Department of Energy Crosscuts Overview

In FY 2024, the Department of Energy (DOE) will increase its emphasis on crosscutting efforts that enable the Department and the Administration to accelerate progress on climate and energy goals through fully integrated science and applied energy research, development, demonstration, and deployment.

DOE's climate and energy crosscuts enhance collaboration, coordination and integration across its science and applied energy programs with oversight provided by the Office of the Under Secretary for Science and Innovation and the Office of the Under Secretary for Infrastructure to ensure that resources are focused on achieving the Nation's most critical energy and climate challenges. This coordination also helps align the considerable capabilities of DOE's stakeholders including National Laboratories, universities, industry, and other partners. Within DOE, crosscutting initiatives may be coordinated through joint strategy teams, Science and Energy Technology Teams, working groups, or other mechanisms.

Where possible, program offices and functional offices have also highlighted crosscut information in their program narratives. Advancements enabled by DOE research and development to develop clean fuels and products, a net-zero power grid and increased electrification, and materials and manufacturing innovations for more efficient heating and cooling systems will support priority areas in the Administration's Net-Zero Game Changers Initiative.[1]

Alignment to key Bipartisan Infrastructure Law and Inflation Reduction Act provisions is noted in each science and energy crosscut narrative. Key contributing offices that are engaged in crosscut activities include Office of Technology Transitions, Loan Programs Office, Office of General Counsel, Office of the Chief Financial Officer, Office of Economic Impact and Diversity, and the Office of Policy. These offices may contribute staff time or funding as noted in specific crosscut narratives to enhance impact of the Department's efforts.

A major focus in key crosscutting efforts is the launch and execution of the Energy Earthshots Initiative™ that targets the major research, development, and demonstration innovation breakthroughs that we know we must achieve to solve the climate crisis and reach a net-zero carbon economy by 2050. The Energy Earthshots™ Initiative is an all-hands-on-deck call for innovation, collaboration, and acceleration of our clean energy economy by tackling the toughest remaining barriers to demonstrate and deploy emerging clean energy technologies at scale. With each Energy Earthshot™, the Department is setting tough, yet achievable cost or performance targets to transform these technologies on a decadal time scale—lowering costs, raising performance, creating new jobs, and clearing the way to our clean energy goals.

To date, DOE launched six Energy Earthshots: Hydrogen Shot™, Long Duration Storage Shot™, Carbon Negative Shot™, Enhanced Geothermal Shot™, Floating Offshore Wind Shot™ and Industrial Heat Shot™. In FY 2024, DOE anticipates scoping two final candidate Energy Earthshot concepts to complete the portfolio of the initiative. Each Energy Earthshot™ is guided by the relevant integrated DOE crosscut team that will create a multi-year roadmap and be implemented with extensive stakeholder engagement from research and National Laboratory, industry, environmental, environmental justice, and interagency partners.

The FY 2024 priority crosscut topic areas and corresponding Energy Earthshots are described below:

Crosscut Narrative Topic Area	Energy Earthshots™ in Scope
Biotechnology	
Carbon Dioxide Removal	Carbon Negative Shot™
Clean Energy Technology Manufacturing (rescoped from FY 2023 Advanced Manufacturing)	Floating Offshore Wind Shot™
Critical Minerals and Materials	
Energy Storage	Long Duration Storage Shot™
Energy-Water	
Grid Modernization	

[1] U.S.-Innovation-to-Meet-2050-Climate-Goals.pdf (whitehouse.gov)

Crosscut Narrative Topic Area	Energy Earthshots™ in Scope
Hydrogen	Hydrogen Shot™
Industrial Decarbonization	Industrial Heat Shot™
Subsurface Energy Innovations	Enhanced Geothermal Shot™

Additional DOE crosscuts include:

- Energy Sector Cybersecurity
- Infrastructure
- Pensions
- Research and Development
- Safeguards and Security (including Cybersecurity)
- Small Business Innovation Research/Small Business Technology Transfer

Biotechnology Crosscut
Funding by Appropriation and Program Control
($K)

Appropriation and Program Control	FY 2022 Enacted	FY 2023 Enacted	FY 2024 Request	FY 2024 vs FY 2023 ($ Change)
Advanced Research Projects Agency - Energy	996	TBD	TBD	N/A
ARPA-E Projects*	996	TBD	TBD	N/A
Energy Efficiency and Renewable Energy	59,750	50,214	50,250	+36
Bioenergy Technologies	59,750	50,214	50,250	+36
Science	686,892	768,951	831,992	+63,041
Advanced Scientific Computing Research	10,000	11,183	22,067	+10,884
Basic Energy Sciences	271,892	294,083	333,425	+39,342
Biological and Environmental Research	405,000	463,685	476,500	+12,815
National Nuclear Security Administration	-	20,000	25,000	+5,000
Defense Nuclear Nonproliferation	-	20,000	25,000	+5,000
Grand Total	**747,638**	**839,165**	**907,242**	**+68,077**

*ARPA-E funding is determined annually based on programs developed through office and stakeholder priorities. Therefore, funding for FY 2023 and FY 2024 is not available currently.

Overview:
Achieving a net-zero emissions economy in 2050 will require advances in every sector. Just as biotechnology is a significant tool in combatting the COVID-19 pandemic, it can also enable energy decarbonization efforts across major sectors such as transportation, industry, and agriculture. Biotechnology refers to a wide array of advanced techniques and tools that harness the power of biology, including bioengineering and bioprocessing technologies, to optimize microbes and plants for the production of biofuels and bioproducts and to enhance the ability of agriculture and forests to help sequester carbon in soils. The goal of this crosscut is to align and coordinate activities across DOE that can increase the impact of biotechnology innovation on decarbonization through efforts that will ultimately translate benchtop discoveries into commercial-scale bioeconomy applications.

Scientific and commercial achievements in biotechnology underpin the bioeconomy which accounts for five percent of U.S. Gross Domestic Product[1]. DOE has supported major advancements in biotechnology and genome sciences including the sequencing of the human genome and development of genetic editing technologies like CRISPR. To take full advantage of progress made over the last decade in genome sequencing cost and speed, and to accelerate the Nation's capabilities to apply biotechnology to address deep decarbonization challenges, integrated research, development, demonstration, and deployment efforts can bring together biological research, data science, high-performance computing (HPC), artificial intelligence (AI) and machine learning (ML), automation, and process engineering realize deep decarbonization benefits for transportation, industry, and agriculture. In addition, advancements in these areas can reduce national security risks associated with biotechnology and biomanufacturing.

Coordination Efforts:
DOE's Biotechnology Working Group is comprised of members from the Office of Science's (SC) Office of Basic Energy Science (BES), Office of Energy Efficiency and Renewable Energy's (EERE) Bioenergy Technologies Office (BETO), Office of Biological and Environmental Research (BER), and Office of Advanced Scientific Computing Research (ASCR), and the Advanced Research Projects Agency - Energy (ARPA-E). In FY 2021, the working group organized the "Designing for Deep Decarbonization: Accelerating the U.S. Bioeconomy" workshop. That workshop report found a substantial role for the bioeconomy in decarbonization across the transportation, industrial, and agricultural sectors potentially resulting in gigaton level reductions in U.S. net emissions. In FY 2022, a follow-on workshop, the AI and ML for Bioenergy Research: Opportunities and Challenges (AMBER) workshop to provide recommendations for how AI could contribute to the bioeconomy. In September 2022, Executive Order (EO) 14081, *Advancing Biotechnology and Biomanufacturing Innovation*

[1] NAS report: Safeguarding the Bioeconomy |The National Academies Press; Schmidt Futures report: Task Force on Synthetic Biology and the Bioeconomy - Schmidt Futures

for a Sustainable, Safe, and Secure American Bioeconomy, was issued, galvanizing a great deal of coordination and across the DOE Biotechnology Working Group member offices. EO 14081 calls for a coordinated approach to using biotechnology and biomanufacturing to advance societal goals, such as Climate and Energy. As a result, DOE is leading and participating in several interagency working groups, initiatives, and reports called for under the EO. These include calls to action for executive branch agencies including DOE to align resources and expand efforts on bioeconomy-related climate and energy goals.

In addition to the funding offices identified here, various crosscutting offices (including the Office of Economic Impact & Diversity, Office of Policy, the Artificial Intelligence and Technology Office, and the Office of Technology Transitions) contribute staff time and coordinate with the research, development, demonstration, and deployment (RDD&D) funding offices to enhance the impact of the Department's investments in biotechnology. The National Nuclear Security Administration also contributes expertise and capabilities that will anticipate and detect threats and strengthen biodefense.

Objectives and Action Areas:

- Objective 1 - Innovation built on strong foundations: Exploit and improve on genomic diversity within nature to identify new biological, bioinspired, and biohybrid functions.
- Objective 2- Enhance access to tools and facilities: Facilitate user access and interoperability between SC user facilities relevant to biotechnology, Bioenergy Research Centers (BRC), and the Agile BioFoundry.
- Objective 3 - Increase range of production of biofuels and bioproducts: Conduct research and development (R&D) to increase the variety of sustainable biofuels and bioproducts made from plants and microbes.
- Objective 4 - Develop advanced modeling and data analytics for biotechnology: Create integrative, collaborative, and open access computational platforms for biotechnology, with capabilities in AI and ML techniques.
- Objective 5 - Reduce risk by advancing biosafety and biosecurity: Assess biotechnology and biomanufacturing risks and develop approaches to reduce risks and integrate security into biotechnology development.

Action Areas:

1. Strengthen Cross-DOE Coordination and Collaboration: Ensure an integrated approach, including clearly defined "swim lanes" and "relay points," to increase collaboration and avoid duplication ; share best practices for management of user facilities and other community resources, facilitate workshops and Principal Investigator meetings, community/stakeholder engagement, and data/information sharing.
2. Support Fundamental and Applied R&D and Technology Transfer: Establish the foundational scientific infrastructure, knowledge base, innovation, and technology transfer to enable dissemination and scale-up for biotechnology.
3. Develop coordinated "use cases" and collaborations to identify technical and process (workflow) challenges: Establish informal working groups and formal collaborations to regularly assess the state of biotechnology and DOE's readiness to facilitate the entire biotechnology workflow.
4. Coordinate on Workforce/Science, Technology, Engineering, and Math (STEM) and Diversity, Equity, and Inclusion (DEI): Collaborate on best practices and accelerate progress towards common goals.

Program Organizations:

1. **Advanced Research Projects Agency-Energy (ARPA-E):** As defined by its authorization under the America COMPETES Act, ARPA-E catalyzes transformational technologies to enhance the economic and energy security of the United States. ARPA-E funds high-potential, high-impact projects that are too risky to attract private sector investment but could significantly advance the ways to generate, store, distribute and use energy. In FY 2022, ARPA-E selected and/or obligated $996,000 in Biotechnology funding to projects aligned with the Crosscut through ARPA-E's Supporting Entrepreneurial Energy Discoveries (SEED) Exploratory Topic. ARPA-E is developing programs for transformational research across a wide range of energy technologies and applications. The assessment process for new programs is now underway and any potential future investments in Biotechnology will be determined in FY 2023.

2. **Energy Efficiency and Renewable Energy (EERE):** EERE's Bioenergy Technologies Office (BETO) focuses on developing bioengineering techniques to optimize production of targets (fuels, chemicals, and materials) in microbes. These research, development, and demonstration (RD&D) activities in FY 2024 include:

a. Agile BioFoundry, a consortium of seven National Laboratories that brings together world-class biotechnology capabilities to target a bring new bio-derived molecules to market by accelerating the Design-Build-Test-Learn cycles in partnership with industry.
b. Biological engineering including cell-free bioprocessing, enzymatic hydrolysis, fermentation, downstream separations, and catalysis to transform renewable carbon feedstocks into transportation fuels, renewable chemicals, and materials.
c. Biological methods for plastic deconstruction and upcycling including optimization of novel enzymes and organisms to achieve commercial relevance.

3. **Science (SC):** There are multiple programs within the Office of Science that are major contributors to the advancement of the biotechnology crosscut objectives and scientific discovery. In FY 2024, SC programs will focus on new and continued research and user facilities as described below.
   a. Advanced Scientific Computing Research (ASCR): ASCR employs HPC and the exascale ecosystem to accelerate progress in biotechnology across mission areas and national priorities. Through partnerships and collaborations within SC, DOE and related mission agencies (National Institutes of Health [NIH], U.S. Department of Agriculture), ASCR is advancing the foundational research, computational readiness, and HPC access for biotechnology applications that underpin predictive capabilities for climate, national preparedness and biosecurity, and other DOE missions. ASCR supports the DOE Energy Earthshots™ through research and advanced methods in applied mathematics, computer science, and high end scientific and engineering simulations, as well as through the capabilities at ASCR scientific user facilities. The ASCR Energy Earthshot funding will contribute computational tools and research to understand basic principles and potentially advance biotechnology concepts relevant to the current Hydrogen, Carbon Negative, and Industrial Heat Energy Earthshots™, as well as potential research in new focus areas.
   b. Basic Energy Sciences (BES): BES supports fundamental chemical and materials research to underpin the development of biotechnology (Objective 1). Research supported by BES may also use biotechnological approaches to understand molecular and atomic mechanisms in biochemical and chemical processes and structures which, in turn, may advance new biotechnologies. These detailed mechanistic studies can enable strategies for biohybrid tool development and biotechnology-based approaches for energy capture, conversion, and/or storage. BES provides tools for characterizing biotechnology-relevant materials and chemical processes through x-ray, neutron, electron beam scattering, and nano-science capabilities (Objective 2). The BES Energy Earthshot funding will contribute use-inspired fundamental research to understand basic principles and potentially advance biotechnology concepts relevant to the Carbon Negative, Industrial Heat, and Enhanced Geothermal Shots, as well as potential research in new focus areas.
   c. Biological and Environmental Research (BER): BER employs biotechnological approaches such as genome sequencing and analysis, proteomics, metabolomics, structural biology, high-resolution imaging and characterization, and integration of biological data into computational models to advance a predictive understanding of biological systems. BER programs have a track record of accomplishment to understand and design new biological systems for carbon management, bioenergy and bioproducts produced from sustainable plant biomass to replace those currently obtained from petroleum. BER supports four BRCs engaged in multidisciplinary genome-enabled biotechnology research to sustainably produce a range of bioenergy and bioproducts from renewable plant biomass. New quantum-enabled instrumentation for imaging biological processes will be explored in Biomolecular Characterization and Imaging Science for visualizing cellular metabolism non-destructively. BER also support the Joint Genome Institute (JGI) which provides users with high quality genome production and new analysis techniques for complex plant and microbiome samples. BER funding for Energy Earthshot Research Centers (EERCs) will contribute the basic research needed to understand carbon sequestration mechanisms within soils for Carbon Negative Shot™ and to also biobased approaches to solve the challenges in the Industrial Heat Shot™.

4. **National Nuclear Security Administration (NNSA):** The NNSA Bioassurance Program will contribute to DOE biotechnology efforts through innovations in biosecurity to reduce risk throughout the biotechnology R&D and biomanufacturing lifecycles. The NNSA Bioassurance Program will focus on anticipating and detecting national security threats and strengthening biodefense, identifying threat signatures, advancing forensics for attribution, and rapidly developing and validating safeguards and threat mitigation approaches. NNSA will integrate its high-security work with the Department's "open" science work, providing the full spectrum of capabilities essential for a bioassurance program

informed by national security expertise drawn from parallel and analogous work on nuclear threats, risks, export controls and licensing, nonproliferation, detection, and verification.

Highlights and Major Changes from FY 2023 Enacted

- Science (SC): The increased investment in the Office of Science focuses on enabling new insights and breakthroughs by leveraging foundational research and the unique capabilities of the scientific user facilities.
  - ASCR facilities provide new capabilities accessible only through large-scale computing resources. Researchers at the Oak Ridge Leadership Computing Facility (OLCF) used Frontier, the world's first exascale computer and the Distributed Accelerating Semiring All-Pairs Shortest Path algorithm, or DSNAPSHOT, uses AI to pinpoint potential links amid millions of concepts across decades of scientific publications. These efforts could accelerate bioproduct discovery.
  - The BES portfolio provided new insights that could potentially enhance bioinspired as well as biotechnology approaches for clean energy such as: understanding of photosynthesis in cyanobacteria, integration of state-of-the-art theory and computation with experimental efforts to understand how enzymes work, and studies of nitrogenase, the enzyme responsible for the reduction of nitrogen to ammonia.
  - Within BER, several improvements towards a better understanding of the capture, cycling and conversion of carbon in the environment and within industrial processes were made across the biological systems science program. Using instruments at the SLAC National Accelerator Laboratory researchers are leading to new ways to design and optimize biomolecules for CO_2 capture. Additionally, a jointly funded project by BER, DOE Bioenergy Technologies Office, and LanzaTech, engineered a bacterial species capable of utilizing gaseous CO_2 in an industrial waste stream and convert it to acetone and isopropanol, valuable chemical products. The work highlights an efficient approach to engineering organisms for industrial-scale purposes.
- National Nuclear Security Administration (NNSA): Defense Nuclear Nonproliferation program major changes include:
  - Initiate prioritized research in accordance with science and technology (S&T) plan to develop computational predictive models of potential threats and impacts, including threat model validation, detection, and characterization acceleration, and to develop safeguards and forensics R&D and threat mitigation approaches.
  - Develop initial operating capability and coordinated DOE program in biosciences, including infrastructure improvements and minor equipment purchases based on a prioritized technical roadmap.

Carbon Dioxide Removal
Funding by Appropriation and Program Control
($K)

Appropriation and Program Control	FY 2022 Enacted	FY 2023 Enacted	FY 2024 Request	FY 2024 vs FY 2023 ($ Change)
Advanced Research Projects Agency - Energy	45,500	TBD	TBD	N/A
ARPA-E Projects*	45,500	TBD	TBD	N/A
Energy Efficiency and Renewable Energy	16,000	23,300	15,000	-8,300
Bioenergy Technologies	13,000	11,000	-	-11,000
Advanced Manufacturing Office (AMO)	-	9,300	-	-9,300
Industrial Efficiency and Decarbonization Office (AMO successor office)	-	-	14,500	+14,500
Water Power Technologies	3,000	3,000	500	-2,500
Fossil Energy and Carbon Management	49,000	70,000	70,000	-
Carbon Dioxide Removal	49,000	70,000	70,000	-
Science	46,700	70,628	102,962	+32,334
Advanced Scientific Computing Research	-	-	20,000	+20,000
Basic Energy Sciences	23,700	28,878	29,962	+1,084
Biological and Environmental Research	23,000	41,750	53,000	+11,250
Grand Total	**157,200**	**163,928**	**187,962**	**+24,034**

*ARPA-E funding is determined annually based on programs developed through office and stakeholder priorities. Therefore, funding for FY 2023 and FY 2024 is not available currently.

Overview:
Nearly all climate models that simulate scenarios for reaching net-zero indicate the need for a near-term focus on carbon dioxide removal (CDR) development and deployment in addition to carbon reduction efforts including mitigative point source carbon capture and sequestration. The Intergovernmental Panel on Climate Change (IPCC) modeling shows that only emissions scenarios including CDR achieve neutrality in 2050. CDR refers to multiple approaches that capture carbon dioxide (CO_2) directly from the atmosphere and durably store it in geological, biobased and ocean reservoirs or in value-added products to create negative emissions. Negative emission technologies at scale are necessary for achieving national and global net-zero greenhouse gas (GHG) emission goals in the coming decades, removing accumulated pools of carbon from the atmosphere, and avoiding the most critical climate consequences.

In recognition of the necessity of CDR, the Department of Energy (DOE) launched its third Energy Earthshot™, Carbon Negative Shot™ at COP26 in November 2021. Carbon Negative Shot™ is a decadal goal to reduce the cost of atmospheric carbon removal to less than $100/net metric ton of CO_2-equivalent (CO_2e). This effort is being deployed to achieve a net-zero carbon economy and eventually remove legacy carbon pollution to help address the climate crisis, with a dedicated focus on doing so in a just and sustainable manner.

Carbon Negative Shot™ defines four criteria that define goals for each CDR pathway: 1) less than $100/net metric ton CO_2e for both capture and storage of CO_2; 2) robust accounting of full lifecycle emissions (i.e., ensures emissions created when running and building the removal technology are accounted for); 3) high-quality, durable storage with costs demonstrated for monitoring, reporting, and verification for at least 100 years; and 4) enables necessary gigaton scale removal.

The diverse suite of technologies and approaches in CDR requires integrated investment across the full research, development, demonstration, and deployment (RDD&D) spectrum such that breakthroughs are rapidly transferred and scaled, and deployment of first-of-its kind technologies quickly informs the next generation of innovation. CDR approaches include, but are not limited to, bioenergy with carbon capture and sequestration (BECCS), direct air capture (DAC) with durable storage (DACS), biological methods to stored products, enhanced mineralization, soil carbon sequestration, and direct ocean capture (DOC) with durable storage (DOCS). Within these approaches, the technology or mechanisms for CO_2

removal are variable, leading to challenges in how to quantify reductions via lifecycle analyses (LCA), and how to accurately define the economics and costs.

The Department has been supporting carbon capture and storage (CCS) research, development, and demonstration (RD&D) projects and programs such as the Carbon Storage Assurance Facility Enterprise (CarbonSAFE) Initiative for years with the goal of addressing the key gaps on the critical path towards CCS deployment. The unique expertise that DOE retains through the world-class group of scientists, engineers, and subject-matter-experts, along with the state-of-the-art technologies and resources in the National Laboratories, puts DOE in a unique position which makes the U.S. the leading nation in the world to drive the research and technology to combat the climate change.

Coordination Efforts:
In addition to developing and implementing a cross-agency CDR strategy, priorities include joint efforts on information sharing and engagement with external stakeholders, technology experts, and other government agencies. There is close coordination between the Department's efforts in the CDR crosscut, the interagency CDR Task Force led by DOE, and Mission Innovation's CDR Mission, which is a Global Initiative. The CDR crosscut group manages the Carbon Negative Shot™.

In addition to the funding offices identified below, various crosscutting offices (including the Office of Economic Impact & Diversity, Office of Policy, the Office of International Affairs, and the Office of Technology Transitions (OTT)) contribute staff time and coordinate with the RDD&D funding offices to enhance the impact of the Department's investments.

Objectives and Action Areas:
The CDR crosscut objectives and action areas are built to enable progress towards the Carbon Negative Shot™ goal and advance the state of the art for CDR technologies.

- Objective 1: Discover, innovate, and enable the deployment of low-cost and scalable CDR pathways to accelerate removal of CO_2 directly from the atmosphere and environment. Foster crosscutting, fundamental science and applied research and development (R&D) to enable breakthroughs along the carbon removal value chain. Identify and address critical barriers to reducing the costs and energy requirements for CDR systems and materials through targeted research investments. Promote and demonstrate the strategic deployment of diverse CDR systems and strategies.
    - Action Area: Advance the technical and commercial readiness for atmospheric carbon capture technologies.
        - Emphasize RD&D to support enhanced biological and natural solutions biomass, soil, ocean capture, mineralization, etc.
        - Execute R&D for carbon capture materials for engineered systems to increase the effectiveness and reduce the cost.
    - Action Area: Support the development of markets for CDR and enabling financing for new CDR projects.
        - Comprehensive technology innovation roadmaps, including commercialization opportunity and needs assessments in collaboration with OTT/Loan Programs Office (LPO) to engage industry in development of CDR solutions.
- Objective 2: Ensure adequate analysis and monitoring, reporting, and verification (MRV). Advance the state-of-the-art standards, and practices for ensuring that carbon is removed from the atmosphere and stored geologically or equivalent for nature-based pathways.
    - Action Area: Emphasize development of tools for assessing soil carbon content and LCA for novel soil capture approaches, as well as Artificial Intelligence (AI) tools for soil carbon sequestration and for characterization of the CO_2 mineralization feedstocks.
    - Action Area: Establish of studies for modeling and evaluation of climate change pathways to demonstrate additional carbon capture benefit in land sinks.
    - Action Area: Establish MRV protocols associated with CDR purchases.
- Objective 3: Engage stakeholders and communicate strategy. Host workshops and public meetings to share information. Engage with communities that could participate in or be affected by CDR including sovereign tribal nations, labor groups, and environmental justice (Justice40), and climate justice organizations. Build awareness, interactions, and community involvement in the siting, build out and management of this new industry.
    - Action Area: Build out Regional Sequestration Partnerships to develop core competencies and engagement tools and resources to promote CDR hub development across the U.S.

- Action Area: Development of the CDR Excellence Centers through partnership with the National Labs as one-stop-shop for stakeholders.

Program Organizations:

1. **Advanced Research Projects Agency–Energy (ARPA-E):** As defined by its authorization under the America COMPETES Act, ARPA-E catalyzes transformational energy technologies to enhance the economic and energy security of the United States. ARPA-E funds high-potential, high-impact energy projects that are too risky to attract private sector investment but could significantly advance the ways to generate, store, distribute and use energy. In FY 2022, ARPA-E selected and/or obligated $45.5 million in CDR funding to projects aligned with the Crosscut through ARPA-E's Supporting Entrepreneurial Energy Discoveries (SEED) Exploratory Topic and Sensing Exports of Anthropogenic Carbon through Ocean Observation (SEA CO_2) programs. ARPA-E is developing programs for transformational research across a wide range of energy technologies and applications. The assessment process for new programs is now underway and any potential future investments in CDR will be determined in FY 2023.

2. **Energy Efficiency and Renewable Energy (EERE):** Within the Office of Energy Efficiency and Renewable Energy, there are two programs that support the efforts of the CDR crosscut:
    a. Industrial Efficiency and Decarbonization Office (IEDO): IEDO supports Objective #1 through the development of technologies and processes to utilize CO_2 as a feedstock for the production of key building block chemicals, like ethylene, to achieve overall emissions reduction of the chemicals sector; as well as the utilization and mineralization of CO_2 in the manufacturing of cement and concrete based building materials.
    b. Water Power Technologies Office (WPTO): WPTO will investigate the role of marine energy in marine carbon dioxide removal (mCDR).

3. **Fossil Energy and Carbon Management (FECM):** FECM focuses primarily on engineered CDR approaches that include chemicals, minerals, and biological pathways. FECM has been working on carbon capture, utilization, and storage (CCUS) projects for almost 20 years and has invested heavily in the development of technologies to capture CO_2 from power plants and industrial sources. Funding is focusing on DAC, BECCS, and mineralization concepts. The CDR subprogram builds upon past CCUS efforts which have been funded through FECM's CCUS activities, such as past work on DAC, mineralization, co-firing of biomass, and capture technology development. RDD&D activities include:
    a. DACS: FECM funds significant DAC RDD&D alongside all carbon storage research at DOE. This includes transformational DAC materials and components, pilot-scale testing, and FEED studies for large-scale demonstrations.
    b. DOCS: Leveraging FECM RDD&D activities on separations that focus on removal of CO_2 from ocean water and ocean alkalinity enhancement.
    c. Biomass waste R&D: R&D on biomass waste coupled with CCUS offers an opportunity for near-term deployment of CDR technologies. This includes gasification of waste feedstocks, such as plastics and sustainably-available biomass waste with CCUS.
    d. Enhanced mineralization: FECM has, and is continuing to, invest in RDD&D for in-situ, ex-situ, and surficial mineralization opportunities.
    e. Crosscutting RDD&D on MRV technologies to validate carbon removal and support LCA.
    f. Significant RDD&D investments and work for geological CO_2 storage and CO_2 transport. Coupled to CO_2 capture processes, such as bioenergy and DAC, reliable storage on timescales that will positively impact climate are of central focus. For example, reliable storage on the scale of 1,000s years is desired, which may include geologic storage deep underground, or the conversion of CO_2 to synthetic aggregates (replaces sand and gravel for construction) or plastics.
    g. Program support for Carbon Negative Shot™, Mission Innovation (MI) CDR Mission and/or CDR Task Force.

4. **Science (SC):** SC provides foundational knowledge and state-of-the-art capabilities in support of crosscut objectives and has supported theoretical and experimental science related to understanding chemical and biological processes, separations, materials, and geochemistry related to carbon capture for many years. Key activities in FY 2024 include:
    a. SC operates major x-ray, neutron, nanoscience, genome sequencing, and high-performance computing user facilities that provide advanced synthesis, fabrication, characterization, and computational capabilities that supports CDR efforts across the spectrum of basic and applied research. (Objective 1)

b. Basic Energy Sciences (BES) continues support for scientific discoveries and major scientific tools to transform our understanding of CO_2 chemistry, separation systems, and materials, including conversion to durable products (e.g., mineralization), important to CDR technologies. BES will continue to support CDR research, including DAC, that spans from single principal investigators to large teams including Energy Frontier Research Centers (EFRCs) and Energy Earthshot Research Centers (EERCs). (Objective 1)
c. Biological and Environmental Research (BER) supports fundamental systems biology research on 1) plants and plant microbiomes to capture atmospheric CO_2 and sequester stabilized forms of carbon in biomass and soil and 2) algal systems to convert gaseous CO_2 waste streams into a broad range of bioproducts in support of other CDR technologies. The EERCs will seek to remove barriers to clean energy production and implementing CDR innovations from basic research into applied solutions. Expanded university research involving Earthshot topics will focus on science at the nexus of carbon management and clean energy production.
d. Advanced Scientific Computing Research (ASCR) supports foundational investments in the applied mathematics and computer science tools, methods and algorithms needed to computationally define realistic physical systems used in CDR and storage models and simulations. In addition, ASCR funds fundamental AI research to ensure that the next generation AI tools are domain-aware, robust, and understandable. Simulations of carbon removal and storage technologies are running on ASCR production and leadership systems.
e. ASCR, BES, and BER will continue to support the EERCs, a new modality of research launched in FY 2023, to bring together multi-investigator, multi-disciplinary teams to perform energy-relevant research with a scope and complexity beyond what is possible in standard or small-group awards. Aligned with both SC and the technology offices, EERCs will address key basic research challenges with relevance to applied R&D activities. (Objective 1 and 2)

Highlights and Major Changes from FY 2023 Enacted

- Energy Efficiency and Renewable Energy:
  - Bioenergy Technologies: No funding is requested in FY 2024 in order to prioritize development of new feedstock-conversion pathways to sustainable aviation fuels (SAF), prior year funding will support projects in this area from previous competitive funding in 2022 and 2023.
  - Industrial Efficiency and Decarbonization Office (IEDO): As a successor office to AMO, IEDO will focus on utilization of CO_2 as a feedstock for commodity chemicals such as ethylene.
  - Water Power Technologies (WPTO): WPTO requests funding to investigate the role of marine energy in marine carbon dioxide removal (mCDR) in FY 2024.
- Fossil Energy and Carbon Management
  - Continues to make investments in direct air capture, biomass with carbon removal and storage, mineralization, direct ocean capture, and lifecycle analyses to reduce costs and continue to improve methodologies to confirm removal.
- Science (SC): The increased investment in the Office of Science focuses on enabling new insights and breakthroughs by leveraging foundational research and the unique capabilities of the scientific user facilities.
  - The increased investment in Advanced Scientific Computing Research facilities focuses on foundational research enabling new capabilities accessible only through large-scale computing resources.
  - The investment growth within the Biological and Environmental Research (BER) portfolio supports several improvements towards a better understanding of the capture, cycling and conversion of carbon in the environment and within industrial processes were made across the biological systems science programs.

Related Bipartisan Infrastructure Law (BIL) or Inflation Reduction Act (IRA) Programs:

In addition to the annual appropriations request, funding from BIL will support the planning and execution of technology development, demonstration, scale-up, and deployment of CO_2 DAC, storage, conversion, and transportation. These investments are essential in building out key components of a nascent industry, key funding opportunities related to DAC Hubs, CCS Demonstrations, CO_2 Storage (CarbonSAFE), Carbon Dioxide Transport front-end engineering and design (FEED) studies and the Carbon Dioxide Transportation Infrastructure Finance and Innovation (CIFIA) guidance have been released or are anticipated for release in the coming year. Expansion of tax credits resulting from IRA will offer additional incentives for CDR.

Clean Energy Technology Manufacturing
Funding by Appropriation and Program Control
($K)

Appropriation and Program Control	FY 2022 Enacted	FY 2023 Enacted	FY 2024 Request	FY 2024 vs FY 2023 ($ Change)
Advanced Research Projects Agency – Energy*	-	TBD	TBD	N/A
ARPA-E Projects	-	TBD	TBD	N/A
Energy Efficiency and Renewable Energy	545,545	321,143	417,682	+96,539
Advanced Manufacturing Office (AMO)	416,000	183,500	-	-183,500
Advanced Materials and Manufacturing Technologies Office (AMO successor office)	-	-	221,497	+221,497
Building Technologies	5,000	-	-	-
Bioenergy Technologies	11,500	7,185	12,185	+5,000
Hydrogen and Fuel Cell Technologies	22,000	30,000	20,000	-10,000
Solar Energy Technologies	37,181	63,500	63,000	-500
Vehicle Technologies	31,000	25,000	25,000	-
Water Power Technologies	5,500	1,500	3,000	+1,500
Wind Energy Technologies	17,364	10,458	73,000	+62,542
Fossil Energy and Carbon Management	7,500	8,000	4,500	-3,500
Carbon Management	7,500	8,000	4,500	-3,500
Nuclear Energy	33,000	8,800	15,000	+6,200
Crosscutting Technology Development	8,000	8,800	15,000	+6,200
Transformational Challenge Reactor	25,000	-	-	-
Science	25,353	27,000	27,000	-
Basic Energy Sciences	17,000	20,000	20,000	-
Biological and Environmental Research	5,000	3,000	3,000	-
Fusion Energy Sciences	3,000	3,000	3,000	-
Isotope R&D and Production	353	1,000	1,000	-
Grand Total	**611,398**	**364,943**	**464,182**	**+99,239**

*ARPA-E funding is determined annually based on programs developed through office and stakeholder priorities. Therefore, funding for FY 2023 and FY 2024 is not available currently.

Overview:
Clean energy technology manufacturing (CETM) is required for a transformation of the national and global energy system to meet our climate goals. It is also an engine that will create good-paying jobs and contribute to a competitive, resilient, and agile domestic manufacturing sector. Responsive to Executive Order (EO) 14017, *America's Supply Chains*, the Department of Energy's (DOE) first-of-a-kind report highlights the importance of a strong manufacturing sector in addressing national security concerns related to reliable supply chains and ensuring U.S. competitiveness and offers dozens of recommendations for executive and legislative action to do so.

Cross-DOE activities in this space will enable new and improved materials, processes, components, and systems across supply chains and product lifecycles for priority clean energy technologies. Working together, DOE can identify key gaps and technical, market, and policy barriers that can be addressed to drive down costs, improve domestic competitiveness, and accelerate technology commercialization.

