic internships in power systems for graduate students associated with OE's electricity distribution activities in FY 2024 | +1,403 |
| **Total, Electricity Innovation and Transition** | **+2,293** |

[a] The FY 2024 Request proposes to consolidate all SBIR, TCF, and workforce development activities under the new EIT program. To allow an apples-to-apples comparison, FY 2022 and FY 2023 are shown as if this approach had been in place since FY 2022, moving $6,226,000 in FY 2022 and $11,070,000 in FY 2023 from OE's other R&D programs to EIT. Details of the funding sources are shown below in the Comparability Matrices section.

**Activities and Explanation of Changes**

| FY 2023 Enacted (Comparable) | FY 2024 Request | Explanation of Changes<br>FY 2024 Request vs FY 2023 Enacted |
|---|---|---|
| **Electricity Innovation and Transition $11,707,000** | **$14,000,000** | **+$2,293,000** |
| *Small Business Innovation Research $5,589,000* | *$6,407,000* | *+818,000* |
| • At least 3.65% of OE's extramural basic and applied research and development funding is set aside for competitive awards to small businesses | • At least 3.65% of OE's extramural basic, applied, and development research funding is set aside for competitive awards to small businesses | • Overall extramural basic and applied research and development funding increases in OE's Request |
| *Technology Commercialization Fund $2,118,000* | *$2,190,000* | *+$72,000* |
| • At least 0.9% of OE's applied research, development, and demonstration funding is set aside for the TCF to promote promising energy technologies for commercial purposes | • At least 0.9% of OE's applied research, development, and demonstration funding is set aside for the TCF to promote promising energy technologies for commercial purposes | • Overall applied research, development, and demonstration funding increases in OE's Request |
| *Workforce Development $4,000,000* | *$5,403,000* | *+$1,403,000* |
| • Partnerships with NSF's EEC division support REU programs focused on the electric power system modeling reliability research<br>• The GSL Fellowship begins in FY 2023 to support early-stage entities and early-career innovators of GSL's testing and validation capabilities for storage development | • Expansion of the NSF EEC partnership supports non-academic graduate student internships for power systems through the NSF's INTERN Program<br>• Continued partnership with NSF on REU programs for power systems supports workforce development in power systems to support the reliability, resilience, security, and efficiency of the electric power grid<br>• The GSL Fellowship supports the 2023 cohort as well as preparations for a second cohort in FY 2024 or later | • Funding increases for NSF partnerships to include non-academic internships to support industry workforce, as well as expansions of the REU programs to promote higher education in power systems applied research<br>• Funding increases for new electricity distribution workforce activities and increased energy storage workforce activities |

**Comparability Matrices**

The tables below show the SBIR, TCF, and workforce development funding in FY 2022 and FY 2023 under both the prior budget structure, where these activities were funded across OE's R&D programs, and the proposed budget structure, where these activities are consolidated under EIT across OE under the new EIT program.

