Basic Energy Sciences

Overview
The mission of the Basic Energy Sciences (BES) program is to support fundamental research to understand, predict, and ultimately control matter and energy at the electronic, atomic, and molecular levels. BES research provides the scientific foundations for innovations in clean energy technologies and related national priorities, to mitigate the climate and environmental impacts of energy generation/use, and to support DOE missions in energy, environment, and national security. BES accomplishes its mission through excellence in scientific discovery and stewardship of world-class scientific user facilities that enable cutting-edge research and development.

The research disciplines that BES supports—condensed matter and materials physics, chemistry, geosciences, and aspects of biosciences—touch virtually every important aspect of energy resources, production, conversion, transmission, storage, efficiency, and waste mitigation, providing a knowledge base for achieving a secure and sustainable clean energy future. The BES Advisory Committee (BESAC) report, "A Remarkable Return on Investment in Fundamental Research,"[a] provides key examples of major technological, commercial, and national security impacts, including clean energy technologies, directly traceable to BES-supported basic research. This mission-relevance of BES research results from a long-standing strategic planning process, which encompasses BESAC reports, community workshops and reports, and rigorous program reviews. BES balances its research investments between discovery-oriented basic research and use-inspired basic research (e.g., Energy Frontier Research Centers [EFRCs], Energy Earthshot Research Centers [EERCs], and Energy Innovation Hubs).

BES scientific user facilities consist of complementary x-ray sources, neutron sources, and centers for research utilizing nanoscale science. Capabilities at BES facilities probe materials and chemical systems with ultrahigh spatial, temporal, and energy resolutions to investigate the critical functions of matter—transport, reactivity, excitations, and motion—to answer challenging science questions and to provide insights on the scientific basis for energy technologies. The above-noted BESAC report recounts the central role of user facilities in U.S. scientific and industrial leadership. During the COVID-19 pandemic, BES facilities were at the forefront of the research to understand the virus, provide therapeutics to combat it, and navigate supply chain issues. BES has a long history of delivering major construction projects on time and on budget, and of providing reliable availability and support to users for operating facilities. This record of accomplishment includes rigorous community engagement in planning and in performance assessment for operating facilities and construction.

Key to exploiting scientific discoveries for future clean energy systems is the ability to create new materials using forefront synthesis and processing techniques, to precisely define the atomic arrangements, and to design chemical processes. These innovations, based on principles revealed by fundamental science and using advanced computational, data science, and experimental tools, will enable better control of physical and chemical transformations and conversions of energy from one form to another for all energy technologies, carbon capture, and sustainable industries. Working closely with other DOE offices, BES research will evolve with awareness of technology challenges and will be disseminated to the broader community to translate federal investments to industrial impact.

BES is focused on enhancing research and user communities to include the full diversity of researchers, students, and institutions. Especially from underserved communities and regions, from across the Nation in order to establish the strongest scientific foundation in the BES ecosystem. Collectively, BES research and facilities provide a significant strategic advantage for the Nation to advance scientific frontiers while laying the foundation for future clean energy innovations and economic prosperity.

Highlights of the FY 2025 Request
The BES FY 2025 Request of $2,582.3 million is an increase of $48.3 million over FY 2023 Enacted.

Research

Guided by BESAC and Basic Research Needs workshop reports, the Request continues support for EERCs, EFRCs, the Batteries and Energy Storage and Fuels from Sunlight Energy Innovation Hub programs, and the National Quantum Information Science (QIS) Research Centers (NQISRCs). Continued funding for the Established Program to Stimulate

[a] https://science.osti.gov/~/media/bes/pdf/BESat40/BES_at_40.pdf

Competitive Research (EPSCoR), Reaching a New Energy Sciences Workforce (RENEW), and Funding for Accelerated, Inclusive Research (FAIR) will strengthen support of emerging research institutions, Historically Black Colleges and Universities (HBCUs) and Minority Serving Institutions (MSIs), and underserved communities and regions, advancing equity and inclusion in a more diverse and inclusive workforce.

- Support continues for research to provide foundational knowledge for clean energy technologies, with investments across the entire portfolio to accelerate innovation. This research will underpin the goals of the DOE Energy Earthshots.[b]
- Funding continues for muti-disciplinary microelectronics research in which materials, chemistries, devices, systems, architectures, algorithms, and software are developed in a closely integrated, co-design approach. As part of this portfolio, the Office of Science (SC) Microelectronics Science Research Centers will comprise a network of multiple team awards, with individual awards focused on a dimension related to a common research topic for each center. The multidisciplinary teams will include researchers from universities, national laboratories, and industry. Materials, chemistries, devices, systems, architectures, algorithms, and software will be developed in a closely integrated fashion in a co-design innovation ecosystem. The Request will support two to three BES research awards that would contribute to one of up to four cross-SC Research Centers.
- Funding increases for Artificial Intelligence and Machine Learning (AI/ML) to accelerate fundamental discoveries and to apply these techniques to user facility operations and interpretation of massive data sets.
- Both the NQISRCs and the Fuels from Sunlight Energy Innovation Hub program complete the initial five-year award periods and will be considered for recompetition/renewal.
- Support continues for QIS, including a robust core research portfolio to complement the NQISRCs; Biopreparedness Research Virtual Environment (BRaVE) to develop and expand capabilities at user facilities for responsiveness to biological threats; Accelerator Science and Technology to provide comprehensive, advanced innovations for BES accelerator-based facilities; basic science for critical materials; and Advanced Computing (with Advanced Scientific Computing Research [ASCR]), which includes computational materials and chemical sciences to deliver shared software infrastructure. BES will prioritize transitioning Exascale Computing Project researchers and software utilization into research efforts.
- BES supports RENEW, expanding targeted efforts, including a RENEW graduate fellowship, to broaden participation in underserved communities and advance equity, and inclusion in SC-sponsored research; and FAIR, improving capability in emerging research institutions, HBCUs and MSIs to perform and propose competitive research and building beneficial relationships with DOE national laboratories and facilities.

<u>Facility Operations</u>

The five BES-supported x-ray light sources, two neutron sources, and five Nanoscale Science Research Centers (NSRCs) are supported at 90 percent of the funding required for re-baselined, full operation—balancing safe, robust operations with user access. Preconceptual planning continues for future Advanced Photon Source (APS), Advanced Light Source (ALS), and Stanford Synchrotron Radiation Lightsource (SSRL) beamline Major Item of Equipment (MIE) projects.

<u>Projects</u>

Support continues for the Linac Coherent Light Source-II High Energy (LCLS-II-HE), Second Target Station (STS), Cryomodule Repair and Maintenance Facility (CRMF), High Flux Isotope Reactor (HFIR) Pressure Vessel Replacement (PVR), and National Synchrotron Light Source (NSLS)-II Experimental Tools-III (NEXT-III) line-item projects.

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[b] https://www.energy.gov/energy-earthshots-initiative

Basic Energy Sciences
Funding

(dollars in thousands)

	FY 2023 Enacted	FY 2024 Annualized CR	FY 2025 Request	FY 2025 Request vs FY 2023 Enacted
Basic Energy Sciences				
Scattering and Instrumentation Sciences Research	105,971	86,313	96,063	-9,908
Condensed Matter and Materials Physics Research	203,807	183,764	201,644	-2,163
Materials Discovery, Design, and Synthesis Research	97,097	79,147	87,547	-9,550
Established Program To Stimulate Competitive Research EPSCoR	25,000	25,000	25,000	–
Energy Frontier Research Centers - Materials	65,000	65,000	65,000	–
Energy Earthshot Research Centers - Materials	12,500	16,000	12,500	–
Energy Innovation Hubs - Materials	25,913	25,913	25,913	–
Computational Materials Sciences	13,492	13,492	13,492	–
Total, Materials Sciences and Engineering	**548,780**	**494,629**	**527,159**	**-21,621**
Fundamental Interactions Research	127,985	129,677	133,416	+5,431
Chemical Transformations Research	129,651	107,158	115,578	-14,073
Photochemistry and Biochemistry Research	130,877	113,714	118,035	-12,842
Energy Frontier Research Centers - Chemical	65,000	65,000	65,000	–
Energy Earthshot Research Centers - Chemical	12,500	16,000	12,500	–
Energy Innovation Hubs - Chemical	20,758	20,758	20,758	–
General Plant Projects - Chemical	1,000	1,000	1,000	–
Computational Chemical Sciences	13,492	13,492	13,492	–
Total, Chemical Sciences, Geosciences, and Biosciences	**501,263**	**466,799**	**479,779**	**-21,484**
X-Ray Light Sources	599,498	679,944	790,347	+190,849
High-Flux Neutron Sources	315,740	371,924	364,692	+48,952
Nanoscale Science Research Centers	153,409	146,801	164,422	+11,013
Other Project Costs	19,500	5,500	9,500	-10,000
Major Items of Equipment	50,000	25,000	–	-50,000

(dollars in thousands)

	FY 2023 Enacted	FY 2024 Annualized CR	FY 2025 Request	FY 2025 Request vs FY 2023 Enacted
Scientific User Facilities, Research	52,610	58,966	62,886	+10,276
Total, Scientific User Facilities (SUF)	**1,190,757**	**1,288,135**	**1,391,847**	**+201,090**
Subtotal, Basic Energy Sciences	**2,240,800**	**2,249,563**	**2,398,785**	**+157,985**
Construction				
24-SC-10 HFIR Pressure Vessel Replacement (PVR), ORNL	–	–	6,000	+6,000
24-SC-12 NSLS-II Experimental Tools - III (NEXT-III), BNL	–	–	5,500	+5,500
21-SC-10 Cryomodule Repair & Maintenance Facility (CRMF), SLAC	10,000	9,000	20,000	+10,000
19-SC-14 Second Target Station (STS), ORNL	32,000	52,000	52,000	+20,000
18-SC-10 Advanced Photon Source Upgrade (APS-U), ANL	9,200	–	–	-9,200
18-SC-11 Spallation Neutron Source Proton Power Upgrade (PPU), ORNL	17,000	15,769	–	-17,000
18-SC-12 Advanced Light Source Upgrade (ALS-U), LBNL	135,000	57,300	–	-135,000
18-SC-13 Linac Coherent Light Source-II-High Energy (LCLS-II-HE), SLAC	90,000	120,000	100,000	+10,000
Subtotal, Construction	**293,200**	**254,069**	**183,500**	**-109,700**
Total, Basic Energy Sciences	**2,534,000**	**2,503,632**	**2,582,285**	**+48,285**

SBIR/STTR funding:

- FY 2023 Enacted: SBIR $35,557,000 and STTR $5,000,000
- FY 2024 Annualized CR: SBIR $31,789,000 and STTR $4,473,000
- FY 2025 Request: SBIR $33,770,000 and STTR $4,749,000

Basic Energy Sciences
Explanation of Major Changes

	(dollars in thousands) FY 2025 Request vs FY 2023 Enacted
Materials Sciences and Engineering Research will continue to support fundamental scientific opportunities for materials innovations. Research priorities include clean energy (e.g., hydrogen, direct air capture of CO_2, energy storage, and wind), microelectronics research, AI/ML, critical materials, computational materials sciences, BRaVE, QIS, strategic accelerator technology, FAIR, and RENEW. The Request also includes funding for continued support of the EFRCs, the Batteries and Energy Storage Energy Innovation Hub, the NQISRCs (recompetition/renewal), EPSCoR, and the EERCs.	**-$21,621**
Chemical Sciences, Geosciences, and Biosciences Research will continue to support fundamental scientific opportunities for innovations in chemistry, geosciences, and biosciences. Research priorities include clean energy (e.g., hydrogen, geothermal, and direct air capture of CO_2), AI/ML, microelectronics research, critical materials, computational chemical sciences (recompetition), QIS, FAIR, and RENEW. The Request also includes funding for continued support of the EFRCs, the Fuels from Sunlight Hubs (renewal), the NQISRCs (recompetition/renewal), and the EERCs.	**-$21,484**
Scientific User Facilities (SUF) The 12 BES user facilities are supported at 90 percent of the re-baselined funding level, balancing safe operation and user access. The facilities will continue to support the BRaVE initiative to maintain and enhance capabilities to tackle biological threats. Continued facilities research priorities include accelerator science and technology, expansion of AI/ML, and RENEW. The Request also provides Other Project Costs to support the HFIR-PVR and NEXT-III projects.	**+$201,090**
Construction The Request provides continuing support for the LCLS-II-HE, STS, CRMF, HFIR-PVR, and NEXT-III projects.	**-$109,700**
Total, Basic Energy Sciences	**+$48,285**

Basic and Applied R&D Coordination

As a program that supports fundamental scientific research relevant to many DOE mission areas, BES strives to build and maintain close connections with other DOE program offices. BES coordinates with DOE R&D programs through a variety of Departmental activities, including workshops, strategic planning activities, solicitation development, and program review, as elaborated below. BES also coordinates with DOE technology offices in the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) program, including topical area planning, solicitations, reviews, and award recommendations.