Through the Energy Earthshots Initiative, DOE has identified six key areas of significant integrated opportunities with individual ambitious RD&D targets. Technology product based, each Earthshot has manufacturing components complementing their core technology suite. The CETM crosscut will most impact the fifth Energy Earthshot, the Floating

Offshore Wind Shot.™ The Floating Offshore Wind Shot™ targets a reduction in the levelized cost of energy to less than $45 per megawatt hour (MWh) by 2035. Keys to achieving this goal are low-cost serial manufacturing of large complex structures like floating platforms, large towers, and blades and development of a robust domestic floating offshore wind supply chain.

This crosscut encompasses multiple offices across DOE that sponsor research, development, demonstration, and deployment (RDD&D) to foster the innovations required to sustainably manufacture the clean energy technologies needed for deep decarbonization of the electricity, industrial, transportation, and buildings sectors. Development and commercialization of advanced approaches to producing these clean energy technologies will accelerate the transition to a decarbonized future and ensure U.S. manufacturing competitiveness as the world transitions to clean energy. Crosscut activities will enable new and improved materials, processes, and systems across clean energy supply chains and product lifecycles, including efforts to address specific challenges faced in clean energy sectors, such as the production of large-scale, heavy equipment or the need for secure and resilient material supply chains.

Coordination Efforts:
The participating DOE offices are increasing intra-departmental collaboration in their Clean Energy Technology Manufacturing activities, pursuing coordinated road mapping exercises, leveraging best practices and advances that are relevant across technologies, and identifying joint funding opportunities where appropriate. Participating DOE offices include Advanced Research Projects Agency – Energy (ARPA-E), Energy Efficiency and Renewable Energy (EERE), Fossil Energy and Carbon Management (FECM), Nuclear Energy (NE), the National Nuclear Security Administration (NNSA), and Science (SC). The Office of Manufacturing and Energy Supply Chain (MESC) will participate to ensure coordination across relevant BIL and IRA provision execution and related analysis work. The effort will be coordinated through the Clean Energy Technology Manufacturing (CETM) Science & Energy Tech Team (SETT).

In addition to the funding offices identified, various crosscutting offices (including the Office of Economic Impact & Diversity, Office of Policy, and the Office of Technology Transitions) may contribute staff time and coordinate with the RDD&D funding offices to enhance the impact of the Department's investments.

Objectives and Action Areas:
- Objective: Drive innovation to accelerate cost reductions, performance improvements, supply chain resilience, diversification, and domestic capacity for the manufacture of clean energy technologies. Address technical and non-technical barriers to clean energy manufacturing growth to enable aggressive climate goals, strengthen the U.S. economy, and create jobs for skilled American workers.
    - Action Area 1 - Rapid Development and Commercialization of Advanced Materials. Improve the development and use of advanced materials needed for innovative clean energy technologies. This includes research and development (R&D) in new, advanced functional materials that support one or more clean energy technologies, as well as activities to accelerate development, qualification, and transition to materials acceptance and first use. It also includes investments in critical materials technology that are crucially needed to accelerate the adoption of clean energy applications.
    - Action Area 2 - Advanced Manufacturing Process Development. Cross-cutting efforts will support the development and accelerated adoption of new manufacturing processes for clean energy systems and components that significantly reduce the cost (including environmental cost), improve performance, and improve manufacturing quality. This includes research, development, and demonstration (RD&D) for efficient manufacturing processes such as additive 3D manufacturing, composite fabrications, smart manufacturing processes, advanced automation and robotics, and use of alternate feedstocks including waste/recycled products to make clean energy products (e.g., batteries) that enable the circular economy.
    - Action Area 3 - Predictive Performance and Advanced Qualification and Certification. Develop and commercialize new approaches to provide system qualification of manufactured products for clean energy technologies. This will include model-based assessments of as-manufactured products without traditional destructive testing, qualification of processes in lieu of product testing, and new approaches to lifetime assessments and re-certification of existing or refurbished systems and components. This area will also identify and seek to address unique qualification challenges relevant to many emerging clean energy technologies – e.g., wind blade qualification, nuclear reaction qualification, etc.

- Action Area 4 - Scale up for Large-scale and "Heavy" Manufacturing. Support the transition of proof-of-principle or demonstration projects to large-volume manufacturing that drives costs down the learning curve, and also for those technologies that have low-volume production and/or intermittent production, such as for nuclear reactors or large power transformers. Specifically, this Action Area will provide support for manufacturing scale-up facilities and incubators working on large-scale product manufacturing.
- Action Area 5 - Resilient Supply Chain Development. Conduct RD&D to promote domestic sources for raw materials, refined materials, components, and manufactured systems for the clean energy economy. This includes activities to develop and commercialize pathways for cost-effectively recovering and recycling waste materials using advanced separation technologies. The Action Area will also support Educational and Workforce Development programming and career pathways for the workforce at all levels, to provide the domestic workforce needed; analysis to understand interconnected supply chains and pathways to meet 2050 climate goals; and demand-pull activities to catalyze investments in domestic supply chains.

Program Organizations:

1. **Advanced Research Projects Agency-Energy (ARPA-E):** As defined by its authorization under the America COMPETES Act, ARPA-E catalyzes transformational technologies to enhance the economic and energy security of the U.S. ARPA-E funds high-potential, high-impact projects that are too risky to attract private sector investment but could significantly advance the ways to generate, store, distribute and use energy. ARPA-E is developing programs for transformational research across a wide range of energy technologies and applications. The assessment process for new programs is now underway and any potential future investments in Clean Energy Technology Manufacturing will be determined in FY 2023.

2. **Office of Energy Efficiency & Renewable Energy (EERE):** Many EERE technology programs support Clean Energy Manufacturing through advanced manufacturing work across programs and in close coordination with other DOE offices. Principal EERE program office activities and contributions include:
    a. Advanced Materials and Manufacturing Technologies Office (AMMTO): AMMTO plays a leading role in the decarbonization of the industrial sector and addressing the climate crisis by driving innovations that lead to a more resilient and competitive domestic manufacturing sector and that deliver the clean energy technologies needed to decarbonize other sectors. In FY 2024, AMMTO will partner with other DOE offices to invest in RD&D to support long duration storage manufacturing technologies that enables decarbonization of the grid; process development and manufacturing of power electronics needed for electrification, design and fabrication of highly efficient microelectronics; advance composite manufacturing processes relevant to wind turbine blades and other clean energy technologies; development of high conductivity materials~~,~~ systems; research to advance materials for harsh service conditions; and foundational manufacturing processes and systems that can apply across multiple clean energy technologies such as smart manufacturing, additive manufacturing, and roll-to-roll manufacturing. AMMTO will also increase its RD&D to support the circular economy including novel approaches to recycling, design for recyclability, and other circular economy approaches.
    b. Bioenergy Technologies Office (BETO): BETO supports the development of valuable chemicals and materials that can replace petrochemicals with renewable alternatives. This work includes R&D on bioderived polymers and other renewable chemicals that provide performance advantages to traditional materials.
        - Action Area 1: In FY 2024, BETO will continue R&D to identify and synthesize biomass-based polymers and renewable chemicals that can deliver performance advantages and lower carbon emissions than incumbent petroleum-based products. BETO will use machine learning and molecular simulation tools to predict properties and performance of novel biomass-based materials, and support synthesis and testing of these performance-advantaged bioproducts.
        - Action Area 2: In FY 2024, BETO will continue to develop biobased plastics designed with superior recyclability and biodegradability as well as new methods to recycle and upcycle existing plastic waste in collaboration with AMMTO.
    c. Hydrogen and Fuel Cell Technologies Office (HFTO): HFTO invests in advanced manufacturing processes to enable accelerating the deployment of hydrogen and fuel cell technologies to address decarbonization of the transportation and industrial sectors. Activities span manufacturing processes for carbon fiber for on-board physical storage, hydrogen refueling components, and materials compatibility.

- Action Area 1: HFTO work includes efforts relevant through collaboration and addressing industry's need to identify advanced materials for safe use of hydrogen and hydrogen blends across sectors in collaboration with FECM.

d. Solar Energy Technologies Office (SETO): SETO supports the RD&D and commercialization of advanced manufacturing relevant technologies to help develop new products for domestic manufacture, support new technologies to drive down domestic manufacturing costs, develop robust domestic supply chains, and mitigate issues related to material availability.
   - Action Area 3: Efforts include new rounds of the American-Made Solar Prize to incentivize and transition new solar technologies into prototypes ready for real world validation. Other efforts supported in the Request to enhance U.S. solar manufacturing include continued support for the American-Made Network to provide commercialization resources; a crosscutting initiative designed to support a qualified, diverse, and inclusive clean energy manufacturing workforce; connecting trainees with the industry; and, continued support for the Incubator program to accelerate the prototyping, development and demonstration of new solar energy technologies for commercialization and domestic manufacturing. :
   - Action Area 5: Activities support the development of a sustainable, robust, and resilient American solar supply chain. Domestic supply chains are critical to ensuring the U.S. has access to the volume of solar energy cells, modules, and system components to meet decarbonization goals.

e. Vehicle Technologies Office (VTO): In FY 2024, VTO priority focus areas include combining new technologies for multi-material structures required in order to incorporate these lightweight polymer matrix composites and other new lightweight materials (aluminum and magnesium) into vehicle applications for increasing fuel economy and reducing the environmental impact of vehicles; supporting the Lightweight Metals Core Program to develop scalable processing methods to locally enhance the properties of aluminum and magnesium; supporting battery materials scale-up at National Laboratories; and supporting Battery Processing Science and Engineering dedicated to solid state materials processing. VTO addresses two Action Areas:
   - Action Area 1: VTO will continue and scale up efforts related to solid state processing and new joining technologies for multi-material structures in vehicles. New joining materials will be required to incorporate these lightweight polymer matrix composites and other new lightweight materials (aluminum and magnesium) into vehicle applications for increasing fuel economy and reducing the environmental impact of vehicles. The Lightweight Metals Core Program will develop scalable processing methods to locally enhance the properties of aluminum and magnesium.
   - Action Area 2: VTO will continue electric vehicle battery innovations to develop novel processing technologies for conventional electrodes as well as lithium metal anodes and solid-state batteries. Projects involve either active materials scale-up or scientific investigations of novel processing approaches for lithium intercalation cathode materials, lithium metal batteries, or solid-state electrolytes.

f. Water Power Technologies Office (WPTO): WPTO has been funding foundational and application-based research for advanced manufacturing opportunities for hydropower. Opportunities analysis is being performed that will support development of a roadmap that will inform the hydropower program and industry towards future research and engagement. The goal of FY 2024 activities is to encourage and enable the hydropower industry to recognize the opportunities to apply advanced manufacturing technologies and techniques to hydropower challenges for existing and new infrastructure. Another opportunities analysis for advanced manufacturing applications for hydropower is currently being prepared by Oak Ridge National Laboratory (ORNL). Outputs will be used to inform a roadmap in FY 2023, and then will build a program in partnership with the Manufacturing Demonstration Facility at ORNL to provide support and validation of technologies for hydropower.
   - Action Area 1: WPTO activities addresses marine energy and builds on a materials strategy, which will be released in FY 2023. WPTO supports advancement of composites and other materials that can withstand the forces and ocean environment necessary to advance marine energy technologies at all scales.

g. Wind Energy Technologies Office (WETO): WETO uses advanced manufacturing to address the issues and challenges associated with turbine scaling for both land-based and offshore wind technologies. These activities will enable wind turbine technologies that overcome transportation constraints, allow for larger and lightweight turbine components through novel designs and materials, and increase material and component production throughput.
   - Action Area 2: WETO activities in FY 2024 continues work leveraging prior R&D in additive manufacturing, in addition to broadening into other advanced manufacturing methods such as high-performance

computing (HPC), artificial intelligence (AI), and advanced machine learning (AML). The use of these methodologies will allow WETO to address issues associated with the scaling of wind turbines through component design and material optimization, and reduction of critical rare-earth materials. This work explores the use of these technologies and their application to wind turbine blades, generators, foundations, and towers. Demonstration activities of these technologies will also be examined in the short to longer term.

3. **Office of Fossil Energy and Carbon Management (FECM):** FECM plays a leading role in the decarbonization of the industrial sector and power sector by developing crosscutting carbon capture, carbon removal, CO_2 conversion, and carbon storage, to decarbonize manufacturing processes and power generation, and clean hydrogen production and utilization technologies to enable fuel switching to zero-carbon fuels. FECM's RDD&D program focuses on technologies that help to ensure clean and affordable energy for all and facilitates the transition towards a carbon-pollution-free economy. This RDD&D is targeted at improving overall system efficiency, reducing capital and operating costs, enabling affordable carbon management, and enabling fuel switching to zero-carbon fuels. Carbon management technologies have an important role in the decarbonization of the manufacturing sector for industries such as steel, cement, and chemicals. Additionally, advanced manufacturing capabilities such as roll-to-roll manufacturing and 3-D printing, can help enable many of the advanced carbon management and hydrogen technologies that are under development today and on the verge of commercial deployment. By applying these techniques to reduce material costs, improve designs and manufacturability of these technologies, advanced manufacturing will enable the potential deployment and buildout of point-source carbon capture and storage, carbon removal, carbon conversion, and clean hydrogen production and utilization technologies. As the Department moves to establish a clean hydrogen economy, additional hydrogen-resistant materials will need to be developed to allow for increased quantities of hydrogen production, use, transport, and storage. These activities address three Action Areas:
    - Action Area 1: Refractory materials for gasification systems and ceramic matrix composites for use in hydrogen turbines.
    - Action Area 2: Embedded sensors for harsh environments.
    - Action Area 5: Design of novel, environmentally responsible mineral processing technologies to be used with a variety of feedstocks.

4. **Office of Nuclear Energy (NE):** NE's goal is to maintain U.S. leadership in the development of materials and manufacturing technologies for nuclear energy applications. NE will enable nuclear reactor technology developers by developing materials and manufacturing technologies to produce components that improve safety and reliability and are more cost effective to produce. Within NE, the Advanced Materials and Manufacturing Technologies (AMMT) effort is working to accelerate the development, qualification, demonstration and deployment of advanced materials and manufacturing technologies to enable reliable and economical nuclear energy. These activities support two Action Areas:
    - Action Area 2: NE plans to partner and leverage joint capabilities to demonstrate technologies through the production of parts, components and subsystems that have the potential for widespread impact in manufacturing for the nuclear sector.
    - Action Area 3: NE is engaging stakeholders to develop an accelerated qualification framework for certifying advanced materials and manufacturing technologies. The framework will focus initially on 316 stainless steel materials, which are understood in traditional manufacturing processes but are new to advanced manufacturing processes.

5. **Office of Science (SC):** In FY 2024, SC will support efforts for fundamental science leading to transformational manufacturing aligned with all the *Crosscut Action Areas.* The opportunities for underpinning science for manufacturing crosses many SC activities, including biomanufacturing, innovations for accelerator technology, science to transform "traditional" chemical and materials manufacturing, materials for extreme environments, biotechnology, and isotope production and enrichment, to name a few. Central to the discovery and application of transformative science are computational tools and a system-based co-design approach to integration of experiments, predictive theory, and AI and machine learning (ML) that cross the interfaces among components in manufacturing systems. SC also provides critical isotopes necessary for clean energy technology manufacturing through the Isotope R&D and Production Program.

a. Basic Energy Sciences (BES): The BES workshop on Basic Research Needs for Transformative Manufacturing complements prior SC workshops and provides priority research directions that form the basis for this initiative. Investments in manufacturing science will be enabling for other science and technology initiative areas within DOE with a focus that includes the science to realize scale-up from laboratory prototypes to larger systems and clean manufacturing.
b. Biological and Environmental Research (BER): BER continues biomanufacturing research that focuses on new biotechnology activities and genome-enabled engineering for new approaches to design of bioproducts and biomaterials.
c. Fusion Energy Sciences (FES): The 2018 SC Fusion Energy Sciences Advisory Committee (FESAC) report on Transformative Enabling Capabilities for Efficient Advance Toward Fusion Energy highlighted the promise of novel synthesis, manufacturing, and materials design to enable fusion energy systems for the future. FES is pursuing these new manufacturing technologies to enable design and advancement of novel material systems capable of surviving the extreme conditions expected in fusion reactors as well as other applications of materials for extreme environments.
d. Isotope R&D and Production (DOE IP): The DOE IP is developing domestic production capabilities and supply chains for radioisotopes that are used as the main component in nuclear batteries. Radioisotopes are used as industrial thickness and density gauges, component qualification, and industrial radiography during manufacturing of clean energy components. Many of these isotopes are only available from Russia and the DOE IP is developing domestic supply chains to remove dependence on foreign supplies. Enriched stable isotopes are functional components of enabling materials for advanced fusion and fission energy systems and efforts to increase their availability is a priority for the Program. Research into the development of production of isotopes needed for molten salt and fusion reactors is also being pursued. Finally, the DOE IP supports the development of robotics, automation, and advanced targetry, such as 3-D printing of targets, that facilitate the development and operations of nuclear reactors.

SC will interact with technology offices to ensure close coordination of FY 2024 funding opportunities to ensure maximum impact of funded research on technology challenges. Research opportunities will include a focus on Established Program to Stimulate Competitive Research (EPSCoR) regions as well as broad outreach to minority serving institutions.

Highlights and Major Changes from FY 2023 Enacted

The Clean Energy Technology Manufacturing Crosscut is a subset of the FY 2023 Advanced Manufacturing Crosscut focused on product manufacturing. This change reflects the organizational changes and makes this work distinctive from the Industrial Decarbonization Crosscut focused on reducing emissions in energy intensive industries such as steel, cement, and chemicals.

- Energy Efficiency and Renewable Energy
  - Advanced Materials and Manufacturing Technologies: AMMTO is a successor office to AMO in this Crosscut and reflects the realignment into AMMTO and IEDO.
  - Bioenergy Technologies: BETO increases support to replace petrochemicals with renewable alternatives such as bioderived polymers.
  - Water Power Technologies: WTPO increases funding foundational and application-based research for advanced manufacturing opportunities for hydropower.
  - Wind Energy Technologies: WETO increases will address the issues and challenges associated with turbine scaling for both land-based and offshore wind technologies.
  - Hydrogen and Fuel Cells Technologies: HFTO reduced funding on liquid fueling components and liquid hydrogen storage tanks to focus resources more directly on the manufacturing processes for carbon fiber for on-board physical storage and hydrogen refueling components.
- Fossil Energy and Carbon Management
  - Carbon Management Technologies: Hydrogen with Carbon Management: Decrease reflects current priorities resulting in a lower level of effort in developing alloy compositions and manufacturing techniques to improve resistance to hydrogen embrittlement.

Related Bipartisan Infrastructure Law (BIL) or Inflation Reduction Act (IRA) Programs:

In addition to the annual appropriations request, BIL funding will support the planning and execution of technology development, demonstration, scale-up, and deployment of battery material processing, manufacturing, and recycling; clean hydrogen production; wind energy technology manufacturing; solar energy manufacturing; and advanced manufacturing techniques. These investments are essential in addressing the development of new technologies and advancing supply chain needs to support growth in clean energy. Expansion of tax credits in IRA offer additional incentives for manufacturing across a range of clean energy technologies.

Critical Minerals and Materials
Funding by Appropriation and Program Control
($K)

Appropriation and Program Control	FY 2022 Enacted	FY 2023 Enacted	FY 2024 Request	FY 2024 vs FY 2022 ($ Change)
Advanced Research Projects Agency - Energy	66,125	TBD	TBD	N/A
ARPA-E Projects*	66,125	TBD	TBD	N/A
Energy Efficiency and Renewable Energy	112,523	157,900	206,087	+48,187
Advanced Manufacturing Office (AMO)	47,000	26,000	-	-26,000
Advanced Materials and Manufacturing Technologies Office (AMO successor office)	-	-	50,000	+50,000
Geothermal Technologies	50	3,000	2,787	-213
Hydrogen and Fuel Cell Technologies	30,000	30,000	22,000	-8,000
Solar Energy Technologies	-	16,000	8,000	-8,000
Vehicle Technologies	34,000	73,700	96,500	+22,800
Wind Energy Technologies	1,473	9,200	26,800	+17,600
Fossil Energy and Carbon Management	23,000	44,000	41,000	-3,000
Mineral Sustainability	23,000	44,000	41,000	-3,000
Nuclear Energy	61,500	136,500	131,500	-5,000
Fuel Cycle Research and Development	60,500	136,500	131,000	-5,500
Nuclear Energy Enabling Technologies	1,000	-	500	+500
Office of Technology Transitions	100	-	-	-
Office of Technology Transitions	100	-	-	-
Science	25,000	25,000	25,000	-
Basic Energy Sciences	25,000	25,000	25,000	-
Grand Total	**288,248**	**363,400**	**403,587**	**+40,187**

*ARPA-E funding is determined annually based on programs developed through office and stakeholder priorities. Therefore, funding for FY 2023 and FY 2024 is not available currently.

Overview:
Critical minerals and materials (CMM) are vital for U.S. energy security and the clean energy transition, for defense applications, and for a broad set of industrial and commercial applications which underpin the U.S. economy. Currently, the United States imports greater than 80% of its rare earth elements (REE) and overall is heavily reliant on foreign sources for 29 of the 35 designated critical minerals.[1]

Developing reliable and secure CMM sources and supply chains; identifying and advancing effective substitutes or alternatives using an assured supply of materials; and developing domestic, responsible, and efficient processing capacity for these minerals and materials can reduce the supply risks faced by the U.S. Foundational supply chain components include, but are not limited to, neodymium, praseodymium, and dysprosium for permanent magnets in electric vehicle (EV) motors and wind turbines; cobalt, lithium, manganese, class 1 nickel, and graphite for EV and grid batteries; platinum group metals in catalysts for catalytic convertors, chemical production, fuel cells, and clean hydrogen production; and gallium and germanium for semiconductors. There are additional minerals such as copper and uranium, which while not on the current U.S. critical minerals list, are recognized as vital for clean and low carbon energy, and for energy system resilience considering the dynamic and constantly changing global supply chains.

[1] USGS Mineral Commodities Summaries 2022, Mineral Commodity Summaries 2022 (usgs.gov)

The development of sustainable, safe, and robust domestic supply chains for CMM can also create high-paying jobs, support both existing and new manufacturing economies, and aid in a just transition for coal and fossil-based communities. CMM supply chains include mining and extraction, processing, manufacturing, and management at end-of-life (including remanufacture, refurbish, repair, reuse, recycle, and repurpose). At the same time, development of more diverse and robust mineral and material supply chains must incorporate engagement and consultation with diverse stakeholder and tribal communities, coupled with deep consideration of and mitigation of the environmental and life cycle impacts of accelerated growth of CMM supply chains. This means that CMM supply chains of the future will be significantly different from those of the past.

Coordination Efforts:
The Department of Energy's (DOE) primary role as part of a broader Federal Strategy[2] to build resilient CMM supply chains is to advance research, development, demonstration (RD&D), and commercialization spanning basic science to technology innovation. Section 7002(g)(1) of the Energy Act of 2020 directs DOE to establish a Critical Materials Research, Development, Demonstration, and Commercialization Application (RDD&CA) Program to:

- develop alternatives to critical materials that do not occur in significant abundance in the United States;
- promote the efficient production, use, and recycling of critical materials, with special consideration for domestic critical materials, throughout the supply chain;
- ensure the long-term, secure, and sustainable supply of critical materials; and
- prioritize work in areas that the private sector by itself is not likely to undertake due to financial or technical limitations.[3]

The CMM Crosscut coordinates and integrates the DOE Critical Materials RDD&CA.[4] The CMM Crosscut Team is comprised of representatives from across DOE to address research needs and related activities across all stages of research, the full supply chain and life cycle.

In addition to the funding offices identified below, key facilitating offices support key portions of this work. The Office of Technology Transitions (OTT), in coordination with DOE program offices, analyzes, identifies, and supports technology commercialization pathways and partnership opportunities. The International Affairs Office (IA) identifies and facilitates opportunities with key foreign and ally partners and serves as a key bridge to other U.S. Government efforts in global supply chains. The Office of Policy (OP) provides in-depth analysis and identifies policy tools which can accelerate technology use and adoption in support of the clean energy transition. The Office of Legacy Management (LM) manages DOE's Uranium Leasing Program. Additionally, Offices under the Under Secretary for Infrastructure, including the Office of Clean Energy Demonstrations (OCED), Office of Manufacturing and Energy Supply Chain (MESC), and the Loan Programs Office (LPO) support demonstration and deployment activities in the CMM space.

FY 2024 coordination activities include developing and executing RDD&CA strategic planning, budget development, and execution for the crosscut through workshops, reports, and strategy updates. Crosscutting priorities will be informed by ongoing analysis, including an update of DOE's critical materials assessment. Strategic planning efforts will build upon previous coordination activities directed by Congress, as well as coordination mandated through Executive Order (EO) 13953, *Addressing the Threat to the Domestic Supply Chain from Reliance on Critical Minerals from Foreign Adversaries and Supporting the Domestic Mining and Processing Industries*, EO 14017, *America's Supply Chains*, and Section 7002(g)(6) of the Energy Act of 2020.[5] This work includes ongoing DOE efforts within DOE's OP to develop and maintain domestic supply chains by increasing raw material availability, expanding domestic manufacturing capabilities, supporting formation of and investment in diverse, secure, and socially responsible foreign supply chains, and enhancing supply chain knowledge and decision making. The CMM crosscut will also coordinate with other priority technology efforts, the most notable and impactful being the Subsurface Energy Innovations crosscut, to ensure that key topics and opportunities are not overlooked.

[2] https://www.commerce.gov/data-and-reports/reports/2019/06/federal-strategy-ensure-secure-and-reliable-supplies-critical-minerals
[3] Consolidated Appropriations Act, 2021, Public Law 116-260 (Dec. 27, 2020), Div. Z, Title VII, section 7002(g)(1) [hereinafter Energy Act of 2020].
[4] Energy Act of 2020, section 7002(g)(6).
[5] Energy Act of 2020, section 7002(g)(6).

CMM development and access within the U.S. requires close coordination between DOE and other agencies which have key leadership, supporting, or facilitating roles. This includes regulatory (Environmental Protection Agency, Department of Interior (DOI)); international (Department of Commerce (DOC), Department of State, Export-Import Bank, Development Finance Corporation (DFC)); technical (DOI-United States Geological Survey, Department of Defense (DOD)); and commercial facing partners (DOC, DOD, Department of Labor). Interagency collaboration is key to advance and secure sustainable mineral extraction, and to address the issues and challenges posed by future possible resources.

Objectives and Action Areas:

- Objective 1: Enable Robust CMM Supply Chains. Create reliable, resilient, affordable, and secure supply chains for critical minerals and materials imperative to the clean energy and national security mission of the Department as part of a U.S. Government-wide strategy that leverages our allied global partners.
    - Action Area 1: Diversify & Expand Supply: Diversify and expand CMM supply from varying sources while minimizing waste and increasing techno-economic co-production of materials, where many materials are produced together, each bringing in similar revenues rather than one material accounting for an overwhelming majority of revenue.
    - Action Area 2: Develop Alternatives: Innovate alternate materials, manufactured components, and technologies that minimize or eliminate the use of CMMs.
    - Action Area 3: Increase Material & Manufacturing Efficiency: Efficient use and processing of materials across supply chain and life cycle.
    - Action Area 4: Enable a Circular Economy: Remanufacture, de-manufacture, refurbish, repair, reuse, upcycle, recycle, and repurpose.
- Objective 2: Increase U.S. Science & Technological Competitiveness. Ensure that DOE is an essential source of science, technology, and engineering solutions for re-establishing U.S. competitiveness in CMM supply chains and maintaining world class science and capabilities.
- Objective 3: Create a Responsible Energy Future. Create economic opportunities in partnership with communities while working to mitigate against adverse impacts on communities and the environment associated with the entire lifecycle of CMM supply chains.
- Objective 4: Expand the Innovation Ecosystem. Foster an inclusive, equitable, and accessible CMM innovation ecosystem that convenes a diverse set of stakeholders, not limited to DOE National Labs, academic – including community colleges and Minority Serving Institutions (MSIs), industry, and small businesses and broadens participation in science and technology.
    - Action Area: Increase Enabling and Crosscutting Work: Enhance collaboration and coordination for cross-cutting functions, such as criticality assessments, education and workforce development, stockpiling approaches, advanced theoretical, computational, and experimental tools, etc. Applies to multiple objectives.

Program Organizations:

1. **Advanced Research Projects Agency-Energy (ARPA-E):** As defined by its authorization under the America COMPETES Act, ARPA-E catalyzes transformational technologies to enhance the economic and energy security of the United States. ARPA-E funds high-potential, high-impact projects that are too risky to attract private sector investment but could significantly advance the ways to generate, store, distribute and use energy. In FY 2022, ARPA-E selected and/or obligated over $66 million in CMM funding to projects aligned with the Crosscut through ARPA-E's Supporting Entrepreneurial Energy Discoveries (SEED) Exploratory Topic, Mining Innovations for Negative Emissions Resource Recovery (MINER), and Seeding Critical Advances for Leading Energy technologies with Untapped Potential 2021 (SCALEUP 2021) programs. ARPA-E is developing programs for transformational research across a wide range of energy technologies and applications. The assessment process for new programs is now underway and any potential future investments in CMM will be determined in FY 2023.

2. **Office of Energy Efficiency & Renewable Energy (EERE):**
    a. Advanced Materials and Manufacturing Technologies Office (AMMTO): Efforts will focus on comprehensive RD&D to reduce supply risk and improve supply resilience for materials and technologies necessary for the clean energy transition (including rare earths, lithium, cobalt, and gallium). These materials are needed for applications such as

magnets in EVs and wind turbines, batteries, efficient lighting, and semiconductors. Strategies include diversifying supply, developing substitutes, improving reuse/recycling, and more efficient use. Efforts will also focus on research and development (R&D) and pilot projects and testbeds that verify economics of scaled continuous operations in real world conditions. Areas of interest for these projects include highly selective separation, metal reduction, magnet manufacturing, materials recovery from secondary and unconventional sources, material reuse, more efficient use, and balanced coproduction.

b. Geothermal Technologies (GTO): Efforts will address technology and process gaps that still exist following the results of the Geothermal Lithium Extraction Prize to generate technical solutions to the Nation's CM supply through geothermal brine and produced water extraction and processing. This may include efforts to scale up technical solutions developed as part of the Geothermal Lithium Extraction Prize to successful demonstration in the Salton Sea area of California. In the Salton Sea alone, there is an estimated annual lithium resource potential of 600,000 tons, which currently exceeds the annual U.S. demand for lithium.
c. Hydrogen and Fuel Cell Technologies Office (HFTO): HFTO supports R&D to reduce Platinum Group Metals (PGM) catalysts for fuel cells and hydrogen production technologies, as well as additional supporting activities to reduce vulnerabilities and build supply chain resilience.
d. Solar Energy Technologies Office (SETO): SETO supports the analysis of potential photovoltaics (PV) deployment limitations related to materials scarcity and the RD&D of materials alternatives, techniques to use materials more efficiently and recycling methods to further utilize existing materials.
e. Vehicle Technologies Office (VTO): Accelerate fundamental research for developing substitutes for graphite, by enabling silicon anodes, and for developing near term lithium chemistries that require very low or no cobalt. Focus research on lithium battery technologies that eliminate the need for cobalt, significantly reduce or eliminate the need for nickel and graphite such as lithium metal and solid-state battery technologies. Battery recycling R&D will advance the scale-up of bench scale processes and validate processes to meet the goal of utilizing mostly recycled material that matches the performance of virgin material.
f. Wind Energy Technologies Office (WETO): Funding for analysis and technology innovation efforts to both understand the vulnerabilities of the wind energy supply chain to critical materials and to mitigate those vulnerabilities by reducing dependence on, and improving recovery of, critical materials within wind energy components.

3. **Office of Fossil Energy and Carbon Management (FECM):**
   a. Minerals Sustainability Division: FY 2024 Key Objectives (Planned): The FY 2024 Budget Request supports further advance production of high purity, commercial grade REE and other critical minerals (CM), which will form next stage development to broadly enable extraction of REEs and other CM from unconventional feedstocks (such as coal refuse, acid mine drainage, and produced water) towards commercial industry adoption.
   b. Funding will also be utilized for Front-End Engineering Design (FEED) studies for an extraction, separation and recovery facility/system that can produce 1-3 metric tons per day of an at least 75% rare earth oxide and/or salt mixed concentrate by weight and assess potential for individual separation and reduction to metal.
   c. Funding would be applied to further regional basin projects (the Carbon Ore, Rare Earth and Critical Minerals (CORE-CM) Initiative). It will continue to support regional characterization and field activities for unconventional/secondary sources, basin commercialization strategic planning/implementation, environmental remediation value streams, basinal technology development and stakeholder outreach and engagement.
   d. Funding would be applied to further Carbon Ore to Products projects to develop synthetic graphite, graphene, and other carbon materials that are critical resources for batteries, electronics, composites, and similar end-uses. This will include technoeconomic analysis (TEA) and life-cycle analysis (LCA), process systems, and market analyses of high value carbon products that will enable CM production from coal-based feedstocks.
   e. The development of a sustainable, safe, and robust domestic supply chain for CMM can also create jobs and aid in a just transition for coal and fossil-based communities. These communities have expertise that could be transferrable to technology development throughout the supply chain including:
      i. Upstream unconventional technology and technique development from resource characterization and prediction, through novel extraction from sources such as acid mine drainage, mine refuse, coal ash, and geothermal and produced water brines.
      ii. Midstream technology development for environmentally sustainable, efficient, and cost-effective extraction, processing, and refining of resources from unconventional and secondary sources.

iii. Downstream technology development for the transformation of carbon ore to synthetic graphite and graphene for battery anodes as well as graphene for quantum dots for use in solar cells.

4. **Office of Nuclear Energy (NE):** NE is taking steps to support a domestic nuclear fuel supply chain including uranium mining, conversion, enrichment, fuel fabrication, and the option of recycling. NE is also developing materials and manufacturing technologies to support advanced reactors and the current fleet of domestic reactors.
   a. In prior years, NE began to identify the CM for the alloys and other applications used by the U.S. nuclear industry for the current fleet and projected for advanced reactors. NE began supporting domestic uranium mining capabilities through R&D activities to reduce lifecycle costs of uranium production; demonstrating the production of high-assay low-enriched uranium (HALEU) using U.S. origin enrichment technology to encourage commercialization by the private sector; and developing advanced recycling technologies as options to improve uranium resource utilization.
   b. Fuel Cycle R&D: A HALEU Availability program has been initiated to support civilian domestic demonstration and commercial use. This program will work to make available small quantities of HALEU from limited DOE uranium inventories and HALEU production in the short term. In addition, the program will work with the private sector in its design and build out of commercial U.S. HALEU production capability in the long term. Additionally, activities for the development and demonstration of different recycling technologies to make available small quantities of HALEU materials will continue, by using the molten salt and hybrid ZIRCEX processes.
   c. Nuclear Energy Enabling Technologies: Perform research on the positive effects of advanced manufacturing techniques to improve use of CM for nuclear energy applications.