FY 2022 Enacted Comparability Matrix

| | FY 2024 Proposed Budget Structure ($K) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | TRR | EDGOT | RDS | SecureNet | Energy Storage | TRAC | EIT | Total |
| **FY 2022 and FY 2023 Budget Structure** | | | | | | | | |
| Transmission Reliability & Resilience | | | | | | | | |
| SBIR | 0 | 0 | 0 | 0 | 0 | 0 | 840 | 840 |
| TCF | 0 | 0 | 0 | 0 | 0 | 0 | 219 | 219 |
| Other TRR | 24,941 | 0 | 0 | 0 | 0 | 0 | 0 | 24,941 |
| Total, TRR | 24,941 | 0 | 0 | 0 | 0 | 0 | 1,059 | 26,000 |
| Energy Delivery Grid Operations Technology | | | | | | | | |
| SBIR | 0 | 0 | 0 | 0 | 0 | 0 | 402 | 402 |
| TCF | 0 | 0 | 0 | 0 | 0 | 0 | 135 | 135 |
| Darknet | 0 | 0 | 0 | 9,672 | 0 | 0 | 0 | 9,672 |
| Other EDGOT | 0 | 12,791 | 0 | 0 | 0 | 0 | 0 | 12,791 |
| Total, EDGOT | 0 | 12,791 | 0 | 9,672 | 0 | 0 | 537 | 23,000 |
| Resilient Distribution Systems | | | | | | | | |
| SBIR | 0 | 0 | 0 | 0 | 0 | 0 | 1,010 | 1,010 |
| TCF | 0 | 0 | 0 | 0 | 0 | 0 | 490 | 490 |
| Other RDS | 0 | 0 | 53,500 | 0 | 0 | 0 | 0 | 53,500 |
| Total, RDS | 0 | 0 | 53,500 | 0 | 0 | 0 | 1,500 | 55,000 |
| Cyber Resilient & Secure Utility Communication Networks (SecureNet) | | | | | | | | |
| SBIR | 0 | 0 | 0 | 0 | 0 | 0 | 351 | 351 |
| TCF | 0 | 0 | 0 | 0 | 0 | 0 | 99 | 99 |
| Other SecureNet | 0 | 0 | 0 | 10,700 | 0 | 0 | 0 | 10,700 |
| Total, SecureNet | 0 | 0 | 0 | 10,700 | 0 | 0 | 450 | 11,150 |

| | FY 2024 Proposed Budget Structure ($K) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | TRR | EDGOT | RDS | SecureNet | Energy Storage | TRAC | EIT | Total |
| Energy Storage | | | | | | | | |
| SBIR | 0 | 0 | 0 | 0 | 0 | 0 | 1,711 | 1,711 |
| TCF | 0 | 0 | 0 | 0 | 0 | 0 | 605 | 605 |
| Other Energy Storage | 0 | 0 | 0 | 0 | 117,684 | 0 | 0 | 117,684 |
| Total, Energy Storage | 0 | 0 | 0 | 0 | 117,684 | 0 | 2,316 | 120,000 |
| Transformer Resilience & Advanced Components | | | | | | | | |
| SBIR | 0 | 0 | 0 | 0 | 0 | 0 | 267 | 267 |
| TCF | 0 | 0 | 0 | 0 | 0 | 0 | 97 | 97 |
| Other TRAC | 0 | 0 | 0 | 0 | 0 | 10,636 | 0 | 10,636 |
| Total, TRAC | 0 | 0 | 0 | 0 | 0 | 10,636 | 364 | 11,000 |
| Total | 24,941 | 12,791 | 53,500 | 20,372 | 117,684 | 10,636 | 6,226 | 246,150 |
| *SBIR Recap* | *0* | *0* | *0* | *0* | *0* | *0* | *4,581* | *4,581* |
| *TCF Recap* | *0* | *0* | *0* | *0* | *0* | *0* | *1,645* | *1,645* |
| *Other Recap* | *24,941* | *12,791* | *53,500* | *20,372* | *117,684* | *10,636* | *0* | *239,924* |

FY 2023 Request Comparability Matrix

| | FY 2024 Proposed Budget Structure ($K) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | TRR | EDGOT | RDS | SecureNet | Energy Storage | TRAC | AGTS | EIT | Total |
| **FY 2022 and FY 2023 Budget Structure** | | | | | | | | | |
| Transmission Reliability & Resilience | | | | | | | | | |
| SBIR | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1,126 | 1,126 |
| TCF | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 287 | 387 |
| Workforce Development | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1,000 | 1,000 |
| Other TRR | 31,587 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 31,587 |
| Total, TRR | 31,587 | 0 | 0 | 0 | 0 | 0 | 0 | 2,413 | 34,000 |
| Energy Delivery Grid Operations Technology | | | | | | | | | |
| SBIR | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 248 | 248 |
| TCF | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 138 | 138 |
| Other EDGOT | 0 | 30,614 | 0 | 0 | 0 | 0 | 0 | 0 | 30,614 |
| Total, EDGOT | 0 | 30,614 | 0 | 0 | 0 | 0 | 0 | 386 | 31,000 |