BES has robust interactions with DOE technology offices through formal and informal coordination activities. Formal coordination includes Joint Strategy Teams (JSTs) and Science and Energy Technology Teams (SETTs) that draw on expertise and capabilities stewarded by multiple DOE offices to address forefront energy challenges. BES participates in all eight of the Energy Earthshots. Historically, co-siting of research by BES and other DOE programs at the same institutions has facilitated close integration of basic and applied research. The DOE national laboratory system plays a crucial role in achieving this integration of basic and applied research.

Informal coordination includes BES program manager participation in intra-DOE information exchange and coordination on solicitations and participation in program reviews and project selections. These activities facilitate cooperation and coordination between BES and other parts of DOE, notably the energy technology offices.

Program Accomplishments

- In FY 2023, over 13,700 unique users accessed BES user facilities, [c] approximately 27 percent taking advantage of remote access, with approximately 13 percent of the users from emerging research institutions, HBCUs and MSIs.
- Two major facility upgrade projects to maintain world-leading capabilities, LCLS-II and APS-U, attained significant milestones. LCLS-II successfully achieved first light at the end of FY 2023 and the project was completed in early FY 2024. APS-U began installation of the upgraded storage ring.
- Led by one of DOE's National QIS Research Centers, the Argonne Quantum Foundry was launched to provide the Nation's QIS research community with high quality, standardized semiconductor materials, tools, and data, offering end-to-end solutions for design, testing, fabrication, and integration of new materials into quantum systems.
- The ANL-led Joint Center for Energy Storage Research (JCESR), the Batteries and Energy Storage Energy Innovation Hub, completed ten years of ground-breaking research for beyond lithium-ion batteries, with over 1,000 journal papers, nearly 100 inventions, 34 patents, and three startups, and, importantly, training for more than 330 students and postdoctoral fellows who now have careers in academia, industry, and at DOE national laboratories.
- EFRC researchers developed a new method for synthesizing mixed halide-perovskite solar cells that enables better control over the rate of crystallization, yielding higher quality materials with improved stability and performance under real world conditions.
- To understand photosynthesis, the final steps of light-driven oxidation of water to oxygen by photosystem II (PSII) were characterized at room temperature using x-ray lasers, including LCLS, revealing for the first time the atomic structure of intermediates in the final step of the PSII reaction cycle.
- Researchers demonstrated rapid and nearly complete disinfection of water containing *E. coli* using a suspended nanostructured powder exposed to direct sunlight. The powder could be removed with a simple magnet and reused in a new contaminated water sample.
- The combination of precise synthesis, operando characterization, and theory uncovered the dynamic behavior of catalytic active sites during a wide range of reactions, providing insights for designing more efficient catalysts and potentially reducing use of critical elements.
- Scientists have developed a nanoscale electron imaging method that unveils the effects of heat in materials with atomic resolution. Understanding thermal transport at this scale is of paramount importance to the field of energy conversion and quantum computing.

[c] Note that the number of users was less than prior fiscal years due to the APS outage for facility upgrades.

- First principles computations provided insight on why, surprisingly, adding salt in chemical vapor deposition of thin films used in electronics enables faster synthesis at lower temperature, with broad implications for optical, electrical, photovoltaic, and catalytic properties.
- Inspired by early experiments of Einstein and de Haas on ferromagnetism, cutting-edge imaging revealed ultrafast mechanical motion tied to a change in magnetic state in a layered material. This now measurable response enriches the toolbox for designing functional nanomechanical devices and other applications requiring ultra-precise and fast motion control.
- A tour de force of characterization tools (in situ nuclear magnetic resonance, x-ray scattering, and atomic force microscopy) has confirmed a long-held view of the multi-step crystallization process for materials with open atomic frameworks that are used in energy technologies from catalysis to carbon capture.
- Using LCLS along with quantum simulations of the reaction dynamics, for the first-time researchers directly imaged the transition state of a chemical reaction in real time, enabling better understanding of the point of no return in a chemical reaction.
- For the first time, a team of scientists demonstrated that x-rays could characterize materials at the single atom limit. This beamline combines x-rays from the APS with a scanning tunneling microscope to characterize metal and rare-earth atoms in molecular systems.
- Research led to a new software package—AtomAI—for analyzing images from electron and scanning probe microscopes that applies deep learning to conduct real-time analysis of atomic resolution data to understand materials behavior.
- The DOE EPSCoR program, designed to enhance geographic balance specifically addressing underserved communities in the DOE portfolio, transitioned to funding from SC's six major research programs. Significantly, EPSCoR added Puerto Rico and Guam to the portfolio. In FY 2023, SC provided $38 million for research at academic institutions in 21 EPSCoR states and jurisdictions. Beyond the EPSCoR program, SC strives to meet the 10 percent threshold encouraged by the CHIPS and Science Act of 2022.
- In use-inspired research, EPSCoR research led to discoveries in ion transport for extraction of metals for lithium- or sodium-ion batteries and desalination, machine learning methodologies for understanding synthesis, and new catalysts that enable sustainable hydrogen production.

Basic Energy Sciences
Materials Sciences and Engineering

Description

Materials are critical to nearly every aspect of energy generation, storage, transmission, and end-use, as well as numerous other critical technologies. Materials limitations are often a significant barrier to improved energy efficiencies, longer lifetimes of infrastructure and devices, or the introduction of new technologies for clean energy to tackle climate change. The Materials Sciences and Engineering subprogram supports research to provide the fundamental understanding and control of materials synthesis, properties, and performance that will enable solutions to wide-ranging challenges in clean energy generation, storage, and use, as well as opening new directions that are not foreseen based on existing knowledge. The research explores the origin of macroscopic material behaviors; their fundamental connections to atomic, molecular, and electronic structures; and their evolution as materials move from nanoscale building blocks to mesoscale systems. At the core of the subprogram is experimental, theoretical, computational, and instrumentation research that will enable the predictive discovery, design, and characterization of new materials with novel structures, functions, and properties.

To accomplish these goals, the portfolio includes three integrated research activities:

- **Scattering and Instrumentation Sciences Research**—Advancing science using new tools and techniques to characterize materials structure and dynamics across multiple length and time scales, including ultrafast science, and to correlate this data with materials performance under real world and extreme conditions.
- **Condensed Matter and Materials Physics Research**—Understanding the foundations of material functionality and behavior including electronic, magnetic, thermal, optical, and mechanical properties that result from material composition and quantum mechanics; and understanding the impact of external stimuli, including extreme environments, on material properties and performance.
- **Materials Discovery, Design, and Synthesis Research**—Developing the knowledge base and synthesis strategies to design and precisely assemble structures to control properties and enable discovery of new materials with unprecedented functionalities, including approaches that limit the need for critical materials, enable more effective polymer chemistries, and are learned from biological systems.

The Request continues the highest-priority fundamental research that supports the DOE mission, including research that will establish the foundational knowledge necessary to accelerate innovation to advance clean energy technologies and other national priorities. The portfolio emphasizes understanding of how to direct and control energy flow in materials systems over multiple time and length scales, and translation of this understanding to prediction of material behavior, transformations, and processes in challenging real-world systems. This will establish a foundational knowledge base for future advanced clean energy technologies and advanced industrial processes. The research supported by this subprogram explores new frontiers of emergent materials behavior; utilization of nanoscale control; and materials systems that are metastable or far from equilibrium to enable novel materials design and sustainable manufacturing. In clean energy-related research, emphasis is on carbon dioxide removal, low-carbon hydrogen production, and energy storage for both transportation and the grid. Also, critical materials research will provide foundational knowledge to enable secure and sustainable supply chains for key clean energy technologies.

Research activities in quantum materials emphasize the development of systems that realize unique properties required for QIS technologies. Materials science for microelectronics will provide the needed advances for future computing, sensors, detectors, and communication that are critical for national priorities in clean energy and for leadership in advanced research over a wide range of fields. An increasingly important aspect of materials research is the use of data science techniques to enhance the utility of both theoretical and experimental data for predictive design and discovery of materials. As an essential element of this research, this subprogram supports the development of advanced characterization tools, instruments, and techniques that can assess a wide range of space and time scales, especially in combination and under dynamic operando conditions to analyze non-equilibrium materials, conditions, and excited-state phenomena.

In addition to a diverse portfolio of single-investigator and small-group research projects, this subprogram supports Computational Materials Sciences, EFRCs, the Batteries and Energy Storage Hub program, and, in partnership with other SC programs, NQISRCs and EERCs. These research modalities support multi-investigator, multi-disciplinary research focused on forefront scientific challenges in support of the DOE clean energy mission.

This subprogram includes the DOE EPSCoR program to expand investments in early-stage clean energy and climate research for U.S. states and territories that do not historically have large federally-supported academic research programs, expanding DOE research opportunities to a broad and diverse scientific community. This subprogram also supports two additional activities aimed at cultivating an equitable and expanded science, technology, engineering, and math (STEM) education, engagement, and workforce ecosystem: the RENEW and FAIR initiatives. The RENEW initiative aims to broaden participation in underserved communities and advance equity and inclusion in SC-sponsored research. The FAIR initiative enhances research capacity for clean energy, climate, and related topics at emerging research institutions, HBCUs and MSIs.

Scattering and Instrumentation Sciences Research

Research in Scattering and Instrumentation Science supports innovative techniques and instrumentation development for advanced materials science research with scattering, spectroscopy, and imaging using electrons, neutrons, and x-rays, including development of science to understand ultrafast dynamics. These techniques provide precise and complementary information about the relationship among structure, dynamics, and properties, as evidenced by the major advances in materials sciences from DOE's world-leading electron, neutron, and x-ray scattering facilities. The importance of imaging and multimodal platforms to reveal the most critical features of a material has been a finding in several of the Basic Research Needs and BESAC reports. These tools and techniques are also critical in advancing understanding and discovery of novel quantum materials, including materials for next-generation systems to advance microelectronics and QIS. The tools and capabilities developed in this program are broadly applicable to other fields including chemistry, biology, and geoscience, and can be a key component in preparedness for biological threats.

The unique interactions of electrons, neutrons, and x-rays with matter enable a range of complementary tools with different sensitivities and resolution for the characterization of materials and other systems at length- and time-scales spanning many orders of magnitude. Included is the use of cryogenic environments to evaluate properties only occurring at low temperatures and to learn about processes and interfaces in materials that are damaged by the probes used to characterize them. As an example, to aid in the design of transformational new materials for clean energy technologies such as batteries, operando experiments contribute to understanding the atomic and nanoscale changes that lead to materials failure in non-equilibrium and extreme environments. Advances in cryogenic microscopy will support the BRaVE initiative since this instrumentation is heavily used to characterize biological systems.

Condensed Matter and Materials Physics Research

This activity supports fundamental experimental and theoretical research to discover, understand, and control novel phenomena in solid materials, generating scientific knowledge that is foundational to the BES mission. These electronic, magnetic, optical, thermal, and structural materials make up the infrastructure for clean energy technologies and innovations to tackle climate change impacts, as well as accelerator and detector technologies for SC facilities and other national priorities such as microelectronics and QIS. Also supported is research to understand the role of critical materials in determining material properties and functionality, so that they can be reduced or eliminated from key energy technology supply chains.