5. **Office of Science (SC):** For many years, SC has supported foundational theoretical and experimental science related to understanding unique chemistry and materials properties associated with REEs, substitution for platinum group element (PGE) catalysts, and novel battery materials and chemistries. SC operates major x-ray, neutron, nanoscience, and high-performance computing user facilities that provide advanced synthesis, fabrication, characterization, and computational capabilities to this community for basic, applied, and industrial research. Research in FY 2024 emphasizes the full breadth of the crosscut.
   a. Basic Energy Sciences (BES): Research continues to focus on understanding the role of REEs, PGEs, and other critical elements in the determination of the properties of materials and molecules at length scales ranging from electronic to atomic and microstructural scales, and on advancing geoscience and separation science to enhance the extraction and chemical processing of critical elements. Also included is understanding of the REE and PGE chemistry, including selective separations from solutions, and dynamics and reactivity at mineral-water interfaces during extraction and recovery. Emphasis will include integration of the related fields of synthesis, characterization, predictive theory/modeling, and data science to advance understanding of the role of REE, PGE and other critical elements in the determination of the properties of functional materials such as magnets and catalysts, and on the use of such knowledge to reduce, eliminate, or find substitutes for critical materials in energy-relevant technologies.
   b. Isotope R&D and Production (DOE IP): REEs and critical materials are often needed to produce isotopes that are required for batteries, semiconductors, and clean energy applications, leading to synergies with the DOE IP that produces isotopes. The DOE IP develops chemical separations that are of interest to the REE community. The DOE IP also coordinates investigation of co-recovery of critical isotope production feedstocks alongside REEs. For example, industrial waste streams containing significant concentrations of Radium-226 are produced through oil and natural gas extraction, geothermal energy production, coal combustion, phosphate fertilizer production, and heavy metal mining. These waste streams also have high concentrations of other valuable materials, such as lithium and REEs, which could be co-recovered alongside Radium-226, an important isotope for producing medical radioisotopes for the treatment of cancer and other diseases.

Highlights and Major Changes from FY 2023 Enacted

- Energy Efficiency and Renewable Energy
  - Advanced Materials and Manufacturing Technologies Office: As a successor office to AMO, AMMTO reflects an increased emphasis on CMM through R&D, pilot projects and testbeds that verify efficiency and economics of scaled continuous operations in real world conditions needed to diversify supply, develop substitutes, and improve reuse/recycling.

- Hydrogen and Fuel Cells Technologies Office: HFTO's support for work to reduce PGM catalysts for fuel cells and hydrogen production technologies remains substantial at decreased funding levels due to prioritization of other work.
- Solar Energy Technologies Office: SETO programs continue work on addressing materials availability at lower levels while the program awaits results of recent BIL investments.
- Vehicle Technologies Office: VTO's increased funding will support research for battery recycling and develop substitutes for graphite and nickel by enabling silicon anodes and for developing near term lithium chemistries that require very low or no cobalt.
- Wind Energy Technologies Office: WETO's increased support provides funding for analysis and technology innovation efforts to both understand the vulnerabilities of the wind energy supply chain to critical materials and to mitigate those vulnerabilities.

Related Bipartisan Infrastructure Law (BIL) Programs:
In addition to the annual appropriations request, BIL funding will support the planning and execution of technology development, demonstration, scale-up, and deployment activities, including battery and CMM recycling, battery material processing, and execution of an REE demonstration facility. These investments are essential in addressing CMM supply chains and technology needs to support growth in clean energy and will expand and accelerate DOE's CMM strategy.

Energy Storage
Funding by Appropriation and Program Control
($K)

Appropriation and Program Control	FY 2022 Enacted	FY 2023 Enacted	FY 2024 Request	FY 2024 vs FY 2023 ($ Change)
Advanced Research Projects Agency – Energy*	43,280	TBD	TBD	N/A
ARPA-E Projects	43,280	TBD	TBD	N/A
Energy Efficiency and Renewable Energy	336,835	352,301	388,100	+35,799
Advanced Manufacturing Office (AMO)	30,000	25,500	-	-25,500
Advanced Materials and Manufacturing Technologies (AMO successor office)	-	-	24,000	+24,000
Building Technologies	6,375	15,000	15,000	-
Geothermal Technologies	250	7,900	5,000	-2,900
Hydrogen and Fuel Cell Technologies	126,000	118,000	104,000	-14,000
Industrial Efficiency and Decarbonization Office (AMO successor office)	-	-	5,000	+5,000
Renewable Energy Grid Integration	10,000	-	-	-
Solar Energy Technologies	13,660	20,851	13,100	-7,751
Strategic Programs	300	350	500	+150
Vehicle Technologies	135,000	146,500	192,500	+46,000
Water Power Technologies	13,850	17,140	19,000	+1,860
Wind Energy Technologies	1,400	1,060	10,000	+8,940
Fossil Energy and Carbon Management	5,000	6,000	6,000	-
Energy Asset Transformation	5,000	6,000	6,000	-
Nuclear Energy	53,000	23,000	13,500	-9,500
Crosscutting Technology Development	10,000	12,000	9,500	-2,500
Demonstration 2 (Natrium)	30,000	-	-	-
Light Water Reactor Sustainability	13,000	11,000	4,000	-7,000
Electricity	117,684	88,965	78,600	-10,365
Energy Storage Research	70,684	88,965	78,600	-10,365
20-OE-100 Grid Storage Launchpad	47,000	-	-	-
Office of Technology Transitions	100	100	100	-
Office of Technology Transitions	100	100	100	-
Science	83,934	130,100	133,382	+3,282
Basic Energy Sciences	83,934	130,100	133,382	+3,282
Grand Total	**639,833**	**600,466**	**619,682**	**+19,216**

*ARPA-E funding is determined annually based on programs developed through office and stakeholder priorities. Therefore, funding for FY 2023 and FY 2024 is not available currently.

Overview:
The Department of Energy (DOE) Energy Storage crosscut encompasses activities to accelerate the research, development, and demonstration (RD&D), as well as market adoption, of transformational energy storage technologies. Energy storage technologies are critical to decarbonizing the power, transportation, buildings, and industrial sectors. To achieve a net-zero emissions economy, DOE activities are focused on demonstrating and validating existing storage technologies for new uses and identifying, developing, and commercializing new storage technologies for market adoption by the end of the decade. Because energy storage services can be provided by a range of distinct technologies, the Energy Storage Grand

Challenge (ESGC) was established in 2020 across DOE offices to improve coordination and alignment of common goals for energy storage use cases. ESGC was formed to manage strategy across DOE on energy storage and coordinates the DOE-wide "Energy Storage System Research, Development, and Deployment Program" required by 42 U.S. Code § 17232(b).

The ESGC goals are guided, in part, by the Long Duration Storage Energy Earthshot™, which is a bold target to achieve 90% cost reductions for technologies that can provide 10 hours or longer duration of energy storage within the coming decade. As an Energy Earthshot™, Long Duration Storage Shot™ highlights a top Administration research, development, demonstration, and deployment (RDD&D) focus area where innovation breakthroughs will address the climate crisis and create high-paying clean energy jobs in the United States.

Since 2020, the ESGC has launched more than $550 million in funding for almost 250 projects in 45 States, including Hawaii and Alaska—and encompassing disadvantaged communities and Tribal areas. These projects—carried out by large and small businesses as well as research institutions and other innovative organizations, partnerships, and consortia—represent the Department's work to advance energy storage technologies across its basic and applied research and development (R&D) portfolios and in applications that range from developing membranes for electrochemical energy storage to processing critical materials and from manufacturing structural battery enclosures to creating durable and cost-effective fuel cell systems and components for vehicles.

Coordination Efforts:
The Energy Storage Grand Challenge is co-chaired by the Offices of Electricity (OE) and Energy Efficiency and Renewable Energy (EERE) and includes the Offices of Fossil Energy and Carbon Management (FECM), Nuclear Energy (NE), Science (SC), Technology Transitions (OTT), Clean Energy Demonstrations (OCED), Manufacturing & Energy Supply Chains (MESC), the Federal Energy Management Program (FEMP) and Advanced Research Projects Agency-Energy (ARPA-E), as well as the Loan Programs Office (LPO) as a key participant. The ESGC coordinates activities aligned with the ESGC Roadmap, which was published in 2020 and updated in 2022.

In addition to the core offices identified above, various crosscutting offices (including the Offices of Economic Impact & Diversity, Policy, and Artificial Intelligence and Technology) contribute staff time and coordinate with the RDD&D funding offices to enhance the impact of the Department's investments. Coordination throughout the Federal Government on batteries is facilitated through the Federal Consortium for Advanced Batteries (FCAB), which brings together Federal agencies that are interested in ensuring a domestic supply of lithium batteries and are committed to accelerating the development of a robust and secure domestic industrial base.

Objectives and Action Areas:
The ESGC is primarily guided by two crosscutting R&D targets:

- Objective 1: Achieve the Long Duration Storage Shot™ Target: $0.05/kilowatt-hour (kWh) levelized cost of storage for long duration (10 or more hours) stationary applications by 2030. Achieving this levelized cost target would support the Administration's 2035 and 2050 decarbonization goals and facilitate commercial viability for storage across a wide range of uses, including in:
    - Remote communities, which are frequently disconnected or may not have access to the grid, and
    - Grid-scale applications, where storage can meet load during periods of peak demand and ensure reliability of critical infrastructure, including communications and information technology.
- Objective 2: Achieve the Electric Vehicles (EV) Battery Target: Reduce EV battery cell cost by 50 percent to $60/kWh manufactured cost for a battery cell by 2030 for a 300-mile range electric vehicle to achieve cost parity with internal combustion engine vehicles. Advances in battery production for transportation applications are anticipated to continue benefitting production, performance, and safety of similar technologies used in batteries for stationary applications.

Throughout the core ESGC DOE offices, DOE has or currently supports over 30 distinct energy storage technologies, including specific methods of storage via electrochemical, electromechanical, thermal, flexible generation, and controllable loads, as well as power electronics. Many of these energy storage technologies have the potential to enable the long duration and EV targets shown above. Achieving these aggressive 2030 targets will require resolution of key barriers throughout value chain, from basic and applied research through analysis, demonstration, manufacturing, and full integration into the power and end-use sectors.

Action Areas: To address these barriers, the ESGC has identified the following priority collaboration action areas:

1. Investment & Finance: Emphasize modeling and development of economic and financial mechanisms necessary for the successful commercial deployment of a given energy storage technology.
2. Markets & Value: Analyze both current and potential future markets to understand how energy storage demand will evolve, what performance and cost characteristics will be needed for individual technologies to be competitive, and how those technologies will be valued and compensated.
3. Thermal Technologies: Continue RDD&D for multiple thermal technology pathways, including high-temperature sensible heat; phase change; low-temperature storage; thermo-photovoltaic; and thermochemical.
4. Power Electronic Systems: Advance power electronics and power conversion systems including magnetics, capacitors, semiconductor switches, optimized power converters for emerging lower voltage battery systems.
5. Electrochemical Batteries: Continue RDD&D or alternative and efficient use of materials, component design and manufacture as well as address end-of-life and material recovery.

Beyond the 2030 goals, the ESGC continues to identify future long-term targets that will enable additional transformative applications. After the diurnal applications for 10-hour storage have been met, weekly, monthly, and seasonal applications will require hundreds of hours of duration. After EVs achieve cost parity, use cases for aviation, shipboard, and other highly constrained applications will have much more demanding cost and density requirements. In FY 2024, the ESGC anticipates a revision to these near- and long-term objectives in an updated strategic plan.

Program Organizations:

1. **Advanced Research Projects Agency-Energy (ARPA-E):** As defined by its authorization under the America COMPETES Act, ARPA-E catalyzes transformational technologies to enhance the economic and energy security of the United States. ARPA-E funds high-potential, high-impact projects that are too risky to attract private sector investment but could significantly advance the ways to generate, store, distribute and use energy. In FY 2022, ARPA-E selected and/or obligated over $43 million in funding to Energy Storage-related projects aligned with the Crosscut through ARPA-E's Supporting Entrepreneurial Energy Discoveries (SEED) Exploratory Topic and Electric Vehicles for American Low-Carbon Living (EVs4ALL) program. ARPA-E is developing programs for transformational research across a wide range of energy technologies and applications. The assessment process for new programs is now underway and any potential future investments in Energy Storage will be determined in FY 2023.

2. **Energy Efficiency and Renewable Energy (EERE):** EERE will continue to fund energy storage R&D for both stationery and mobility applications in support of both the Long Duration Storage Energy Earthshot™ and EV battery cell's goal.
    a. Advanced Materials and Manufacturing Office (AMMTO): AMMTO will continue to collaborate with multiple offices, including OE and sister offices in EERE, on projects to overcome manufacturing barriers and eliminate gaps in manufacturing capabilities of innovative integrated long duration energy storage systems and will pursue advances in materials to support thermal storage. AMMTO will support early applied stage projects for enabling passive components such as capacitors and inductors to expand the application space of power electronics and will support device prototype fabrication for wide (e.g., SiC, GaN)/ultra-wide (e.g., Ga2O3, AlN, diamond) bandgap semiconductor materials and devices.
    b. Building Technologies Office (BTO): BTO will continue its support for energy storage, focusing primarily on thermal energy storage research, more sophisticated controls for storage enabling grid-interactive buildings, deployment of heat pumps with thermal energy storage (TES), and cost reductions of heat pumps with TES.
    c. Geothermal Technologies Office (GTO): GTO will support the assessment of deep, low temperature resources in the U.S. for thermal energy storage as well as continue its Reservoir Thermal Energy Storage Initiative.
    d. Hydrogen Fuel Cell Technologies Office (HFTO): HFTO's work in energy storage includes RD&D related to hydrogen production, hydrogen storage, and reversible fuel cell technologies, as well as systems integration RD&D. For example, HFTO funds efforts focused on integrating renewables, nuclear, and other resources with hydrogen production, storage, and end uses across applications as well as infrastructure components. Work also includes support for the National Renewable Energy Lab's (NREL) Advanced Research on Integrated Energy Systems (ARIES).
    e. Industrial Efficiency and Decarbonization Office (IEDO): IEDO's work will focus on innovation related to incorporating energy storage into manufacturing processes and/or facilities to manage power and thermal energy and reduce industrial greenhouse gas (GHG) emissions.

f. Solar Energy Technologies Office (SETO): SETO's work in energy storage focuses on TES integrated with concentrating solar-thermal power (CSP) systems, both for electricity generation as well as industrial process heating applications. CSP funding will continue to support high-efficiency, reliable TES technologies to support the Energy Storage Grand Challenge and Long Duration Storage Energy Earthshot™, with a particular focus on technologies using solid particles as the heat transfer medium, leveraging the SETO funded megawatt-scale Generation 3 Concentrating Solar Power Systems (Gen3 CSP) test facility currently under construction.
g. Strategic Programs (SP): SP will continue to support the ESGC Policy & Valuation Track, which provides data, tools, and technical analysis that help policymakers and other energy system decision-makers maximize the value of energy storage.
h. Vehicle Technologies Office (VTO): VTO's Battery R&D activity supports early-stage R&D of high-energy and high-power battery materials, cells, and battery development that can enable industry to significantly reduce the cost, weight, volume, and charge time of plug-in EV batteries.
i. Water Power Technologies Office (WPTO): WPTO, through the HydroWIRES Initiative (hydropower's contributions to reliability, resilience, and integration), will provide funding for hydropower hybrid demonstrations, a comprehensive Hydropower Futures Study to quantify emission and cost reductions enabled by increased hydropower flexibility and new pumped storage hydropower (PSH) development, and expansion of the PSH Valuation Guidebook to include non-power value.
j. Wind Energy Technologies Office (WETO): WETO supports the energy storage crosscut through multi-office collaboration in hybrid system design, hardware, control, and demonstration to hybrid systems involving combinations of technologies such as wind, hydropower, solar, battery storage, or hydrogen.

3. **Fossil Energy and Carbon Management (FECM):** To achieve ESGC objectives, FECM's Energy Asset Transformation program focuses on the integration of long-duration energy storage technologies with a variety of fossil assets, including co-locating energy storage with some strategic fossil assets, which provides many benefits including improved asset flexibility and efficiency, improved grid reliability, and reduced GHG emissions.

   Additionally, energy storage enables many heavily decarbonized use cases, for example, the integration of hydrogen energy storage systems with hydrogen turbine power production. In FY 2022, FECM down-selected three promising projects from the original twenty-nine energy storage projects. The FY 2024 Budget Request supports:
   a. Fossil asset transformation efforts across the U.S., through both direct assistance (e.g., funding an ongoing project in a community hosting an asset undergoing transition, through mechanisms like prizes, competitive solicitations, and Partnership Intermediary Agreements (PIAs)) and paper case studies (e.g., through supporting work at headquarters, the National Labs, or contractor funding);
   b. Place-based interagency efforts related to energy transition and fossil asset transformation, including by contributing to DOE's funding of the Rapid Response Teams associated with the Interagency Working Group on Coal and Power Plant Communities;
   c. Concept development through prizes or a competitive solicitation to repurpose the existing fossil asset, with the intent of supporting transformation efforts in seeking additional support for FEED studies and other work;
   d. Research and case studies focused on safety and reliability challenges for assets reaching end of life in the near and medium term, particularly given dynamic operational constraints; and
   e. Advancing energy storage concepts that can leverage abandoned or under-utilized energy assets, including repurposing power plants with TES and repurposing oil and gas infrastructure for geologic Hydrogen (H_2) storage.

4. **Nuclear Energy (NE):** NE supports Objective 1, Achieve the Long Duration Storage Shot Target™, through R&D to enable flexible generation, electrochemical and TES, and controllable loads. These technologies allow nuclear plants to be used at full capacity, even during times of low demand, while helping to balance the grid. Nuclear plants can produce hydrogen to store energy electrochemically for conversion back to electricity or produce heat for thermal energy storage for later conversion to electricity. Hydrogen may be used for electrochemical energy storage and conversion back to electrical energy or for industrial applications. For industrial applications, the electrolyzers can serve as a controllable load, providing one-way energy storage for the grid (ramping the electrolyzers down when demand is high, and ramping electrolyzers up when demand is low). NE's thermal energy storage R&D includes thermal extraction and distribution systems for providing both industrial process heat and energy storage for the grid, where peak power turbines can be used to convert the stored thermal energy into electricity. NE is assessing thermal storage with various

types of reactors, including current light water reactors and advanced reactors with various operating temperatures ranging from 300 to 900 degrees Celsius.

In FY 2024, NE will support activities in:

a. Energy system modeling and simulation to develop a modeling framework for economic dispatch optimization of integrated energy systems;
b. Fail-safe control systems development for thermal distribution systems, with operator interface and operational procedures;
c. Thermal distribution components and systems R&D to characterize and verify the cost and performance of thermal energy distribution systems;
d. Energy storage R&D to evaluate performance, reliability, and cost for TES systems, including molten salt, sand, and concrete based systems; and
e. Energy conversion R&D to assess thermal storage capacity and efficiency of energy conversion with thermochemical heat pump cycles.

5. **Office of Electricity (OE):** The Office of Electricity supports activities that primarily contribute to the ESGC Long Duration Storage Shot™ objectives. In FY 2024, these activities, leveraging the new Grid Storage Launchpad facility, will include:
    a. Facilitating investment industry familiarity with energy storage through OE's annual workshop series on storage finance;
    b. Accelerating commercial financing and deployment of new storage technologies by expanding the Rapid Operational Validation Initiative (ROVI) to improve the performance projection methodologies of non-lithium technologies;
    c. Helping communities analyze and demonstrate new use cases showing storage and community benefit outcomes by launching an expanded cohort in the Energy Storage for Social Equity (ES4SE) program;
    d. Continuing technical assistance to utility commissions and other decisionmakers;
    e. Developing new materials and technologies for efficient power conversion and grid integration;
    f. Simplifying battery deployments through analysis to support strong safety standards; and
    g. Resolving key R&D objectives for the next generation of battery chemistries with secure supply chains.

6. **Office of Technology Transitions (OTT):** OTT leads the Technology Transition track for ESGC and leverages that role to conduct coordinated market and economic analyses to pursue energy storage commercialization opportunities. Prior efforts include publication of the Energy Storage Market Report and analysis of energy storage for remote and underserved communities. In FY 2024, OTT efforts will include market and economic analysis to identify and pursue technology commercialization opportunities and coordination of energy storage-related technology transfer activities across the DOE lab complex. This work will build on foundational analysis conducted through the Long-Duration Energy Storage Demonstration & Deployment Pathways report being developed through FY 2023.

7. **Science (SC):** Basic Energy Sciences (BES) continues support in FY 2024 for foundational, crosscutting, fundamental energy storage research that underpins the technology offices activities, including through the Batteries and Energy Storage Energy Innovation Hub program (recompeted in FY 2023) and Energy Frontier Research Centers (EFRCs). Core research activities include crosscutting science that is relevant to electrochemical energy storage, hydrogen, and fuel cells. Included in the hydrogen portion of the crosscut is the Fuels from Sunlight Energy Innovation Hub program and EFRCs related to hydrogen research. The research emphasizes fundamental understanding of phenomena and discoveries of new materials and chemistries that could lead to advances for these technologies. In FY 2024, the Request continues support for Energy Earthshot Research Centers (EERCs), which will work toward the stretch goals of the DOE Energy Earthshots™ and will provide a solid bridge between SC and the Energy Technology Offices. Through strong alignment with the technology offices, EERCs will address key basic research challenges, with relevance to applied R&D activities.

Highlights and Major Changes from FY 2023 Enacted

- Energy Efficiency and Renewable Energy
    - Geothermal Technologies: GTO will support the assessment of deep, low temperature resources in the U.S. for thermal energy storage as well as continue its Reservoir Thermal Energy Storage initiative at substantial but lower levels than FY 2023 enacted to emphasize other activities.

- Hydrogen and Fuel Cell Technologies: HFTO continues to support hydrogen production, hydrogen storage, advanced fuel cell technologies and systems integration RD&D at substantial levels though less than FY 2023 with shifts in subprogram priorities.
- Industrial Efficiency and Decarbonization: As a successor office to AMO, IEDO funds work on integrating storage into industrial processes.
- Solar Energy Technologies: SETO programs decrease reflects a focus on a smaller set of issues as the program awaits results from ongoing projects.
- Vehicle Technologies: Increased funding in VTO continues research for next generation lithium-ion batteries.
- Water Power Technologies increases funding on hydropower hybrid demonstrations and studies to quantify emission and cost reductions enabled by increased hydropower flexibility and new PSH development.
- Wind Energy Technologies funding reflects increased support for multi-office collaboration in hybrid system design, hardware, control, and demonstration to hybrid systems.

- Nuclear Energy
  - In FY 2024, NE will reduce work related to hydrogen-based energy storage but continue to focus its resources on technical and economic analysis of TES systems for the current fleet and advanced reactors.
- Electricity
  - In FY 2024, the OE Energy Storage program reduces overall support for planned storage activities, as FY 2023 congressionally directed activities will be completed with funding provided in FY 2023. This reduction is partially offset by increases to:
    - Expand safety and reliability outreach to key stakeholders (including fire safety, codes and standards, and other groups),
    - Expand ROVI to improve the performance projection methodologies of 2–3 new non-lithium electrochemistries, and
    - Launch the new ES4SE cohort with 5–10 communities in the initial technical assistance phase and 2–4 communities reaching the second, pilot phase.
- Science
  - In FY 2024, BES (SC) increases support for DOE's Energy Earthshots™, which include the Hydrogen and Long Duration Storage Shots associated with this crosscut. The new Batteries and Energy Storage Energy Innovation Hub projects started in FY 2023 will ramp up operations, providing foundational understanding to drive energy storage applications for both transportation and the grid.

Related Bipartisan Infrastructure Law (BIL) or Inflation Reduction Act (IRA) Programs:
In addition to the annual appropriations request, BIL funding will support the planning and execution of technology development, demonstration, scale-up, and deployment of battery and critical mineral (CM) recycling, battery material processing, and long duration energy storage. These investments are essential in addressing the supply chain and technology needs to support the storage needs for intermittent renewables and grid reliability. Expanded tax credits now available in IRA offer incentives for supply chain development.

Energy-Water Crosscut
Funding by Appropriation and Program Control
($K)

Appropriation and Program Control	FY 2022 Enacted	FY 2023 Enacted	FY 2024 Request	FY 2024 vs FY 2023 ($ Change)
Advanced Research Projects Agency – Energy*	-	TBD	TBD	N/A
ARPA-E Projects	-	TBD	TBD	N/A
Energy Efficiency and Renewable Energy	65,445	75,815	131,750	+55,935
Advanced Manufacturing Office (AMO)	25,000	25,000	-	-25,000
Industrial Efficiency and Decarbonization Office (AMO successor office)	-	-	35,000	+35,000
Bioenergy Technologies	5,500	5,000	500	-4,500
Solar Energy Technologies	810	750	750	-
Water Power Technologies	34,135	45,065	95,500	+50,435
Fossil Energy and Carbon Management	-	10,000	-	-10,000
Resource Sustainability	-	10,000	-	-10,000
Nuclear Energy	3,000	300	500	+200
Fuel Cycle Research and Development	2,000	-	-	-
Light Water Reactor Sustainability	1,000	300	500	+200
Science	8,500	14,500	14,500	-
Basic Energy Sciences	8,500	9,500	9,500	-
Biological and Environmental Research	-	5,000	5,000	-
Grand Total	**76,945**	**100,615**	**146,750**	**+46,135**

*ARPA-E funding is determined annually based on programs developed through office and stakeholder priorities. Therefore, funding for FY 2023 and FY 2024 is not available currently.

Overview

Energy and water systems are inherently linked, often dependent on one another for normal, vital operations. As a strongly coupled system, they share efficiencies, resilience, and vulnerabilities, one affecting the other. Recognizing this interdependence is critical to successfully addressing the energy and environmental challenges that drive the Department of Energy's (DOE) mission. DOE has a major stake and fundamental role to play in advancing the integrated systems solutions that will address the Nation's combined water-energy challenges. Such solutions require a deeper understanding of the strongly connected nature of climate, water, energy, carbon, and broader biogeochemical cycles to inform the efficient and resilient systems of the future and, importantly, the research, development, and deployment of innovative, integrated water and energy science and technologies. The DOE Energy-Water crosscut is focused on advancing the science, transformational technologies, and innovations, and using an integrated systems perspective, to meet the need for sufficient, safe, secure, and affordable water and energy.

Coordination Efforts

Through enhanced coordination within DOE and by extension the necessary interagency partners, the Energy-Water Crosscut aims to create more resilient, equitable, efficient, and safe interdependent energy and water systems to ensure America's energy, environmental, and economic security. The Energy-Water crosscut employs an integrated systems approach to coupled energy-water initiatives and activities in the DOE, recognizing the importance of considering energy, carbon, and waters cycles, holistically. Through investments in research, development, demonstration, and deployment (RDD&D) that consider the interdependence of energy, water, carbon, and climate, the Department can address core problems in resource and environmental resiliency and sustainability for the future.

The Energy-Water crosscut provides RDD&D, technology, climate modeling and analysis, assessment tools, technical support to manufacturers and wastewater treatment facilities, informed policy, planning and financing tools, and workforce development to aid in new uses of water and replace America's outdated and deteriorating water infrastructure across

municipalities, industry, utilities, agriculture, and resource extraction (i.e., oil and gas, mining), integrated with the rebuilding of the energy infrastructure and implementation of green energy systems. The Energy-Water crosscut team will develop a strategy for Energy-Water and increase coordination for RDD&D across DOE.

In addition, the Energy Act of 2020 section 1010, authorizes the Nexus of Energy-Water for Sustainability (NEWS) research, development, and demonstration (RD&D) Interagency Coordination Committee and the mandate to develop common Federal goals and plans on energy-water activities as well as to issue a strategic plan, priorities, and objectives in conjunction with the Department of the Interior (DOI). The Energy-Water crosscut supports the activities of NEWS RD&D.

The Offices of Energy Efficiency and Renewable Energy (EERE), Fossil Energy and Carbon Management (FECM), Science (SC), Nuclear Energy (NE) and Advanced Research Projects Agency-Energy (ARPA-E) participate in the Energy-Water crosscut with support from additional Offices such as Arctic Energy (AE), Clean Energy Demonstrations (OCED), Grid Deployment Office (GDO), and the National Nuclear Security Administration (NNSA).

In addition to the funding offices identified here, various crosscutting offices (including the Office of Economic Impact & Diversity, Office of Policy, and the Office of Technology Transitions) may contribute staff time and coordinate with the RDD&D funding offices to enhance the impact of the Department's investments.

Objectives and Action Areas

- Objective 1: Enable a Diverse, Safe, and Secure Water Supply: Ensure RDD&D activities are built from an integrated view of water and energy systems and a circular water economy mindset that supports: 1) increases in viable resource recovery from aqueous waste streams, 2) fit for use water treatment processes, 3) cutting edge water based clean energy and decarbonization technologies, and 4) more resilient and integrated energy-water systems.

- Objective 2: Provide Technical Assistance for Energy-Water Efficiency: Partner with stakeholders across the country to make water and wastewater treatment more energy- and water-efficient by providing robust technical assistance and tools as well as facilitating the sharing of best practices. This effort also includes building out a workforce that is well trained, diverse, and inclusive to meet the needs of a more sustainable and secure 21st century energy-water infrastructure and beyond.

Action Areas:

1. Advance Understanding of the Integrated Water Cycle and Multi-sector Dynamics: Improve understanding of the forces and processes that shape local to global water cycles and the associated multi-sector dynamics, risks, and potential responses, including those of the energy sector. Advance predictive modeling of the most significant natural and human influences and stressors, their compounding effects, and regional specificity. Pursue systems-level insights into new and/or alternative response options for more resilient water and interacting water-dependent systems while revealing multi-scale behaviors, strong co-evolutionary processes, and systems-of-systems resilience. Continue working with other Federal partners to produce new and improved, open-source modeling frameworks, data sets, analysis capabilities (including artificial intelligence (AI)/machine learning (ML)-based), and visualization tools for researchers, operators, and planners.
2. Advance Science and Develop Technologies for Non-traditional Water Sources: Continue to support ongoing RD&D and analysis activities to be closely coordinated across DOE offices and other agencies such as the Environmental Protection Agency, DOI, and the U.S. Department of Agriculture, who were involved in roadmaps developed in 2021. This includes efficient treatment of non-traditional waters for fit for purpose use as well as energy and resource recovery from water sources. The science of separations and membranes funded in SC will feed into the technology-focused aims of applied programs.
3. Develop Efficient, Low-carbon Methods for Water Use: Many clean energy technologies utilize water as a key resource. Similarly, water is the backbone for many carbon capture technologies. Support RDD&D for efficient and effective water use for these applications.
4. Develop Resilient Energy-Water Systems: Continue to build and ramp up climate change and hydrologic modelling work as well as develop integrating models built for water and grid purposes. Leverage ongoing work related to quantification of resilience benefits from integration and development opportunities as they relate to hydropower infrastructure.

5. Provide Tools and Training for Water Efficiency: Enable an increase in technical assistance for water efficiency to provide tools and training for water efficiency improvements and sharing of best practices at existing production plants and facilities.
6. External Engagement and Partnerships: Stay abreast of the innovations and engage with local entities to maximize the impact of DOE and U.S. Government investments in the energy-water space. Support the U.S.'s ability to be a world leader in next generation energy-water systems.

Program Organizations:

1. **Advanced Research Projects Agency-Energy (ARPA-E):** As defined by its authorization under the America COMPETES Act, ARPA-E catalyzes transformational technologies to enhance the economic and energy security of the United States. ARPA-E funds high-potential, high-impact projects that are too risky to attract private sector investment but could significantly advance the ways to generate, store, distribute and use energy. ARPA-E is developing programs for transformational research across a wide range of energy technologies and applications. The assessment process for new programs is now underway and any potential future investments in Energy-Water will be determined in FY 2023.

2. **Energy Efficiency and Renewable Energy (EERE):** EERE will continue to focus on energy-water nexus activities including:
   a. Bioenergy Technologies Office (BETO): DOE's Bioenergy Technologies Office (BETO) supports RD&D on strategies to manage wet wastes, including municipal wastewater, food waste, and manures. In FY 2024, BETO will provide community-based technical assistance to identify waste management solutions that can support local environmental and environmental justice objectives.
   b. Industrial Efficiency and Decarbonization Office (IEDO): IEDO activities in FY 2024 will include advancements in decarbonization water/wastewater treatment systems through research, development, and pilot scale demonstration of new technologies. IEDO also supports analysis to inform understanding of further decarbonization opportunities in the water sector. In addition, IEDO will support technical assistance for energy and water efficiency in industrial facilities, as well as water and wastewater facilities.
   c. Solar Energy Technologies Offices (SETO): SETO activities in FY 2024 will primarily consist of market and technology analysis to help support the development and identification of promising solar thermal desalination systems and markets. This supports the two ongoing rounds of the Solar Desalination Prize, funded in FY 2019-FY 2021, which are working on developing pilot tests of innovative technologies.
   d. Water Power Technologies Office (WPTO): WPTO will continue in FY 2024 to build on prior work in Irrigation Modernization to launch a larger demonstration and deployment program by developing digital tools to assist local irrigation district in developing future modernization projects, initiate work on advanced sensors for improved dam safety, and partner with local communities with energy and or water needs to identify sites for deployment of advanced hydrologic sensors. WPTO also funds scoping, planning grants, and ultimately selection of one or more Regional Energy-Water Demonstration Facilities focused on validating and testing technologies and solutions to scale water and energy management solutions that address needs in specific watershed regions.

3. **Fossil Energy and Carbon Management (FECM):** In FY 2024, FECM is not requesting additional funds and will execute programs in FY 2023.

4. **Nuclear Energy (NE):** NE supports early stage, cost-shared R&D to increase the efficiency of commercial nuclear power plants and enables technological advances in uranium mining, conversion, and transportation capabilities in the U.S. as well as conducting evaluations and assessments related to these areas including:
   a. Fuel Cycle Research and Development / Mining, Conversion, and Transportation: R&D that reduces water usage and/or improves the extraction efficiency associated with uranium production. Mining sites are often located in underserved communities and locations with limited water resources; improvements to mining technology spurred by R&D may enable local economic opportunities while reducing the amount of water used during uranium production.
   b. Light Water Reactor Sustainability: The increasing impacts of climate change and the competition for water resources currently impact the operation of nuclear power plants regionally and could become a limiting factor in some plants continued operation. In the U.S. and worldwide, a number of plants regionally curtail power output in response to seasonal variation in water sources, and signs point to this trend continuing and growing. Research in FY 2024 will identify issues underlying water usage for nuclear power plants and develop near term and longer-term risk mitigation approaches. This research will form the basis for a strategy to address water issues that may impact the long-term operation of nuclear energy systems.