| | FY 2024 Proposed Budget Structure ($K) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | TRR | EDGOT | RDS | SecureNet | Energy Storage | TRAC | AGTS | EIT | Total |
| Resilient Distribution Systems | | | | | | | | | |
| SBIR | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 961 | 961 |
| TCF | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 491 | 491 |
| Other RDS | 0 | 0 | 53,548 | 0 | 0 | 0 | 0 | 0 | 53,548 |
| Total, RDS | 0 | 0 | 53,548 | 0 | 0 | 0 | 0 | 1,452 | 55,000 |
| Cyber Resilient & Secure Utility Communication Networks (SecureNet) | | | | | | | | | |
| SBIR | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 274 | 274 |
| TCF | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 135 | 135 |
| Other SecureNet | 0 | 0 | 0 | 14,591 | 0 | 0 | 0 | 0 | 14,591 |
| Total, SecureNet | 0 | 0 | 0 | 14,591 | 0 | 0 | 0 | 409 | 15,000 |
| Energy Storage | | | | | | | | | |
| SBIR | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2,303 | 2,303 |
| TCF | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 732 | 732 |
| Workforce Development | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3,000 | 3,000 |
| Other Energy Storage | 0 | 0 | 0 | 0 | 88,965 | 0 | 0 | 0 | 88,965 |
| Total, Energy Storage | 0 | 0 | 0 | 0 | 88,965 | 0 | 0 | 6,035 | 95,000 |
| Transformer Resilience & Advanced Components | | | | | | | | | |
| SBIR | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 640 | 640 |
| TCF | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 245 | 245 |
| Other TRAC | 0 | 0 | 0 | 0 | 0 | 26,615 | 0 | 0 | 26,615 |
| Total, TRAC | 0 | 0 | 0 | 0 | 0 | 26,615 | 0 | 885 | 27,500 |
| Applied Grid Transformation Solutions | | | | | | | | | |
| SBIR | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 37 | 37 |
| TCF | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 90 | 90 |
| Other AGTS | 0 | 0 | 0 | 0 | 0 | 0 | 9,873 | 0 | 9,873 |
| Total, AGTS | 0 | 0 | 0 | 0 | 0 | 0 | 9,873 | 127 | 10,000 |

| | FY 2024 Proposed Budget Structure ($K) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | TRR | EDGOT | RDS | SecureNet | Energy Storage | TRAC | AGTS | EIT | Total |
| Total | 31,587 | 30,614 | 53,548 | 14,591 | 88,965 | 26,615 | 9,873 | 11,707 | 267,500 |
| *SBIR Recap* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *5,589* | *5,589* |
| *TCF Recap* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *2,118* | *2,118* |
| *Workforce Development Recap* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *4,000* | *4,000* |
| *Other Recap* | *31,587* | *30,614* | *53,548* | *14,591* | *88,965* | *26,615* | *9,873* | *0* | *255,793* |

## 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 and Carbon Management (FECM) 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, Territories, 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 organizational knowledge, track performance and inventory data, and facilitate staff use of the information

**Other Related Expenses** includes corporate IT support (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 2024 Budget Request

The Program Direction Request reflects a small increase in Headquarters staffing to support the growing portfolio of activities in OE's programs. The increases also address promotions and within-grade 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 also supports staffing to address skill gaps and succession planning.