Experimental research in this program emphasizes discovery and characterization of materials' properties that have the potential to be exploited for new technological functionalities. Complementary theoretical research aims to explain such properties across a broad range of length- and time-scales. Theoretical research also includes development and integration of predictive theory and modeling for discovery of materials with targeted properties. Advanced computational and data science techniques, including AI/ML, are increasingly enabling knowledge to be extracted from large materials databases of theoretical calculations and experimental measurements. This program also supports the development of such databases as well as the computational tools that can take advantage of them.

This program continues to emphasize understanding and control of quantum materials whose properties result from interactions of the constituent electrons with each other, the atomic lattice, or light. The research advances the fundamental understanding of electronic, magnetic, thermal, and optical properties relevant to energy-efficient microelectronics and QIS. Activities also emphasize research to understand how materials respond to temperature, light, radiation, corrosive chemicals, and other environmental conditions.

In FY 2025, BES will continue to partner with other SC programs in the recompetition/renewal of the NQISRC funding as the original awards complete their five-year award period. Research supported by this program will include theory of materials for quantum applications in computing, communication, and sensing; device science for next-generation QIS systems, including interface science and modeling of materials performance; and synthesis, fabrication, and characterization of quantum materials, including integration into novel device architectures to explore QIS functionality.

In partnership with other SC programs, BES will continue activities to support multi-disciplinary basic research to accelerate the advancement of microelectronic technologies in a co-design innovation ecosystem, as called for by the Basic Research Needs for Microelectronics report.[d]

As part of this portfolio, the Office of Science Microelectronics Science Research Centers will comprise a network of multiple team awards, with individual awards focused on a dimension related to a common research topic for each Center. The multidisciplinary teams will include researchers from universities, national laboratories, and industry. Materials, chemistries, devices, systems, architectures, algorithms, and software will be developed in a closely integrated fashion in a co-design innovation ecosystem. The request will support two to three BES research awards that would contribute to one of up to four cross-SC Research Centers.

Materials Discovery, Design, and Synthesis Research
The predictive design, discovery, and development of new materials with desired properties has long been recognized as the engine that drives science frontiers and technology innovations. This activity aims to grow and maintain U.S. leadership in materials discovery by investing in advanced synthesis capabilities and by coupling these with state-of-the-art user facilities and advanced computational capabilities at DOE national laboratories, generating scientific knowledge that is foundational to the BES mission, including clean energy and tackling the impacts of climate change.

The BESAC report on transformative opportunities for discovery science reinforced the importance of the continued growth of synthesis science, recognizing the opportunity to realize targeted functionality in materials by controlling the synthesis and assembly of hierarchical architectures and beyond equilibrium matter. The FY 2025 Request continues support of materials discovery and synthesis research to understand the unique properties of critical materials, with the goal of reducing their use. Research directions will be inspired by recent BES reports, including low-carbon hydrogen and carbon dioxide removal. Understanding of synthesis science will enable design of new systems that are easier to efficiently convert into similar products with comparable or enhanced complexity, functionality, and value.

The portfolio supports fundamental research in solid-state chemistry to enable discovery of new functional materials and the development of new crystal growth methods and thin film deposition techniques to create complex materials with targeted structure and properties. In addition to research on chemical and physical synthesis processes, an important element of this portfolio is research to understand how to use bio-mimetic and biology-inspired approaches to design and synthesize novel materials with some of the unique properties found in nature.

Established Program to Stimulate Competitive Research (EPSCoR)
The DOE EPSCoR program funds early-stage research that supports DOE's energy mission in states and territories with historically lower levels of federal academic research funding. Eligibility determination for the DOE EPSCoR program follows the National Science Foundation's eligibility analysis. Managed by BES, the funding for the EPSCoR program is distributed among the six major research programs within SC per direction from the FY 2023 Enacted Appropriation.

The DOE EPSCoR program emphasizes research that will improve the capability of designated states and territories to conduct sustainable and nationally competitive fundamental and early-stage energy-related research; jumpstart research capabilities in designated states and territories through training scientists and engineers in energy-related areas; and build

[d] https://science.osti.gov/-/media/bes/pdf/reports/2019/BRN_Microelectronics_rpt.pdf

beneficial relationships between scientists and engineers in the designated jurisdictions and world-class national laboratories managed by the DOE.

Annual EPSCoR funding opportunities alternate between a focus on research performed in collaboration with the DOE national laboratories and a focus on larger-team implementation awards. The FY 2025 program will focus on implementation awards for development of research capacity and infrastructure, including equipment, for competitive research in EPSCoR jurisdictions. The technical scope will focus on the research topics supported by SC program offices and clean energy research broadly, expanding these important research communities. The program will continue to support other SC initiatives, including Early Career, RENEW, and FAIR.

Energy Frontier Research Centers

The EFRC research modality brings together the skills and talents of teams of investigators to combine discovery science and energy-relevant, basic research whose scope and complexity is beyond what is possible in standard single-investigator or small-group awards. These multi-investigator, multi-disciplinary centers foster, encourage, and accelerate basic research to enable transformative scientific advances and uncover new and innovative solutions to the most difficult problems in materials sciences. The EFRCs supported in this subprogram focus on: the design, discovery, synthesis, characterization, and understanding of novel, solid-state materials that convert energy into electricity; the understanding of materials and processes that are foundational for electrical energy storage; quantum materials and QIS; microelectronics; and materials for future nuclear energy and waste storage.

In FY 2025, BES will continue support for EFRC awards made in FY 2022 and FY 2024.

Energy Earthshot Research Centers

The EERC program was launched in FY 2023, building on the success of the EFRCs. Like the EFRCs, EERCs bring together multi-investigator, multi-disciplinary teams to perform energy-relevant research with a scope and complexity beyond what is possible in standard single-investigator or small-group awards. Beyond the scope of the EFRCs, the EERC program addresses the knowledge gaps that are key to realizing the stretch goals of the DOE Energy Earthshots,[e] with joint planning by SC and energy technology offices. The funding will focus on efforts to ensure that fundamental research and capabilities tackle the most challenging barriers identified in the applied research and development activities.

From a science perspective, many research gaps for the Energy Earthshots can provide a foundation for other clean energy technology challenges, including biotechnology, critical materials/minerals, energy-water, subsurface science, and materials and chemical processes under extreme conditions for nuclear applications. These gaps require multiscale computational and modeling tools, new AI/ML technologies, real-time characterization, including in extreme environments, and basic science to co-design processes and systems rather than individual materials, chemistries, and components. EERCs can cross-fertilize the ideas that emerge in one topic area to benefit others with similar challenges, accelerating scientific discovery as well as technology development.

The FY 2025 Request will continue support for the EERCs established in prior fiscal years.

Energy Innovation Hubs

The Batteries and Energy Storage Energy Innovation Hub program will continue to tackle forefront, basic scientific challenges for next-generation electrochemical energy storage. Energy Innovation Hubs focus on collaborative research to overcome key scientific barriers for major energy challenges that require large, multidisciplinary teams to provide the required science foundations and innovations. In FY 2025, BES will continue to support Batteries and Energy Storage Energy Innovation Hub awards initiated in prior years through an open recompetition of the program.

Computational Materials Sciences

Awards in this program focus on research leading to computational codes and associated experimental/computational databases for the design of materials with advanced functionalities. The research includes development of new ab initio theory, contributing the generated data to databases, as well as advanced characterization and controlled synthesis to

[e] https://www.energy.gov/energy-earthshots-initiative

provide the data to validate the computational predictions. The computational codes are designed for DOE's leadership computational facilities to take advantage of today's exascale high-performance computers. This will result in open source, robust, experimentally validated, user-friendly software that captures the essential physics of relevant materials systems.

In FY 2025, BES will continue support for awards made in prior years.

Activities and Explanation of Changes

(dollars in thousands)

FY 2023 Enacted		FY 2025 Request	Explanation of Changes FY 2025 Request vs FY 2023 Enacted
Materials Sciences and Engineering	**$548,780**	**$527,159**	**-$21,621**
Scattering and Instrumentation Sciences Research	$105,971	$96,063	-$9,908
Funding continues to focus on the development and use of advanced characterization tools to address the most challenging fundamental questions in materials science, including quantum behavior and properties. The use of multiscale and multimodal techniques to extract information on multiple length and time scales is a growing emphasis, as is the development and application of cryogenic microscopy techniques to answer open questions in physical sciences. Advanced instrumentation research can be applied to diverse national priorities, including QIS, clean energy science, advanced manufacturing, and preparedness for biological threats. Funding supports the RENEW, FAIR, and Accelerate initiatives.		The Request will continue to focus on the development and use of advanced characterization tools, including the use of multiscale, multimodal, and cryogenic techniques to extract information on multiple length and time scales. Advanced instrumentation research can be applied to diverse national priorities, including QIS, clean energy science, advanced industrial processes, and preparedness for biological threats (cryogenic microscopy). The RENEW initiative expands targeting efforts to increase participation and retention of individuals from underserved communities, and from emerging research institutions, HBCUs and MSIs in SC research activities.	Reductions will target mature research topics in the portfolio to allow expanded investments in RENEW activities, which will emphasize basic energy sciences research topics and will provide research and training opportunities for emerging research individuals from underserved communities, and from emerging research institutions, HBCUs and MSIs.

(dollars in thousands)

FY 2023 Enacted	FY 2025 Request	Explanation of Changes FY 2025 Request vs FY 2023 Enacted
Condensed Matter and Materials Physics Research $203,807	$201,644	-$2,163
Funding continues to emphasize the understanding and control of the fundamental properties of materials that are central to their functionality in a wide range of clean energy-relevant technologies, including critical materials/minerals, and for reduction of climate change impacts. Exploration of quantum materials remains a high priority, and particularly the role that these materials play in microelectronics, accelerators, and the broad emerging field of QIS. The program continues to partner with other SC program offices to support the NQISRCs that were initiated in FY 2020. Additional investments support the SC Energy Earthshots initiative, including the response of materials to environmental conditions, such as temperature, light, corrosive chemicals, and radiation, particularly in the context of future clean energy technologies.	The Request will continue to emphasize the understanding and control of the fundamental properties of materials, including critical materials, that are central to their functionality in a wide range of clean energy-relevant technologies. Exploration of quantum materials remains a high priority, and particularly the role that these materials play in microelectronics, accelerators, and QIS. The program will partner with other SC program offices in the recompetition of the NQISRCs as the original awards complete five years of research. Additional investments will support the SC Energy Earthshots initiative and awards as part of the Microelectronics Science Research Centers.	Expanded investments will focus on gaps in the current portfolio of condensed matter research that supports science foundations for DOE’s Energy Earthshots. In addition, investments in AI/ML will aim to maximize the value of data in scientific discovery. Funding will support awards as part of the Microelectronics Science Research Centers. Reductions will target mature research topics in the portfolio.

(dollars in thousands)

FY 2023 Enacted		FY 2025 Request	Explanation of Changes FY 2025 Request vs FY 2023 Enacted
Materials Discovery, Design, and Synthesis Research	$97,097	$87,547	-$9,550
Funding continues support for the design, discovery, and synthesis of novel forms of matter with desired properties and functionalities with an emphasis on advancing the fundamental science relevant to future low-carbon manufacturing and reduction of climate change impacts, including innovative approaches to scalable assembly and integration of characterization and predictive modeling. Research continues to explore science-based solutions to materials criticality. Research on bio-mimetic and biologyinspired materials is relevant to energy technologies as well as other national priorities such as preparedness for and response to biological threats. Additional investments in these topical areas focus on support for the SC Energy Earthshots initiative.		The Request will continue support for the design, discovery, and synthesis of novel forms of matter with desired properties and functionalities with an emphasis on advancing the fundamental science relevant to future low-carbon industrial processes and clean energy technologies. Research on bio-mimetic and biology-inspired materials is relevant to energy technologies as well as other national priorities such as preparedness for and response to biological threats.	Reductions will target mature research topics in the portfolio.
Established Program to Stimulate Competitive Research (EPSCoR)	$25,000	$25,000	$ —
Funding continues to support early-stage R&D, including research that underpins DOE energy technology programs, the SC Energy Earthshots initiative, and innovations for climate science. Following the previous year's focus on State-National Laboratory Partnership awards, FY 2023 emphasizes Implementation Awards to larger multiple investigator teams that develop research capabilities in EPSCoR jurisdictions. The FY 2023 funding opportunity considers new and renewal proposals. Investment continues in early career research faculty from EPSCoR-designated jurisdictions and in coinvestment with other programs for awards to eligible institutions.		The Request will continue to support early-stage R&D, including research that underpins DOE energy technology programs, the SC Energy Earthshots initiative, and innovations for climate science. Following the previous year's focus on State-Lab partnership awards, FY 2025 will emphasize Implementation awards, larger multiple investigator teams that develop research capabilities, including investment in instrumentation, in EPSCoR jurisdictions. Investment will continue in early career research faculty from EPSCoR-designated jurisdictions and in co-investment with other initiatives such as FAIR, RENEW, and Energy Earthshots for awards to eligible institutions.	Funding will focus on Implementation Awards, with the aim to improve the capability of designated states and territories to conduct sustainable and nationally competitive fundamental and early-stage energy-related research.