5. **Science (SC):** SC provides foundational knowledge and state-of-the-art capabilities in support of crosscut objectives and has supported theoretical and experimental science related to understanding chemical and biological processes, separations, materials, geochemistry, and Earth systems modeling, related to energy-water research for many years.
    a. Basic Energy Sciences (BES): For BES, the research focus in this area is identified in the Basic Research Needs (BRN) workshop for Energy and Water. Priority research directions identified in the workshop report include the prediction and control of molecular-to-macroscopic properties and behavior of complex, multicomponent fluids; mechanistic understanding and control of interfaces and transport in complex and extreme environments; the codesign of dynamic interactions between materials and reactive fluids for unprecedented tunability of purification, transformation, and transport processes in energy-water systems; and revolutionary advances in approaches to quantify, sense, predict, and manipulate coupled physical, chemical, and biological processes in subsurface environments. In FY 2022, three Energy Frontier Research Centers (EFRC) successfully recompeted for support and each received four-year renewal awards. Support for the Energy-Water Nexus crosscut will continue through the EFRCs in FY 2024.
    b. Biological and Environmental Research (BER): In FY 2024, BER research continues to contribute to reducing the greatest uncertainties in climate and Earth system model predictions, e.g., involving clouds and aerosols, the cryosphere, biosphere, and water cycle. In the last decade, DOE research has made considerable advances in increasing the reliability and predictive capabilities of these models using applied mathematics, access to DOE's fastest computers, and systematic comparisons with observational data to improve confidence in model predictions and the ability to use the model predictions to design and deploy climate resilient infrastructure, including the Nation's energy infrastructure.
        i. Specifically, the current research will begin to incorporate AI/ML capabilities and enable more sophisticated research based on higher model resolution, and the new version will add advanced capabilities for exploring changing water cycles on watershed and both urban and coastal hydrological systems down to spatial scales of 3 km. Additional core research to underpin emerging and future Earthshots will also be initiated.
        ii. Overall, BER's research focuses on quantifying and reducing the uncertainties in these system models (including the Earth's water cycle), based on more advanced process representations, sophisticated software, robust couplers, diagnostics, performance metrics, and advanced data analytics. Priority model components include the ocean, sea-ice, land-ice, atmosphere, terrestrial ecosystems, the cryosphere, and human activities.

Highlights and Major Changes from FY 2023 Enacted

- **Energy Efficiency and Renewable Energy:**
    - Bioenergy Technologies Office: BETO provides technical assistance to communities on wet waste management strategies to address local challenges and no funds requested for feasibility studies in FY 2024.
    - Industrial Efficiency and Decarbonization Office: As a successor office to AMO, IEDO increases support for advancements in decarbonization of water and wastewater treatment systems through R&D and pilot scale demonstration.
    - Water Power Technologies Office: The increase in WPTO supports the Energy-Water crosscut through the regional testing facilities and developing digital tools to assist local irrigation districts on modernization projects and advanced sensors.
- **Fossil Energy and Carbon Management:**
    - FECM is not requesting funds in the Energy-Water Crosscut. The Environmentally Prudent Stewardship effort within FECM's Advanced Remediation Technologies program supports work on produced water remediation as part of the overall effort to reduce environmental impacts of continued oil and gas production.

Related Bipartisan Infrastructure Law (BIL) Programs:

In addition to the annual appropriations request, BIL funding will support enhanced generation, efficiency, resiliency, safety and environmental impacts of hydroelectric facilities specifically through incentives managed by the Grid Deployment Office (GDO).

Grid Modernization Crosscut
Funding by Appropriation and Program Control
($K)

Appropriation and Program Control	FY 2022 Enacted	FY 2023 Enacted	FY 2024 Request	FY 2024 vs FY 2023 ($ Change)
Advanced Research Projects Agency - Energy	8,190	88,000	TBD	N/A
ARPA-E Projects*	8,190	88,000	TBD	N/A
Cybersecurity, Energy Security & Emergency Response	129,804	125,000	135,000	+10,000
Risk Management Tools and Technology	129,804	125,000	135,000	+10,000
Energy Efficiency and Renewable Energy	161,488	162,440	251,413	+88,973
Advanced Materials and Manufacturing Technologies	-	-	15,000	+15,000
Building Technologies	-	300	300	-
Hydrogen and Fuel Cell Technologies	30,000	16,000	8,075	-7,925
Renewable Energy Grid Integration	40,000	45,000	59,066	+14,066
Solar Energy Technologies	50,000	55,000	79,000	+24,000
Vehicle Technologies	18,000	18,000	20,000	+2,000
Water Power Technologies	13,850	17,140	19,000	+1,860
Wind Energy Technologies	9,638	11,000	50,972	+39,972
Fossil Energy and Carbon Management	2,726	3,700	3,700	-
Crosscutting Research	1,518	-	-	-
Hydrogen with Carbon Management	1,107	1,000	1,000	-
Point-Source Carbon Capture	101	1,200	1,200	-
Carbon Dioxide Removal	-	750	750	-
Carbon Transport and Storage	-	750	750	-
Grid Deployment Office	8,000	59,500	93,500	+34,000
Transmission Planning & Permitting	8,000	-	56,500	+56,500
Distribution & Markets	-	-	36,750	+36,750
Hydropower Incentives	-	-	250	+250
Grid Planning & Development	-	16,000	-	-16,000
Grid Technical Assistance	-	25,000	-	-25,000
Interregional & Offshore Transmission Planning	-	2,000	-	-2,000
Wholesale Market Technical Assistance & Grants	-	16,500	-	-16,500
Nuclear Energy	233,000	188,000	23,500	-164,500
Advanced Reactor Demonstrations	60,000	-	-	-
Advanced SMR RD&D	150,000	165,000	10,000	-155,000
Crosscutting Technology Development	10,000	12,000	9,500	-2,500
Light Water Reactor Sustainability	13,000	11,000	4,000	-7,000
Office of Clean Energy Demonstrations	-	50,000	-	-50,000
Demonstration of Renewable and Distributed Energy Systems	-	50,000	-	-50,000
Electricity	249,000	267,500	278,800	+11,300
Transmission Reliability & Resilience	24,941	31,587	42,500	+10,913
Energy Delivery Grid Operations Technology	12,791	30,614	30,000	-614
Resilient Distribution Systems	53,500	53,548	47,300	-6,248
Cyber Resilient & Secure Utility Communications	20,372	14,591	15,000	+409

Appropriation and Program Control	FY 2022 Enacted	FY 2023 Enacted	FY 2024 Request	FY 2024 vs FY 2023 ($ Change)
Energy Storage Research	70,684	88,965	78,600	-10,365
20-OE-100 Grid Storage Launchpad	47,000	-	-	-
Transformer Resilience & Advanced Components	10,636	26,615	21,700	-4,915
Applied Grid Transformation Solutions	-	9,873	29,700	+19,827
Electricity Innovation & Transition	6,226	11,707	14,000	+2,293
Congressionally Directed Spending	2,850	-	-	-
Grand Total	**792,208**	**944,140**	**785,913**	**-70,227**

*ARPA-E funding is determined annually based on programs developed through office and stakeholder priorities. Therefore, funding for FY 2024 is not available currently.

Overview:
The Department of Energy's (DOE) Grid Modernization crosscut encompasses activities focused on research, development, demonstration, and deployment (RDD&D) to ensure an affordable, resilient, flexible, secure, sustainable, equitable, and reliable grid. The portfolio of work helps integrate all sources of electricity, improve the security of our Nation's grid, solve challenges of energy storage and distributed generation, and provide a critical platform for U.S. competitiveness and innovation in a global energy economy. These efforts directly enable this Administration's goals to achieve a 50-52 percent reduction in greenhouse gas (GHG) emissions by 2030, zero emissions grid by 2035, and a net-zero GHG emissions economy by 2050.

The Grid Modernization Initiative (GMI) is a core partnership of DOE Offices to drive the crosscut and to co-fund foundational research through competitive opportunities, as well as work with the National Laboratories, especially through the Grid Modernization Laboratory Consortium (GMLC).

Coordination Efforts:
Through the Grid Modernization crosscut, DOE coordinates activities across the Offices of Electricity (OE), Energy Efficiency and Renewable Energy (EERE), Fossil Energy and Carbon Management (FECM), Grid Deployment Office (GDO), Nuclear Energy (NE), Science (SC), Cybersecurity, Energy Security, and Emergency Response (CESER), Technology Transitions (OTT), Economic Impact & Diversity (ED), Clean Energy Demonstrations (OCED), and Advanced Research Projects Agency-Energy (ARPA-E).

In addition to the offices identified above, others such as the Office of Policy and Loan Programs Office, may contribute staff time and coordinate with the RDD&D funding offices to enhance the impact of the Department's investments.

Objectives and Action Areas:
The Grid Modernization crosscut works to address barriers to achieving key objectives concerning the complex U.S. grid system.

- Clean Energy Integration: Connection of clean energy loads and resources to the electricity transmission and distribution system, either in front of or behind the meter.
- Grid Infrastructure Expansion: There is broad agreement, supported by the work of DOE and many others, on the need for massive amounts of new transmission capacity. A variety of studies have shown that tens of gigawatts (GW) (equivalent to millions of solar panels or billions of light-emitting diode (LED) bulbs) of long-distance transmission capability will be needed facilitate the export of zero-carbon wind and solar from resource-rich regions to load centers. Increased transmission interconnection between regions will provide additional benefits, including improved system reliability, resilience to extreme weather and physical disasters, and operating economy.
- Managing Electrification: Massive electrification of transportation, industrial, and building loads will add considerable complexity and present a challenge for the power system. However, it also presents a huge opportunity to help meet grid modernization objectives. Newly electrified sectors can provide demand shifting and leveling, supply firming, and essential reliability services.

- Reliability, Resilience, and Security: Operational reliability of the design and engineering of energy delivery is essential in grid expansion along with the functional preservation of electric grid operations in the face of natural and man-made threats and hazards. Cybersecurity, enhanced grid operations, energy storage and other solutions are needed to ensure our energy infrastructure.
- Affordability: A household's energy burden—the percentage of household income spent on energy bills—provides an indication of energy affordability. Researchers define households with a 6 percent energy burden or higher to experience a high burden.[1] According to DOE's Low-Income Energy Affordability Data (LEAD) Tool, the national average energy burden for low-income households is 8.6 percent, three times higher than for non-low-income households which is estimated at 3 percent. In some areas, depending on location and income, energy burden can be as high as 30 percent. Of all U.S. households, 44 percent, or about 50 million, are defined as low-income.

The Grid Modernization crosscut organizes around six pillars or action areas to address the barriers to achieving the power system objectives identified above:

- Action Area 1 - Devices and Integrated Systems: The electrical grid is fundamentally comprised of devices physically connected together and linked by control systems and markets, and form integrated systems that provide specific functions that in aggregate enable the electrical power to operate effectively as a whole.
- Action Area 2 - Operations: Procedures and technologies are needed to run the grid reliably during normal or steady-state situations, as well as extreme situations. Work in this area is focused on solutions to achieve these needs.
- Action Area 3 - Planning: The grid community uses planning and development tools for policy analysis, expansion planning, and day-ahead planning and to support policy development, economic assessments, engineering design, and risk and vulnerability analysis impacting billions of dollars of capital investments and operational costs.
- Action Area 4 - Markets, Policies, and Regulations: This area is focused on research on the current market, policy, and regulatory environment aimed at developing strategies for a grid which is efficient and capable of ensuring a reliable energy supply, while achieving the Administration's deep decarbonization targets in an equitable and just way.
- Action Area 5 - Resilient and Secure Systems: Work in this area will improve the resilience of the electric sector by developing physical and cybersecurity solutions; analyzing criticality and assessing impacts to minimize risk; providing solutions for supply chain risks (specifically for transformers); and providing situational awareness/incident support during energy-related emergencies.
- Action Area 6 - Flexible Generation and Load: Work in this area will develop technologies that allow energy generation or loads to respond to the variability and uncertainty of conditions at one or more timescales, in a range of energy future grid scenarios.

Program Organizations:

1. **Advanced Research Projects Agency-Energy:** As defined by its authorization under the America COMPETES Act, ARPA-E catalyzes transformational energy technologies to enhance the economic and energy security of the United States ARPA-E funds high-potential, high-impact energy projects that are too risky to attract private sector investment but could significantly advance the ways to generate, store, distribute and use energy. In FY 2022, ARPA-E selected and/or obligated $8 million in grid modernization funding to projects aligned with the GMI through ARPA-E's Supporting Entrepreneurial Energy Discoveries (SEED) Exploratory Topic and Grid Optimization (GO) Competition. In FY 2023, ARPA-E selected and/or obligated $88 million in grid modernization funding to projects aligned with the grid modernization crosscut through ARPA-E's Grid Overhaul with Proactive, High-speed Undergrounding for Reliability, Resilience, and Security (GOPHURRS) and Unlocking Lasting Transformative Resiliency Advances by Faster Actuation of Power Semiconductor Technologies (ULTRAFAST) programs. ARPA-E is developing programs for transformational research across a wide range of energy technologies and applications. The assessment process for new programs is now underway and any potential future investments in grid modernization will be determined in FY 2023.

2. **Cybersecurity, Energy Security and Emergency Response:** CESER integrates cybersecurity activities across the Department and coordinates with other DOE offices to ensure cybersecurity is built in across different research and development (R&D) programs. CESER leverages DOE's National Laboratories to advance the goal of securely modernizing the Nation's electric grid. All of CESER's cybersecurity risk management tools and technology funding are

[1] American Council for Energy Efficient Economy energy-affordability.pdf (aceee.org)

included in the GMI. For FY 2024, this includes developing cyber situational awareness and analytics; cradle to grave supply chain cybersecurity, including programs like Energy Cyber Sense, digital subcomponent enumeration and mitigation efforts; developing tools, guidance, and practices that help energy organizations' understanding and management of cybersecurity risk; cyber resilience through cyber engineering by way of programs such as the Consequence-driven Cyber-informed Engineering (CCE); and collaborations with universities to support workforce development and to stimulate innovation by students to address cyber risks to energy infrastructure.

3. **Energy Efficiency and Renewable Energy:**
   a. Advanced Materials and Manufacturing Technology Office (AMMTO): Building off the success of the Conductivity-enhanced materials for Affordable, Breakthrough Leapfrog Electric and thermal applications (CABLE) Conductor Manufacturing Prize, AMMTO will continue to invest in the development and demonstration of highly conductive materials that can provide significant efficiency improvements to the grid and grid-connected applications.
   b. Building Technologies Office (BTO): BTO's RDD&D on advanced and grid-interactive technologies, such as controls, interoperability, and energy storage, will partner with industry stakeholders to develop and deploy grid-interactive efficient buildings related systems, capable of connecting with the power grid in new and increasingly adaptive manners to help with overall energy system efficiency, reliability, resilience, environmental performance, and energy affordability. These capabilities are an integral and necessary part of a decarbonized power system that maximizes use of renewable resources and can significantly reduce energy use at times when this provides a valuable option for utilities and their customers.
   c. Hydrogen and Fuel Cell Technologies Office (HFTO): HFTO funds RD&D in energy storage and grid integration (including the National Renewable Energy Laboratory's (NREL) Advanced Research on Integrated Energy Systems (ARIES)). In addition, HFTO's portfolio includes systems development and integration, including hybrid energy systems such as wind/offshore-wind to hydrogen, microgrids for underserved communities, along with their supporting analysis. These activities support three Objectives: Clean Energy Integration; Reliability, Resilience, and Security and Affordability and three Crosscut Action Areas: 2, 5 and 6.
   d. Vehicle Technologies Office (VTO): VTO will continue laboratory and industry-led projects to develop secure vehicle-grid connection and communication technologies, as well as high power grid-tied charging systems.
   e. Wind Energy Technology Office (WETO): WETO will prioritize RD&D in offshore transmission analysis and technology advancement, grid reliability and resilience, wind control and cybersecurity research, and crosscutting demonstrations in grid-enhancing technologies and hybrid energy systems. This body of work will align with the Renewable Energy Grid Integration Action Plan, developed to align grid activities across EERE and OE to enable an equitable transition to a grid that supports a decarbonized power system by 2035 and a zero-emission economy by 2050, all while maintaining the reliability, affordability, security, and resilience of the energy system.
   f. Solar Energy Technologies Office (SETO): SETO will support analysis and RDD&D of grid integration technologies at the bulk power and distribution system levels to allow reliable, resilient, and secure grid planning and operation with increasing amounts of solar, energy storage, hybrid systems, and other inverter-based assets.
   g. Renewable Energy Grid Integration (REGI): REGI will expand power system planning and operations support to communities looking to deploy larger amounts of renewable energy, provide analysis-based technical assistance to power system operators and regulators, provide technical assistance for siting and permitting of renewable energy projects, and support investments in power electronics and clean energy modeling.
   h. Water Power Technologies Office (WPTO): WPTO, through the HydroWIRES Initiative, will provide funding for hydropower hybrid demonstrations through a comprehensive Hydropower Futures Study to quantify emission and cost reductions enabled by increased hydropower flexibility and new pumped storage hydropower (PSH) development, and expansion of the PSH Valuation Guidebook to include non-power values.

4. **Fossil Energy and Carbon Management:** FECM ensures that the perspective for fossil generation and fuel security is reflected in the Department's grid modernization efforts. In FY 2024, FECM will seek to directly fund FECM projects involving several GMI topic areas: 1) Climate Change Impacts; 2) Post-Quantum Cyber-Security; 3) Energy Justice; and 4) Deep Decarbonization Grid Planning Analyses. FECM has an extensive portfolio of research, development, and demonstration (RD&D) activities, that also contribute to the Department's Grid Modernization crosscut efforts. Execution of these projects will be done through GMI's GMLC or joint funding opportunity announcements (FOA) funding mechanisms in coordination with other program offices.

5. **Grid Deployment Office:** GDO catalyzes development of new and upgraded high-capacity electric transmission lines nationwide and deployment of transmission and distribution technologies to improve the resilience of our Nation's

electric infrastructure. Massive deployment of renewable energy and build out of transmission infrastructure is necessary to power a clean energy economy. GDO works in partnership with energy sector stakeholders on a variety of initiatives to achieve a clean, reliable, resilient, and equitable grid.

All GDO activities fall under the Grid Modernization crosscut and all GDO program funding except GDO Program Direction is included in the crosscut. In FY 2024, GDO will accelerate the planning and development of transmission through the National Transmission Planning Study and interregional transmission plans; provide grid technical assistance to enable policy and investment decisions; assist regions and states in improving or establishing wholesale electricity markets; conduct siting and permitting activities, such as improving Federal coordination and providing support to states and local communities; and help develop offshore wind transmission infrastructure.

6. **Nuclear Energy:** In FY 2024, NE will continue to support targeted research across all six Crosscut Action Areas with industry, universities, and National Laboratories through competitive FOAs and directed research to enhance nuclear energy's contribution to a clean, reliable, resilient, and equitable electrical grid.
   a. Integrated Energy Systems (IES): The IES Program conducts RD&D activities to expand the role of nuclear energy beyond direct electricity grid support, to include industrial and transportation applications. In FY 2024, the IES program is performing a study to understand how variation in electricity market structure, policy, and competition affects how nuclear plants operate and engage with the grid.
   b. Light Water Reactor Sustainability (LWRS): The LWRS Program conducts R&D to develop the technical basis and economic justification for commercial light water reactors (LWR) to operate more flexibly, including the use of nuclear power to produce products other than electricity and optimize participation in electricity markets. In FY 2024, the program will continue to advance the technical, economic, and regulatory evaluations for utilizing commercial LWR to produce hydrogen. The resulting hydrogen can be used as storage to support the grid during periods of high demand or for seasonal storage.
   c. Advanced Small Modular Reactor (SMR) RD&D: The Advanced SMR RD&D program works with industry through private-public partnerships (PPP) to conduct RD&D on advanced SMR designs that have the potential to provide safe, clean, and affordable energy generation options. In FY 2024, the program will continue to support industry efforts needed to successfully demonstrate SMR technology.

7. **Office of Clean Energy Demonstrations:** No new funding in FY 2024 is requested related to the Grid Modernization crosscut. In FY 2023, OCED will support commercial-scale demonstrations related to the integration of renewable and distributed energy systems. The goal of this new investment area is to support demonstrations that de-risk controlling flexible loads from renewable energy, energy storage, electric vehicle (EV) charging, and other facilities into the U.S. transmission and distribution grids.

8. **Office of Electricity:** Grid modernization is a critical aspect of all OE programs and all OE program funding except OE Program Direction is included in the Grid Modernization crosscut. In FY 2024, OE plans to continue pursuing research for technologies to improve grid reliability, resilience, efficiency, flexibility, and functionality that are built from inception to automatically detect, reject, and withstand cyber incidents, regardless of the threat to the electricity delivery system. OE will also continue to develop core analytic, assessment, and engineering capabilities that can evolve as technology and policy needs mature to support decision making involving complex interdependencies among energy infrastructure systems, such as between electricity and natural gas systems. OE plans to continue support for private sector innovation investment in data platforms and advanced communications/control designs as well as regional and national deployment through cooperative agreements.

Highlights and Major Changes from FY 2023 Request

- Energy Efficiency and Renewable Energy
  - The AMMTO is a successor to the Advanced Manufacturing Office (AMO) in this crosscut and increases RD&D investment in manufacturing advances for high performance materials, emerging battery technologies, and power electronics crucial to Grid Modernization.
  - HFTO's reduced funding reflects a focus on research of hybrid wind to hydrogen and includes funding for NREL's ARIES program.
  - The REGI increase supports power system planning and operations work, analysis, and technical assistance to enable the overall GMI goals.

- The increased funding for SETO supports demonstration of technologies to operate and control a power system with increasing levels of solar energy.
- The VTO investment supports increased funding for demonstration and deployment projects to accelerate the nationwide adoption and deployment of EVs and charging infrastructure, especially to benefit underserved communities.
- The FY 2024 Budget Request for WPTO provides for increased funding in hydropower hybrid demonstrations to quantify emission and cost reductions enabled by increased hydropower flexibility and new PSH development.
- The WETO funding increase prioritizes RD&D in offshore transmission analysis and technology advancement.

- Nuclear Energy - In FY 2024, NE's Budget Request for the GMI is lower due to the successful completion of Federal support for the development of the NuScale technology, a U.S. SMR, for development in domestic and international markets and a prioritization of programmatic efforts on pursuing a commercial demonstration of that technology via the Carbon Free Power Project (CFPP), one of three advanced reactor demonstration projects.
- Office of Electricity
  - Transmission Reliability and Resilience: 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.
  - Resilient Distribution Systems: The Request expands microgrid building block development to advance virtual prototype design performance and sector coupling analysis to look at structural and architectural aspects and control and coordination approaches addressing vehicle-grid integration issues. Offsetting reductions are due to congressionally directed activities that were fully funded in FY 2023.
  - Energy Storage: The Request launches a new cohort for the Energy Storage for Social Equity (ES4SE) 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 (ROVI) to improve the performance projections methodologies of 2–3 new non-lithium electrochemistries. Given the growing number of energy storage installations, the Request also expands outreach to key deployment stakeholders, including fire safety, codes and standards, and other groups. Offsetting reductions are due to congressionally directed activities that were fully funded in FY 2023.
  - Transformer Resilience & Advanced Components: The Request accelerates addressing high-voltage direct current (HVDC) hardware technical challenges to perform a field validation of the Smart Universal Power Electronics Regulators (SUPER) device and expands the development of modular and scalable transformers. Offsetting reductions are due to congressionally directed activities that were fully funded in FY 2023.
  - Applied Grid Transformation Solutions: The Request supports at least 2 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.

Related Bipartisan Infrastructure Law (BIL) or Inflation Reduction Act (IRA) Programs:
In addition to annual appropriations, BIL funding will support planning and execution of technology development, demonstration, scale-up, and deployment of cybersecurity and cyber resilience for the energy sector and rural and municipal utilities; advanced nuclear reactor demonstration; energy storage and system reliability work; smart grid investments and programs to assess risks, prevent outages, improve grid resilience, and facilitate transmission. IRA funding will deepen the Department's investments in transmission expanding interregional and offshore wind transmission planning efforts, offering additional financing to accelerate transmission deployment, and developing a new grant program to address transmission siting and permitting challenges. These investments are essential in addressing the supply chain and technology needs to support growth in clean energy and the grid.

Hydrogen
Funding by Appropriation and Program Control
($K)

Appropriation and Program Control	FY 2022 Enacted	FY 2023 Enacted	FY 2024 Request	FY 2024 vs FY 2023 ($ Change)
Advanced Research Projects Agency – Energy*	1,995	TBD	TBD	N/A
ARPA-E Projects	1,995	TBD	TBD	N/A
Energy Efficiency and Renewable Energy	163,400	216,160	206,575	-9,585
Advanced Manufacturing Office (AMO)	-	25,000	-	-25,000
Hydrogen and Fuel Cell Technologies	157,500	170,000	163,075	-6,925
Industrial Efficiency and Decarbonization Office (AMO successor office)	-	-	30,000	+30,000
Solar Energy Technologies	5,100	7,500	3,500	-4,000
Vehicle Technologies	-	10,000	-	+10,000
Water Power Technologies	800	2,600	-	-2,600
Wind Energy Technologies	-	1,060	10,000	+8,940
Fossil Energy and Carbon Management	113,000	128,000	112,000	-16,000
Carbon Management Technologies	88,000	101,000	91,000	-10,000
Resource Sustainability	20,000	26,000	20,000	-6,000
Energy Asset Transformation	5,000	1,000	1,000	-
Nuclear Energy	23,000	23,000	13,500	-9,500
Crosscutting Technology Development	10,000	12,000	9,500	-2,500
Light Water Reactor Sustainability	13,000	11,000	4,000	-7,000
Office of Technology Transitions	-	-	100	+100
Office of Technology Transitions	-	-	100	+100
Science	17,386	50,299	49,506	-793
Basic Energy Sciences	17,386	50,299	49,506	-793
Grand Total	**318,781**	**417,459**	**381,681**	**-35,778**

*ARPA-E funding is determined annually based on programs developed through office and stakeholder priorities. Therefore, funding for FY 2023 and FY 2024 is not available currently.

Overview:

The Department of Energy (DOE) Hydrogen crosscut encompasses activities across multiple offices in DOE that sponsor research, development, demonstration, and deployment (RDD&D) to foster innovations and develop widely available, net-zero emission, cost-competitive technologies for the production, storage, and delivery of clean hydrogen (H_2), and for its end use as a chemical feedstock or fuel. Hydrogen is a versatile energy carrier that can be produced with net-zero greenhouse gas (GHG) emissions by using diverse domestic resources including renewables, nuclear, and fossil fuels with carbon capture and storage. Accordingly, clean hydrogen is an enabling piece of DOE's portfolio of solutions to achieve an abundant, reliable, and affordable supply of clean energy to meet our climate goals and maintain our prosperity throughout the 21st century and beyond.

Crosscut activities will focus on enabling clean hydrogen for hard-to-decarbonize applications in industry and heavy-duty transport, as well as in power generation and energy storage. Hydrogen can be used in a wide range of end-use sectors and several DOE offices are involved in developing different hydrogen production and delivery methods as well as application spaces. By integrating those efforts, each office benefits from joint analyses and assessments and therefore more effectively targets their funding to the highest priority areas and avoids duplication of efforts.

Coordination Efforts:
A crosscutting team of DOE program offices including Science (SC), Energy Efficiency and Renewable Energy (EERE), Fossil Energy and Carbon Management (FECM), Nuclear Energy (NE), Technology Transitions (OTT), and the Advanced Research Projects Agency-Energy (ARPA-E) coordinates activities aligned with the DOE Hydrogen Program Plan. The Program Plan outlines key activities and a matrix of roles and responsibilities across the pipeline of hydrogen production, delivery, storage, conversion, and end use RDD&D efforts.

In FY 2022, the DOE established a Hydrogen joint strategy team (JST), co-led by EERE's Hydrogen and Fuel Cell Technologies Office (HFTO) and the Office of Clean Energy Demonstrations (OCED), to facilitate coordination of RDD&D activities within the Hydrogen Program supported by appropriations, as well as coordination with demonstration and deployment activities supported by BIL funding. Working groups under the JST covering clean hydrogen production, storage and delivery, conversion and end-use applications meet regularly to coordinate. The working groups share status, progress, identify gaps and develop plans to execute on the DOE Hydrogen Program strategy as well as meet monthly with other agencies involved in hydrogen activities. Coordinated activities also include a joint Annual Merit Review and Peer Evaluation Meeting, joint regional analysis, lifecycle emissions and supply chain assessments, joint summits, workshops, and requests for information, coordinated funding opportunities, and joint proposal peer reviews for solicitations.

In addition to the funding offices identified here, technical coordination with the Office of Electricity (OE), which leads DOE's grid modernization and long duration energy storage research, development, and deployment (RD&D) efforts including utilization of clean hydrogen as an option for clean heat, power, and energy storage applications, is important. Various crosscutting offices such as the Offices of Economic Impact & Diversity (ED) and Policy also may contribute staff time and coordinate with the RDD&D funding offices to enhance the impact of the Department's investments. As mentioned, coordination with OCED will be essential to maximize BIL related hydrogen provisions going forward.

Objectives and Action Areas:
Following are objectives and anticipated FY 2024 action areas within the DOE-wide, Hydrogen crosscut. A key aim is to strengthen Science-Applied Office Collaboration (e.g., joint or coordinated funding opportunity announcements (FOA) in RD&D through the DOE H2@Scale initiative to accelerate progress towards clean hydrogen goals and to accelerate pre-commercial demonstrations and development to ensure success of Clean-Hydrogen Hub deployments in future years.

- Clean Hydrogen Production: The first Energy Earthshot™, launched June 7, 2021—Hydrogen Shot™—seeks to reduce the cost of clean hydrogen by 80% to $1 per 1 kilogram in 1 decade ("1 1 1"). Achieving the Hydrogen Shot's 80% cost reduction goal can unlock new markets for hydrogen, including steel manufacturing, clean ammonia, energy storage, and heavy-duty trucks. This would create more clean energy jobs, reduce GHG emissions, and position America to compete in the clean energy market on a global scale. These efforts would ensure that environmental protection and benefits for local communities are a priority. As an interim goal, the DOE Hydrogen Program is targeting $2 per kilogram of clean hydrogen by 2026.
    - Complete designs and initiate pre-commercial demonstration of integrated energy systems coupling optimized wind-turbine and electrolyzer technologies and assess technoeconomic potential to meet cost targets (with HFTO, Wind Energy Technologies Office (WETO), Industrial Efficiency and Decarbonization Office (IEDO)).
    - Action Area: Advance technical feasibility, economic potential, and licensing considerations to validate the viability and business case for producing low-cost clean hydrogen with nuclear power (with HFTO, NE).
    - Action Area: Complete plans for pre-commercial demonstration of integrated energy systems for direct solar water-splitting, leveraging prior-year foundational materials development, computational studies, analysis, and laboratory demonstrations (with EERE's HFTO and Solar Energy Technologies Office (SETO), SC).
- Hydrogen for Industrial Applications: Collaboration supporting H2@Scale coordinated by HFTO and IEDO with anticipated participation by other DOE Offices such as EERE's SETO, Wind Energy Technologies Office (WETO) and Water Power Technologies Office (WPTO), FECM, and NE, with a short-term goal of developing cost-effective technology solutions leveraging clean hydrogen for high-impact industrial-sector decarbonization; and a long-term goal of deep decarbonization through widespread adoption of these solutions.
    - Action Area: Initiate pre-commercial demonstration projects of clean hydrogen use in high-impact sectors such as ammonia and steel production, as well as heavy-duty transportation (e.g., marine, rail, off-road).
    - Action Area: Demonstrate industrial/fuel/chemical hydrogen applications using hydrogen produced with heat and electricity from existing nuclear reactors to include both pressurized and boiling water reactors.

- Stationary Fuel Cell/Hybrid Systems: Collaboration between HFTO and FECM focused on advancing fuel-cell-based technologies for stationary power, heat, and/or hydrogen generation, with a short-term objective of developing cost-effective solutions for decarbonization in heat, power, and energy storage applications; and a long-term goal of deep decarbonization through widespread adoption of these solutions.
  - Action Area: Complete pre-front end engineering and design (FEED) studies for combined cycle systems and initiate pre-commercial demonstration projects of most promising advanced fuel cell systems (including reversible fuel cells) and/or hybrid systems (including polygeneration systems) based on analysis and laboratory validation work.
  - Action Area: Integration and demonstration of next generation fuel cells with potential to meet cost and durability, including reversible fuel cells.
- Low Nitric Oxide (NOx) Hydrogen-fired Turbines: Collaboration coordinated by FECM with participation from the Office of Electricity (OE), SC, and EERE's IEDO, with a near-term goal of demonstrating viability of clean hydrogen combustion for power generation and/or heavy-duty transportation; with a long-term goal for industrial adoption impacting decarbonization in these sectors.
  - Action Area: Implementation of a pre-commercial low-NOx pilot demonstration at a scale >25 megawatts (MW), leveraging prior-year analysis, design, laboratory tests, and pilot-scale combustor demonstration advances.
- Climate Science of Hydrogen Release: Cross-Office/Agency collaboration coordinated by HFTO and SC at DOE with the National Oceanic and Atmospheric Administration (NOAA) with a near-term goal of quantifying any global-warming impacts of hydrogen releases into the atmosphere; and a long-term goal of developing and implementing mitigation strategies to minimize the impacts.
  - Action Area: Complete initial impact study and the development of a mitigation roadmap including implementation of advanced sensors and leak monitoring.
- Workforce Development and Energy and Environmental Justice (EEJ) Priorities: Collaboration across all DOE Hydrogen Program Offices, with a near-term goal of enabling greater ED engagement in clean hydrogen technologies and policies; and a long-term goal of widespread adoption of clean hydrogen for environmental and economic benefits to society, including traditionally underserved communities.
  - Action Area: Implementation of workforce development and EEJ plans developed in FY 2022 and FY 2023 based on extensive stakeholder engagements, including with Tribal leaders and representatives from other underserved communities.

Program Organizations:

1. **Advanced Research Projects Agency - Energy (ARPA-E):** As defined by its authorization under the America COMPETES Act, ARPA-E catalyzes transformational technologies to enhance the economic and energy security of the United States. ARPA-E funds high-potential, high-impact projects that are too risky to attract private sector investment but could significantly advance the ways to generate, store, distribute and use energy. In FY 2022, ARPA-E selected and/or obligated over $1.9 million in hydrogen-related funding to projects aligned with the Crosscut through ARPA-E's Supporting Entrepreneurial Energy Discoveries (SEED) Exploratory Topic. ARPA-E is developing programs for transformational research across a wide range of energy technologies and applications. The assessment process for new programs is now underway and any potential future investments in Hydrogen will be determined in FY 2023.

2. **Energy Efficiency and Renewable Energy (EERE):** Work in EERE includes a broad portfolio of programs focused on the production, storage, delivery, conversion, and end use of clean hydrogen from renewable resources.