## Program Direction
## Funding ($K)

| | FY 2022 Enacted | FY 2022 Enacted (Comparable)[a] | FY 2023 Enacted | FY 2023 Enacted (Comparable)[a] | FY 2024 Request | FY 2024 Request vs FY 2023 Comp. Enacted ($) | FY 2024 Request vs FY 2023 Comp. Enacted (%) |
|---|---|---|---|---|---|---|---|
| **Program Direction Summary** | | | | | | | |
| **Washington Headquarters** | | | | | | | |
| Salaries and Benefits | 11,137 | 9,177 | 13,542 | 10,182 | 10,927 | +745 | +7.3% |
| Travel | 460 | 410 | 430 | 400 | 430 | +30 | +7.5% |
| Support Services | 1,312 | 949 | 2,290 | 1,179 | 1,186 | +7 | +0.6% |
| Other Related Expenses | 3,643 | 3,346 | 3,132 | 2,897 | 2,910 | +13 | +0.4% |
| **Total, Washington Headquarters** | **16,552** | **13,882** | **19,394** | **14,658** | **15,453** | **+795** | **+5.4%** |
| **National Energy Technology Laboratory** | | | | | | | |
| Salaries and Benefits | 1,734 | 1,502 | 1,953 | 1,511 | 1,595 | +84 | +5.6% |
| Travel | 74 | 44 | 49 | 45 | 50 | +5 | +11.1% |
| Support Services | 376 | 325 | 324 | 324 | 340 | +16 | +4.9% |
| Other Related Expenses | 1,264 | 1,247 | 1,280 | 1,255 | 1,237 | -18 | -1.4% |
| **Total, National Energy Technology Laboratory** | **3,448** | **3,118** | **3,606** | **3,135** | **3,222** | **+87** | **+2.8%** |
| **Total Program Direction** | | | | | | | |
| Salaries and Benefits | 12,871 | 10,679 | 15,495 | 11,693 | 12,522 | +829 | +7.1% |
| Travel | 534 | 454 | 479 | 445 | 480 | +35 | +7.9% |
| Support Services | 1,688 | 1,274 | 2,614 | 1,503 | 1,526 | +23 | +1.5% |
| Other Related Expenses | 4,907 | 4,593 | 4,412 | 4,152 | 4,147 | -5 | -0.1% |
| **Total, Program Direction** | **20,000** | **17,000** | **23,000** | **17,793** | **18,675** | **+882** | **+5.0%** |
| **Federal FTEs** | **70** | **63** | **82** | **63** | **64** | **+1** | **+1.6%** |
| Additional FE FTEs at NETL supporting OE[b] | 12 | 11 | 13 | 10 | 10 | 0 | 0.0% |
| Total OE-funded FTEs | 82 | 74 | 95 | 73 | 74 | +1 | +1.4% |

[a] The FY 2023 Budget Request to Congress proposed to split the Electricity appropriation account into two accounts: Electricity and Grid Deployment. To allow an apples-to-apples comparison with FY 2024, the comparable amounts for FY 2022 and 2023 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 since FY 2022.

[b] OE funds FTEs at FECM's NETL that support OE activities. The FTEs are included in FECM's FTE totals and not in the OE FTE totals shown on the "Federal FTEs" line.

| | FY 2022 Enacted | FY 2022 Enacted (Comparable)[a] | FY 2023 Enacted | FY 2023 Enacted (Comparable)[a] | FY 2024 Request | FY 2024 Request vs FY 2023 Comp. Enacted ($) | FY 2024 Request vs FY 2023 Comp. Enacted (%) |
|---|---|---|---|---|---|---|---|
| **Support Services and Other Related Expenses** | | | | | | | |
| **Support Services** | | | | | | | |
| Technical Support | 927 | 707 | 1,421 | 844 | 853 | +9 | +1.1% |
| Management Support | 761 | 567 | 1,193 | 659 | 673 | +14 | +2.1% |
| **Total, Support Services** | **1,688** | **1,274** | **2,614** | **1,503** | **1,526** | **+23** | **+1.5%** |
| **Other Related Expenses** | | | | | | | |
| Other Services | 1,488 | 1,472 | 1,515 | 1,319 | 1,208 | -111 | -8.4% |
| EITS Desktop Services | 714 | 652 | 736 | 672 | 440 | -232 | -34.5% |
| WCF | 2,705 | 2,469 | 2,161 | 2,161 | 2,499 | +338 | +15.6% |
| **Total, Other Related Expenses** | **4,907** | **4,593** | **4,412** | **4,152** | **4,147** | **-5** | **-0.1%** |