(dollars in thousands)

FY 2023 Enacted		FY 2025 Request	Explanation of Changes FY 2025 Request vs FY 2023 Enacted
Energy Frontier Research Centers	$65,000	$65,000	$ —
Funding provides the fourth year of support for the four-year EFRC awards that were made in FY 2020 and the second year of support for awards that were made in FY 2022.		The Request will provide the fourth year of support for four-year EFRC awards that were made in FY 2022 and the second year of funding for awards made in FY 2024 in a broad range of topics relevant to clean energy and other national priorities.	Technical emphasis for the EFRC program will continue to include research directions identified in recent strategic planning activities related to clean energy, QIS, microelectronics, and other national priorities.
Energy Earthshot Research Centers	$12,500	$12,500	$ —
Funding supports a FOA to be released by SC (BES, ASCR, BER), in coordination with the DOE Technology Offices, for the initial cohort of EERCs. EERCs will bring together the multi-investigator, multi-disciplinary teams necessary to perform energy-relevant research that bridges the gap between basic research and applied research and development activities. They emphasize the innovations at the basic-applied interface required to advance the current Energy Earthshot topics and those announced by DOE prior to release of the FOA.		The Request will provide support for the EERCs that were initiated in prior fiscal years.	Funding will continue to support development of science foundations for DOE's Energy Earthshots.
Energy Innovation Hubs	$25,913	$25,913	$ —
Funding supports an open re-competition of the Batteries and Energy Storage Hub program.		The Request will support the third year of funding for new Batteries and Energy Storage Hub awards initiated in prior years through an open competition.	No change.

(dollars in thousands)

FY 2023 Enacted		FY 2025 Request		Explanation of Changes FY 2025 Request vs FY 2023 Enacted
Computational Materials Sciences	$13,492		$13,492	$ —
Funding continues research that focuses on development of computational codes and associated experimental and computational databases for the predictive design of functional materials. The research includes development of new ab initio theory, populating databases, and advanced characterization and controlled synthesis to validate the computational predictions. The goal is open source, validated software that uses today's DOE's leadership computational facilities and is poised to take advantage of tomorrow's exascale high-performance computers. BES plans to issue a FOA in FY 2023 to recompete awards made in FY 2019.		The Request will support the third year of funding for awards made in FY 2023 and the second year of funding for awards planned for FY 2024. The Request will continue to support research aimed at the development of open source, validated software that takes advantage of DOE's leadership computing facilities.		No change.

Note:

- *Funding for the subprogram above, includes 3.65 percent of research and development (R&D) funding for the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) Programs, excluding facility operations.*

Basic Energy Sciences
Chemical Sciences, Geosciences, and Biosciences

Description

Development of innovative clean energy technologies relies on understanding and ultimately controlling transformations of energy among forms and conversions of matter across multiple scales starting at the atomic level. The Chemical Sciences, Geosciences, and Biosciences subprogram supports research to discover fundamental knowledge of chemical reactivity and energy conversion foundational to energy-relevant chemical processes, such as catalysis, synthesis, separations, and light-driven chemical transformations. The research addresses how physical and chemical phenomena at the scales of electrons, atoms, and molecules control complex and collective behavior of macroscopic-scale energy and matter conversion systems. Fundamental knowledge developed through this subprogram can enable ground-breaking science to tailor chemical transformations with atomic and molecular precision. The challenge is to achieve predictive understanding of complex chemical, geochemical, and biochemical systems at the same level of detail now known for simpler molecular systems.

To address these challenges, the portfolio includes coordinated research activities in three areas:

- **Fundamental Interactions Research**—Discover the foundational factors controlling chemical reactivity and dynamics based on the understanding of fundamental quantum interactions in gases, condensed phases, and at interfaces.
- **Chemical Transformations Research**—Understand and control the mechanisms of chemical catalysis, synthesis, separation, stabilization, and transport in complex chemical and subsurface systems, from atomic to geologic scales.
- **Photochemistry and Biochemistry Research**—Elucidate the molecular mechanisms of the capture of light energy and its conversion into electrical and chemical energy through biological and chemical pathways.

The Request continues the highest-priority fundamental research, including scientific knowledge to accelerate innovation that can reduce climate change impacts and advance clean energy technologies, infrastructure, and a circular economy. Support will continue for research to discover and develop chemical processes for low-carbon, efficient, and circular approaches for advanced industrial processes and for reduced dependence on critical materials and minerals. Fundamental biochemistry will discover principles that could enable biomimetic and biohybrid clean energy systems and guide new biotechnology approaches. Research on molecular science will advance innovations for microelectronics and increase understanding of the phenomena relevant to QIS and quantum computing. Integration of data science and computational chemistry will provide tools and infrastructure needed for shared data repositories.

The subprogram advances fundamental science through a diverse portfolio of research including single investigators, small groups, and large multi-investigator, cross-disciplinary teams through EFRCs, the Fuels from Sunlight Energy Innovation Hub program, and Computational Chemical Sciences (CCS). The subprogram also partners across SC to support the NQISRCs and EERCs. This subprogram also supports two activities aimed at cultivating an equitable and expanded STEM education, engagement, and workforce ecosystem: the RENEW and FAIR initiatives. The RENEW initiative aims to broaden participation in underserved communities and regions and advance equity, and inclusion in SC-sponsored research. The FAIR initiative enhances research capacity for clean energy, climate, and related topics at emerging research institutions, HBCUs and MSIs.

<u>Fundamental Interactions Research</u>

This activity emphasizes structural and dynamical studies of atoms, molecules, and nanostructures, and the description of their interactions in full quantum detail. The goal is to achieve a complete understanding of reactive chemistry in the gas phase, in condensed phases, and at interfaces. This activity provides leadership for ultrafast chemistry and advances ultrafast tools and approaches to probe and control chemical processes. Research is conducted at the boundary of chemistry and physics to understand chemical, physical, and electron- and photon-driven processes at interfaces and in liquids. This activity also supports theory and computation for accurate descriptions of molecular reactions and chemical dynamics, optimal use of exascale computing facilities, and potential application of future quantum computers to computational quantum chemistry. These efforts provide the foundational knowledge and state-of-the-art experimental and computational tools necessary to advance the subprogram's research activities and the BES mission, including clean energy approaches that can reduce impacts contributing to climate change.

In FY 2025, BES will continue to partner with other SC programs in the recompetition/renewal of the NQISRC funding as the original awards complete their five-year award terms. Research in this program will advance the current state-of-the-art science and technology toward realizing the full potential of quantum-based applications, from computing to communication to sensing and may include cross-cutting research such as sensors, quantum emulators/simulators, and enabling technologies that can pave the path to quantum computing in the longer term.

Continuing ongoing activities, FY 2025 research in microelectronics will unravel the complex mechanisms of chemical reactions at interfaces to inform the design and synthesis of new materials.[f] Research in clean energy will address basic science for novel synthesis, processing, modeling, operando characterization, and validation approaches. The Fundamental Interactions activity will continue to advance data science and computational approaches for chemical sciences with a focus on computational chemistry tools to generate scientific knowledge foundational to the BES mission.

SC Microelectronics Science Research Centers will comprise a network of multiple team awards, with individual awards focused on a dimension related to a common research topic for each Center. The multidisciplinary teams will include researchers from universities, national laboratories, and industry. Chemistries, materials, devices, systems, architectures, algorithms, and software will be developed in a closely integrated fashion in a co-design innovation ecosystem. The request will support two to three BES research awards that would contribute to one of up to four cross-SC Research Centers.

<u>Chemical Transformations Research</u>
This activity seeks fundamental knowledge of chemical reactivity, matter and charge transport, and chemical separation and stabilization processes that are foundational for development of future clean energy technologies and for innovations to mitigate or adapt to climate change. Fundamental research in this activity spans catalysis science, separation science, heavy element chemistry, and geosciences. This research advances the understanding of charge transport and reactivity, which determine the kinetics of electrocatalytic, separation, and geochemical processes; identifies mechanisms for catalytic efficiency and selectivity, critical materials recovery, and sustainable conversion of energy resources; explores the influence of complex interfaces on chemical transformations; develops mechanistic insights needed to control reaction pathways in diverse catalytic, separation, and geological environments; and develops understanding of chemistry in subsurface and aqueous systems important in sustainable chemical processes.

In FY 2025, this activity will continue to support efforts central to transformative approaches for clean energy,[g] including predictive design of catalytic and separations processes for circular use of natural and synthetic resources with atom and energy efficiency.[h] In support of the Energy Earthshots initiative, this activity will focus on discovery and design of sustainable cycles for carbon and hydrogen–including enhanced carbon separation from dilute and concentrated sources and clean energy cycles of hydrogen generation, storage, and use–and provide fundamental knowledge of subsurface processes such as mineralization, crack propagation, and rock fracture to foster innovative clean energy subsurface technologies. Research will continue to address critical materials with a focus on novel approaches for resource identification and extraction, selective separation, and substitution of critical elements. Research will also investigate the unique quantum phenomena enabled by rare earth elements and actinides. The use of data science and AI/ML approaches will be emphasized to accelerate the generation and propagation of scientific knowledge foundational to the BES mission.

<u>Photochemistry and Biochemistry Research</u>
This activity supports research on the molecular mechanisms of light energy capture and its conversion into electrical and chemical energy in both natural and man-made systems. This mechanistic understanding can inspire strategies to control reaction pathways for clean energy conversions and to tackle climate change. This activity integrates research at the interface of chemistry, physics, and biology and plays a leadership role in the support of basic research in both natural photosynthesis and solar photochemistry. Research explores the dynamic mechanisms of charge transport and reactivity to understand absorption, transfer, and conversion of energy across spatial and temporal scales and redox interconversion of atoms and small molecules (e.g., carbon dioxide/methane, nitrogen/ammonia, and protons/hydrogen) important for clean fuels. Research aims to understand complex interfaces and aqueous environments in enzyme function, natural and artificial

[f] https://science.osti.gov/-/media/bes/pdf/reports/2019/BRN_Microelectronics_rpt.pdf
[g] https://science.osti.gov/-/media/bes/pdf/reports/2020/Transformative_Mfg_Brochure.pdf
[h] https://science.osti.gov/-/media/bes/pdf/reports/2020/Chemical_Upcycling_Polymers.pdf

membranes, and nano- to meso-scale structures. Research also examines the effects of ionizing radiation on chemical reactions in extreme environments, providing insights for remediation, fuel-cycle separation, and nuclear reactor design.

In FY 2025, research will continue to establish a molecular-level understanding of biochemical and photochemical processes. BES biochemistry and biophysics research will discover and design chemical processes and complex structures for innovations in clean energy technologies, microelectronics, and climate change mitigation, including bio-inspired and biohybrid systems with desired functions and properties. In support of the Energy Earthshots initiative, research includes new approaches for harnessing solar energy for chemical conversions, providing knowledge for carbon-neutral hydrogen production technologies and potentially for use of photo-driven quantum coherence to enhance fuel generation. Research will also address challenges for reducing use of critical and rare earth elements in light absorbers and catalysts. This activity supports the RENEW and FAIR initiatives to build strong programs at emerging research institutions, underserved communities, HBCUs and MSIs, and to enhance research on clean energy and climate.