   - Hydrogen and Fuel Cells Technologies Office: EERE's entire HFTO activity portfolio is included in this crosscutting investment. Efforts supported include clean hydrogen production, storage and delivery/infrastructure, fuel cells, and end uses, including systems development and integration, as well as analysis, safety, codes, standards, and workforce development. HFTO serves as the primary coordinator of DOE Hydrogen Program activities.
   - Industrial Efficiency and Decarbonization Office: IEDO invests in process innovations to advance the economic use of low-carbon hydrogen for industrial processes. These innovations include RD&D for hydrogen-compatible equipment to enable high-impact end uses (e.g., combustion, ammonia, steel, etc.).
   - Solar Energy Technologies Office: SETO supports the RD&D of concentrating solar thermal power systems that can be used for hydrogen production or in conjunction with hydrogen as a chemical feedstock for decarbonized industrial processes and of hybrid energy systems combining solar power with H2-based energy storage/transport.

- Wind Energy Technologies Office: WETO supports the hydrogen crosscut through multi-office collaboration in hybrid system design, hardware, control, and demonstration to hybrid systems involving combinations of generation technologies such as onshore and offshore wind, solar, geothermal, and hydropower, with energy storage through batteries and/or hydrogen.

3. **Fossil Energy and Carbon Management (FECM):** FECM focuses primarily on hydrogen production from carbon-based or fossil resources coupled to carbon capture and storage (CCS) to achieve carbon-neutral hydrogen, as well as large scale hydrogen storage and delivery infrastructure options and hydrogen conversion. The Office of Carbon Management Technologies includes RD&D on gasification of diverse carbon-based feedstocks (including fossil, biomass, waste, and plastics) with CCS, on pre-combustion CCS for natural gas reforming, as well as conversion based on solid-oxide fuel cells or combustion/turbines. The Office of Resource Sustainability includes RD&D on large-scale geological H_2 storage, pipeline transport of H_2/blends, as well as conversion of natural gas to hydrogen plus value-add products that incorporate the carbon.

4. **Nuclear Energy (NE):** NE supports the Hydrogen Production Target, Hydrogen for Industrial Applications, High-temperature Nuclear/Hydrogen Integrated Systems, and Workforce Development and EEJ Priorities by focusing on enabling hydrogen production from nuclear power. This support includes a portfolio of hydrogen-related RD&D such as thermal integration of efficient high-temperature hydrogen production technologies with nuclear power systems and pre-commercial demonstrations of integrated energy systems leveraging nuclear power generation for production of value-add hydrogen or other hydrogen-based co-products (such as ammonia or synthetic fuel).

   In FY 2024, NE will:
   - Develop site integration, safety basis, and licensing considerations for collocating nuclear reactors with hydrogen applications for use of both clean heat and clean electrical power from nuclear energy;
   - Perform R&D on the physics, performance, and cost of thermal distribution system components that couple nuclear reactors to high-temperature steam electrolysis at increasing scale;
   - Develop fail-safe control systems for nuclear thermal distribution systems, with operator interface and operational procedures;
   - Demonstrate industrial/fuel/chemical hydrogen applications using hydrogen produced with heat and electricity from existing nuclear reactors to include both pressurized and boiling water reactors (in collaboration with EERE);
   - Develop capability to test microreactors with emulated dynamic electrical and thermal electrolysis loads; and
   - Coordinate with other offices to enable addressing workforce development and EJ.

5. **Office of Technology Transitions (OTT):** OTT will continue to collaborate with DOE offices to:
   - Conduct market and economic analysis to identify commercialization opportunities, risks, and challenges across the RDD&D continuum; and
   - Expand analysis and industry engagement activities to identify and accelerate commercialization pathways for a broad spectrum of clean hydrogen and fuel cell technologies.

6. **Science (SC):** Basic Energy Sciences (BES) provides foundational knowledge and state-of-the-art capabilities in support of the Hydrogen Crosscut objectives and continues to support theoretical and experimental science related to understanding hydrogen technologies and materials that will continue through FY 2024. The Request continues support for a new research modality, the Energy Earthshot Research Centers (EERCs), which focus on the stretch goals of the DOE Energy Earthshots™ and provide a solid bridge between SC and the Energy Technology Offices. Through strong alignment with the technology offices, EERCs will address key basic research challenges, with relevance to applied research and development activities.

   Scientific opportunities were further defined by a BES roundtable on Foundational Science for Carbon-Neutral Hydrogen Technologies, organized with input from the DOE technology offices. Key activities include supporting scientific discoveries and major scientific tools to transform our understanding of clean hydrogen-related technologies including hydrogen storage, production, utilization, and conversion. SC operates major x-ray, neutron, nanoscience, and high-performance computing user facilities that provide advanced synthesis, fabrication, characterization, and computational capabilities to this community for basic, applied, and industrial research.

BES research enables breakthrough advances for clean hydrogen production beyond conventional approaches such as electrolysis; related work is conducted by the Fuels from Sunlight Hub program and the Energy Frontier Research Centers, which complement the technology-specific RD&D supported by DOE's applied energy offices and provide foundational knowledge that can bring advances to many areas of technology development.

Highlights and Major Changes from FY 2023 Request

- Energy Efficiency and Renewable Energy:
  - Industrial Efficiency and Decarbonization Office: As a successor office to AMO, IEDO increases support for investment in process innovations to advance the economic use of low-carbon hydrogen for industrial processes and will allow funding to develop combustion equipment and related technologies to advance industrial capabilities to utilize low carbon fuels and feedstocks like hydrogen.
  - Solar Energy technologies: Increases funding to support RD&D of concentrating solar thermal power systems that can be used for hydrogen production or in conjunction with hydrogen as a chemical feedstock.
  - Water Power Technologies: Reduced investment in the Hydrogen crosscut to focus on other priorities.
  - Wind Energy Technologies: WETO increase reflects support for multi-office collaboration in hybrid system design, hardware, control, and demonstration to hybrid systems involving combinations of technologies.
- Fossil Energy and Carbon Management:
  - Resource Sustainability: Natural Gas Decarbonization and Hydrogen Technologies: Maintain progress at a reduced level of funding for research on utilizing natural gas storage for hydrogen and pilot-scale technology demonstration.
  - Carbon Management Technologies: Hydrogen with Carbon Management: Maintain progress at a reduced level of funding to develop alloy compositions and manufacturing techniques to improve resistance to hydrogen embrittlement, as well as a reduced effort in basic RDD&D to mature Reversible Solid Oxide Fuel Cell (R-SOFC) technologies, including operating as Solid Oxide Electrolysis Cells (SOEC).
- Nuclear Energy:
  - In FY 2024, NE will begin decreasing its investment in hydrogen production through the existing fleet of nuclear reactors and focus its overall investment on developing hydrogen production through advanced nuclear reactors by developing high-temperature thermal integration with high-temperature advanced reactors, fail-safe control systems and developing the capabilities necessary to test microreactors with emulated loads.

Related Bipartisan Infrastructure Law (BIL) or Inflation Reduction Act (IRA) Programs

In addition to the annual appropriations request, BIL funding will support the initial stages of planning and execution of technology development, demonstration, scale-up, and deployment for clean hydrogen hubs, clean hydrogen electrolysis and clean hydrogen manufacturing and recycling. These investments are essential in addressing the supply chain and technology needs to support growth in clean energy. Tax credits in IRA will additionally incentivize the hydrogen supply chain.

Industrial Decarbonization
Funding by Appropriation and Program Control
($K)

Appropriation and Program Control	FY 2022 Enacted	FY 2023 Enacted	FY 2024 Request	FY 2024 vs FY 2023 ($ Change)
Advanced Research Projects Agency - Energy*	996	TBD	TBD	N/A
ARPA-E Projects	996	TBD	TBD	N/A
Energy Efficiency and Renewable Energy	422,950	612,788	716,845	104,057
Advanced Manufacturing Office (AMO)	176,000	309,500	-	-309,500
Industrial Efficiency and Decarbonization Office (AMO successor office)	-	-	394,245	+394,245
Advanced Materials and Manufacturing Technologies (AMO successor office)	-	-	75,000	+75,000
Bioenergy Technologies	108,000	147,982	132,000	-15,982
Geothermal Technologies	-	7,900	5,000	-2,900
Hydrogen and Fuel Cell Technologies	122,500	124,000	90,000	-34,000
Solar Energy Technologies	16,450	19,056	17,600	-1,456
Strategic Programs	-	4,350	3,000	-1,350
Fossil Energy and Carbon Management	188,500	258,000	270,000	+12,000
Carbon Management Technologies	188,500	258,000	270,000	+12,000
Nuclear Energy	58,700	66,000	40,300	-25,700
Light Water Reactor Sustainability	13,000	11,000	4,000	-7,000
Advanced Reactor Technologies	13,000	17,000	15,800	-1,200
Crosscutting Technology Development	10,000	12,000	9,500	-2,500
National Reactor Innovation Center	22,700	26,000-	11,000	-15,000
Office of Clean Energy Demonstrations	-	-	160,000	+160,000
Clean Energy Demonstrations	-	-	160,000	+160,000
Science	65,700	69,678	70,762	+1,084
Basic Energy Sciences	65,700	69,678	70,762	+1,084
Grand Total	**736,846**	**1,006,466**	**1,257,907**	**+251,441**

*ARPA-E funding is determined annually based on programs developed through office and stakeholder priorities. Therefore, funding for FY 2023 and FY 2024 is not available currently.

Overview:

The Industrial Decarbonization crosscut engages multiple offices across the Department of Energy (DOE) to foster innovations and enable scale-up of cost-competitive, low-emissions technologies to achieve the United States' goal of decarbonizing energy intensive and high greenhouse gas (GHG)-emitting industries to achieve net-zero GHG emissions, economy-wide, no later than 2050. The crosscut leverages research, development, demonstration, and deployment (RDD&D) across the pillars of industrial decarbonization identified in DOE's Industrial Decarbonization Roadmap[1]: energy efficiency; electrification; low carbon input sources; and carbon capture and storage (CCS), as well as development of alternative strategies – including manufacturing technology innovation and negative emissions technologies – that reach beyond the four pillars.

[1] DOE, Industrial Decarbonization Roadmap, September 7, 2022, https://www.energy.gov/eere/doe-industrial-decarbonization-roadmap

The U.S. industrial sector is considered a hard-to-decarbonize sector of the energy economy, due to the diverse energy inputs needed for a wide array of heterogeneous industrial processes and operations. In 2020, the industrial sector accounted for 33 percent of the nation's primary energy use and 30 percent of energy-related carbon dioxide (CO_2) emissions[2] with refining, chemicals, iron and steel, cement, aviation and food products representing the top energy-consuming sectors.

Given the technologies and systems interdependencies across the decarbonization pillars, crosscut activities are a key piece of DOE's portfolio of solutions to achieve a net zero carbon economy by 2050, with the potential to contribute to a reduction of 400 million metric tons (MMT) of CO_2 of industrial emissions in the most energy and emissions intensive industrial subsectors by 2050. Additionally, industrial decarbonization investments can improve manufacturing productivity, develop innovative products, and meet expanding societal needs while enabling jobs and maintaining the Nation's prosperity throughout the 21st Century and beyond.

Coordination Efforts:
In FY 2023, DOE established the Industrial Technologies joint strategy team (JST), led by the Manufacturing and Energy Supply Chain (MESC) Office and the Office of Energy Efficiency and Renewable Energy's (EERE) Industrial Efficiency and Decarbonization Office (IEDO), which is charged with developing an integrated DOE-wide strategy and align RDD&D activities supported by annual appropriations with the BIL and IRA funding for demonstration, scale-up, and deployment activities.

Technology development priorities and objectives are identified and coordinated across the basic and applied research technology offices through a crosscutting Industrial Emissions Reductions Technology Development Program, as directed by Congress. Cross-office activities include developing and executing RDD&D coordination, budget development, and strategic planning for the crosscut, informed by the DOE Industrial Decarbonization Roadmap. As a priority activity, the Offices at DOE prioritize work in support of the Industrial Heat Shot™ goal of achieving cost competitive technologies with greater than 85 percent lower GHG emissions.

DOE Program Offices from EERE, Fossil Energy and Carbon Management (FECM), Science (SC), Nuclear Energy (NE), Clean Energy Demonstrations (OCED), Technology Transitions (OTT), and Advanced Research Projects Agency-Energy (ARPA-E) participate in these crosscutting efforts. Other technology offices, such as the Office of Electricity, Office of Cybersecurity, Energy Security and Emergency Response and other crosscutting offices such as Office of Economic Impact & Diversity, Office of Policy, and Loan Programs Office may contribute staff time, provide expertise, and coordinate with the RDD&D funding offices to enhance the impact of the Department's investments.

Objectives and Action Areas:
- Objective 1**:** Create and implement an integrated RDD&D strategy across the Department to drive the development and deployment of energy efficiency and decarbonization technologies that reduce emissions and increase competitiveness of the U.S. industrial sector in a net zero economy.
- Objective 2**:** DOE announced the launch of the Industrial Heat Shot™ in September 2022, a new effort aimed at dramatically reducing the cost, energy use, and carbon emissions associated with the heat used to make everything from food to cement and steel. The 6th in the DOE Energy Earthshots™ Initiative, the Industrial Heat Shot™ seeks to develop cost-competitive solutions for industrial heat with at least 85 percent lower GHG emissions by 2035.

The reliance on carbon and variation of energy sources, uses, and product mixes, it will be critical to proactively pursue multiple decarbonization approaches in parallel, which include the following:

Action Areas:
1. Energy Efficiency: RDD&D focuses on enabling energy efficiency in hard-to-decarbonize sectors ranging from energy intensive unit operations (e.g., process heating) to facilities/systems operations. This includes waste heat recovery and flexible combined heat & power (CHP) approaches that could significantly reduce energy consumption and

[2] EIA (Energy Information Administration), Annual Energy Outlook 2021 with Projections to 2050. https://www.eia.gov/outlooks/aeo/pdf/AEO_Narrative_2021.pdf.

associated GHG emissions in the near term enabling a transition to fully clean (zero carbon-emitting) energy sources in the mid- to long-term (i.e., ensure that unintended fossil fuel lock-in does not occur). This also includes research, development, and demonstration (RD&D) efforts for process intensification approaches for large scale systems, modular chemical processes for distributed manufacturing, and advanced chemistry and reactor designs for feedstock degradation.

2. Carbon Capture, Utilization and Sequestration (CCUS): Fossil fuel energy use in operations as well as some processes inherent to manufacturing (e.g., cement production, fermentation of biofuels) generate CO_2. In addition to utilizing zero carbon generation electricity, carbon capture and sequestration (CCS) can reduce emissions at the source. RDD&D focuses on technologies that can improve capture performance; generate lower carbon intensive products (i.e., ethanol, hydrogen (H_2), cement); convert CO_2 into valuable products – in some cases augmenting products produced in the industrial sector such as cement and curing to concrete; and safely store CO_2 in geologic formations. Viable CCS and CO_2 conversion pathways need both a value proposition as well as assessment of the availability of primary energy, water, and other inputs to ensure holistic, sustainable, low-life cycle emissions pathways, ensuring stewardship of our communities and the environment.
3. Transition Energy Sources – Low Carbon Fuels, Feedstocks and Energy Sources: RDD&D focuses on hydrogen, low carbon fuels and feedstocks, solar thermal, and other sources to be cost-effectively used to reduce energy and emission intensity. Low-carbon and sustainably sourced biomass feedstocks offer an effective alternative to replace current petroleum-based feedstocks for a variety of high-volume chemical products leading to significant GHG emissions reductions. This also includes enhanced thermal conversion systems, integrated energy systems for CHP from a range of clean energy sources.
4. Industrial Electrification: Electrification, particularly from thermal processes, provides an opportunity to leverage decarbonized and inexpensive electricity sources - including an electric grid that will undergo a clean energy transformation over the next decade - and reduce industrial emissions from onsite combustion of fossil fuels. Significant RDD&D opportunities exist to develop indirect and direct electrification systems for heat generation, innovation in electrochemical or electromechanical systems, and overcoming economic and technical barriers to implementation of existing electrified technologies.
5. Manufacturing Technology Innovation and Alternate Pathways: The current predominantly linear production system of materials extraction to manufacturing to product use to disposal is not optimized around energy or GHG emissions. Circular economy approaches and reverse supply chain processes provide entirely new opportunities for energy and emissions improvements in concert with new economic opportunities for transformative material and resource utilization. Opportunities exist to foster fundamental science and applied research and development (R&D) efforts to align with other crosscuts and DOE priorities. These can include advanced manufacturing including biomanufacturing; circularity for critical materials, plastics, and water; as well as entirely new pathways for carbon dioxide removal (CDR) approaches via reaction of CO_2 with alkaline by-products or waste (e.g., mine tailings) to produce synthetic aggregates, which can serve as replacements for sand and gravel.
6. Crosscutting Activities: Work that crosses these technical focus areas includes robust systems analysis including life-cycle analysis (LCA), resource, regional and techno-economic analysis (TEA); coordination on workforce development and best practices to diversify the industrial workforce and ensuring Energy and Environmental Justice (EJ) principles are embedded throughout the development and implementation of industrial decarbonization solutions.

Program Organizations:

1. **Advanced Research Projects Agency-Energy:** As defined by its authorization under the America COMPETES Act, ARPA- E catalyzes transformational technologies to enhance the economic and energy security of the United States. ARPA-E funds high-potential, high-impact projects that are too risky to attract private sector investment but could significantly advance the ways to generate, store, distribute and use energy. In FY 2022, ARPA-E selected and/or obligated almost $1 million in Industrial Decarbonization funding to projects aligned with the Crosscut through ARPA-E's Supporting Entrepreneurial Energy Discoveries (SEED) Exploratory Topic. ARPA-E is developing programs for transformational research across a wide range of energy technologies and applications. The assessment process for new programs is now underway and any potential future investments in Industrial Decarbonization will be determined in FY 2023.

2. **Energy Efficiency & Renewable Energy:** EERE supports the following Program activities:
    a. Industrial Efficiency and Decarbonization Office: IEDO supports industry-specific decarbonization investments with initiatives focusing on the chemicals, forest products, iron and steel, cement, and other high carbon-emitting industries such as food processing, including a new FY 2024 effort focused on utilization of CO_2 as a feedstock for chemicals such as ethylene. Ramped up investments in priority cross-sector technologies for decarbonization based on the DOE Industrial Decarbonization Roadmap, including thermal-process electrification will be a focus in FY 2024. Expanded programs include DOE's Better Climate Challenge, a national public-private partnership (PPP) that calls on organizations across the country to set bold, portfolio-wide GHG reduction targets and share their innovative solutions and best practices.
    b. Bioenergy Technologies Office (BETO): BTO supports industrial decarbonization through the development of alternative feedstocks, and energy efficient conversion processes to produce fuels, chemicals, and materials. BETO's alternative feedstocks R&D focuses on technologies to produce sustainable, cost-effective, conversion-ready feedstocks, including biomass and wastes, such as CO_2. BETO also supports RD&D conversion technologies that can use these alternative feedstocks to replace traditional manufacturing processes and fossil-derived chemicals with leap-frog technologies that use significantly less energy inputs and reduce GHG emissions.
    c. Geothermal Technologies Office (GTO): GTO supports the development and demonstration of geothermal heat pump systems at different industrial scales as well as demonstrations of thermal energy storage (TES) for manufacturing applications. These efforts will be supported by assessments of deep, low temperature resources in the U.S. for TES and industrial direct use systems as well as the development of local and regional partnerships to enhance deployment of geothermal heat pumps.
    d. Hydrogen and Fuel Cell Technologies Office (HFTO): HFTO funds RD&D to enable affordable carbon-free hydrogen to address hard-to-decarbonize applications across sectors. Within the hard-to-decarbonize industrial and chemical applications, HFTO supports RD&D focused on demonstrating clean hydrogen as a feedstock or fuel (ammonia production) or as a direct reducing agent (i.e., steel production). Efforts may also include demonstrating clean hydrogen as a heat source for processes like steel and cement production. These efforts support the following FY 2024 Action Areas: Energy Efficiency; Carbon Capture, Sequestration and Utilization, and Transition Energy Sources.
    e. Solar Energy Technologies Office (SETO): SETO supports RD&D of both low-temperature systems – in the range of 100 to 400 °C – integrated with existing technologies, as well as the development of components and high-temperature system designs that are difficult to decarbonize through electrification. Low-temperature applications include the development of thermal processes, including thermal desalination, which can efficiently couple with a solar thermal energy input. High temperature systems work includes the development of solar thermal pathways for the carbon-emission-free production of energy-intensive chemicals, commodities, and fuels, like ammonia, steel, cement, and hydrogen.
    f. Strategic Programs (SP): SP will significantly expand the development of data and analysis tools for difficult to decarbonize sectors of the economy, such as industry, and identify key opportunities for economic growth and job creation in the decarbonized U.S. economy.
    g. Advanced Materials and Manufacturing Technologies Office (AMMTO): AMMTO advances economy-wide decarbonization, including industrial decarbonization, through a variety of programs. In FY 2024, these programs include RD&D in the following areas: circular economy of manufactured materials that reduce emissions through material efficiency and reducing the embodied energy of feedstocks; advanced materials for applications in industry that include harsh service environments and/or that can leverage high conductivity for improved efficiency; semiconductor manufacturing for use in industrial applications; and smart manufacturing, including high performance computing (HPC), to leverage plant data to make process and product design improvements.

3. **Fossil Energy and Carbon Management:** FECM will conduct RDD&D on:
    a. CCUS including technical feasibility, economic potential, and siting/systems considerations to co-locate large industrial facilities with CCUS availability;
    b. The production of hydrogen with CCUS from fossil resources/wastes (such as plastics and co-production using biomass, where available);
    c. Turbines that can utilize hydrogen, ammonia, and other low carbon fuels for power generation to be used in industrial applications, as well as hybrid and integrated systems to maximize efficiency;

d. Reversible solid oxide fuel cells/solid oxide electrolyzer cells, focused on natural gas and co-producing hydrogen, in coordination with EERE's HFTO; and
e. Large scale transport and geological energy storage, including hydrogen or hydrogen carriers such as ammonia at scale to support bulk power generation and conduct related analysis.
f. FECM will collaborate with international partners to share lessons learned and leverage capabilities to facilitate carbon management development and deployment for the industrial sector.

4. **Nuclear Energy:** NE supports R&D to enable the use of existing light water reactors and new, advanced reactors to provide clean and reliable electricity and heat to a wide range of industrial customers. In FY 2024, NE will support industrial decarbonization in several ways:
   a. Develop the methods and models for thermal extraction, storage, and distribution as well as operations and control systems for direct use of heat generated from nuclear reactors;
   b. Develop preliminary front-end engineering and design studies to detail the opportunities to scale up clean thermal and energy extraction and distribution systems for industrial applications;
   c. Develop site integration and safety basis information for co-locating reactors with distributed industrial applications;
   d. Develop reactor technologies that produce high grade heat (500 °C to 900 °C) suitable for use in most chemical and industrial processes and performing R&D on thermal upgrading technologies to upgrade lower temperature (300 °C) heat sources with heat pumps or thermo-chemical systems;
   e. Perform cost analysis of advanced reactor technologies to identify pathways for cost reduction and determining the economic viability for integration of advanced reactors with industrial applications;
   f. Perform energy system modeling and simulation to develop a modeling framework for economic dispatch optimization of integrated energy systems;
   g. Perform R&D on thermal distribution components and systems to characterize and verify the cost and performance of thermal energy distribution systems;
   h. Complete installation and fueling of the Microreactor Applications Research, Validation, and Evaluation (MARVEL) microreactor which will serve as a unique nuclear test platform for demonstrating microreactor operations and end-use applications; and
   i. Continue construction of the Demonstration and Operation of Microreactor Experiments (DOME) test bed at the Idaho National Laboratory (INL) which will be capable of siting experiments to support testing and development of microreactor technologies as well an advanced reactor integrated energy system demonstration platform.

5. **Office of Clean Energy Demonstrations:** OCED's potential areas of interest include projects that demonstrate smart manufacturing principles, energy efficiency, carbon management, alternative low-carbon feedstocks or fuels, circular economies through reuse of waste streams in other industries, and electrification of industrial processes.

6. **Science:** Basic Energy Sciences (BES) provides foundational knowledge and state-of-the-art capabilities in support of crosscut objectives, including theoretical and experimental science related to understanding opportunities for decarbonizing industry. The research to support this crosscut is also discussed in the CDR, Critical Materials and Minerals, Hydrogen, and the Clean Energy Technology Manufacturing, formerly Advanced Manufacturing, crosscuts. SC operates major x-ray, neutron, nanoscience, and HPC user facilities that provide advanced synthesis, fabrication, characterization, and computational capabilities to this community for basic, applied, and industrial research. In FY 2024, BES supports the Industrial Decarbonization crosscut:
   a. Scientific discoveries and major scientific tools to transform our understanding of materials and conversion processes related to chemicals, low carbon fuels (including hydrogen and biofuels), and manufacturing processes.
   b. Advances in synthesis, catalysis, modeling, artificial intelligence (AI)/machine learning (ML), analytical instrumentation at user facilities, HPC, and bio-inspired approaches. Key basic research focus areas include: Novel materials for low carbon fuels/feedstocks (e.g., hydrogen in coordination with the Hydrogen crosscut), membranes for separations, design of catalysts at the nanoscale, co-design for manufacturing (combining disciplines and computation for a "whole systems" approach), manufacturing processes that reduce/eliminate need for process heat, and synthesis science for scale-up from initial discoveries to bridge the gap to applied research and commercial application.

Highlights and Major Changes from FY 2023 Enacted

- Energy Efficiency and Renewable Energy:
  - Industrial Efficiency and Decarbonization: As a successor office to AMO, IEDO increases investment in industry-specific decarbonization RD&D with initiatives focusing on energy and emission-intensive industries as well as in priority cross-sector technologies for decarbonization based on DOE's Industrial Decarbonization Roadmap and continued technical assistance to increase the adoption of decarbonization technologies.
  - Bioenergy Technologies: BETO increases support for sustainable aviation fuels (SAF) RDD&D, including funds to construct and operate integrated industry biorefineries at demonstration scale that are capable of producing SAFs reducing industry carbon sources through identified alternative pathways and feedstocks.
  - Geothermal Technologies Office: In FY 2024, GTO supports TES and demonstrations for manufacturing applications.
  - Hydrogen and Fuel Cells Technologies: HFTO continues to support RD&D to enable affordable carbon-free hydrogen to address hard-to-decarbonize industrial and chemical applications such as ammonia and steel production.
- Fossil Energy and Carbon Management: Increase reflects expanded efforts on industrial decarbonization, covering a broader range of industrial sources, additional research, and pilot-scale testing.
- Nuclear Energy: In FY 2024, NE increased its overall investment for industrial decarbonization to support completing construction of the Microreactor Applications Research, Validation, and Evaluation (MARVEL) microreactor test platform and continuing construction of the Demonstration and Operation of Microreactor Experiments (DOME) test bed at INL, both of which will enable demonstration of microreactor technologies and their integrated operations with non-electric end-use applications.
- Office of Clean Energy Demonstrations: In FY 2024, OCED plans to sponsor a new competition focused on demonstrating solutions for carbon and other pollutant emission reductions at industrial facilities. OCED will fund up to five demonstration projects to reduce carbon and other pollutant emissions for the industrial sector while maximizing benefits to underserved and overburdened host communities. To achieve the greatest emissions reduction possible, OCED may fund projects that integrate multiple technology pathways.

Related Bipartisan Infrastructure Law (BIL) or Inflation Reduction Act (IRA) Programs:

In addition to the annual appropriations request, BIL and IRA funding will support the planning and execution of demonstration, scale-up, and deployment for advanced industrial technologies. These investments are essential in addressing the technology needs to support growth in decarbonizing industry and increasing U.S. competitiveness in a net zero economy.

Subsurface Energy Innovations
Funding by Appropriation and Program Control
($K)

Appropriation and Program Control	FY 2022 Enacted	FY 2023 Enacted	FY 2024 Request	FY 2024 vs FY 2023 ($ Change)
Advanced Research Projects Agency – Energy	40,376	TBD	TBD	N/A
ARPA-E Projects*	40,376	TBD	TBD	N/A
Energy Efficiency and Renewable Energy	109,500	118,000	163,787	+45,787
Geothermal Technologies	109,500	118,000	163,787	+45,787
Fossil Energy and Carbon Management	12,250	38,000	38,000	-
Carbon Management	10,000	35,000	35,000	-
Resource Sustainability	2,250	3,000	3,000	-
Science	16,017	36,191	45,487	+9,296
Advanced Scientific Computing Resources	6,017	6,017	9,578	+3,561
Basic Energy Sciences	10,000	30,174	35,909	+5,735
Grand Total	**178,143**	**192,191**	**247,274**	**+55,083**

*ARPA-E funding is determined annually based on programs developed through office and stakeholder priorities. Therefore, funding for FY 2023 and FY 2024 is not available currently.

Overview:

Subsurface clean energy applications hold massive untapped potential for solving the climate crisis. However, our ability to assess, access, and monitor the subsurface quickly and economically is insufficient to mitigate financial and environmental risk for rapid deployment of key subsurface technologies. Common risk drivers include a) uncertainty in subsurface resource properties; b) inability to monitor reservoir dynamics that can trigger seismicity and/or leakage; and c) prohibitive costs and timelines to access subsurface resources. The Subsurface Energy Innovation (SEI) Crosscut funds research, development, demonstration, and deployment (RDD&D) to improve the accuracy, precision, and speed with which subsurface resources can be assessed, accessed, and monitored. Such advancements will allow the technologies listed below to become market-competitive, scalable, and permanent clean energy solutions, and create tens of thousands of good-paying jobs:

- Geothermal energy, which requires dramatic cost reductions in Enhanced Geothermal System (EGS) capability to increase its footprint beyond 0.5 percent of U.S. electricity generation;
- Geologic carbon storage, currently happening at 0.1 percent of the rate necessary to meet climate goals;
- Geologic hydrogen storage, currently only feasible in unique and rare geologic features;
- Sustainable critical mineral (CM) extraction, necessary to reduce high American import reliance; and
- Geologic hydrogen sourcing, a new and potentially cost-effective, zero-emission source of hydrogen.

In recognition of the potential of EGS to provide plentiful clean, dispatchable electricity, the Department of Energy (DOE) launched its fourth Energy Earthshot™, the Enhanced Geothermal Shot™, in September 2022. The Enhanced Geothermal Shot™ aims to reduce the cost of EGS by 90 percent, to $45 per megawatt hour (MWh), by 2035. This effort is being deployed to realize the potential of EGS to power more than 40 million American homes and businesses, increase opportunities for geothermal heating and cooling solutions nationwide, and provide career opportunities, leveraging tools and best practices from the oil and gas industry to advance clean energy. Investments in EGS could unlock up to 90 gigawatts of affordable clean electricity and exponentially increase opportunities for geothermal heating and cooling solutions nationwide.

SEI Crosscut activities reduce the uncertainty and cost burden facing these technologies through the production and application of tools, data products, and workstreams that improves observational, decision-making, and operational capabilities. Such activities require advancements across fundamental science, and applied RDD&D. The SEI Crosscut will leverage the integration of state-of-the-art High-Performance Computing (HPC) resources, Artificial Intelligence (AI), Machine Learning (ML), and simulation capabilities with applied technology workstreams necessary to build subsurface simulation and interpretation visualization, prediction, and decision-making tools.

Coordination Efforts:
The Department houses an entire range of technological expertise across the RDD&D chain required for innovation in the subsurface for clean energy advancement including: Office of Science's (SC) Basic Energy Sciences (BES) and Advanced Scientific Computing Research (ASCR) Offices, Energy Efficiency and Renewable Energy's (EERE) Geothermal Technologies Office (GTO), Advanced Research Projects Agency-Energy (ARPA-E), Fossil Energy and Carbon Management Office (FECM), and Office of Clean Energy Demonstrations (OCED), with the National Nuclear Security Administration's (NNSA) Office of Defense Nuclear Nonproliferation (DNN), Artificial Intelligence and Technology Office (AITO) providing technical support and staff time. In addition, the Office of Policy's Office of Energy Jobs will support engagement with workers and labor unions to develop a safe and skilled geothermal workforce.

In addition to developing and implementing a cross-agency subsurface RDD&D Strategy, priorities include joint efforts on information sharing and engagement with external stakeholders and technology experts. Additionally, the SEI Crosscut will prioritize the establishment of new partnerships and maintenance of existing partnerships with other Federal agencies, such as the Department of Interior and the United States Geological Survey (USGS), the National Science Foundation, and the National Aeronautics and Space Administration.

Objectives and Action Areas:
- Objective 1 – Improve Characterization: Significantly improves understanding of the nation's deep subsurface resources.
  - Action Area: Modernize subsurface data analytics. Develop tools to gather, standardize, rescue, and reinterpret legacy data, as well as incentive structures to allow for data sharing between the public and private sectors.
- Objective 2 - Enhance Monitoring: Observe and modify operations below ground in real time to ensure safe, economic operation.
  - Action Area: Assessing the "value" of different types of information. Engage in research and development (R&D) to assess the value of different information being collected over time and space to identify what parameters are imperative for different subsurface projects in different places, enabling real-time decision making.
- Objective 3 - Faster and Safer Drilling: Access the deep subsurface quickly, economically, and safely.
  - Action Area: Leverage drilling activities funded through the BIL. Engage in iterative drilling research, development, and demonstration (RD&D) on wells funded through BIL to drive process improvements in drilling speeds, and support tech transfer of drilling workflows across different subsurface technology areas to ensure drilling best practices are adopted across these provisions.
- Objective 4 - Subsurface Engineering: Safely modify subsurface environments to meet our specific clean energy demands.
  - Action Area: Managing uncertainty in frontier subsurface engineering environments. Coordinate RDD&D to build confidence in developing the subsurface and reduce uncertainty in new geological settings and with new technologies. Leverage EGS demonstration activities funded through BIL.

Program Organizations:
1. **Advanced Research Projects Agency-Energy (ARPA-E):** As defined by its authorization under the America COMPETES Act, ARPA-E catalyzes transformational technologies to enhance the economic and energy security of the United States. ARPA-E funds high-potential, high-impact projects that are too risky to attract private sector investment but could significantly advance the ways to generate, store, distribute and use energy. In FY 2022, ARPA-E selected and/or obligated $40 million in Subsurface Energy funding to projects aligned with the Crosscut through ARPA-E's Supporting Entrepreneurial Energy Discoveries (SEED) Exploratory Topic and Mining Innovations for Negative Emissions Resource Recovery (MINER) programs. ARPA-E is developing programs for transformational research across a wide range of energy technologies and applications. The assessment process for new programs is now underway and any potential future investments in Subsurface Energy will be determined in FY 2023.