## Program Direction

**Activities and Explanation of Changes**

| FY 2023 Enacted | FY 2024 Request | Explanation of Changes FY 2024 Request vs FY 2023 Enacted |
|---|---|---|
| **Program Direction $17,793,000** | **$18,675,000** | **+$882,000** |
| *Salaries and Benefits $11,693,000* | *$12,522,000* | *+$829,000* |
| • Salaries and Benefits support 73 FTEs at Headquarters and NETL that provide executive management, programmatic oversight, and analysis for the effective implementation of the OE program | • Salaries and Benefits support 74 FTEs at Headquarters and NETL that provide executive management, programmatic oversight, and analysis for the effective implementation of the OE program | • Supports 1 additional FTE and the 2024 Federal pay increase |
| *Travel $445,000* | *$480,000* | *+$35,000* |
| • 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 | • Supports additional laboratory and site visits to oversee OE's research portfolio |

| FY 2023 Enacted | FY 2024 Request | Explanation of Changes<br>FY 2024 Request vs FY 2023 Enacted |
|---|---|---|
| *Support Services $1,503,000* | *$1,526,000* | *+$23,000* |
| • Support Services includes contractor support directed by the Federal staff to perform administrative tasks and provide analysis to management<br>• 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<br>• Support Services may include support for post-doctoral fellows and IPA assignments | • Increase reflects contract cost escalation |
| *Other Related Expenses $4,152,000* | *$4,147,000* | *-$5,000* |
| • Other Related Expenses includes EITS desktop services and WCF expenses, such as rent, supplies, copying, graphics, mail, printing, and telephones<br>• It also includes equipment upgrades and replacements, commercial credit card purchases using the simplified acquisition procedures to the maximum extent possible, security clearances, and other needs | • Other Related Expenses includes EITS desktop services and WCF expenses, such as rent, supplies, copying, graphics, mail, printing, and telephones<br>• It also includes equipment upgrades and replacements, commercial credit card purchases using the simplified acquisition procedures to the maximum extent possible, security clearances, and other needs | • WCF increases are offset by reduced equipment purchases |

**Electricity**
**Research and Development ($K)[a]**

| | FY 2022 Enacted | FY 2023 Enacted | FY 2024 Request | FY 2024 Request vs FY 2023 Enacted ($) | FY 2024 Request vs FY 2023 Enacted (%) |
|---|---|---|---|---|---|
| Basic | 9,055 | 13,363 | 12,117 | -1,246 | -9.3% |
| Applied | 63,980 | 66,498 | 74,589 | +8,091 | +12.2% |
| Development | 63,917 | 86,292 | 104,224 | +17,932 | +20.8% |
| Total, R&D | 136,952 | 166,153 | 190,930 | +24,777 | +14.9% |
| R&D-related construction | 50,658 | 0 | 0 | 0 | N/A |
| Total, R&D and related facilities | 187,610 | 166,153 | 190,930 | +24,777 | +14.9% |

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

| | FY 2022 Enacted Transfer | FY 2023 Enacted Projected Transfer | FY 2024 Request Projected Transfer[b] | FY 2024 Request vs FY 2023 Enacted ($) | FY 2024 Request vs FY 2023 Enacted (%) |
|---|---|---|---|---|---|
| Transmission Reliability and Resilience | 840 | 1,126 | 0 | -1,126 | -100.0% |
| Energy Delivery Grid Operations Technology | 402 | 248 | 0 | -248 | -100.0% |
| Resilient Distribution Systems | 1,010 | 961 | 0 | -961 | -100.0% |
| Cyber Resilient and Secure Utility Communication Networks (SecureNet) | 351 | 274 | 0 | -274 | -100.0% |
| Energy Storage | 1,711 | 2,303 | 0 | -2,303 | -100.0% |
| Transformer Resilience and Advanced Components | 267 | 640 | 0 | -640 | -100.0% |
| Applied Grid Transformation Solutions | 0 | 37 | 0 | -37 | -100.0% |
| Electricity Innovation and Transition[b] | 0 | 0 | 6,407 | +6,407 | N/A |
| Total, SBIR/STTR | 4,581 | 5,589 | 6,407 | +818 | +14.6% |

[a] R&D reporting includes a proportional share of program direction funding in addition to direct R&D funding.
[b] The FY 2024 Request transfers all SBIR funding, along with technology transition and workforce development funding, from OE R&D programs to the new Electricity Innovation and Transition program.