Energy Frontier Research Centers

The EFRC research modality brings together the skills and talents of teams of investigators to combine discovery science and energy-relevant, basic research whose scope and complexity is beyond what is possible in standard single-investigator or small-group awards. These multi-investigator, multi-disciplinary centers foster, encourage, and accelerate basic research to enable transformative scientific advances and uncover new and innovative solutions to the most difficult problems in chemical sciences, geosciences, and biosciences. The EFRCs supported in this subprogram focus on the design, discovery, characterization, and control of chemical, biochemical, and geological processes for improved electrochemical conversion and storage of energy; the understanding of catalytic chemistry and biochemistry that are foundational for fuels, chemicals, separations, and upcycling; interdependent energy-water issues; QIS; future nuclear energy and the chemistry of waste processing; and the advanced interrogation and characterization of the earth’s subsurface.

In FY 2025, BES will continue support for EFRC awards made in FY 2022 and FY 2024.

Energy Earthshot Research Centers

SC launched the EERC program in FY 2023, building on the success of the EFRCs. Like the EFRCs, EERCs bring together multi-investigator, multi-disciplinary teams to perform energy-relevant research with a scope and complexity beyond what is possible in standard single-investigator or small-group awards. Beyond the scope of the EFRCs, the EERC program addresses the knowledge gaps that are key to realizing the stretch goals of the DOE Energy Earthshots,[i] with joint planning by SC and energy technology offices. In FY 2025, the funding will focus efforts to ensure that fundamental research and capabilities tackle the most challenging barriers identified in the applied research and development activities.

From a science perspective, many research gaps for the Energy Earthshots can provide a foundation for other clean energy technology challenges, including biotechnology, critical materials/minerals, energy-water, subsurface science, and materials and chemical processes under extreme conditions for nuclear applications. These gaps require multiscale computational and modeling tools, new AI/ML technologies, real-time characterization, including in extreme environments, and basic science to co-design processes and systems rather than individual materials, chemistries, and components. EERCs can cross-fertilize the ideas that emerge in one topic to benefit others with similar challenges, accelerating scientific discovery as well as technology development.

Energy Innovation Hubs

Energy Innovation Hubs focus on collaborative research to overcome key scientific barriers for major energy challenges that require large, multidisciplinary teams to provide the required science foundations and innovations. The Fuels from Sunlight Hub program addresses both new directions and long-standing challenges identified in the report from the Liquid Solar Fuels Roundtable.[j]

The two Fuels from Sunlight Hub awards conduct fundamental research on key scientific challenges for solar fuels production that uses solar energy, water, and carbon dioxide as the only inputs. These awards received the final year of

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[i] https://www.energy.gov/energy-earthshots-initiative

[j] https://science.osti.gov/-/media/bes/pdf/reports/2020/Liquid_Solar_Fuels_Report.pdf

funding for their initial five-year award term in FY 2024. As part of BES oversight, both projects have been evaluated via peer review on an annual basis since their initiation. Given the latest review results, the overall scientific and technological progress of both projects, and the distinct role of the Hub research in the BES portfolio, the Department will consider both awards for renewal in FY 2025 and make renewal determinations based on the outcome of external peer review. Renewals would allow the projects to capitalize on their achievements during the initial funding period and to further advance research efforts addressing critical needs in solar fuels development.

Computational Chemical Sciences

The CCS supports basic research to develop validated, open-source codes and associated experimental/computational databases for modeling and simulation of complex chemical processes and phenomena and that can take advantage of today's exascale high-performance computers. This research supports a publicly accessible website[k] of open source, robust, validated, user-friendly software that captures the essential physics and chemistry of relevant chemical systems. The goal is use of these codes/data by the broader research community and by industry to dramatically accelerate chemical research in the U.S.

In FY 2025, BES will recompete the CCS awards from FY 2021 and FY 2022. BES will prioritize transitioning Exascale Computing Project (ECP) researchers and use of ECP software for research in this recompetition.

General Plant Projects

General Plant Projects funding provides for minor new construction, for other capital alterations and additions, and for improvements to land, buildings, and utility systems to maintain the productivity and usefulness of DOE-owned facilities and to meet requirements for safe and reliable facilities operation.

[k] https://ccs-psi.org/

Activities and Explanation of Changes

(dollars in thousands)

FY 2023 Enacted		FY 2025 Request	Explanation of Changes FY 2025 Request vs FY 2023 Enacted
Chemical Sciences, Geosciences, and Biosciences	**$501,263**	**$479,779**	**-$21,484**
Fundamental Interactions Research	$127,985	$133,416	+$5,431
Funding continues to develop forefront ultrafast approaches, with emphasis on the use of x-ray free electron lasers, including LCLS and its upgrades. Gasphase research continues studies of how reactive intermediates impact reaction pathways. Continued emphasis is placed on quantum phenomena underlying QIS, such as coherence and entanglement. Research expands efforts to understand and control chemical processes and quantum phenomena at the molecular level. In FY 2023, research continues to emphasize understanding and control of interfacial chemical conversion mechanisms for clean energy applications and of designing and synthesizing new materials relevant to microelectronics. This activity continues to develop advanced theoretical and computational approaches that can be scaled to operate on exascale computers. Development of data science methods increase to enable novel approaches for knowledge discovery. This activity provides continued support for the NQISRCs established in FY 2020.		The Request will continue to develop innovative ultrafast approaches, with emphasis on use of x-ray free electron lasers; determine how reactive intermediates affect reaction pathways; and characterize quantum phenomena underlying QIS. Research will also target the understanding and control of interfacial chemical conversion mechanisms and quantum phenomena to advance clean energy technologies, climate mitigation technologies (e.g., emissions mitigation), AI/ML, and microelectronics. This activity will generate and use advanced theoretical and computational approaches that can take advantage of exascale computing capabilities and data science methods for knowledge discovery. The program will partner with other SC program offices in the recompetition/renewal of the NQISRCs as the original awards complete five years of research. Additional investments will support awards as part of the Microelectronics Science Research Centers.	Expanded investments will include additional support for microelectronics and AI/ML. Investments will emphasize basic research related to clean energy and climate. Funding will support awards as part of the Microelectronics Science Research Centers. Reductions will target mature research topics in the portfolio.

(dollars in thousands)

FY 2023 Enacted	FY 2025 Request	Explanation of Changes FY 2025 Request vs FY 2023 Enacted
Chemical Transformations Research $129,651	$115,578	-$14,073
Funding continues supporting fundamental research to understand catalytic mechanisms for thermo- and electro-chemical conversions important in clean energy and advanced manufacturing technologies, including chemical upcycling of polymers, and in innovations to reduce climate change impacts. Separation science research continues to focus on innovative mechanisms for high-efficiency processes, including reactive and electro-separations, and novel solvents. Heavy element research continues to deepen understanding of actinide speciation and reactivity and fundamental theories of f-electron systems. Geosciences research continues to elucidate subsurface phenomena, such as mineralization and rock fracture propagation under extreme subsurface conditions. Areas for increased emphasis include atomically precise synthesis of new catalysts and studies of chemical processes required to develop clean energy technologies: multiscale phenomena in extreme and constrained environments in the subsurface; separations and extraction of rare earth elements from complex and dilute mixtures; and alternative approaches that reduce use of critical elements.	The Request will continue fundamental research to understand catalytic mechanisms for thermo- and electro-chemical conversions and to develop atomically precise synthesis of catalysts important for clean energy and climate change mitigation. Research in separation science will continue to focus on innovative mechanisms for high-efficiency chemical separations and processes. Heavy element research will continue to advance understanding of actinide speciation and reactivity and f-electron systems. Geosciences research will continue to reveal subsurface phenomena, such as mineralization and rock fracture propagation, that can be foundational to climate mitigation strategies. Research will continue to advance the separations and extraction of rare earth elements from complex and dilute mixtures and the development of alternative approaches to reduce use of critical elements. Additional investments will support the SC Energy Earthshots initiative.	Reductions will target mature research topics in the portfolio. Expanded investments will include support for the SC Energy Earthshots initiative, including innovations in catalysis, geosciences, and separations. Investments will emphasize basic research related to clean energy, climate, and microelectronics.

(dollars in thousands)

FY 2023 Enacted		FY 2025 Request	Explanation of Changes FY 2025 Request vs FY 2023 Enacted
Photochemistry and Biochemistry Research	$130,877	$118,035	-$12,842
Funding continues support of core research to understand physical, chemical, biophysical, and biochemical processes of light energy capture and conversion. Studies of light absorption, energy transfer, charge transport, separation processes, and photocatalysis provides fundamental insights that can lead to innovations in the design of new clean energy systems and processes and in reduction of climate change impacts. Study of biochemical processes and structures provides a foundation for bio-inspired, biohybrid, and biomimetic systems with desired functions and properties, including design of efficient catalysts and reaction pathways. Solar fuels research continues to address the molecular mechanisms of photon capture, charge transport, product selectivity and separation from non-target molecules, and the reduction of critical elements in photoabsorbers and catalysts. Biological and chemical studies investigates how quantum phenomena affect energy conversion efficiency and fidelity. Funding supports the SC Energy Earthshots, FAIR, RENEW, and Accelerate initiatives.		The Request will continue research on physical, chemical, biophysical, and biochemical processes of light energy capture and conversion which could inspire innovations for clean energy and climate change mitigation. Biochemical studies can provide insights for bio-inspired and biohybrid systems with desired functions and properties, as well as for new strategies for artificial photosynthesis, carbon dioxide removal, and biotechnology. Solar fuels research will address molecular mechanisms of photon capture, charge transport, product selectivity, and reduced critical element use in photoabsorbers and catalysts. Biological and chemical studies will examine the role of quantum phenomena in energy conversion. The FAIR and RENEW initiatives continue efforts to increase participation and retention of researchers from underserved communities, as well as from emerging research institutions, HBCUs and MSIs in SC research activities. Additional investments will support the RENEW and SC Energy Earthshots initiatives.	Reductions will target mature research topics in the portfolio. Expanded investments will include support for the SC Energy Earthshots initiative including innovations in solar and bio-based fuels and other products and will broaden RENEW activities to provide research and training opportunities for emerging research institutions, HBCUs, MSIs and underserved communities.
Energy Frontier Research Centers	$65,000	$65,000	$ —
Funding provides the final year of support for four-year EFRC awards that were made in FY 2020 and the second year of support for awards that were made in FY 2022.		The Request will provide the fourth year of support for four-year EFRC awards that were made in FY 2022 and the second year of funding for awards made in FY 2024 in a broad range of topics relevant to clean energy and other national priorities.	Technical emphasis for the EFRC program will continue to include research directions related to clean energy, QIS, microelectronics, and other national priorities.