2. **Energy Efficiency & Renewable Energy (EERE):** The primary office in EERE driving innovation in subsurface technologies is the Geothermal Technologies Office (GTO). GTO supports SEI Crosscut objectives through RD&D that focuses on exploration, characterization, reservoir monitoring, and drilling-based verification of advanced exploration technologies

and methods. Exploration and characterization activities will focus on improving targeting the breadth of geothermal resources across temperature ranges and applications through improvements in multi-physics inversion methods and incorporation of ML models. Additionally, broad data collection efforts will enable a significant increase in the discovery of hidden geothermal systems. All subsurface related GTO activities will also play a role in advancing the Enhanced Geothermal Shot™, which sets a target to dramatically reduce the cost of EGS to $45/MWh by 2035.

Subsurface accessibility efforts within GTO focus on RD&D directed at lowering the time to drill geothermal wells and decrease the costs of required materials and equipment. Activities will include efforts to adopt data driven workflows to increase the efficiency of geothermal drilling, adapting applicable technologies proven in the oil and gas well construction industry, directly addressing primary causes of "non-productive time", and the implementation of RD&D programs to reduce the materials costs associated with geothermal well development. These efforts also include development and deployment of surface and subsurface reservoir monitoring technologies focusing on microseismic, electrical, and optical methods. Crosscutting activities such as ML, advanced manufacturing, and a focus on technology commercialization will support the program in its focus on the energy transition.

3. **Fossil Energy and Carbon Management:** FECM supports the FY 2024 SEI Crosscut objectives through extensive expertise and capability related to the characterization, management, and extraction of subsurface resources, such as critical mineral (CM) extraction, as well as geologic storage of hydrogen and CO_2. FECM launched the Carbon Ore, Rare Earth, and Critical Minerals (CORE-CM) initiative designed to address the upstream and midstream CM supply chain and downstream manufacturing of high-value, nonfuel, carbon-based products (CBP), to accelerate the realization of full potential for carbon ores and CM within the U.S basins. FY 2024 activities in this area include novel monitoring technologies, including geochemical and biological approaches, which will help characterize mineral resources.

   FECM activities in FY 2024 will capitalize on and integrate recent advances in geochemical, wellbore integrity, and fluid-structure interaction modeling derived from decades of field experience with underground gas storage in the oil and gas industry to drive greater uptake and acceptance of underground hydrogen storage (UHS). Such activities will allow for UHS operators to both dynamically track and adaptively manage UHS reservoirs to ensure existing barriers, such as induced seismicity and sulfate-reducing bacteria, are mitigated. Extensive outreach to and cooperation with the public and regulatory bodies are central to FECM UHS activities and are key to widespread application of the technology.

   FECM is currently developing and validating new and innovative approaches in carbon storage technologies in the lab and in the field, including advanced data management. In FY 2024, FECM can advance SEI Crosscut objectives 1 and 2 by including focus within on-going initiatives to develop ML-driven tools that gather, standardize, rescue, analyze, and value-assess new and existing subsurface data with cross-cutting applicability.

4. **Science (SC):** SC provides foundational knowledge and state-of-the-art capabilities in support of crosscut objectives, such as novel computational algorithms in material properties and fluid flow data analysis and management, high performance computation, and subsurface material characterization.
   a. Advanced Scientific Computational Resources: ASCR provides state-of-the-art HPC facilities as well as R&D that develops physics-informed deep learning techniques to address long-standing subsurface challenges. The Subsurface project, funded through ASCR's Exascale Computing Project (ECP), is developing a high-resolution reservoir simulator, integrating the complex multiphysics processes occurring from kilometer to micron scales to study and prevent well bore failure for CO_2 sequestration in saline reservoirs. In addition, ECP's Earthquake Simulation (EQSIM) project is creating an end-to-end capability to simulate earthquakes from the initiation of a fault rupture to surface ground motions and ultimately to infrastructure response. ASCR also supports a Mathematical Multifaceted Integrated Capability Center (MMICC) focused on Sparse data structures to support subsurface modeling. Simulations of subsurface challenges are running on ASCR production and leadership computing systems.
   b. Basic Energy Sciences: BES supports computational/theoretical and experimental science to understand geomechanical, geochemical, hydrological, and interfacial chemical and materials behavior to provide foundational knowledge to advance subsurface energy technologies, including support for the Enhanced Geothermal Shot™. Specific areas include (Objective 1):

i. Mineral dissolution, nucleation, and phase equilibria in confined and interfacial environments, including characterization at the molecular level.
ii. Understanding how geophysical signals–such as lab measurements of active and passive emissions and field measurements of seismic signals–arise from geophysical processes, with a goal to develop improved predictions and ultimately control these.
iii. Leverage of the unique capabilities at SC scientific user facilities, such as x-ray light sources (high-resolution imaging of the time-dependence of geochemical/mechanical interactions in rock samples) and leadership class computing (for predictive modeling of processes across scales and ML simulations of massive data sets to connect data to the underlying processes).

Highlights and Major Changes from FY 2023 Enacted

- Energy Efficiency & Renewable Energy (EERE): Geothermal Technologies Office increase will support the Enhanced Geothermal Shot™ effort in various technical areas with a focus on learning-by-doing and well construction cost reductions, as well as a new portfolio focused on advanced materials and high temperature components to enable downhole development in EGS environments and includes exploration and characterization R&D and analysis.
- Science (SC): The increased investment in the Office of Science focuses on enabling new insights and breakthroughs by leveraging foundational research and the unique capabilities of the scientific user facilities.
    - The increased investment in ASCR facilities focuses on foundational research enabling new capabilities accessible only through large-scale computing resources.

Related Bipartisan Infrastructure Law (BIL) or Inflation Reduction Act (IRA) Programs

In addition to the annual appropriations request, BIL funding will support the planning and execution of demonstration, scale-up, and deployment of carbon storage and geothermal systems. In addition, expansion of tax credits in IRA have increased incentives in several subsurface technologies.

Energy Sector Cybersecurity
($K)

Appropriation and Program Control	FY 2022 Enacted	FY 2023 Enacted	FY 2024 Request	FY 24 vs. FY 23 ($ Change)
Cybersecurity, Energy Security, and Emergency Response	**112,404**	**120,357**	**159,000**	**+38,643**
Risk Management Technology & Tools	92,804	95,000	115,000	+20,000
Preparedness, Policy and Risk Analysis	12,000	13,357	17,000	+3,643
Response and Restoration	7,600	12,000	27,000	+15,000
Electricity	**20,372**	**14,591**	**15,000**	**+409**
Cyber Resilient and Secure Utility Communication Networks (SecureNet)	20,372	14,591	15,000	+409
Energy Efficiency and Renewable Energy	**13,100**	**9,750**	**11,300**	**+1,550**
Building Technologies (BTO)	6,000	300	300	0
Hydrogen and Fuel Cell Technologies (HFTO)	0	200	0	-200
Solar Energy Technologies (SETO)	3,500	5,000	5,000	0
Vehicle Technologies (VTO)	2,000	2,000	2,000	0
Water Power Technologies Office (WPTO)	350	0	0	0
Wind Energy Technologies Office (WETO)	1,250	2,250	4,000	+1,750
Nuclear Energy	**4,500**	**4,500**	**4,500**	**0**
Fossil Energy and Carbon Management	**1,800**	**1,200**	**333**	**-867**
Chief Information Officer	**1,303**	**1,553**	**1,553**	**0**
Total, Energy Sector Cybersecurity	**153,479**	**151,951**	**191,686**	**39,735**

Overview

The Department of Energy's (DOE's) FY 2024 budget request is aligned with the National Cyber Strategy and demonstrates the Administration's commitment to strengthening the Nation's cybersecurity capabilities and addressing the most pressing cyber threats. The FY 2024 budget supports DOE's responsibilities as Sector Risk Management Agency (SRMA) for cybersecurity for the energy sector, as established under the Fixing America's Surface Transportation (FAST) Act of 2015. As SRMA, DOE works closely with the critical infrastructure lead, the Department of Homeland Security (DHS), and our other federal partners including law enforcement and the intelligence community, as well as stakeholders across industry, and state and local governments, to secure the Nation's critical energy infrastructure from cyber threats and attacks.

Departmental Collaboration

As adversaries increase the frequency and sophistication of their malicious cyber activities, the Department has increased investment in cybersecurity to identify solutions to reduce risk for the energy sector, as well as the enterprise systems supporting the Department's internal operations. The FY 2024 request builds upon the strategy outlined in the Multiyear Plan (MYP) for Energy Sector Cybersecurity and the Office of Cybersecurity, Energy Security and Emergency Response (CESER) leading the efforts to strengthen the security and resilience of the U.S. energy infrastructure.

Highlights and Major Changes

Office of Cybersecurity, Energy Security, and Emergency Response

CESER is lead for energy sector cybersecurity initiatives across the Department.

In FY 2024, CESER will make investments in the following programmatic areas of Risk Management Tools & Technologies:

- RD&D of Cybersecurity Tools and Technologies
  Research, develop, demonstrate and transition to practice next generation cybersecurity tools and technologies that provide energy companies protection, monitoring, detection, response, containment, forensics, and recovery

capabilities. These tools will leverage operational data and the physics of energy delivery to inform owners and operators of anomalous cyber activities on their industrial controls systems and networks. These efforts will primarily be executed through competitive funding opportunities and research calls for energy companies, academia, national laboratories, and/or manufacturers. This work focus on tools that enable individual utilities to manage cyber risks to next generation energy systems, such as microgrids, automated OT infrastructure, virtual power plants, and cloud-connected systems, positioning the industry to stay ahead of the threat.

- Energy Cyber Sense and Cyber Testing for Resilient Industrial Control Systems (CyTRICS)
  The Energy Cyber Sense program is CESER's overarching supply chain cybersecurity risk management effort. The program comprises a range of activities including the CyTRICS testing. In FY 2024, CESER RMT will expand the reach of the CyTRICS testing activities; with a focus on risk-based prioritized systems and components. RMT will develop partnerships with the operational technology manufacturers and integrate the testing pipeline with the broader Energy Cyber Sense program. RMT will work with interagency partners and industry on a pilot effort to research, design and develop cybersecurity label for an industrial IoT technology in the energy sector. The labeling pilot will not include enforcement or certification but will include work on promotion through standards and guidance. The CyTRICS program will also work to analyze no less than 15% of critical components in energy sector systems; and expand manufacturers participating in the program to cover no less than 30% of the market share of critical components.

- CYBER RISK ASSESSMENTS, FRAMEWORKS, AND R&D COORDINATION
  RMT has a number of programs and tools in this area, to include the National Cyber-Informed Engineering (CIE) Strategy, the Consequence-Driven Cyber Informed Engineering (CCE) program, the Cybersecurity for Operational Technology Environment (CyOTE), and the Cybersecurity Capability Maturity Model (C2M2) tool. The CIE strategy will expand implementation of security by design to major U.S. research universities and work with asset owners and operators to enable CIE principles within engineering design and infrastructure improvement efforts. RMT's CCE effort focuses on critical function assurance of energy sector and national defense high-risk/strategically critical infrastructure and in FY 2024 will complete the R&D phase, with potential transfer to commercial partners and another CESER division. Additionally, in FY 2024, RMT will further the underlying CyOTE research and innovation, transition the CyOTE tool to practice with new features and functionality, and refine training for OT and non-OT stakeholders. Specifically, advancing from methodology research, the program will focus on smart data mining, reporting insights to industry, and expanding understanding of additional technical domains that matters to industry. Finally, the C2M2 tool will continue development and maintenance of features and resources including user community forum, facilitated evaluations, and updates needed to align with Cybersecurity Framework (CSF) V2.0. RMT will also continue research of usage and impacts of NIST CSF, C2M2, and C2M2 derivatives.

  CESER is a voting member of the Grid Modernization Laboratory Consortium (GMLC) committing to drive cybersecurity across DOE GMLC efforts. As such, CESER has committed to at least $3 million annually for GMLC Lab calls and plans to participate in a 3-year lab call. Finally, as directed by Congress in FY 2023, CESER will ensure cybersecurity research, development, and demonstration projects being performed across the Department are coordinated. CESER will establish a formal coordination structure to cybersecurity RD&D efforts across the department to ensure the Department is taking a strategic and coordinated approach going forward. CESER will work with relevant DOE program offices and develop a Multi-Year Cybersecurity RD&D Roadmap for Energy Sector Cybersecurity to guide DOE's overall efforts.

In FY 2024, CESER will make investments in the following programmatic areas of Preparedness, Policy, and Risk Analysis:

- MANAGE ENERGY SECTOR RISK AND ENABLE RISK MANAGMENT, CYBERSECURITY EXERCISES, TRAINING AND WORKFORCE DEVELOPMENT
  PPRA will continue to lead the department's activities on sector-wide energy security policy and represent DOE at the National Security Council and across the interagency for cross-sector energy security policy and risk management. This includes leading interagency risk management activities for the energy critical infrastructure including policy development. Additionally, the energy sector is experiencing a significant increase in vacant cybersecurity jobs. In the attempt to mitigate the workforce gap, CESER is developing a cybersecurity workforce framework that will identify options to support the expansion of the qualified talent pipeline, broadening opportunities for non-traditional and

underrepresented groups, hosting cyber defense competitions, and emphasizing the concepts of apprenticeships and upskilling.

In FY 2024, CESER will make investments in the following programmatic areas of Response & Restoration:

- CYBER INCIDENT RESPONSE AND CYBER SITUATIONAL AWARENESS
  CESER is the lead for the cybersecurity of the energy sector as the SRMA, pursuant to the FAST Act, Executive Order 13636, and Presidential Policy Directive-41 (PPD-41). CESER also supports federal response efforts, when there is a significant cyber incidents impacting the energy sector, pursuant to the National Cyber Incident Response Plan. To fulfill DOE's responsibilities, CESER will continue to develop and expand cyber situational awareness and response capabilities for the current threat landscape and to provide cyber response technical assistance and expertise unique to the energy sector while expanding regional steady state and response presence in accordance with the 2021 Regional Response Operations Strategic Plan (2021-2026). CESER will continue the development of collaboration tools and products to provide enhanced energy sector situational awareness to interagency and industry partners, and the CESER Response Team and further develop operational concepts for a CESER Watch Office and conduct feasibility studies for a physical facility.

Electricity (OE)

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 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.

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.

The Request also 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.

Office of Energy Efficiency and Renewable Energy

In FY 2024, EERE requests $11.3 million for high priority RD&D with a clear path to deployment, technical assistance, and Development best practices to identify and mitigate cyber risks. Work supported by EERE complements the DOE Multiyear Plan for Energy Sector Cybersecurity and includes the following:

- Cybersecurity work though the Building Technologies the Grid-interactive Efficient Buildings (GEB) Initiative. In addition to improving the energy efficiency of the overall building, this research focuses on making equipment more intelligent through next-generation sensors, controls, connectivity, and communication.

- Integration of cybersecurity into relevant distributed energy resource controls, bulk power system protections, and other Grid Modernization Lab Consortium activities supported by Solar Energy Technologies.
- Sustained support for cyber physical security of the charging of Plug-in Electric Vehicles (PEV) and the interface between PEV charging and the electric grid through Vehicles Technologies.
- Support for efforts focused on setting up wind plant communication, control, and power system co-simulation environment and conducting wind plant cybersecurity assessment and risk mitigation through Wind Energy Technologies.
-

Office of Nuclear Energy

In FY 2024, NE requests $4.5 million for the Nuclear Energy Enabling Technologies (NEET) Crosscutting Technology Development (CTD) subprogram to conduct research and development on methods to incorporate cybersecurity by design into advanced reactor concepts, advanced control architectures including autonomous and remote operations, standards for reducing supply chain risks, and the cost-effective integration of nuclear safety risk management with cybersecurity risk management.

Office of Fossil Energy and Carbon Management (FECM)

In FY 2024, the Office of Fossil Energy and Carbon Management (FECM) (Headquarters) requests $0.333 million to support a proposed GMI lab call for Post-Quantum Cyber Security.

Office of the Chief Information Officer

In FY 2024, CIO requests $1.553M for the DOE Spectrum Management Program for technical, logistical, and administrative support, as well as ongoing oversight and advocacy at an inter-agency level in the National Capital Region. The DOE Spectrum Program is mandated under Title 47, U.S. Code of Federal Regulations, 901, et. seq., and manages DOE radio frequency spectrum-dependent resources for NNSA, Power Marketing Administrations (PMAs), Office of Secure Transportation, and National Laboratory spectrum-dependent assets. DOE is the 9th largest holder of radio frequencies with more than 7,300 individual radio assignments across 34 sites receiving services from OSM including Headquarters, the National Labs, the PMAs, and NNSA sites. Critical DOE missions and essential functions utilizing Spectrum services include the National Power Grid, Interstate Electricity Transmission, Satellite Missions, Nuclear Emergency Search, Radiological Assistance, Secure Transportation and Safeguards, and Protective Force Communications.

Infrastructure

Infrastructure funding is managed within several programs and includes direct and indirect funding for capital equipment, maintenance and repair, minor construction, line-item construction, and excess facilities. The DOE program offices and 17 National Laboratories are working to ensure that the community has the facilities to conduct cutting edge scientific research and meet DOE goals and objective. Infrastructure funding improves the reliability, efficiency, and capability of core infrastructure to meet mission requirements. The Department's Infrastructure activities are tied to its programmatic missions, goals, and objectives that will met be in a safe, secure, and cost-effective manner. DOE will also use its expansive loan authority to invest in American products, and its regulatory authority to innovate in advanced building technologies and energy efficient appliances.

DOE prioritizes infrastructure investments to reduce safety risk by addressing numerous obsolete support and safety systems, to reduce mission risk by revitalizing facilities that are beyond the end of their design life, and to maximize return on investment while considering mission risk, improving sustainability, and working toward meeting the Department's climate action goals by addressing climate adaptability and resilience. This crosscut summarizes the infrastructure funding that is distributed through the budget volumes.

Descriptions of each program's Infrastructure components can be found in the budget justifications for:

- Defense and Non-defense Environmental Cleanup
- Defense Nuclear Nonproliferation
- Electricity
- Energy Efficiency and Renewable Energy
- Enterprise Assessments
- Fossil Energy Research and Development
- Legacy Management
- Naval Reactors
- Nuclear Energy
- Science
- Strategic Petroleum Reserve
- Weapons Activities

Table 1 provides a department-wide summary of infrastructure funding by Program, while Table 2 provides the breakout by category of expenditures.

Table 1. Overall DOE Infrastructure Funding by Program (FY 2022 – FY 2024)

Infrastructure by Program[2]	FY 2022 Enacted	FY 2023 Enacted	FY2024 Request	FY 2024 vs FY 2023	% Change
Defense Environmental Cleanup	1,748,741	2,071,243	2,063,199	(8,044)	-0.4%
Defense Nuclear Nonproliferation	287,007	306,910	293,317	(13,593)	-4.4%
Electricity	47,000	0	-	-	
Energy Efficiency and Renewable Energy	65,092	103,893	162,626	58,733	56.5%
Enterprise Assessments	1,720	1,771	1,824	53	3.0%
Fossil Energy & Carbon Management	51,820	19,820	19,820	-	0.0%
Legacy Management	1,912	4,964	4,872	(92)	-1.9%
Naval Reactors	522,210	695,991	411,407	(284,584)	-40.9%
Nuclear Energy	261,572	63,868	87,337	23,469	36.7%
Science	1,801,647	2,074,262	2,288,584	214,322	10.3%
Strategic Petroleum Reserve	36,322	530,899	137,744	(393,155)	-74.1%
UED&D Fund	74,135	56,040	74,552	18,512	33.0%
Weapons Activities	4,667,354	5,688,965	6,220,641	531,676	9.3%
Total, Infrastructure	**9,566,532**	**11,618,626**	**11,765,923**	**147,297**	**1.54%**

Table 2. Overall DOE Infrastructure Funding by Category (FY 2022 – FY 2024)

Infrastructure Category	FY 2022 Enacted	FY 2023 Enacted	FY 2024 Request	FY 2024 vs FY 2023	% Change
Capital Equipment					
Defense Environmental Cleanup	0	0	16,500	16,500	0.00%
Defense Nuclear Nonproliferation	114,659	186,435	169,050	(17,385)	-9.32%
Energy Efficiency and Renewable Energy	12,360	7,220	19,612	12,392	171.63%
Naval Reactors	7,000	41,805	12,900	(28,905)	-69.14%
Nuclear Energy	4,580	2,115	2,867	752	35.56%
Science	258,389	253,699	222,001	(31,698)	-12.49%
Strategic Petroleum Reserve	4,209	0	49,337	49,337	0.00%
Weapons Activities	1,124,252	1,271,020	1,431,293	160,273	12.61%
Subtotal, Capital Equipment	**1,525,449**	**1,762,294**	**1,923,560**	**161,266**	**9.15%**
Excess Facilities					
Defense Environmental Cleanup	52,000	75,519	33,843	(41,676)	-55.19%
Fossil Energy & Carbon Management	40	40	40	-	0.00%
Naval Reactors	14,364	44,979	33,531	(11,448)	-25.45%
Science	1,291	4,722	5,377	655	13.87%
Weapons Activities	52,976	39,000	50,106	11,106	28.48%
Subtotal, Excess Facilities	**120,671**	**164,260**	**122,897**	**(41,363)**	**-25.18%**

Infrastructure Category	FY 2022 Enacted	FY 2023 Enacted	FY 2024 Request	FY 2024 vs FY 2023	% Change
Line Item Construction[3]					
Defense Environmental Cleanup	1,009,501	1,169,874	1,079,543	(90,331)	-7.72%
Defense Nuclear Nonproliferation	156,000	71,764	77,211	5,447	7.59%
Electricity	47,000	0	0	-	0.00%
Energy Efficiency and Renewable Energy	8,000	45,000	57,000	12,000	26.67%
Fossil Energy & Carbon Management	20,000	0	0	-	0.00%
Naval Reactors	446,720	534,218	299,284	(234,934)	-43.98%
Nuclear Energy	41,850	27,300	32,000	4,700	17.22%
Science	1,096,500	1,147,550	1,247,007	99,457	8.67%
Strategic Petroleum Reserve	0	500,000	0	(500,000)	-100.00%
UED&D Fund	74,135	56,040	74,552	18,512	33.03%
Weapons Activities	2,039,352	3,026,662	3,336,939	310,277	10.25%
Subtotal, Line Item Construction	**4,939,058**	**6,578,408**	**6,203,536**	**(374,872)**	**-5.70%**
Maintenance and Repair[4]					
Defense Environmental Cleanup	583,188	732,392	752,833	20,441	2.79%
Energy Efficiency and Renewable Energy	19,622	22,129	23,014	885	4.00%
Enterprise Assessments	1,720	1,771	1,824	53	2.99%
Fossil Energy & Carbon Management	19,780	19,780	19,780	-	0.00%
Legacy Management	1,912	4,964	4,872	(92)	-1.85%
Naval Reactors	17,526	20,424	23,112	2,688	13.16%
Nuclear Energy	59,820	33,503	34,450	947	2.83%
Science	303,867	361,428	365,544	4,116	1.14%
Strategic Petroleum Reserve	32,113	30,899	88,407	57,508	186.12%
Weapons Activities	860,819	821,682	833,029	11,347	1.38%
Subtotal, Maintenance and Repair	**1,900,367**	**2,048,972**	**2,146,865**	**97,893**	**5.15%**
Minor Construction[1]					
Defense Environmental Cleanup	104,052	93,458	180,480	87,022	93.11%
Defense Nuclear Nonproliferation	16,348	48,711	47,056	(1,655)	-3.40%
Energy Efficiency and Renewable Energy	25,110	29,544	63,000	33,456	113.24%
Fossil Energy & Carbon Management	12,000	0	0	-	#DIV/0!
Naval Reactors	36,600	54,565	42,580	(11,985)	-21.96%
Nuclear Energy	155,322	950	18,020	17,070	1796.84%
Science	141,600	306,863	448,655	141,792	46.21%
Weapons Activities	589,955	530,601	569,274	38,673	7.29%
Subtotal, Minor Construction	**1,080,987**	**1,064,692**	**1,369,065**	**304,373**	**28.16%**
Total, Infrastructure	**9,566,532**	**11,618,626**	**11,765,923**	**147,297**	**1.54%**

Capital Equipment

Capital equipment funding includes the cost of equipment either acquired by purchase or fabricated by a site/facility management contractor that exceeds the capitalization threshold of $500,000. Included in the capital equipment funding are major items of equipment (MIEs). MIEs are listed individually in each program's budget justification.

Minor Construction

Minor Construction funding includes all minor construction projects. A Minor Construction Project is any construction project not specifically authorized by law for which the approved total estimated cost does not exceed the minor construction threshold[1]. Minor Construction Projects, including Accelerator Improvement Projects (AIPs), that exceed $5 million are listed individually in each program's budget justification.

Line-Item Construction

Line-Item Construction funding includes all construction projects specifically authorized by law for which the approved total estimated cost exceeds the minor construction threshold [50 US Code 2741]. The funding captured in this crosscut includes the annual total project costs – both total estimated costs and other project costs. The individual line-item construction projects can be found in both the programs' construction projects summary and the individual project data sheets.

Maintenance and Repair

The Facilities Maintenance and Repair activities funded by this budget are intended to improve asset condition and maintain operability. This excludes maintenance of excess facilities (including high-risk excess facilities) necessary to minimize the risk posed by those facilities prior to disposition.

Excess Facilities

Excess Facilities are facilities no longer required to support the Department's needs, present or future missions or functions, or the discharge of its responsibilities. The funding to deactivate and dispose (D&D) of excess infrastructure, including stabilization and risk reduction activities at high-risk excess facilities, resulting in surveillance and maintenance cost avoidance and reduced risk to workers, the public, the environment, and programs is included. Also included is the maintenance of excess facilities (including high-risk excess facilities) necessary to minimize the risk posed by those facilities prior to disposition.

[1] 50 USC 2743 only allows authorized programs to conduct minor construction projects under annual National Defense Authorization Acts; 50 USC 2741 sets the minor construction threshold

[2] Does not include annual lease costs

[3] Reflects Total Project Costs (TPC) for each Line-Item Construction Project

[4] Includes both direct- and indirect-funded dollars.

Contractor Pensions and Other Postretirement Benefits

This section of the budget provides projected costs of contractor defined benefit (DB) pension plan contributions and other postretirement benefit reimbursements. The DB pension plan contributions are provided in Section I below for FY 2022 through FY 2024 by plan. The section also shows the allocations of those contributions to the following Department of Energy (DOE) Departmental Elements:[a]

- National Nuclear Security Administration (NNSA)
- Office of Environmental Management (EM)
- Office of Science (SC)
- Office of Energy Efficiency and Renewable Energy (EERE)
- Office of Nuclear Energy (NE)

Information regarding projected reimbursements for other postretirement benefits (primarily medical) is provided in Section II below.

Contractors that manage and operate DOE's laboratories, weapons plants, and execute environmental cleanup projects at various government-owned sites and facilities are contractually required by DOE to assume sponsorship of the existing contractor DB pension plans and other postretirement benefit plans for incumbent employees. DOE reimburses the costs of the contractors' contributions to DB pension plans and the benefits paid from other postretirement benefit plans. These costs are typically allocated as indirect costs, though DOE does directly pay the costs of some legacy plans.[b]

Due to the timing of the required annual valuation for the contractor DB pension plans, the actual amount of the contractors' annual contributions to these DB pension plans that DOE will reimburse each fiscal year will not generally be known until after budget development. Budgetary line items that include DOE reimbursement of contractor contributions to DB pension plans assume an indirect rate anticipated to be sufficient to meet reimbursement requirements. In the case of plans covering contractor employees whose costs are reimbursed by various programs, the allocation of contributions among NNSA, the Program Offices, and Reimbursable Work is done based on each site's best estimate of the allocation of work based on current and anticipated work for the various parties that the site serves.[c]

[a] Tables include projected contributions from "Reimbursable Work" and "Other" entities (e.g., DOE departmental administration, classified programs, etc.). Reimbursable Work also includes the costs associated with the Naval Reactors contractor's plans covered by its contract with the Department of the Navy.

[b] The NNSA legacy University of California (UC) plans and the Oak Ridge Reservation Cleanup Contract Pension Plan for Grandfathered Employees (formerly called the East Tennessee Technology Park Pension Plan for Grandfathered Employees) rely on direct funding. For fiscal years starting in FY 2022, NNSA and EM plan to directly fund the reimbursement of the unfunded liability of the Savannah River Nuclear Solutions, LLC Multiple Employer Pension Plan.

[c] These allocations were provided by the contractors to the DOE in July 2022 and represent contractors' expectation of work for these years.

Section I - Contractor DB Pension Plan Contributions[d]

DOE reimburses contractors for pension contributions at levels that are at least equal to the minimum required contribution (MRC) by the Employee Retirement Income Security Act (ERISA), as amended. The MRC is determined on a plan year basis. Only two of the contractor plans have a plan year that coincides with the federal fiscal year and, therefore, the majority of fiscal year pension allocations are spread across two plan years. At a minimum, plan sponsors of single or multiple employer plans [e] in which the plan assets were less than liabilities in the prior year must make quarterly contributions during the plan year with the first contribution due 3½ months after the beginning of the plan year and any outstanding amount due 8½ months after the plan year ends.

Contractors develop long-term projections of future asset investment returns that affect estimates of future MRCs for each plan. Asset returns that are higher or lower than the projected long-term investment returns affect future MRCs, though the provisions of ERISA ensure that these effects are somewhat smoothed by allowing recognition over a two (single/multiple) or a five-year period (multiemployer/state). In calendar year 2022, market returns were negative compared to contractors' expected asset return for 2022. The actual investment returns in calendar year 2022 will predominantly affect MRCs beginning in Fiscal Year 2025 though there could be some impact earlier depending on the funded status of the plan. DOE evaluated the impact of the year-to-date actual calendar year 2022 investment returns on the individual DB plans as part of its annual 2022 budget review process conducted in July 2022. The contribution amounts reflect the lower-than-expected asset return through June 2022. DOE will have insight to final 2022 market impacts during the FY2023 Pension Management Plan process.

Reimbursement of contractor costs in excess of the MRC requires specific approval. Reimbursements requested in excess of the MRC are reviewed by the cognizant program office, the Office of the Chief Financial Officer, the Office of Management, and the Office of the General Counsel through an annual pension management plan process. Table 1 provides information related to plans where funding in excess of the MRC was requested during FY 2022, and it includes the MRC, the contribution approved, and the actual amount contributed during FY 2022. In FY 2022, contractors requested reimbursement of contributions in excess of the MRC for 21 plans and were approved. Contributions in excess of the MRC were approved primarily to minimize volatility for future payments and mitigate increases in future contribution requirements.

Table 1: FY 2022 Contributions in Excess of the MRC ($K)

Plan	Program Office	FY 2022 Congressional Budget Justification	FY 2022 Estimated Minimum Required Contribution	Preliminary Additional Amount Requested in Year of Execution	Amount Reported in September 2022	Final FY 2022 Amount Approved and Contributed
Oak Ridge Reservation Cleanup Contract Pension Plan for Grandfathered Employees	EM	26,951	4,600	12,750	17,350	17,350
Pension Plan for Eligible Bettis Employees and Retirees	NNSA	38,411	-	25,900	25,900	25,900
Pension Plan of the Pacific Northwest Laboratories, Battelle Memorial Institute	Science	55,000	-	45,000	45,000	45,000
Retirement Program for Employees of Consolidated Nuclear Security, LLC at the U. S. Department of Energy Facilities at Oak Ridge, Tennessee	NNSA	52,200	-	58,400	58,400	58,400
Idaho National Laboratory Employee Retirement Plan	NE	50,000	-	50,000	50,000	50,000
Salaried Employee Pension Plan for KAPL Employees and Retirees	NNSA	22,000	-	26,900	26,900	26,900

[d] DOE has reimbursed contributions for 32 funded DB pension plans and 12 non-qualified DB pension plans in FY 2022. Non-qualified plans have no assets and are funded on a pay-as-you-go basis.

[e] A single employer plan is a plan sponsored by only one employer; a multiple employer plan is a plan sponsored by 2 or more unrelated employers and not maintained pursuant to a collective bargaining agreement; a multiemployer plan is a plan maintained pursuant to a collective bargaining agreement between an employee organization and more than one employer.

Plan	Program Office	FY 2022 Congressional Budget Justification	FY 2022 Estimated Minimum Required Contribution	Preliminary Additional Amount Requested in Year of Execution	Amount Reported in September 2022	Final FY 2022 Amount Approved and Contributed
Pension Plan for KAPL Employees in Participating Bargaining Units	NNSA	2,200	-	2,700	2,700	2,700
Triad Defined Benefit Pension Plan (TCP1)	NNSA	137,300	-	132,600	132,600	132,600
LLNS Defined Benefit Pension Plan	NNSA	100,000	-	95,700	95,700	95,700
National Renewable Energy Laboratory Retirement Plan	EERE	31,000	-	23,000	23,000	23,000
Mission Support and Test Services, LLC (MSTS) Employee Retirement Plan	NNSA	17,590	630	16,670	17,300	17,300
Consolidated Nuclear Security, LLC Retirement Plan for Bargaining Unit Members of the Pantex Guards Union	NNSA	2,500	-	2,800	2,800	2,800
Retirement Plan for Bargaining Unit Employees of the Metal Trades Council of Consolidated Nuclear Security, LLC	NNSA	8,800	-	8,200	8,200	8,200
Consolidated Nuclear Security Retirement Plan for Non-Bargaining Pantex Location Employees	NNSA	14,600	-	15,200	15,200	15,200
NTESS Retirement Income Plan	NNSA	115,485	-	103,121	103,121	103,121
Savannah River Nuclear Solutions, LLC Multiple Employer Pension Plan	EM	296,000	112,000	184,000	296,000	296,000
Pension Plan for Employees at ORNL	Science	150,000	-	150,000	150,000	150,000
Waste Isolation Pilot Plant Pension Plan	EM	13,888	-	25,000	25,000	25,000
NNSS Staff Pension Plan	NNSA	927	-	187	187	187
NNSS IGAN Pension Trust Fund	NNSA	2,071	-	1,046	1,046	1,046
West Valley Pension Plan	EM	4,691	-	13,700	13,700	13,700
Total		**1,141,614**	**117,230**	**992,875**	**1,110,105**	**1,110,105**

Projections of future DB pension plan contributions are highly sensitive to underlying data, methods, and assumptions. Changes in the population data that are different from the expected data impact the future costs of these plans; participants retiring earlier and/or living longer than expected may increase costs; compensation increases that are higher than expected will increase the costs. The most significant assumptions affecting the contribution amounts are those assumptions with respect to future market conditions. In particular, the difference between actual experience of the markets and the assumption of the expected return on investments earned by the plans each future year, as well as future corporate bond yields, have the largest impact on the ultimate contributions that will be reimbursed by the DOE. For example, the actual contributions for fiscal year 2024 will not be known until January 2024 at the earliest because these contributions will be determined based on the asset value as of December 31, 2023, and the discount rate in effect at that time. Estimated contributions above the MRC submitted during this budget process do not receive final approval until the year of execution.

Therefore, it is important to emphasize that the actual amounts reimbursed for the applicable fiscal years shown will almost certainly vary from the projections provided in this section. The information provided for the funded plans (excluding the non-qualified plans) is based on plan contributions projected by the DOE's contractors in July 2022. The non-qualified plan amounts equal the expected benefit payments which were provided by the contractors for the prior year's financial statements. This information has been reviewed by NNSA, relevant DOE Program Offices, and by the Office of the Chief Financial Officer.

- Table 2 provides aggregate FY 2022 actual and FY 2023 through FY 2024 estimated pension plan contributions eligible for reimbursement for all plans.
- Table 3 provides plan-by-plan FY 2022 actual contributions and FY 2023 and FY 2024 estimated pension contributions eligible for reimbursement by NNSA, the DOE, and reimbursable work customers.

Table 2: NNSA and DOE Program Office Actual Contributions for FY 2022 and Projected Contributions for FY 2023 through FY 2028 ($K)

Based on July 2022 data and allocated by Program Office [f]

Program Office	FY 2022	FY 2023	FY 2024
NNSA	548,138	372,244	521,257
EM	364,715	326,044	252,212
SC	145,865	79,281	92,506
EERE	49,340	32,073	38,501
NE	17,552	2,998	4,693
Reimbursable Work	138,856	70,817	112,337
Other	33,606	18,077	25,303
Total	**1,298,072**	**901,533**	**1,046,810**

There may be small variances in totals due to rounding. Numbers may not add.

Tables 3 and 4 provide the following information for each plan:

Plan name and Plan type: Single employer, multiemployer, multiple employer, state, or non-qualified.

Status: *Open* means that the plans are open to new employees who earn benefits under a traditional defined benefit formula. *Closed* means that the qualified plans are closed to new employees, but active employees who were employed prior to the plan being closed continue to earn benefits; this includes plans where new entrants only or new entrants and legacy employees receive benefits under reduced hybrid formulas which are much less volatile (indicated by the word hybrid after closed). For non-qualified plans, "closed" means that the universe of possible participants is limited to individuals who are currently accruing benefits in the closed qualified plan at the respective site and who may at some point qualify for the non-qualified plan under the terms of the non-qualified plan). *Partially Closed* means that the plan is closed to some subset of the employee population, but that certain represented employees covered by collective bargaining agreements are still becoming members of the plan at the time of hire. *Frozen* means that plan liabilities are frozen (*i.e.,* that there are no longer any employees accruing credit for current service under the plan).

Reimbursements & Allocations: Expected contributions are allocated by program office for fiscal years 2022-2024 with 2022 representing actual contributions and contributions for later years based on submissions as outlined in footnote f.

[f] Final information for FY 2022 contributions was reported in October 2022 while projected contributions for FY 2023 and on were reported in July 2022 for all departmental elements.

Table 3: Projected FY 2022 through FY 2024 Contributions by Plan, NNSA, and Program Office ($K)
Based on July 2022 data and allocated by Program Office [g]

Plan Name	Plan status	Fiscal Year	Total	NNSA	EM	SC	EERE	NE	Reimbursable Work	Other
Oak Ridge Reservation Cleanup Contract (formerly East Tennessee Technology Park) Pension Plan for Grandfathered Employees	EM-Partially Closed	2022	17,350	-	17,350	-	-	-	-	-
	Multiemployer	2023	27,739	-	27,739	-	-	-	-	-
		2024	15,151	-	15,151	-	-	-	-	-
University of California Retirement Plan - Lawrence Berkeley National Laboratory	SC-Open	2022	55,327	586	105	38,657	7,110	255	7,834	780
	State	2023	46,840	497	89	32,727	6,019	215	6,633	660
		2024	48,168	511	92	33,655	6,190	222	6,821	679
Pension Plan for Eligible Bettis Employees and Retirees	NA-Closed	2022	25,900	14,245	-	-	-	-	11,655	-
	Single	2023	23,100	12,705	-	-	-	-	10,395	-
		2024	28,700	15,785	-	-	-	-	12,915	-
Pension Plan of the Pacific Northwest Laboratories, Battelle Memorial Institute	SC-Open	2022	45,000	9,945	900	7,875	5,805	1,125	13,905	5,445
	Single	2023	-	-	-	-	-	-	-	-
		2024	30,000	6,630	600	5,250	3,870	750	9,270	3,630
Retirement Program for Employees of Consolidated Nuclear Security, LLC at the U. S. Department of Energy Facilities at Oak Ridge, Tennessee	NA-Closed	2022	58,400	56,064	-	-	-	-	2,336	-
	Single	2023	21,870	20,995	-	-	-	-	875	-
		2024	48,500	46,560	-	-	-	-	1,940	-
HPMC Occupational Health Services Retirement Plan	EM-Closed	2022	-	-	-	-	-	-	-	-
	Single	2023	-	-	-	-	-	-	-	-
		2024	91	-	91	-	-	-	-	-
Hanford Multi-Employer Pension Plan	EM-Closed	2022	99,859	-	99,859	-	-	-	-	-
	Multiemployer	2023	98,371	-	98,371	-	-	-	-	-
		2024	108,045	-	108,045	-	-	-	-	-

[g] May be small variances in totals due to rounding. For the Naval Reactors contractor's plans, Reimbursable Work includes the portion of contributions covered by the contract with the Department of the Navy.

Table 3: Projected FY 2022 through FY 2024 Contributions by Plan, NNSA, and Program Office ($K)

Based on July 2022 data and allocated by Program Office [g]

Plan Name	Plan status	Fiscal Year	Total	NNSA	EM	SC	EERE	NE	Reimbursable Work	Other
Idaho National Laboratory Employee Retirement Plan	NE-Closed	2022	50,000	2,795	26,500	140	860	10,320	8,775	610
	Multiple	2023	-	-	-	-	-	-	-	-
		2024	-	-	-	-	-	-	-	-
Salaried Employee Pension Plan for KAPL Employees and Retirees	NA-Closed	2022	26,900	14,795	-	-	-	-	12,105	-
	Single	2023	25,000	13,750	-	-	-	-	11,250	-
		2024	20,000	11,000	-	-	-	-	9,000	-
Pension Plan for KAPL Employees in Participating Bargaining Units	NA-Closed	2022	2,700	1,485	-	-	-	-	1,215	-
	Single	2023	2,400	1,320	-	-	-	-	1,080	-
		2024	1,000	550	-	-	-	-	450	-
Kansas City Division Hourly Employees' Pension Plan	NA-Closed	2022	-	-	-	-	-	-	-	-
	Single	2023	-	-	-	-	-	-	-	-
		2024	-	-	-	-	-	-	-	-
Honeywell Retirement Earnings Plan for Aerospace Employees at the Kansas City Division	NA-Closed	2022	-	-	-	-	-	-	-	-
	Single	2023	-	-	-	-	-	-	-	-
		2024	-	-	-	-	-	-	-	-
Triad Defined Benefit Pension Plan (TCP1)	NA-Closed	2022	132,600	113,771	1,591	3,580	530	530	10,608	1,989
	Multiple	2023	69,165	59,344	830	1,867	277	277	5,533	1,037
		2024	159,066	136,479	1,909	4,295	636	636	12,725	2,386
University of California Retirement Plan - Lawrence Livermore National Laboratory Retained Segment	NA-Frozen	2022	1,109	1,109	-	-	-	-	-	-
	State	2023	24,192	24,192	-	-	-	-	-	-
		2024	20,151	20,151	-	-	-	-	-	-

[g] May be small variances in totals due to rounding. For the Naval Reactors contractor's plans, Reimbursable Work includes the portion of contributions covered by the contract with the Department of the Navy.

Table 3: Projected FY 2022 through FY 2024 Contributions by Plan, NNSA, and Program Office ($K)

Based on July 2022 data and allocated by Program Office [g]

Plan Name	Plan status	Fiscal Year	Total	NNSA	EM	SC	EERE	NE	Reimbursable Work	Other
LLNS Defined Benefit Pension Plan	NA-Closed	2022	95,700	73,689	-	2,871	957	-	14,355	3,828
	Single	2023	47,025	36,680	-	941	470	-	7,054	1,881
		2024	100,000	77,000	-	3,000	1,000	-	15,000	4,000
Fluor-BWXT Portsmouth, LLC USW Career Pension Plan for Appendix A USW-Represented Employees	EM-Closed	2022	2,067	-	2,067	-	-	-	-	-
	Single	2023	858	-	858	-	-	-	-	-
		2024	928	-	928	-	-	-	-	-
University of California Retirement Plan - Los Alamos National Laboratory Retained Segment	NA-Frozen	2022	18,472	18,472	-	-	-	-	-	-
	State	2023	32,036	32,036	-	-	-	-	-	-
		2024	28,658	28,658	-	-	-	-	-	-
National Renewable Energy Laboratory Retirement Plan	EE-Closed - Hybrid	2022	23,000	-	-	1,380	17,480	-	2,990	1,150
	Single	2023	23,000	-	-	1,380	17,480	-	2,990	1,150
		2024	23,000	-	-	1,380	17,480	-	2,990	1,150
Golden SVCS, LLC Pension Plan	SC-Closed	2022	1,422	-	1,052	370	-	-	-	-
	Multiple	2023	430	-	275	155	-	-	-	-
		2024	430	-	258	172	-	-	-	-
Mission Support and Test Services, LLC (MSTS) Employee Retirement Plan	NA-Closed-Hybrid	2022	17,300	15,016	865	-	-	-	986	433
	Single	2023	8,190	7,109	410	-	-	-	467	205
		2024	21,100	18,315	1,055	-	-	-	1,203	528
Consolidated Nuclear Security, LLC Retirement Plan for Bargaining Unit Members of the Pantex Guards Union	NA-Closed	2022	2,800	2,800	-	-	-	-	-	-
	Single	2023	1,260	1,260	-	-	-	-	-	-
		2024	2,500	2,500	-	-	-	-	-	-

[g] May be small variances in totals due to rounding. For the Naval Reactors contractor's plans, Reimbursable Work includes the portion of contributions covered by the contract with the Department of the Navy.

Table 3: Projected FY 2022 through FY 2024 Contributions by Plan, NNSA, and Program Office ($K)

Based on July 2022 data and allocated by Program Office [g]

Plan Name	Plan status	Fiscal Year	Total	NNSA	EM	SC	EERE	NE	Reimbursable Work	Other
Retirement Plan for Bargaining Unit Employees of the Metal Trades Council of Consolidated Nuclear Security, LLC	NA-Closed	2022	8,200	8,200	-	-	-	-	-	-
	Single	2023	3,555	3,555	-	-	-	-	-	-
		2024	7,800	7,800	-	-	-	-	-	-
Consolidated Nuclear Security Retirement Plan for Non-Bargaining Pantex Location Employees	NA-Closed	2022	15,200	14,896	-	-	-	-	304	-
	Single	2023	6,255	6,130	-	-	-	-	125	-
		2024	12,700	12,446	-	-	-	-	254	-
NTESS Retirement Income Plan	NA-Closed	2022	103,121	65,791	619	1,959	2,062	928	29,905	1,856
	Single	2023	45,275	28,659	272	860	1,041	453	13,175	815
		2024	97,260	61,079	681	2,140	2,334	973	28,205	1,848
Savannah River Nuclear Solutions, LLC Multiple Employer Pension Plan	EM-Closed	2022	296,000	112,717	172,982	-	-	-	-	10,301
	Multiple	2023	296,000	110,023	177,067	-	-	-	-	8,910
		2024	170,000	61,149	101,303	-	-	-	-	7,548
DUF6 Pension Plan for Grandfathered Employees	EM-Partially Closed	2022	-	-	-	-	-	-	-	-
	Single	2023	-	-	-	-	-	-	-	-
		2024	1,709	-	1,709	-	-	-	-	-
USW Career Pension Plan for Appendix A USW-Represented Employees (Paducah)	EM-Closed	2022	1,619	-	1,619	-	-	-	-	-
	Single	2023	631	-	631	-	-	-	-	-
		2024	900	-	900	-	-	-	-	-

[g] May be small variances in totals due to rounding. For the Naval Reactors contractor's plans, Reimbursable Work includes the portion of contributions covered by the contract with the Department of the Navy.

Table 3: Projected FY 2022 through FY 2024 Contributions by Plan, NNSA, and Program Office ($K)
Based on July 2022 data and allocated by Program Office [g]

Plan Name	Plan status	Fiscal Year	Total	NNSA	EM	SC	EERE	NE	Reimbursable Work	Other
Pension Plan for Employees at ORNL	SC-Open	2022	150,000	15,750	150	88,500	14,400	4,350	19,800	7,050
	Single	2023	69,000	7,245	69	40,710	6,624	2,001	9,108	3,243
		2024	71,000	7,455	71	41,890	6,816	2,059	9,372	3,337
Waste Isolation Pilot Plant Pension Plan	EM-Open	2022	25,000	-	25,000	-	-	-	-	-
	Single	2023	19,100	-	19,100	-	-	-	-	-
		2024	19,100	-	19,100	-	-	-	-	-
West Valley Pension Plan	EM-Closed	2022	13,700	-	13,700	-	-	-	-	-
	Single	2023	-	-	-	-	-	-	-	-
		2024	-	-	-	-	-	-	-	-
NNSS Staff Pension Plan	NA-Closed	2022	187	187	-	-	-	-	-	-
	Single	2023	327	327	-	-	-	-	-	-
		2024	481	481	-	-	-	-	-	-
NNSS IGAN Pension Trust Fund	NA-Closed	2022	1,046	1,046	-	-	-	-	-	-
	Single	2023	1,528	1,528	-	-	-	-	-	-
		2024	1,626	1,626	-	-	-	-	-	-
Battelle Memorial Institute Excess Benefit and Supplemental Executive Pension Plans	NA-Closed	2022	10	2	0	2	1	0	3	1
	Non-Qualified	2023	8	2	0	1	1	0	2	1
		2024	7	2	0	1	1	0	2	1
Executive and Supplemental Pension Plans for Designated Bettis Employees	NA-Closed	2022	1,909	1,050	-	-	-	-	859	-
	Non-Qualified	2023	1,962	1,079	-	-	-	-	883	-
		2024	2,005	1,103	-	-	-	-	902	-

[g] May be small variances in totals due to rounding. For the Naval Reactors contractor's plans, Reimbursable Work includes the portion of contributions covered by the contract with the Department of the Navy.

Table 3: Projected FY 2022 through FY 2024 Contributions by Plan, NNSA, and Program Office ($K)

Based on July 2022 data and allocated by Program Office [g]

Plan Name	Plan status	Fiscal Year	Total	NNSA	EM	SC	EERE	NE	Reimbursable Work	Other
Excess and Supplemental Pension Plan for Designated KAPL Employees	NA-Closed	2022	353	194	-	-	-	-	159	-
	Non-Qualified	2023	340	187	-	-	-	-	153	-
		2024	336	185	-	-	-	-	151	-
Triad 401(a)(17) Restoration Plan	NA-Closed	2022	267	229	3	7	1	1	21	4
	Non-Qualified	2023	267	229	3	7	1	1	21	4
		2024	271	233	3	7	1	1	22	4
Triad Restoration Plan	NA-Closed	2022	152	131	2	4	1	1	12	2
	Non-Qualified	2023	187	160	2	5	1	1	15	3
		2024	207	177	2	6	1	1	17	3
LLNS 401(a)(17) Restoration Plan	NA-Closed	2022	1,326	1,021	-	40	13	-	199	53
	Non-Qualified	2023	1,340	1,045	-	27	13	-	201	54
		2024	1,519	1,170	-	46	15	-	228	61
LLNS Restoration Plan	NA-Closed	2022	296	228	-	9	3	-	44	12
	Non-Qualified	2023	441	344	-	9	4	-	66	18
		2024	538	414	-	16	5	-	81	22
NTESS Nonqualified Pension Plan	NA-Closed	2022	2,350	1,499	14	45	47	21	681	42
	Non-Qualified	2023	2,274	1,439	14	43	52	23	662	41
		2024	2,240	1,407	16	49	54	22	650	43
Savannah River Nuclear Solutions, LLC Nonqualified Pension Plan	EM-Frozen	2022	446	170	261	-	-	-	-	16
	Non-Qualified	2023	411	153	246	-	-	-	-	12
		2024	386	139	230	-	-	-	-	17

[g] May be small variances in totals due to rounding. For the Naval Reactors contractor's plans, Reimbursable Work includes the portion of contributions covered by the contract with the Department of the Navy.

Table 3: Projected FY 2022 through FY 2024 Contributions by Plan, NNSA, and Program Office ($K)

Based on July 2022 data and allocated by Program Office [g]

Plan Name	Plan status	Fiscal Year	Total	NNSA	EM	SC	EERE	NE	Reimbursable Work	Other
Washington Government Services Executive Pension Plan (TRU Solutions Participants Only)	EM-Frozen	2022	75	-	75	-	-	-	-	-
	Non-Qualified	2023	68	-	68	-	-	-	-	-
		2024	67	-	67	-	-	-	-	-
Washington Government Services Executive Pension Plan (West Valley Participants Only)[g]	EM-Frozen	2022	-	-	-	-	-	-	-	-
	Non-Qualified	2023	-	-	-	-	-	-	-	-
		2024	-	-	-	-	-	-	-	-
Consolidated Nuclear Security, LLC Equalization Retirement Income Plan and Supplemental Retirement Income Plan	NA-Closed	2022	185	177	-	-	-	-	7	-
	Non-Qualified	2023	161	154	-	-	-	-	6	-
		2024	154	148	-	-	-	-	6	-
UT-Battelle Equalization Retirement Income Plan and Supplemental Retirement Income Plan	SC-Open	2022	723	76	1	427	69	21	95	34
	Non-Qualified	2023	929	98	1	548	89	27	123	44
		2024	1,016	107	1	600	98	29	134	48
Total		**2022**	**1,298,072**	**548,138**	**364,715**	**145,865**	**49,340**	**17,552**	**138,856**	**33,606**
		2023	**901,533**	**372,244**	**326,044**	**79,281**	**32,073**	**2,998**	**70,817**	**18,077**
		2024	**1,046,810**	**521,257**	**252,212**	**92,506**	**38,501**	**4,693**	**112,337**	**25,303**

[g] May be small variances in totals due to rounding. For the Naval Reactors contractor's plans, Reimbursable Work includes the portion of contributions covered by the contract with the Department of the Navy. Reimbursement for the Washington Government Services Executive Pension Plan (West Valley Participants Only) is currently under review by Department of Energy.

Section II - Other Postretirement Benefit Plans

For the most part, contractors do not fund other postretirement benefit plans in advance, but instead pay the claims incurred by the retired members or the premiums required to cover the plan benefits. The other postretirement benefits covered by the contractors are primarily medical, including prescription drugs, but may also include dental, vision, and life insurance benefits that are provided upon retirement from the contractor. The costs associated with these plans are expected to grow as the retired population grows and as healthcare cost trends continue to increase.

Due to the fact that the claims are not paid until incurred and processed, the actual amounts of contractors' payment of claims that DOE will reimburse for FY 2023 and FY 2024 will not be known until after budget development. The contractor costs are included in indirect costs. The budget assumes an indirect rate sufficient to meet reimbursement requirements. [h] As mentioned in the pension section, the allocation of contributions among NNSA, the Program Offices, and Reimbursable Work, is done based on each site's best estimate of the allocation of work based on current and anticipated work for the various parties that the site serves.

The contractors are making concerted efforts to reduce the costs associated with these plans as the costs have steadily increased. In recent years, contractors have made changes to their other postretirement benefit plans in an effort to reduce the costs associated with them, simplify administration, or increase the efficiency of the delivery of benefits. These changes include adjusting plan options to include high deductible health plan options, putting in place Employer Group Waiver Plans (EGWP) and other programs to manage prescription drug costs, adjusting the premiums for health and dental plans, and adjusting eligibility rules for retiree health plans.

Projections of future postretirement benefits to be paid are highly sensitive to underlying data, methods, and assumptions, particularly assumptions related to future increases in the expected claims paid each year as well as the underlying assumptions regarding usage and coverage. Thus, the actual amounts reimbursed in a future fiscal year may be different. All of the information for FY 2023 and FY 2024 is based on expected reimbursements as reported by the DOE's respective contractors in July 2022; this information has been reviewed by the appropriate NNSA and DOE program office and the Office of the Chief Financial Officer. The information reported for FY 2022 is primarily based on information of final employer contributions as reported by the contractors for the FY 2022 agency financial statements. Table 5 provides these aggregate FY 2022-2024 projected other postretirement benefit reimbursements.

Table 5: FY 2022-2024 NNSA and DOE Program Office Projected Other Postretirement Benefits Payments ($K)
Based on July 2022 data and allocated by Program Office [h]

Program Office	FY 2022	FY 2023	FY 2024
NNSA	159,312	180,437	182,434
EM	66,452	67,742	67,920
SC	50,440	58,145	61,526
EERE	6,043	7,298	7,690
NE	6,044	7,231	7,680
Reimbursable Work	40,323	46,245	47,247
LM	35,000	36,957	36,405
Other	7,541	8,177	9,200
Total	**371,155**	**412,231**	**420,104**

There may be small variances in totals due to rounding. Numbers may not add in total.

[h] The LM plans rely on direct costs.

Research and Development Crosscut

(dollars in thousands)

R&D and Related Equipment and Construction	FY 2022 Enacted	FY 2023 Enacted	FY 2024 Request	FY 2024 vs FY 2023	% Change
Basic Research	5,970,625	6,581,153	6,998,899	417,745	6%
Applied Research	6,163,425	6,643,892	7,126,628	482,736	7%
Development	4,427,316	3,921,722	4,395,219	473,497	12%
Subtotal, Research and Development	**16,561,366**	**17,146,768**	**18,520,746**	**1,373,978**	**8%**
R&D Related Construction	2,172,715	1,901,732	1,963,587	61,855	3%
R&D Related Equipment	2,082,138	1,308,893	1,411,957	103,065	8%
Subtotal, R&D and Related Facilities	**4,254,854**	**3,210,625**	**3,375,544**	**164,920**	**5%**
Total, R&D and Related Equipment and Construction	**20,816,220**	**20,357,393**	**21,896,290**	**1,538,897**	**8%**

Summary

The FY 2024 Request includes an overall increase of $1.5 billion (or 8 percent) in Research and Development (R&D) and Related Equipment and Construction compared with FY 2023 Enacted. The Department has identified challenging goals in the effort to avoid the worst effects of anthropogenic climate change and mitigate the effects of changes that can no longer be avoided. These goals towards decarbonization across all segments of the economy will be managed across the Department through crosscutting activities, enabling synergies that can be developed only through the collaboration and coordination of multiple Department offices. Each R&D related crosscut is described in its own section in the budget justification and new crosscuts have been added in response to the Administration goal of a carbon free economy by 2050 through a concerted effort in transportation, agriculture, industry, and electric power generation. Each DOE office has contributions to the overall success of our R&D efforts. These are summarized as follows.

Office of Science (SC) supports a balanced research portfolio of basic scientific research probing some of the most fundamental questions in areas such as: high energy, nuclear, and plasma physics; materials and chemistry; biological and environmental systems; applied mathematics; next generation high-performance computing and simulation capabilities; and basic research for advancement in new energy technologies. The SC FY 2024 Request increases investments in Administration priorities including basic research on climate change and clean energy, artificial intelligence (AI) and machine learning (ML), and biopreparedness. SC's Reaching a New Energy Sciences Workforce (RENEW) initiative doubles to expand targeted efforts to increase participation and retention of underrepresented groups in SC research activities. The Request also supports ongoing investments in priority areas including fusion, microelectronics, critical materials, quantum information science (QIS), exascale computing, fundamental science to transform manufacturing, and accelerator science and technology. These initiatives position SC to address new research opportunities through more collaborative, cross-program efforts.

The SC portfolio has two principal thrusts: direct support of scientific research and direct support of the design, development, construction, and operation of unique, open-access scientific user facilities. The SC basic research portfolio includes extramural grants and contracts supporting nearly 29,000 researchers located at over 300 institutions and the 17 DOE national laboratories, spanning all fifty states and the District of Columbia. The portfolio of 28 scientific user facilities serves nearly 34,000 users per year. SC programs invest in foundational

science, including basic research for the advancement of clean energy, to transform our understanding of nature and strengthen the connection between advances in fundamental science and technology innovation.

Energy Efficiency and Renewable Energy (EERE) accelerates the research, development, demonstration, and deployment (RDD&D) of technologies and solutions to equitably transition America to net-zero greenhouse gas emissions economy-wide by no later than 2050, creating good paying jobs, and ensuring the clean energy economy benefits all Americans, especially workers and communities impacted by the energy transition and those historically underserved by the energy system and overburdened by pollution. To achieve this mission, EERE is increasing investment in the integration of clean energy technologies that are ready to be demonstrated and deployed, as well as R&D activities that advance early-stage technologies with a clear path to deployment. The Request prioritizes increased investments in these priority areas critical to reduce emissions in the near term drastically, while investing in research to ensure American leadership and competitiveness in advanced clean energy technology.

Office of Cybersecurity, Energy Security, and Emergency Response (CESER) seeks to enhance the security and resilience of the r nation's critical energy infrastructure from all hazards. CESER's R&D investments aim to bolster capabilities by developing game-changing cybersecurity tools, technologies, methodologies, and guidance that aid in securing energy infrastructure. These tools and technologies will help energy industry identify, protect, detect, respond, and recover in the face of increasingly advanced cyber threats. CESER has instituted coordination and integration of cybersecurity requirements in research and development efforts across DOE's science and energy programs, building cybersecurity into the energy delivery system components. CESER will supplement these efforts with development, demonstration and deployment of crosscutting tools leveraging emerging technologies and techniques CESER also includes RD&D to address risks to the energy sector from non-cyber hazards such as physical attack and impacts of climate change, e.g., increased wildfires and severe hurricanes. CESER will develop tools that help with risk characterization and analysis and enable early detection and mitigation of these risks.

Office of Electricity (OE) supports R&D for new technologies to strengthen, transform, and improve electricity delivery infrastructure so consumers have access to resilient, secure, and clean sources of electricity. OE provides solutions to technical, market, institutional, and operational failures that go beyond any one utility's ability to solve. OE works to ensure that our Nation's electricity delivery system can accommodate all the changes at generation and load sides of the grid and ensure reliable, resilient, and secure operations of the decarbonized electric grid.

Nuclear Energy (NE) supports the diverse civilian nuclear energy programs of the U.S. Government to research and develop nuclear energy technologies, including generation, safety, and security technologies, assisting in unleashing the clean energy transition through strategic and innovative methods. NE seeks to enhance availability, economics, and security of nuclear-generated electricity in the United States (U.S.). NE focuses on small modular reactor research as well as materials aging and degradation, safety margin characterization, safety technologies, and instrumentation and controls. Research into other Advanced Reactor Technologies, such as fast reactor technologies and high temperature reactor technologies for the production of electricity and high temperature process heat to improve the economic competitiveness and flexibility of nuclear energy is also conducted. Additionally, NE provides research and development activities in advanced manufacturing methods, fabrication, and instrumentation technologies that includes strong investments in modeling and simulation tools.

Fossil Energy and Carbon Management (FECM) supports increased funding for a revitalized perspective on fossil energy that advances carbon reduction and mitigation in sectors and applications that are difficult to decarbonize, including the industrial sector, with technologies and methods such as carbon capture and storage, hydrogen, and direct air capture—all while ensuring that overburdened communities are protected from increases in cumulative pollution. The FECM Request will help support communities left behind, workers translating their skills to new positions in various areas, such as, building carbon capture and hydrogen systems on existing industrial and power plant facilities, and reinforcing existing pipelines to minimize methane emissions.

Advanced Research Projects Agency – Energy (ARPA-E) supports the delivery of innovative, investable opportunities to the commercial sector. ARPA-E will continue to deliver value to the U.S. economy with continued emphasis on maintaining a healthy portfolio of projects. These projects cover a broad range of topics, with a growing focus on additional scale-up of the most promising projects that have demonstrated success in technical development, project management, and definition of commercial pathways. ARPA-E executes its budget through funding opportunity announcements that address applications that are not represented in its present portfolio and develops new opportunities opened by the outcomes of previous programs.

National Nuclear Security Administration contributes directly and crucially to U.S. nuclear security R&D by supporting key investments in science and technology innovation that support the stewardship of the nuclear weapons stockpile, modernize the nuclear security enterprise, protect the United States from weapons of mass destruction threats, enable science-based certification of the stockpile, and provide the U.S. Navy with nuclear reactors that meet complex evolving requirements.

Administrative and Support Functions: The Department's funding estimates of R&D activities include those administrative and support functions that are necessary to the success of the R&D programs consistent with government-wide and international reporting practices. These include program direction, safeguards and security, and infrastructure costs. The following table details funding of R&D in the budget by categories; basic, applied, development, equipment, and related construction; and program office.

Basic Research	FY 2022 Enacted	FY 2023 Enacted	FY 2024 Request	FY 2024 vs FY 2023	% Change
Cybersecurity, Energy Security & Emergency Response	5,000	12,320	9,418	(2,902)	-58%
Defense Nuclear Nonproliferation	161,165	180,633	169,889	(10,745)	-7%
Electricity	9,055	13,363	12,117	(1,246)	-9%
Science	5,795,405	6,374,837	6,807,475	432,638	7%
Subtotal, Basic Research	**5,970,625**	**6,581,153**	**6,998,899**	**417,745**	**6%**

Applied Research	FY 2022 Enacted	FY 2023 Enacted	FY 2024 Request	FY 2024 vs FY 2023	% Change
Advanced Research Projects Agency-Energy	225,000	235,000	325,100	90,100	38%
Bonneville Power Administration Fund	1,000	1,000	1,000	-	N/A
Cybersecurity, Energy Security, & Emergency Response	-	59,000	63,000	4,000	7%
Defense Environmental Cleanup (EM)	10,890	14,190	10,890	(3,300)	-23%
Defense Nuclear Nonproliferation	193,973	205,570	193,967	(11,603)	-6%
Electricity	63,980	66,498	74,589	8,091	12%
Energy Efficiency and Renewable Energy	676,784	836,967	1,275,590	438,623	52%
Fossil Energy and Carbon Management	738,520	843,070	844,040	970	0%
Naval Reactor	191,110	141,400	137,000	(4,400)	-3%
Nuclear Energy	965,099	1,001,402	962,535	(38,867)	-4%
Weapons Activities	3,082,069	3,262,813	3,263,833	1,019	0%
Subtotal, Applied Research	**6,148,425**	**6,666,910**	**7,151,544**	**484,634**	**7%**

Development	FY 2022 Enacted	FY 2023 Enacted	FY 2024 Request	FY 2024 vs FY 2023	% Change
Advanced Research Projects Agency-Energy	225,000	235,000	325,100	90,100	38%
Bonneville Power Administration Fund	1,000	1,000	1,000	-	N/A
Cybersecurity, Energy Security, & Emergency Response	70,000	29,000	31,000	2,000	7%
Defense Environmental Cleanup (EM)	22,110	28,810	22,110	(6,700)	-23%
Defense Nuclear Nonproliferation	133,285	129,361	139,121	9,760	8%
Electricity	63,917	86,292	104,224	17,932	21%
Energy Efficiency and Renewable Energy	1,378,725	607,324	817,959	210,635	35%
Fossil Energy and Carbon Management	1,000,000	1,000,000	1,000,000	-	N/A
Naval Reactors	616,255	700,073	815,180	115,107	16%
Nuclear Energy	309,492	336,816	327,065	(9,751)	-3%
Weapons Activities	662,532	777,348	822,704	45,356	6%
Subtotal, Development	**4,482,316**	**3,931,024**	**4,405,464**	**474,440**	**12%**

R&D Construction	FY 2022 Enacted	FY 2023 Enacted	FY 2024 Request	FY 2024 vs FY 2023	% Change
Electricity	50,658	-	-	-	N/A
Energy Efficiency and Renewable Energy	73,421	1,688	57,000	55,312	3277%
Naval Reactors	567,620	554,218	246,284	(307,934)	-56%
Nuclear Energy	41,850	7,300	-	(7,300)	-100%
Science	1,261,206	1,255,013	1,383,973	128,960	10%

Weapons Activities	177,960	83,513	276,330	192,817	231%
Subtotal, R&D Related Facilities	**2,172,715**	**1,901,732**	**1,963,587**	**61,855**	**3%**

R&D Equipment	**FY 2022 Enacted**	**FY 2023 Enacted**	**FY 2024 Request**	**FY 2024 vs FY 2023**	**% Change**
Bonneville Power Administration Fund	267,000	-	-	-	N/A
Construction, Rehabilitation, Operation & Maintenance, Western Area Power Administration	3,000	-	-	-	N/A
Construction, Rehabilitation, Office of Nuclear Energy	37,000	-	-	-	N/A
Defense Nuclear Nonproliferation	30,396	31,339	32,228	889	3%
Energy Efficiency and Renewable Energy	20,262	38,775	66,526	27,751	72%
Fossil Energy and Carbon Management	29,000	25,000	26,000	1,000	4%
Naval Reactors	6,900	23,005	8,800	(14,205)	-62%
Operation and Maintenance, Southwestern Power Administration	10,000	-	-	-	N/A
Transmission Facilitation Fund	380,000	-	-	-	N/A
Science	258,389	251,699	212,901	(38,798)	-15%
Weapons Activities	640,191	939,075	1,065,502	126,428	13%
Western Area Power Administration, Borrowing Authority, Recovery Act	400,000	-	-	-	N/A
Subtotal, R&D Equipment	**2,082,138**	**1,308,893**	**1,411,957**	**103,065**	**8%**

R&D and Related Equipment & Construction	**FY 2022 Enacted**	**FY 2023 Enacted**	**FY 2024 Request**	**FY 2024 vs FY 2023**	**% Change**
Advanced Research Projects Agency-Energy	450,000	470,000	650,200	180,200	38%
Bonneville Power Administration Fund	269,000	2,000	2,000	-	N/A
Construction, Rehabilitation, Operation & Maintenance, Western Area Power Administration	3,000	-	-	-	N/A
Construction, Rehabilitation, Office of Nuclear Energy	37,000	-	-	-	N/A
Cybersecurity, Energy Security, & Emergency Response	75,000	100,320	103,418	3,098	3%
Defense Environmental Cleanup (EM)	33,000	43,000	33,000	(10,000)	-23%
Defense Nuclear Nonproliferation	518,819	546,903	535,205	(11,698)	-2%
Electricity	187,610	166,153	190,930	24,777	15%
Energy Efficiency and Renewable Energy	2,149,192	1,484,754	2,217,075	732,321	49%
Federal Energy Management Program	-	25,000	26,000	1,000	4%
Fossil Energy and Carbon Management	767,520	843,070	844,040	970	0%
Naval Reactors	1,381,885	1,418,696	1,207,264	(211,432)	-15%
Nuclear Energy	1,316,441	1,345,518	1,289,600	(55,918)	-4%

Operation and Maintenance, Southwestern Power Administration	10,000	-	-	-	N/A
Transmission Facilitation Fund	380,000	-	-	-	N/A
Science	7,315,000	7,881,549	8,404,349	522,800	7%
Weapons Activities	4,562,753	5,062,749	5,428,370	365,620	7%
Western Area Power Administration, Borrowing Authority, Recovery Act	400,000	-	-	-	N/A
R&D and Related Equipment & Construction	**20,856,220**	**20,389,713**	**21,931,451**	**1,541,738**	**8%**

Safeguards and Security
Crosscut

Program Mission

The Safeguards and Security (S&S) program at headquarters and each DOE field site focuses on enterprise security, protecting against theft, diversion, sabotage, espionage, unauthorized access, compromise, and other hostile acts which may cause damage to national security, program continuity, the health and safety of employees, the public or the environment. The 'crosscut' summarizes the S&S programs that are distributed through the budget volumes. Each program's S&S components are described in the budget justifications for:

- Science
- Weapons Activities
- Defense Nuclear Nonproliferation
- Naval Reactors
- Defense Environmental Cleanup
- Nuclear Energy
- Energy Efficiency and Renewable Energy
- Fossil Energy R&D
- Strategic Petroleum Reserve
- Legacy Management
- Loans Program Office
- Enterprise Assessments
- Environment, Health, Safety and Security
- Energy Information Administration
- Specialized Security Activities
- NNSA Federal Salaries and Expenses
- Chief Financial Officer
- Chief Information Officer

Program Overview

The budget for the direct funded S&S programs is organized to ensure consistency in program and budget execution and ensure management, direction, tracking and monitoring of security costs throughout the Department. Each program budget provides visibility for S&S issues to help management ensure effective and efficient S&S program implementation. Figure 1 shows comparable overall funding for S&S in the FY 2022 Enacted, FY 2023 Enacted and the FY 2024 Request.