(dollars in thousands)

FY 2023 Enacted		FY 2025 Request	Explanation of Changes FY 2025 Request vs FY 2023 Enacted
Energy Earthshot Research Centers	$12,500	$12,500	$ —
Funding supports a FOA to be released by SC (BES, ASCR, BER), in coordination with the DOE Technology Offices, for the initial cohort of EERCs. EERCs will bring together the multi-investigator, multi-disciplinary teams necessary to perform energy-relevant research that bridges the gap between basic research and applied research and development activities. They emphasize the innovations at the basic-applied interface required to advance the current SC Energy Earthshot topics and those announced by DOE prior to release of the FOA.		The Request will provide support for the EERCs that were initiated in prior fiscal years.	Funding will continue to support the development of science foundations for DOE's Energy Earthshots.
Energy Innovation Hubs	$20,758	$20,758	$ —
Funding continues support of fundamental research to address both long-standing and emerging new scientific challenges for solar fuels generation. Research continues to focus on innovative artificial photosynthesis approaches to generate liquid fuels using only sunlight, carbon dioxide, and water as inputs. Experiment and theory are integrated for the design of processes, components, and systems for selective, stable, and efficient liquid solar fuels production for clean energy.		The two Hub awards will be considered for renewal of up to five years. Renewal would allow each project to capitalize on its achievements during the initial funding period and to further advance research efforts on solar fuels generation for clean energy, climate change mitigation, and sustainability. The Department will base its renewal decisions on research progress, external peer review, and programmatic priorities.	The research scope of the renewal projects will build on the accomplishments of the first phase of these Hub awards and continue fundamental research on innovative artificial photosynthesis approaches for liquid fuels generation using only sunlight, carbon dioxide, and water as inputs.
Computational Chemical Sciences	$13,492	$13,492	$ —
Funding continues CCS awards made in FY 2021 and FY 2022, with ongoing research to develop public, open-source codes for future exascale computer platforms.		The Request continues funding to develop public, validated, open-source software that takes advantage of DOE's leadership computing facilities. BES plans to issue a FOA in FY 2025 to recompete awards made in FY 2021 and 2022. BES will prioritize transitioning ECP researchers and software utilization into these research efforts.	Funding will continue to support research focused on the development of computational codes and associated experimental and computational databases for the predictive design of chemical processes and assemblies.

(dollars in thousands)

FY 2023 Enacted		FY 2025 Request	Explanation of Changes FY 2025 Request vs FY 2023 Enacted
General Plant Projects	$1,000	$1,000	$ —
Funding supports minor facility improvements at Ames Laboratory.		The Request will support minor facility improvements at Ames National Laboratory.	No change.

Note:
- *Funding for the subprogram above, includes 3.65 percent of research and development (R&D) funding for the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) Programs, excluding facility operations.*

Description

The Scientific User Facilities subprogram supports operation of a geographically diverse suite of major research facilities that provide unique tools to thousands of researchers from a wide diversity of universities, industry, and government laboratories to advance a broad range of sciences. The BES user facilities portfolio consists of a complementary set of intense x-ray sources, neutron scattering facilities, and research centers for nanoscale science. These facilities allow researchers to probe materials in space, time, and energy with the resolution to interrogate the inner workings of matter to help understand the fundamental aspects of the natural world. Operated on an open access, competitive, merit review basis, scientists from every state can utilize the facilities' capabilities and sophisticated instrumentation.

The 12 BES scientific user facilities collectively contribute to important scientific results across basic and applied research in chemistry, physics, geology, materials science, environmental science, biology, and biomedical science that can lead to the discovery and design of advanced materials and novel chemical processes with broad societal impacts. Before the COVID-19 pandemic, more than 16,000 scientists and engineers in many fields of science and technology used BES scientific facilities annually. In FY 2023, user populations at most BES user facilities approached or exceeded pre-pandemic levels.

During the pandemic, user facilities were available mainly through remote access with the priority to support the development of potential therapeutic drugs and vaccines through structural studies of the proteins of the SARS-CoV-2 virus, which causes COVID-19. The BES facilities continue to support ongoing research efforts to evolve the tools and expertise needed for future public health challenges. In FY 2025, continued support to enhance user capabilities for research on biological threats is included in the BRaVE initiative.

User facilities conduct hundreds of experiments simultaneously around the clock, generating vast quantities of raw experimental data that must be stored and analyzed to translate the data into information to yield answers to important scientific questions. The data challenges continue to grow as new capabilities and advanced detector technologies come online. Data science and AI/ML methods coupled with advanced computing hardware are required to address these challenges and get the highest value data from user experiments. There are also AI/ML opportunities to improve the efficiency and reliability of accelerator and instrument operations. In FY 2025, there is increased investment to support the research needed to realize these opportunities in AI/ML.

Maintaining world-leading capabilities is crucial for competitiveness as advances in tools and instruments often drive scientific discovery. Major upgrades to BES facilities are supported through line-item construction and MIEs, including support for new/upgraded x-ray and neutron experimental stations and forefront nanoscience instrumentation. The subprogram also supports research in accelerator and detector development to explore technology options for the next generations of x-ray and neutron sources. Keeping BES accelerator-based facilities at the forefront requires continued, transformative advances in accelerator science and related technologies.

The FY 2025 Request supports user facilities at 90 percent of the operational budget requirements determined by the user facilities. Base requirements for operating user facilities continue to increase due to the steady rise in the cost of staff, utilities, maintenance, and materials; evolution of the user needs for remote use; increased data and computational costs; and transitioning of new capabilities from facility upgrades to operations. While requiring additional staff and capabilities, remote use of the facilities allows access to researchers from institutions, underserved regions, and companies that otherwise would not be able to take advantage of these resources to advance their programs and products. Funding at the 90 percent level will require a careful balance to meet costs to ensure safe, robust operations and world-leading user access.

<u>X-Ray Light Sources</u>

X-rays are an essential tool for studying the structure of matter and have long been used to see things that visible light cannot resolve, such as the arrangement of atoms in metals, semiconductors, biological molecules, and other materials and chemical systems. Beyond structure, x-rays are critical tools for assessing dynamics as materials and chemistries evolve. Large-scale light source facilities have vastly enhanced the utility of existing x-ray techniques such as diffraction, spectroscopy, and imaging, and have given rise to entirely new ways to do experiments that would not otherwise be feasible with conventional x-ray machines. Owing to their broadly tunable wavelengths (from the infrared to hard x-rays), coherence, ultrafast pulses, and control of the polarization, light source facilities are incisive probes for advanced research in physical and chemical sciences, materials, metrology, geosciences, environmental sciences, and life sciences.

BES operates five light sources, including a free electron laser, the LCLS at SLAC, and four storage ring-based sources—the ALS at LBNL, the APS at ANL, SSRL at SLAC, and NSLS-II at BNL. BES provides funding to support facility operations, technical support, computational tools required to translate data into understanding of phenomena, and user program administration to enable cutting-edge research at these facilities, which are made available to all researchers with access determined via peer review of user proposals. All facilities have extensive outreach efforts to ensure that researchers have fair and equitable access for their science and engineering research regardless of the focus of their research (these are multidisciplinary research facilities), their geographical location, or the size of their institution.

Upgrade projects are underway for the APS, ALS, and LCLS to ensure ongoing world leadership for these facilities. Since completing construction of NSLS-II in FY 2015, the initial suite of seven beamlines has expanded to the current 29 beamlines with three under construction, and room for about 30 more. To adopt the most up-to-date technologies and provide the most advanced capabilities, BES has a phased approach to new beamlines at NSLS-II, as was done for other BES facilities. The NSLS-II Experimental Tools-II (NEXT-II) MIE project, started in FY 2020, provides three best-in-class beamlines to support the needs of the U.S. research community. In FY 2024, planning and conceptual design funds were requested for NEXT-III, a line-item construction project to deliver the next cadre of beamlines.

In FY 2025, preliminary planning will continue for future APS, ALS, and SSRL beamline MIEs.

High-Flux Neutron Sources
BES supports two neutron sources at ORNL, HFIR and SNS. Neutron sources are used to understand the factors that determine the properties and functions of matter and provide foundational insights for development of new materials and molecules with desired functionality. Thermal and cold neutrons are a unique tool for the study of atomic-scale structure and dynamics. The wavelength and energy of neutrons are similar to interatomic distances and elementary excitations in materials, allowing atomic-resolution studies of structure and an investigation of material dynamics. As they carry no charge, neutrons can assess bulk properties. Critically, neutrons can discriminate different isotopes of the same element, making them a unique probe to resolve, for example, the location of hydrogen atoms in organic and biological materials via isotope substitution of deuterium for hydrogen. In addition, their magnetic moments allow investigation of magnetism, important for electronic technologies and systems.

The HFIR generates neutrons via fission. HFIR operates at 85 megawatts and provides state-of-the-art facilities for neutron scattering, isotope production, materials irradiation, and neutron activation analysis. It is the world’s leading production source of elements heavier than plutonium for medical, industrial, and research applications. There are 12 neutron scattering beamlines in the user program at HFIR, which include state-of-the-art instruments for spectroscopy, diffraction, imaging, and small angle scattering. In FY 2025, operations funding will continue to support efforts to replace the beryllium reflector at HFIR. In addition, funding is requested to continue planning, design, R&D, analysis, engineering, and prototyping to advance the replacement of the aging HFIR pressure vessel.

The SNS uses a different approach to produce neutron beams, where an accelerator generates proton pulses that strike a heavy-metal target such as mercury. As a result of impacts, cascades of neutrons are produced in a process known as spallation. The SNS is the world’s brightest pulsed neutron facility, and presently offers 19 beamlines. This is a world-leading suite of instruments for very high-resolution spectroscopy and diffraction, reflectometry, spin echo, and small angle spectrometers. All the SNS instruments are in extreme demand by U.S. researchers and world-wide in a very broad range of scientific disciplines. Current construction projects at SNS focus on maintaining world-leadership for neutron scattering.

At both HFIR and SNS, investments will advance data science, AI/ML, and computing hardware to plan experiments, analyze data, and efficiently operate the accelerator, reactor, and beamlines. In addition, support will continue development of new tools for biopreparedness (under the BRaVE initiative).

Nanoscale Science Research Centers

Developments at the nanoscale are foundational for delivery of remarkable scientific discoveries that transform our understanding of energy and matter to advance national priorities and energy security. The NSRCs provide the tools and capabilities for experimental and computational research that lead to technology innovations, new experimental tools, and new computational and modelling capabilities. Distinct from the x-ray and neutron sources, NSRCs comprise a suite of smaller unique tools and platforms, as well as expert scientific staff that enable and advance probing, manipulating, and assembling single atoms, clusters of atoms, and molecular structures for transformative science.

The five NSRCs are the Center for Nanoscale Materials (CNM) at ANL, the Center for Functional Nanomaterials (CFN) at BNL, the Molecular Foundry (MF) at LBNL, the Center for Nanophase Materials Sciences (CNMS) at ORNL, and the Center for Integrated Nanotechnologies (CINT) at SNL and LANL. Each center has unique and distinct expertise and capabilities for synthesis and assembly; theory, modeling, and simulation; imaging and spectroscopy, including electron and scanning probe microscopy; and nanostructure fabrication and integration. Selected thematic areas include quantum materials, next generation semiconductors, nanoscale photonics, catalysis, and soft/biological materials. These facilities include clean rooms, nanofabrication resources (crucial for semiconductor and QIS research), one-of-a-kind signature tools, custom advanced instrumentation laboratories, and unique AI/ML and data science analytical capabilities. Operating funds ensure cutting-edge research capabilities, technical support, and administration of the user program, which serves academic, government, and industry researchers with open access determined through external peer review of user proposals.

Going forward, the NSRCs will continue to spearhead the development of flexible infrastructure and enabling capabilities for materials synthesis, device fabrication, metrology, modeling, and simulation. Investments will focus on evolving these capabilities to address the most pressing national needs, including clean energy and next generation tools, including AI/ML.

Other Project Costs

The total project cost (TPC) is comprised of total estimated cost (TEC) and OPC. TEC includes post-Critical Decision (CD)-1 costs for engineering; the acquisition of equipment; and construction/fabrication. OPC represents all other costs incurred during the initiation and definition phase for planning, conceptual design, research, and development, and during the execution phase for startup and commissioning. OPC is always funded via operating funds.

Major Items of Equipment

BES supports MIE projects to ensure the continual development and upgrade of major scientific facility capabilities, by fabricating upgraded and new stand-alone instruments and capabilities at X-Ray Light Sources, High-Flux Neutron Sources, and NSRCs.

Research

This activity supports research from conceptual studies of accelerator physics and instrumentation to their translation into components or techniques that improve BES user facilities and maintain international competitiveness. Production of beams with increased average flux/brightness and detection tools responsive to the high beam intensities are required components for the advancement of light and neutron sources. Research on superconducting undulators will focus on increasing magnetic fields and eliminating the use of liquid helium, reducing cost and environmental impact. Higher beam availability is needed to respond to the increasing number of facility users, requiring research on techniques to support multiple beamlines simultaneously. Detectors require higher computational capabilities per pixel, improved readout rates, radiation hardness, and better energy and temporal resolutions. Higher neutron-flux capabilities at the SNS will demand tight control of beam losses and detectors designed for advanced neutron imaging. BES coordinates with the SC Office of Accelerator R&D and Production on crosscutting research and technology areas.