Figure 1: Overall DOE S&S Funding

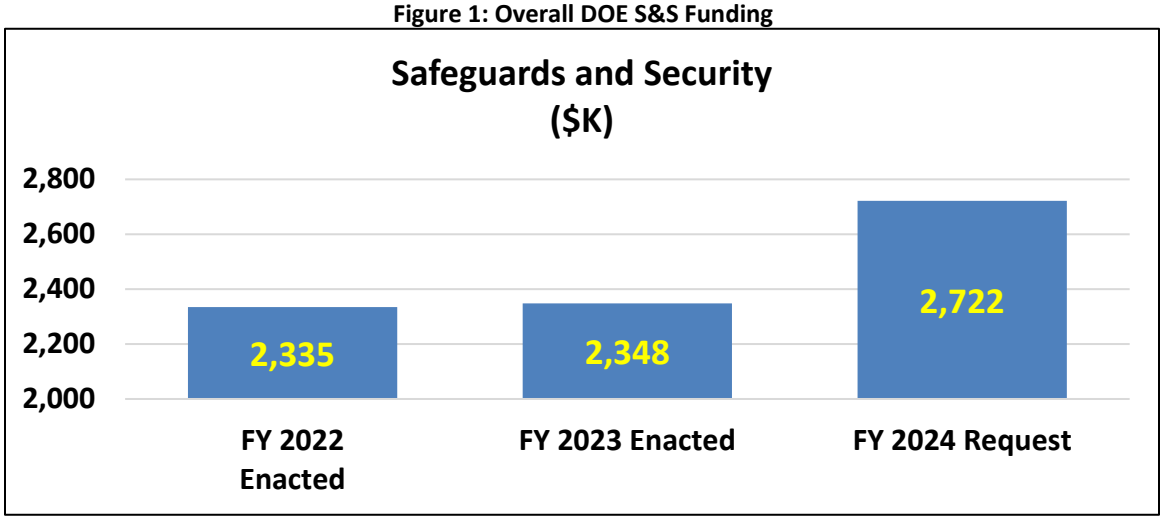

Table 1: Functional Components of S&S

The S&S crosscut budget is comprised of the functional components shown in the following table.

Protective Forces	Provides for the protection of special nuclear materials, information, employees, and government property from theft, diversion, sabotage, and malicious destruction.
Physical Security Systems	Addresses access control and interior/exterior intrusion detection systems.
Information Security	Ensures that individuals protect classified matter and sensitive unclassified matter and establishes protection systems that require degrees of protection for each classification level.
Cybersecurity	Assures protection of IT resources and networks, to include modernizing cybersecurity defenses by protecting federal networks, improving information-sharing between the U.S. government and the private sector on cyber issues, and strengthening the United States' ability to respond to incidents when they occur.
Personnel Security	Supports activities associated with the access authorization program.
Material Control and Accountability	Provides assurance that the nuclear materials used and/or stored at DOE facilities are always properly controlled and accounted for.
Program Management	Assures a framework for efficient and effective security operations.
Security Investigations	Provides for background investigations for access authorizations.
Transportation Security	Provides secure transportation of nuclear materials.
Security Infrastructure/ Construction	Provides for update and repair of security-related infrastructure and construction for that purpose.

Table 2 shows S&S funding by program cost elements; and Table 3 by functional cost elements. Subsequent sections break out each functional element of safeguards and security by program.

Highlights:
In FY 2024, the Department's overall S&S investment (field and HQ) is $2.7 billion, an increase of +$374 million, or 15.9%, above the FY 2023 Enacted level.

By functional element, DOE is making strategic investments in Cybersecurity (+$118 million, or +23.6%), Protective Forces (+$85 million, or +9.8%), Physical Security Systems (+$30.9 million, or 15.1%), Information Security (+$11.5 million, 12.3%) and Security infrastructure (+$193 million).

By program, there are significant increases from FY 2023 Enacted to FY 2024 Request for Weapons Activities (+$258 million, or +18%) for additional security requirements associated with mission growth across the nuclear security enterprise, including plutonium pit production and preparation for operation of the Uranium Processing Facility at the Y-12 National Security Complex. Additionally, there are notable increases in the Office of Science (+$16 million, or +8.6%) Fossil Energy & Carbon Management (+$7.7 million, or +74.5%) and the Office of the Chief Information Officer (+$6.7 million or +7.3%) primarily for investments in cybersecurity in response to Executive Order 14028, Improving the Nation's Cybersecurity by moving to Zero Trust Architecture.

Table 2: S&S Funding by Program ($K)

Safeguards and Security (S&S) by Program	FY 2022 Enacted	FY 2023 Enacted	FY 2024 Request	$ Change FY24 vs. FY23	% Change FY24 vs. FY23
Chief Financial Officer	1,692	2,450	3,650	1,200	49.0%
Chief Information Officer	71,800	92,361	99,097	6,736	7.3%
Defense Environmental Cleanup	323,144	329,220	332,645	3,425	1.0%
Defense Nuclear Nonproliferation	336	380	400	20	5.3%
Energy Efficiency and Renewable Energy	15,200	16,750	17,950	1,200	7.2%
Energy Information Administration	1,105	1,405	2,015	610	43.4%
Enterprise Assessments	9,505	9,535	10,273	738	7.7%
Environment, Health, Safety and Security	74,903	80,430	84,575	4,145	5.2%
Federal Salaries and Expenses	2,588	2,822	2,882	60	2.1%
Fossil Energy & Carbon Management	9,869	10,392	18,132	7,740	74.5%
Legacy Management	2,244	2,676	2,698	22	0.8%
Naval Reactors	1,381	1,441	1,359	-82	-5.7%
Nuclear Energy	149,800	149,820	177,773	27,913	18.6%
Science	170,000	184,099	200,000	15,901	8.6%
Strategic Petroleum Reserve	25,950	28,475	74,367	45,892	161.2%
Title 17: Loan Guarantee Program	304	543	560	17	3.1%
Weapons Activities	1,475,245	1,435,313	1,693,522	258,209	18.0%
Total, Program S&S	**2,335,066**	**2,348,112**	**2,721,858**	**373,746**	**15.9%**

Table 3: S&S Funding by Functional Cost Element ($K)

S&S by Functional Cost Element	FY 2022 Enacted	FY 2023 Enacted	FY 2024 Request	$ Change FY24 vs. FY23	% Change FY24 vs. FY23
Protective Forces	827,169	865,214	950,326	85,112	9.8%
Physical Security Systems	182,382	204,263	235,190	30,927	15.1%
Information Security	87,062	93,342	104,866	11,524	12.3%
Cybersecurity	560,671	499,148	616,865	117,717	23.6%
Personnel Security	83,401	86,750	94,697	7,947	9.2%
Material Control and Accountability	57,586	60,720	66,493	5,773	9.5%
Program Management	145,546	133,831	141,035	7,204	5.4%
Security Investigations	10,364	10,902	11,336	434	4.0%
Transportation Security	330,979	344,652	357,279	12,627	3.7%
Security Infrastructure/Construction	49,906	49,290	143,771	193,061	391.7%
Total, Functional S&S	**2,335,066**	**2,348,112**	**2,721,858**	**373,746**	**15.9%**

Protective Forces
Funding Schedule ($K)

	FY 2022 Enacted	FY 2023 Enacted	FY 2024 Request	$ Change FY24 vs. FY23	% Change FY24 vs. FY23
Protective Forces					
Defense Environmental Cleanup	181,805	194,598	202,659	8,061	4.1%
Energy Efficiency and Renewable Energy	3,470	3,600	3,890	290	8.1%
Environment, Health, Safety and Security	35,419	40,000	43,500	3,500	8.8%
Fossil Energy & Carbon Management	3,164	3,164	4,325	1,161	36.7%
Legacy Management	642	670	681	11	1.6%
Nuclear Energy	85,356	88,497	92,922	4,425	5.0%
Science	46,710	52,341	53,911	1,570	3.0%
Strategic Petroleum Reserve	18,691	21,407	20,872	-535	-2.5%
Weapons Activities	451,912	460,937	527,566	66,630	14.5%
Total, Protective Forces	**827,169**	**865,214**	**950,326**	**85,113**	**9.8%**

Mission

The Protective Forces element of field and headquarters S&S provides funding to protect the Department's critical assets, which include nuclear weapons in DOE custody, nuclear weapons components, special nuclear materials, classified information, and DOE facilities against a spectrum of threats, including terrorist activity, sabotage, espionage, theft, diversion, loss, or unauthorized use.

Protective Forces programs throughout the complex provide for personnel salaries, wages, and benefits for personnel; management and supervision; and well-maintained and logically deployed equipment and facilities to ensure effective performance of assigned functions and tasks under normal and emergency conditions.

Protective Forces programs include the conduct of access control and security response operations; the physical protection of special nuclear material, classified matter and information, and government property; emergency response forces and tactical assistance during events as well as an on-scene security commander; random patrols; coordination with local law enforcement and protective force elements aimed at providing effective response to emergency situations; random prohibited article inspections; security alarm monitoring and dispatch services; the collection and destruction of classified matter; and testing of the protective force to respond to various event scenarios.

Protective Forces programs maintain a Special Response Team capability to provide resolution of incidents that require effective and timely response with force options that exceed the capability of front-line protective force personnel. This includes prevention, recapture and recovery operations involving the use of special weapons systems and tactics to prevent access to special nuclear material or effect recovery from unauthorized control.

Highlight:

- For Weapons Activities, increase reflects additional security requirements associated with growth across the nuclear security enterprise, in particular the plutonium pit production mission at Los Alamos National Laboratory, and Kansas City expansion.

Physical Security Systems
Funding Schedule ($K)

	FY 2022 Enacted	FY 2023 Enacted	FY 2024 Request	$ Change FY24 vs. FY23	% Change FY24 vs. FY23
Physical Security Systems					
Defense Environmental Cleanup	28,504	29,944	29,077	-867	-2.9%
Energy Efficiency and Renewable Energy	875	925	1,000	75	8.1%
Environment, Health, Safety and Security	6,138	6,238	6,238	0	0.0%
Fossil Energy & Carbon Management	171	171	150	-21	-12.3%
Legacy Management	120	127	130	3	2.4%
Nuclear Energy	11,575	12,023	12,853	830	6.9%
Science	22,490	24,693	35,812	11,119	45.0%
Strategic Petroleum Reserve	1,075	1,123	1,143	20	1.8%
Weapons Activities	111,434	129,019	148,787	19,768	15.3%
Total, Physical Security Systems	**182,382**	**204,263**	**235,190**	**30,927**	**15.1%**

Mission

The Physical Security Systems element of field and headquarters S&S provides for the physical protection of special nuclear material and equipment, sensitive information, Departmental property, and unclassified facilities. Included are buildings, fences, barriers, lighting, sensors, surveillance devices, entry control devices, access control systems, explosive detection systems, power systems and other real property and hardware designed for or affecting security. This hardware and equipment are operated and used to support the protection of DOE property and other interests of national security.

Security Systems programs support DOE-wide efforts required to conduct performance assurance testing. These programs also ensure that security alarm systems are operational and functioning in accordance with applicable DOE requirements. Physical Security System programs are also responsible for two subprograms: (1) a barriers, secure storage, and lock program to restrict, limit, delay or deny entry into a designated area; and (2) an entry control and access program that provides positive identification of personnel requiring access to facilities and initial access to facilities in general, ensuring that persons entering or leaving facilities are authorized, and do not introduce prohibited articles into or remove Government property from Departmental facilities.

The budget estimates include all access control administrative activity involving production, accountability and destruction of access authorization badges and firearms credentials. They also include systems components and tamper-safe oversight by monitoring and responding to alarms, determining access, and securing all alarmed structures on site. In addition, this element provides for handling all radio communications for the protection of the facilities.

Highlights:

- For Science, the increase will support the continued implementation of new standards to conduct investigations for uncleared long-term contractor personnel and the associated modernization of select risk and priority-driven-systems. These systems also mitigate active shooter, as well as providing control and compartmentalization of classified matter, intellectual property, sensitive information, and hazardous materials.
- For Weapons Activities, the increase is associated with mission growth across the nuclear security enterprise (NSE) including pit production and UPF preparation efforts.

Information Security
Funding Schedule ($K)

	FY 2022 Enacted	FY 2023 Enacted	FY 2024 Request	$ Change FY24 vs. FY23	% Change FY24 vs. FY23
Information Security					
Defense Environmental Cleanup	5,911	6,697	6,472	-225	-3.4%
Energy Efficiency and Renewable Energy	550	575	620	45	7.8%
Environment, Health, Safety and Security	13,179	13,679	13,679	0	0.0%
Fossil Energy & Carbon Management	156	163	3,239	3,076	1887.1%
Legacy Management	71	72	72	0	0.0%
Nuclear Energy	6,174	5,016	5,748	732	14.6%
Science	4,490	5,660	5,830	170	3.0%
Strategic Petroleum Reserve	238	241	246	5	2.1%
Weapons Activities	56,293	61,239	68,960	7,721	12.6%
Total, Information Security	**87,062**	**93,342**	**104,866**	**11,524**	**12.3%**

Mission

The Information Security element of field and headquarters S&S ensures that material and documents that may contain sensitive and classified information are accurately and consistently identified, properly reviewed for content, appropriately marked, and protected from unauthorized disclosure, and ultimately destroyed in an approved manner.

Information Security programs provides for plans, policies, procedures, and training to ensure that all employees are aware of the requirements for the identification, review, classification, declassification, marking, protection and proper disposal of sensitive information and classified material. In addition, operational security considerations are used to preclude inadvertent compromise of classified material.

Highlight:

For Weapons Activities, the increase in Information Security is associated with mission growth including pit production and Kansas City expansion efforts.

Cybersecurity
Funding Schedule ($K)

	FY 2022 Enacted	FY 2023 Enacted	FY 2024 Request	$ Change FY24 vs. FY23	% Change FY24 vs. FY23
Field Cybersecurity*					
Defense Environmental Cleanup	50,600	45,454	42,150	-3,304	-7.3%
Energy Efficiency and Renewable Energy	9,200	10,500	11,200	700	6.7%
Fossil Energy & Carbon Management	4,416	4,416	7,398	2,982	67.5%
Legacy Management	1,067	1,383	1,159	-224	-16.2%
Nuclear Energy	21,912	23,916	27,612	3,696	15.5%
Science	81,260	81,260	83,697	2,437	3.0%
Strategic Petroleum Reserve	3,763	3,144	4,177	1,033	32.9%
Weapons Activities	297,243	215,451	315,902	100,451	46.6%
Total, Field Cybersecurity	**469,461**	**385,524**	**493,295**	**107,771**	**28.0%**

*Cybersecurity amounts shown do not include Working Capital Fund or Energy Information Technology System contributions

Cybersecurity (including Headquarters Offices)					
Field Cybersecurity	**469,461**	**385,524**	**493,295**	**107,771**	**28.0%**
Headquarters Cybersecurity	**91,210**	**113,624**	**123,570**	**9,946**	**8.8%**
Chief Financial Officer	1,692	2,450	3,650	1,200	49.0%
Chief Information Officer	71,800	92,361	99,097	6,736	7.3%
Energy Information Administration	1,105	1,405	2,015	610	43.4%
Enterprise Assessments	9,335	9,335	10,123	788	8.4%
Environment, Health, Safety and Security	5,734	5,830	5,925	95	1.6%
Title 17: Loan Guarantee Program	244	443	460	17	3.8%
Fossil Energy & Carbon Management	1,300	1,800	2,300	500	27.8%
Total, Cybersecurity (Field & HQ)	**560,671**	**499,148**	**616,865**	**117,717**	**23.6%**

Mission

The Cybersecurity element of field and headquarters S&S improves the nation's cybersecurity and protects the federal government networks, in line with Executive Order 14028, Improving the Nation's Cybersecurity by moving to Zero Trust Architecture. Recent cybersecurity incidents such as SolarWinds, Microsoft Exchange, and the Colonial Pipeline incident are a sobering reminder that U.S. public and private sector entities increasingly face sophisticated malicious cyber activity from both nation-state actors and cyber criminals. These incidents share commonalities, including insufficient cybersecurity defenses that leave public and private sector entities more vulnerable to incidents.

In FY 2024, the Department of Energy is making significant contributions toward modernizing cybersecurity defenses by protecting federal networks, improving information-sharing between the U.S. government and the private sector on cyber issues, and strengthening the United States' ability to respond to incidents when they occur. Investments in Cybersecurity at the Department will focus on the following key areas, as identified in EO 14028:

- Remove Barriers to Threat Information Sharing Between Government and the Private Sector. Ensure that IT Service Providers can share information with the government and require them to share certain breach information. Removing any contractual barriers and requiring providers to share breach information that could impact Government networks is necessary to enable more effective defenses of Federal departments, including DOE, and to improve the Nation's cybersecurity.

- Modernize and Implement Stronger Cybersecurity Standards. Help move DOE enterprise to secure cloud services and a zero-trust architecture, and mandate deployment of multifactor authentication and encryption within a

specific time period. Outdated security models and unencrypted data have led to compromises of systems in the public and private sectors. DOE will increase its adoption of security best practices, by accelerating movement to a zero-trust security model and secure cloud services, and consistently deploying foundational security tools such as multifactor authentication and encryption.

- Improve Software Supply Chain Security. Continue to mature and expand the Information and Communication Technology Supply Chain Risk Management Program to improve the security of software and hardware. Too much of our hardware and critical software is shipped with significant vulnerabilities that our adversaries exploit.

- Improve Investigative and Remediation Capabilities. Improve cybersecurity threat hunting and response through improved logging and data analytics. Create cybersecurity event log and data retention requirements for DOE enterprise. Modernized perimeter sensors, improved data storage and search capabilities will improve the organization's ability to detect intrusions, mitigate those in progress, and determine the extent of an incident after the fact.

The amounts given here are program funds and do not include security elements that are within software applications developed for the Department's programmatic or administrative purposes, whether directly or indirectly funded. They do include IT Security and Compliance entries within the IT Investment portfolio. Highlights of cybersecurity activities can be found within the individual program budget requests.

Field Cybersecurity Highlights:

- Increase for Science will support investments in cyber infrastructure and cyber capability including new cyber tools, incident response enhancements, cyber workforce development, data protections, and protections for unique SC facilities and capabilities that cannot be protected with commercial tools and to strengthen protection at federal and M&O sites in the areas of: Cyber Threat Intelligence, Incident Response, Incident Recovery, Novel Security Techniques, Infrastructure Refresh, Industrial Control System Protection, Continuous Diagnostics and Mitigation, and Controlled Unclassified Information Protection. Additionally, the Request will continue implementation of Executive Order 14028 requirements at both federal and Management & Operating contract sites.
- Increase for Weapons Activities reflects investments in ZTA, Endpoint Detection and Response (EDR), operational technology, and other cybersecurity tools and services through the Enterprise Operations subprogram and supports labor rate increases and workforce growth at the laboratories, plants, and sites to address the significant increase in technology use as the NNSA mission has grown through the Site Infrastructure subprogram.

Headquarters (HQ) Cybersecurity Highlights:

- Increase for Chief Information Officer reflects dedicated cyber reserve fund for the entire DOE complex to address requirements of Executive Order 14028 Improving the Nation's Cybersecurity.

Personnel Security
Funding Schedule ($K)

	FY 2022 Enacted	FY 2023 Enacted	FY 2024 Request	$ Change FY24 vs. FY23	% Change FY24 vs. FY23
Personnel Security					
Defense Environmental Cleanup	12,647	11,892	11,949	57	0.5%
Energy Efficiency and Renewable Energy	230	240	260	20	8.3%
Environment, Health, Safety and Security	6,192	6,192	6,742	550	8.9%
Fossil Energy & Carbon Management	346	358	383	25	7.0%
Legacy Management	76	76	77	1	1.3%
Nuclear Energy	4,714	5,593	5,953	0	6.4%
Science	5,750	9,055	9,327	272	3.0%
Strategic Petroleum Reserve	580	902	930	28	3.1%
Title 17: Loan Guarantee Program	60	100	100	0	0.0%
Weapons Activities	52,806	52,342	58,976	6,634	12.7%
Total, Personnel Security	**83,401**	**86,750**	**94,697**	**7,947**	**9.2%**

Mission

The Personnel Security element of field and headquarters S&S supports the access authorization program and ensures security sensitivity through security briefings such as the initial refresher and termination briefings, re-orientations, computer-based training, special workshops and classes, publications, closed circuit television programs, signs, posters, and special event days. Support for the access authorization program includes: (1) personnel security assurance program, adjudications, screening, and analysis of personnel security cases for determining eligibility for access authorizations, administrative reviews, and handling of Freedom of Information Act and Privacy Act requests related to security access authorizations; (2) security awareness and education; and (3) activities associated with classified and unclassified visits and assignments by foreign nationals.

Highlights:

- For Weapons Activities, the increase reflects additional security requirements associated with mission growth across the nuclear security enterprise, in particular the plutonium pit production mission at Los Alamos National Laboratory and Kansas City expansion efforts.
- For Science, the increase will provide additional FTEs to support the increased HSPD-12 access authorization functions and the increased functions for the increased processing and vetting of foreign nationals.

Material Control and Accountability
Funding Schedule ($K)

	FY 2022 Enacted	FY 2023 Enacted	FY 2024 Request	$ Change FY24 vs. FY23	% Change FY24 vs. FY23
Material Control and Accountability					
Defense Environmental Cleanup	7,176	6,805	7,331	526	7.7%
Nuclear Energy	6,376	5,825	6,525	700	12.0%
Science	2,500	2,965	3,054	89	3.0%
Weapons Activities	41,534	45,125	49,583	4,458	9.9%
Total, Material Control and Accountability	**57,586**	**60,720**	**66,493**	**5,773**	**9.5%**

Mission

The Material Control and Accountability (MC&A) element of field S&S provides assurance that nuclear materials are properly controlled and always accounted for. MC&A provides evidence that all nuclear materials are accounted for appropriately and that theft, diversion, or operational loss has not occurred. MC&A also supports weapons production, nuclear nonproliferation, nuclear materials operations, facility closure, and nuclear critical safety by determining and documenting the amounts of nuclear materials in weapons and packaged items. MC&A administration includes the following: (1) assessing the levels of protection, control and accounting required for the types and quantities of materials at each facility; (2) documenting facility plans for nuclear materials control and accounting; (3) assigning authorities and responsibilities for MC&A functions; (4) ensuring that facility MC&A personnel are trained and qualified to perform their responsibilities; (5) establishing programs to report occurrences such as nuclear material theft, the loss of control or inability to account for nuclear materials, or evidence of malevolent acts; (6) conducting performance testing of required program elements; and (7) establishing facility programs to conduct and document internal assessments of their operations and MC&A programs.

Highlight:

- For Weapons Activities, the increase is associated with mission growth across NNSA's NSE, including for pit production and UPF preparation efforts.
- For Nuclear Energy, the increase is consistent with research and development operational schedules.

Program Management
Funding Schedule ($K)

	FY 2022 Enacted	FY 2023 Enacted	FY 2024 Request	$ Change FY24 vs. FY23	% Change FY24 vs. FY23
Program Management					
Defense Environmental Cleanup	25,742	26,579	26,098	-481	-1.8%
Energy Efficiency and Renewable Energy	690	720	780	60	8.3%
Environment, Health, Safety and Security	7,341	7,591	7,591	0	0.0%
Fossil Energy & Carbon Management	316	320	337	17	5.3%
Legacy Management	268	348	579	231	66.4%
Nuclear Energy	10,175	8,000	8,100	100	1.3%
Science	6,800	8,125	8,369	244	3.0%
Strategic Petroleum Reserve	1,603	1,658	1,677	19	1.1%
Weapons Activities	92,611	80,490	87,504	7,014	8.7%
Total, Program Management	**145,546**	**133,831**	**141,035**	**7,204**	**5.4%**

Mission

The Program Management element of field and headquarters S&S develops the framework for efficient and effective security operations. This includes the development and updating of S&S plans, conducting vulnerability assessments to determine if assets are at risk, modeling to ensure the plans and operations meet mission objectives, identifying assets that need protection, developing local threat assessments and participating in the S&S quality panel process and security education. In addition, these programs ensure that plans are developed and revised in accordance with DOE requirements, professional and technical training is administered, and Departmental S&S goals and objectives are implemented complex wide.

The programs develop S&S plans or other applicable security plans and implement S&S requirements, conduct surveys to determine whether S&S requirements have been implemented, respond to national and local threats, and perform a vulnerability analysis that measures the risk of S&S assets. Program Management includes participation in the quality panel process, which raises issues from the field to the headquarters managers and ensures that the staff is properly educated in security matters.

Highlight:

- For Weapons Activities, the increase is due to requirements associated with growth across the nuclear security enterprise (NSE), including plutonium pit production and UPF preparation efforts.

Security Investigations
Funding Schedule ($K)

	FY 2022 Enacted	FY 2023 Enacted	FY 2024 Request	$ Change FY24 vs. FY23	% Change FY24 vs. FY23
Security Investigations					
Defense Environmental Cleanup	1,656	1,644	1,645	1	0.1%
Defense Nuclear Nonproliferation	336	380	400	20	5.3%
Energy Efficiency and Renewable Energy	185	190	200	10	5.3%
Enterprise Assessments	170	200	150	-50	-25.0%
Environment, Health, Safety and Security	900	900	900	0	0.0%
Federal Salaries and Expenses	2,588	2,822	2,882	60	2.1%
Naval Reactors	1,381	1,441	1,359	-82	-5.7%
Weapons Activities	3,148	3,325	3,800	475	14.3%
Total, Security Investigations	**10,364**	**10,902**	**11,336**	**434**	**4.0%**

Mission

The Security Investigations element of field and headquarters S&S funds background investigations associated with providing access authorizations (security clearances) to DOE Federal and contract personnel who, in the performance of their official duties, require access to classified information or certain quantities of special nuclear material. Background investigations are required by Section 145 of the Atomic Energy Act of 1954, as amended, and Executive Order 12968, Access to Classified Information. The investigations are performed, and access authorizations granted based on 10 C.F.R. 710, Criteria and Procedures for Determining Eligibility for Access to Classified Matter or Special Nuclear Material. Funding provides for initial single scope background investigations, periodic reinvestigations, and initial and reinvestigation national agency checks.

Highlight:

- No major changes in Security Investigations funding from FY 2023 Enacted to the FY 2024 Request.

Transportation Security
Funding Schedule ($K)

	FY 2022 Enacted	FY 2023 Enacted	FY 2024 Request	$ Change FY24 vs. FY23	% Change FY24 vs. FY23
Transportation Security					
Defense Environmental Cleanup	215	215	215	0	0.0%
Weapons Activities	330,764	344,437	357,064	12,627	3.7%
Total, Transportation Security	**330,979**	**344,652**	**357,279**	**12,627**	**3.7%**

Mission

Transportation security provides for the secure transport of weapons, weapons components, and nuclear materials to support Stockpile Management and consolidation and disposition of nuclear material within the complex; to meet DOE, DOD, and other customer requirements. This functional component of S&S is funded primarily within NNSA's Secure Transportation Asset (STA) Program.

STA provides safe and secure shipments for Weapons Activities and other Department elements requiring this capability. The STA program supports Departmental initiatives to convert weapons-grade material for use or disposal. STA supports other DOE programs, including Environmental Management; and others, including the National Aeronautics and Space Administration, and international shipments in cooperation with Canada, the United Kingdom, and France.

Highlight:

- For Weapons Activities, the increase reflects for the Mobile Guardian Transporter (MGT) and for Program Direction.

Security Infrastructure/Construction
Funding Schedule ($K)

	FY 2022 Enacted	FY 2023 Enacted	FY 2024 Request	$ Change FY24 vs. FY23	% Change FY24 vs. FY23
Security Infrastructure/Construction					
Defense Environmental Cleanup	8,888	5,392	5,049	-343	-6.4%
Nuclear Energy	3,518	950	18,020	17,070	1796.8%
Strategic Petroleum Reserve			45,322	45,322	
Weapons Activities	37,500	42,948	75,380	32,432	75.51%
Total, Security Infrastructure/Construction	**49,906**	**49,290**	**143,771**	**94,481**	191.68%

Mission

Security Infrastructure provides critical security infrastructure investments and protection enhancements necessary to ensure adequate protection of DOE sites and personnel.

Highlights:

- For Weapons Activities, the increase reflects SIRP projects to be executed that include sensor, camera, lighting, and communication refreshes, and smaller capital equipment projects, as well as an increase to continue construction of the West-End Protected Area Reduction project.
- For Nuclear Energy, the increase reflects replacement of the Entrance Control Facility at the Materials and Fuels Complex to provide adequate space and flow to perform personnel inspections.

Small Business Innovation Research/Small Business Technology Transfer (SBIR/STTR)

(dollars in thousands)

SBIR/STTR	FY 2022 Enacted	FY 2023 Enacted	FY 2024 Request	FY 2024 vs FY 2023	% Change
Advanced Research Projects Agency-Energy	15,111	15,805	21,718	+5,913	+37.4%
Cybersecurity, Energy Security & Emergency Response	1,185	2,482	2,491	+9	+0.4%
Defense Environmental Cleanup	1,205	1,570	1,205	-365	-23.2%
Defense Nuclear Nonproliferation	14,785	14,735	13,972	-763	-5.2%
Electricity	4,581	5,589	6,407	+818	+14.6%
Energy Efficiency and Renewable Energy	68,102	71,183	96,406	+25,223	+35.4%
Fossil Energy and Carbon Management	15,922	20,493	18,964	-1,529	-7.5%
Nuclear Energy	28,512	26,673	24,311	-2,362	-8.9%
Science[1]	196,613	115,032	126,322	+11,290	+9.8%
Total, SBIR/STTR	**346,016**	**273,562**	**311,796**	**+38,234**	**+13.98%**

The Department of Energy (DOE) manages two separate Small Business Innovation Research (SBIR) & Small Business Technology Transfer (STTR) programs, one administered by the Office of Science (SC) and the other by the Advanced Research Projects Agency – Energy (ARPA-E). SC has managed the DOE SBIR and STTR programs for the Department since the SBIR program was created in 1982 and the STTR program was created in 1992. The ARPA-E SBIR/STTR programs were created in FY 2012 to manage ARPA-E's SBIR & STTR allocations independently.

The SBIR and STTR Extension Act of 2022 (P.L. 117-183) reauthorizes the SBIR and STTR programs through September 30, 2025. DOE is required to expend not less than 3.2 percent of nonexempt extramural research and development (R&D) for SBIR and 0.45 percent on nonexempt extramural R&D for STTR, a total of 3.65 percent assessed for all contributing programs. The above table shows only the total by program with the precise splits by program determined in execution. The required percentages for SBIR and STTR are met on a Department-wide basis. By statute, "amounts obligated for Atomic Energy Defense Programs solely for Weapons Activities or for Naval Reactor Programs" are exempt [15 USC 638(e)(1)].

DOE SBIR/STTR Programs Office

The SBIR/STTR Programs Office works collaboratively with nine participating R&D program offices to administer the programs: SC; Cybersecurity, Energy Security and Emergency Response; Environmental Management (Defense Environmental Cleanup); Defense Nuclear Nonproliferation (within the National Nuclear Security Administration); Electricity; Energy Efficiency and Renewable Energy; Fossil Energy and Carbon Management; and Nuclear Energy. Each office makes awards commensurate with its allocation and collaborates with other offices during execution, as necessary.

The participating programs are responsible for topic selection, reviewer assignment, award selection, and project oversight. Each program office considers its high priority research needs and program mission, as well as the Department's goals for the program in developing research topics. The specific research topics selected for the SBIR and STTR programs are developed by the Department's technical program managers.

The SBIR/STTR Programs Office is responsible for issuing topics and solicitations, managing the peer review and award selection process, working with SC's Office of Acquisition and Assistance to award SBIR/STTR Phase I and Phase II grants, issuing annual reports to the U.S. Small Business Administration, performing outreach, and setting overall policy for the Department regarding the two programs.

In the implementation of SBIR/STTR, DOE assesses each program office at the minimum required percentages for both SBIR and STTR to meet expenditure requirements. DOE's current methodology is to vary the allocations such that each office will make the same total SBIR and STTR contribution, but the amounts given to SBIR and STTR will be adjusted to provide executable amounts, while in total DOE will meet the expenditure requirements for both SBIR and STTR.

[1] Starting in FY 2023, the Office of Science will not include facility operations funding as part of the extramural research and development total for calculating the SBIR/STTR estimates.

ARPA-E SBIR/STTR Program

ARPA-E executes its SBIR/STTR programs separate from the DOE-wide SBIR/STTR program. The ARPA-E SBIR/STTR program employs the same rigorous merit review, accelerated contracting, funding, and active project management as all other ARPA-E programs. The ARPA-E SBIR/STTR Program focuses on targeted, mission-relevant areas where the agency believes that small business provides the best opportunity for innovative technology development.