Investments will continue to support the development of data science methods and tools to address data and information challenges. Funding continues for the RENEW initiative that provides undergraduate and graduate training at DOE national laboratories and user facilities for individuals from HBCUs and MSIs. Investment will also support the BRaVE initiative, which will maintain and evolve capabilities at user facilities related to responsiveness to biological threats.

Activities and Explanation of Changes

(dollars in thousands)

FY 2023 Enacted		FY 2025 Request	Explanation of Changes FY 2025 Request vs FY 2023 Enacted
Scientific User Facilities (SUF)	**$1,190,757**	**$1,391,847**	**+$201,090**
X-Ray Light Sources	$599,498	$790,347	+$190,849
Funding supports operations at five BES light sources (LCLS, APS, ALS, NSLS-II, and SSRL).		The Request will support operations at five BES light sources (LCLS, APS, ALS, NSLS-II, and SSRL). Development of capabilities for biopreparedness, computational techniques, and data will continue.	Funding will support LCLS, APS, ALS, NSLS-II and SSRL operations at 90 percent of required funding, accounting for inflation, supply chain costs, staffing support, remote operations, and costs for operation of new/upgraded capabilities.
High-Flux Neutron Sources	$315,740	$364,692	+$48,952
Funding supports operations at SNS and HFIR.		The Request will support operations at SNS and HFIR (including ongoing funding for maintenance of HFIR with the beryllium reflector replacement). Development of capabilities for biopreparedness, computational techniques, and data will continue.	Funding will support operations for SNS and HFIR at 90 percent of required funding, accounting for inflation, supply chain costs, staffing support, remote operations, and costs for operation of new/upgraded SNS capabilities.
Nanoscale Science Research Centers	$153,409	$164,422	+$11,013
Provides funding for five NSRCs (CFN, CNM, CNMS, MF, and CINT). The NSRCs continue to develop nanoscience and QIS-related research infrastructure and capabilities for materials synthesis, device fabrication, metrology, modeling and simulation.		The Request will provide funding for five NSRCs (CFN, CNM, CNMS, MF, and CINT). The NSRCs will continue to develop infrastructure and capabilities to maintain world-leading synthesis, device fabrication, characterization, modeling, and simulation.	Funding will support operations for the five NSRCs at 90 percent of required funding, accounting for inflation, supply chain costs, staffing support, remote operations, and other costs.
Other Project Costs	$19,500	$9,500	-$10,000
Funding supports OPC for the LCLS-II-HE project at SLAC, the STS project at ORNL, the APS-U project at ANL, and the CRMF project at SLAC. Funds also initiate OPC for the HFIR-PVR project at ORNL and the NEXT-III project at BNL.		The Request will support OPC for the HFIR-PVR project at ORNL and the NEXT-III project at BNL.	Funding will support the HFIR-PVR project at ORNL, and the NEXT-III project at BNL. OPC will support conceptual design and planning for these projects.

(dollars in thousands)

FY 2023 Enacted	FY 2025 Request	Explanation of Changes FY 2025 Request vs FY 2023 Enacted
Major Items of Equipment $50,000	$ —	-$50,000
Funding continues the beamline project for NEXT-II at BNL and the recapitalization project for the NSRCs. Both projects received CD-2/3 approval in FY 2022.	No MIE funding is requested in FY 2025.	Final funding for the NEXT-II and NSRC Recapitalization MIE projects was requested in FY 2024.
Research $52,610	$62,886	+$10,276
Funding supports high-priority research activities for advanced seeded FEL schemes that provide several orders of magnitude performance enhancement, detectors with high read out rate, optics that can handle high heat load and preserve the coherent wave front, and applications of data science techniques to accelerator optimization, control, prognostics, and data analysis. Research emphasizes transformative advances in accelerator science and technology that lead to significant improvements in very high brightness and high current electron sources and in high intensity proton sources. In addition, research expands to include enabling capabilities for response to biological threats and RENEW internships.	The Request will support high-priority research activities for accelerators, detectors, and applications of data science techniques to accelerator optimization, control, prognostics, and data analysis. Research will emphasize transformative advances in accelerator science and technology that lead to significant improvements in very high brightness and high current electron sources and in high intensity proton sources. In addition, research will expand to include enabling capabilities for data science/AI/ML and continue for response to biological threats and to increase the diversity of the research performers.	Funding will support investment in future accelerator and detector technologies to continue to provide the world's most comprehensive and advanced accelerator-based facilities for scientific research. Funding will expand investments in data science/AI/ML methods and tools to address data and information challenges at the BES user facilities, including accelerator control and experiment automation with real time data analysis.

Note:

- *Funding for the subprogram above, includes 3.65 percent of research and development (R&D) funding for the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) Programs, excluding facility operations.*

Basic Energy Sciences
Construction

Description

Accelerator-based x-ray light sources, accelerator-based pulsed neutron sources, reactor-based neutron sources, and nanoscale science research centers are essential user facilities that enable critical DOE mission-driven science, including research in support of clean energy. These user facilities provide the academic, laboratory, and industrial research communities with the tools to fabricate, characterize, and develop new materials and chemical processes to advance basic and applied research, advancing chemistry, physics, earth science, materials science, environmental science, biology, and biomedical science. Regular investments in construction of new user facilities and upgrades to existing user facilities are essential to maintaining U.S. leadership in these research areas.

24-SC-10, HFIR Pressure Vessel Replacement (PVR), ORNL

The HFIR PVR project will replace the aging HFIR pressure vessel to extend facility lifetime, enable resumption of 100 MW operations, and enhance isotope production and scattering research. These upgrades will maintain a domestic high-flux, steady-state neutron source for diverse and critical missions. For example, in addition to the hundreds of neutron scattering users, isotope production supports research, clinical and medical uses, and federal and industrial applications, including NASA deep space missions. The project received CD-0, Approve Mission Need, on October 28, 2020, with a current preliminary Total Project Cost (TPC) range of $300,000,000–$740,000,000, updated by preliminary planning for the project. A combined CD-1, Approve Alternative Selection and Cost Range, and CD-3A, Approve Long Lead Procurements, is expected in 4Q FY 2026.

24-SC-12, NSLS-II Experimental Tools - III (NEXT-III), BNL

The NEXT-III project will provide a pathway for the construction of an additional suite of up to 12 beamlines that will be optimized to enhance the capability of NSLS-II. These beamlines will enable cutting-edge research in clean sustainable energy, sustainable manufacturing, carbon sequestration and storage, materials for environmental remediation, automated structure analysis of biological macromolecules, drug discovery, bio-preparedness, quantum materials, and quantum information science, as well as developing novel instrumentation and tools required to maintain the global competitiveness of the U.S. light sources. NEXT-III beamlines will also enable multimodal research for a larger, more diverse community to broaden industrial research and provide new avenues to introduce new users to synchrotron research, including those from under-represented institutions and regions. The project received CD-0, Approve Mission Need, on September 30, 2022, with a preliminary TPC range of $350,000,000–$500,000,000. CD-1, Approve Alternative Selection and Cost Range, is expected in 4Q FY 2024.

21-SC-10, Cryomodule Repair & Maintenance Facility (CRMF), SLAC

The CRMF project will provide a much-needed capability to maintain, repair, and test superconducting radiofrequency (SRF) accelerator components. These components include but are not limited to superconducting RF cavities and cryomodules that make up the new superconducting accelerator being constructed by the LCLS-II and LCLS-II-HE projects, high brightness electron injectors, and superconducting undulators. The facility will provide for the full disassembly and repair of the SRF cryomodule; the ability to disassemble, clean, and reassemble the SRF cavities and cavity string; testing capabilities for the full cryomodule; and separate testing capabilities for individual SRF cavities. To accomplish this, the project requires a building up to 24,000 gross square feet to contain the necessary equipment, tools, and fixtures, as well as a control room, clean rooms, and liquid helium distribution system. The project received CD-1, Approve Cost Range and Analysis of Alternatives, on October 11, 2023, with a current TPC range of $70,000,000–$98,000,000. A combined CD-2/3, Approve Performance Baseline and Approve Start of Construction, is expected in 1Q FY 2026.

19-SC-14, Second Target Station (STS), ORNL

The STS project will expand SNS capabilities for neutron scattering research by exploiting 0.7 MW of the 2.8 MW SNS accelerator proton beam power enabled by the PPU project. The STS will provide high brightness, cold neutrons complementary to the first target station (FTS). Instruments will feature advanced neutron optics, optimized geometry, and high resolution, advanced detectors, enabling new research opportunities. The project received CD-1, Approve Alternative Selection and Cost Range, on November 23, 2020, establishing the approved TPC range of $1,800,000,000–$3,000,000,000. CD-3A, Approve Long Lead Procurements, is expected in 4Q FY 2025.

18-SC-13, Linac Coherent Light Source-II-High Energy (LCLS-II-HE), SLAC

The LCLS-II-HE project will expand the capabilities of the LCLS to maintain U.S. leadership in ultrafast and ultrabright x-ray science. The project will increase the energy of the superconducting linac from 4 GeV to 8 GeV and thereby expand the high repetition rate operation (1 million pulses per second) into the hard x-ray regime (5-12 keV). The project received CD-3B, Approve Long Lead Procurements, on January 27, 2023. The project established an original TPC range of $290,000,000–$480,000,000, but due to maturing design efforts that identified additional costs across the project scope, and increases in the project's contingency to address several future risks, the TPC estimate has increased to $710,000,000. A combined CD-2/3, Approve Performance Baseline and Approve Start of Construction, is expected in 3Q FY 2024.

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Activities and Explanation of Changes

(dollars in thousands)

FY 2023 Enacted		FY 2025 Request	Explanation of Changes FY 2025 Request vs FY 2023 Enacted
Construction	**$293,200**	**$183,500**	**-$109,700**
24-SC-10, HFIR Pressure Vessel Replacement (PVR), ORNL	$ —	$6,000	+$6,000
No funding is requested in FY 2023.		The Request will continue planning, design, R&D, analysis, engineering, and prototyping to advance design toward readiness for a combined CD-1/3A in 4Q FY 2026.	Funding will advance progress on the HFIR-PVR project.
24-SC-12, NSLS-II Experimental Tools - III (NEXT-III), BNL	$ —	$5,500	+$5,500
No funding is requested in FY 2023.		The Request will support activities to secure CD-3A approval, expected in 3Q FY 2025, to start long lead procurements of the first group of beamlines and continue with design of the second group of beamlines.	Funding will advance progress on the NEXT-III project.
21-SC-10, Cryomodule Repair & Maintenance Facility (CRMF), SLAC	$10,000	$20,000	+$10,000
Funding continues the initial design effort and initiate long-lead procurements and site preparations for civil construction upon associated CD approvals. CD-1 is expected for 4Q FY 2023 and CD-3A expected for 1Q FY 2024.		The Request will support the continuation of activities required to secure a combined CD-2/3 approval and initiation of construction contracts, expected in 1Q FY 2026.	Funding will advance progress on the CRMF project.

(dollars in thousands)

FY 2023 Enacted		FY 2025 Request	Explanation of Changes FY 2025 Request vs FY 2023 Enacted
19-SC-14, Second Target Station (STS), ORNL	$32,000	$52,000	+$20,000
The project continues the activities of planning, R&D, and engineering to mature the project's preliminary design, scope, cost, schedule, and key performance parameters.		The Request will continue planning, R&D, design, engineering, prototyping, and testing to advance the highest-priority activities. Funding will also initiate a potential long lead procurement for civil construction site preparation upon associated CD approvals.	Funding will advance progress on the STS project.
18-SC-10, Advanced Photon Source Upgrade (APS-U), ANL	$9,200	$ —	-$9,200
Funding supports ongoing construction activities to include civil construction associated with the long beamline building. Dark time for installation is projected to begin 2Q FY 2023.		No funding is requested in FY 2025.	Final funding for this project was provided in FY 2023.
18-SC-11, Spallation Neutron Source Proton Power Upgrade (PPU), ORNL	$17,000	$ —	-$17,000
The project supports the installation of additional cryomodules and related radiofrequency systems, operation of the second PPU test target at increased power levels, and construction of the tunnel stub that will facilitate connection to the future STS.		No funding is requested in FY 2025.	Final funding for this project was requested in FY 2024.
18-SC-12, Advanced Light Source Upgrade (ALS-U), LBNL	$135,000	$ —	-$135,000
The project continues to advance construction activities.		No funding is requested in FY 2025.	Final funding for this project was requested in FY 2024.

(dollars in thousands)

FY 2023 Enacted	FY 2025 Request	Explanation of Changes FY 2025 Request vs FY 2023 Enacted
18-SC-13, Linac Coherent Light Source-II-High Energy (LCLS-II-HE), SLAC $90,000	$100,000	+$10,000
Funding supports engineering, design, R&D prototyping, continuing long lead procurements of construction items and preparation of the project baseline. Other tasks as required. A combined CD- 2/3 approval is expected for 2Q FY 2024 and CD-4 is expected for 2Q FY 2030.	Funding will support production of the cryomodules, continue long lead procurements, and begin remaining scope design efforts and initiate installation/construction contracts. Other tasks as required. A combined CD-2/3 approval is expected for 3Q FY 2024.	Funding will advance progress on the LCLS-II-HE project at SLAC and the three partner labs (Fermi National Accelerator Lab, Thomas Jefferson Lab, and Lawrence Berkeley National Lab).

Basic Energy Sciences
Capital Summary

(dollars in thousands)

	Total	Prior Years	FY 2023 Enacted	FY 2024 Annualized CR	FY 2025 Request	FY 2025 Request vs FY 2023 Enacted
Capital Operating Expenses						
Capital Equipment	N/A	N/A	80,698	57,394	56,641	-24,057
Minor Construction Activities						
General Plant Projects	N/A	N/A	3,400	22,040	31,228	+27,828
Accelerator Improvement Projects	N/A	N/A	14,010	81,169	55,682	+41,672
Total, Capital Operating Expenses	**N/A**	**N/A**	**98,108**	**160,603**	**143,551**	**+45,443**

Capital Equipment

(dollars in thousands)

	Total	Prior Years	FY 2023 Enacted	FY 2024 Annualized CR	FY 2025 Request	FY 2025 Request vs FY 2023 Enacted
Capital Equipment						
Major Items of Equipment						
Scientific User Facilities (SUF)						
NSLS-II Experimental Tools-II (NEXT-II), BNL	92,283	47,283	25,000	20,000	–	-25,000
NSRC Recapitalization	79,150	49,150	25,000	5,000	–	-25,000
Total, MIEs	N/A	N/A	50,000	25,000	–	-50,000
Total, Non-MIE Capital Equipment	N/A	N/A	30,698	32,394	56,641	+25,943
Total, Capital Equipment	**N/A**	**N/A**	**80,698**	**57,394**	**56,641**	**-24,057**

Note:

- *The Capital Equipment table includes MIEs located at a DOE facility with a Total Estimated Cost (TEC) > $10M and MIEs not located at a DOE facility with a TEC >$2M.*

Minor Construction Activities

(dollars in thousands)

	Total	Prior Years	FY 2023 Enacted	FY 2024 Annualized CR	FY 2025 Request	FY 2025 Request vs FY 2023 Enacted
General Plant Projects (GPP)						
GPPs (greater than $5M and $34M or less)						
Spallation Neutron Source Sample Environmental Building	700	–	–	–	700	+700
HFIR Guide Hall Extension	19,900	–	1,400	18,500	–	-1,400
HFIR Fabrication, Alignment & Manufacturing (FAM) Bldg., ORNL	1,540	–	–	1,540	–	–
Technical and Storage Space	9,528	–	–	–	9,528	+9,528
SLAC, SSRL, B120 Expansion for Beamline Upgrade	1,200	–	–	–	1,200	+1,200
SLAC, LCLS, Far Experimental Hall	14,800	–	–	–	14,800	+14,800
Total GPPs (greater than $5M and $34M or less)	N/A	N/A	1,400	20,040	26,228	+24,828
Total GPPs $5M or less	N/A	N/A	2,000	2,000	5,000	+3,000
Total, General Plant Projects (GPP)	**N/A**	**N/A**	**3,400**	**22,040**	**31,228**	**+27,828**
Accelerator Improvement Projects (AIP)						
AIPs (greater than $5M and $34M or less)						
3rd Harmonic Cavity, National Synchrotron Light Source-II	10,720	–	–	4,720	6,000	+6,000
Spallation Neutron Source Cold Box-Engineering	10,500	–	–	10,500	–	–
Cold Source Helium Refrigerator System	21,939	9,339	–	12,600	–	–
160kW Solid State Amplifier Hardware and Utilities - Phase 2 (APS)	11,934	–	5,967	5,967	–	-5,967
Flexon 2nd Endstation, LBNL	8,500	–	–	8,500	–	–
New SAX/WAX Beamline, LBNL	25,250	–	–	17,750	7,500	+7,500
ALARA lead shielding upgrade	9,405	–	–	–	9,405	+9,405
Roof block shielding upgrade	6,577	–	–	–	6,577	+6,577

(dollars in thousands)

	Total	Prior Years	FY 2023 Enacted	FY 2024 Annualized CR	FY 2025 Request	FY 2025 Request vs FY 2023 Enacted
Total AIPs (greater than $5M and $34M or less)	N/A	N/A	5,967	60,037	29,482	+23,515
Total AIPs $5M or less	N/A	N/A	8,043	21,132	26,200	+18,157
Total, Accelerator Improvement Projects (AIP)	**N/A**	**N/A**	**14,010**	**81,169**	**55,682**	**+41,672**
Total, Minor Construction Activities	**N/A**	**N/A**	**17,410**	**103,209**	**86,910**	**+69,500**

Notes:

- *GPP activities $5M and less include design and construction for additions and/or improvements to land, buildings, replacements or addition to roads, and general area improvements. AIP activities $5M and less include minor construction at an existing accelerator facility.*
- *The Total funding for the HFIR Guide Hall Extension GPP project is approximately $19,900,000. This project, originally requested in FY 2021, has been delayed. Design efforts will be fully funded in FY 2023 and the remaining funds are requested in FY 2024.*
- *The Total funding for the Cold Source Helium Refrigerator System (AIP) project is $12,600,000. This project, originally requested in FY 2021, has been deferred until FY 2024.*
- *The Total funding for the SNS Cold Box-Engineering (AIP) project is $10,500,000. This project, originally requested in FY 2023, has been deferred until FY 2024.*
- *The Total funding for the 3rd Harmonic Cavity (AIP) project is $6,000,000. This project, originally requested in FY 2024, has been deferred until FY 2025.*
- *The Total funding for the SAX/WAX Beamline (AIP) project is $9,000,000. This project, originally requested in FY 2024, has been deferred with revised scope until FY 2025.*

Basic Energy Sciences
Construction Projects Summary

(dollars in thousands)

	Total	Prior Years	FY 2023 Enacted	FY 2024 Annualized CR	FY 2025 Request	FY 2025 Request vs FY 2023 Enacted
24-SC-10, HFIR Pressure Vessel Replacement (PVR), ORNL						
Total Estimated Cost (TEC)	675,000	-	-	-	6,000	+6,000
Other Project Cost (OPC)	44,000	-	3,000	3,000	5,000	+2,000
Total Project Cost (TPC)	**719,000**	**-**	**3,000**	**3,000**	**11,000**	**+8,000**
24-SC-12, NSLS-II Experimental Tools - III (NEXT-III), BNL						
Total Estimated Cost (TEC)	477,444	-	-	-	5,500	+5,500
Other Project Cost (OPC)	17,500	-	1,500	1,500	4,500	+3,000
Total Project Cost (TPC)	**494,944**	**-**	**1,500**	**1,500**	**10,000**	**+8,500**
21-SC-10, Cryomodule Repair & Maintenance Facility (CRMF), SLAC						
Total Estimated Cost (TEC)	88,800	22,000	10,000	9,000	20,000	+10,000
Other Project Cost (OPC)	5,700	3,700	1,000	1,000	-	-1,000
Total Project Cost (TPC)	**94,500**	**25,700**	**11,000**	**10,000**	**20,000**	**+9,000**
19-SC-14, Second Target Station (STS), ORNL						
Total Estimated Cost (TEC)	2,145,000	124,700	32,000	52,000	52,000	+20,000
Other Project Cost (OPC)	94,960	45,805	5,000	-	-	-5,000
Total Project Cost (TPC)	**2,239,960**	**170,505**	**37,000**	**52,000**	**52,000**	**+15,000**
18-SC-10, Advanced Photon Source Upgrade (APS-U), ANL						
Total Estimated Cost (TEC)	796,500	787,300	9,200	-	-	-9,200
Other Project Cost (OPC)	18,500	13,500	5,000	-	-	-5,000
Total Project Cost (TPC)	**815,000**	**800,800**	**14,200**	**-**	**-**	**-14,200**
18-SC-11, Spallation Neutron Source Proton Power Upgrade (PPU), ORNL						

(dollars in thousands)

	Total	Prior Years	FY 2023 Enacted	FY 2024 Annualized CR	FY 2025 Request	FY 2025 Request vs FY 2023 Enacted
Total Estimated Cost (TEC)	257,769	225,000	17,000	15,769	-	-17,000
Other Project Cost (OPC)	13,798	13,798	-	-	-	-
Total Project Cost (TPC)	**271,567**	**238,798**	**17,000**	**15,769**	**-**	**-17,000**
18-SC-12, Advanced Light Source Upgrade (ALS-U), LBNL						
Total Estimated Cost (TEC)	562,000	369,700	135,000	57,300	-	-135,000
Other Project Cost (OPC)	28,000	28,000	-	-	-	-
Total Project Cost (TPC)	**590,000**	**397,700**	**135,000**	**57,300**	**-**	**-135,000**
18-SC-13, Linac Coherent Light Source-II-High Energy (LCLS-II-HE), SLAC						
Total Estimated Cost (TEC)	678,000	268,657	90,000	120,000	100,000	+10,000
Other Project Cost (OPC)	32,000	23,000	4,000	-	-	-4,000
Total Project Cost (TPC)	**710,000**	**291,657**	**94,000**	**120,000**	**100,000**	**+6,000**
Total, Construction						
Total Estimated Cost (TEC)	**N/A**	**N/A**	**293,200**	**254,069**	**183,500**	**-109,700**
Other Project Cost (OPC)	**N/A**	**N/A**	**19,500**	**5,500**	**9,500**	**-10,000**
Total Project Cost (TPC)	**N/A**	**N/A**	**312,700**	**259,569**	**193,000**	**-119,700**

Note:

- *The current estimated TPC for the STS project is $2,242,000,000. In FY 2023, an additional $2,040,000 in OPC funding was obligated that is not reflected in this table.*

Basic Energy Sciences
Scientific User Facility Operations

The treatment of user facilities is distinguished between two types: TYPE A facilities that offer users resources dependent on a single, large-scale machine; TYPE B facilities that offer users a suite of resources that is not dependent on a single, large-scale machine.

(dollars in thousands)

	FY 2023 Enacted	FY 2023 Current	FY 2024 Annualized CR	FY 2025 Request	FY 2025 Request vs FY 2023 Enacted
Scientific User Facilities - Type A					
Advanced Light Source	**74,934**	**75,434**	**101,693**	**118,439**	**+43,505**
Number of Users	1,500	1,602	1,496	1,224	-276
Achieved Operating Hours	–	3,763	–	–	–
Planned Operating Hours	3,880	–	2,915	2,938	-942
Advanced Photon Source	**173,142**	**173,642**	**168,891**	**201,758**	**+28,616**
Number of Users	3,440	3,932	1,760	1,845	-1,595
Achieved Operating Hours	–	3,067	–	–	–
Planned Operating Hours	3,152	–	2,013	1,852	-1,300
National Synchrotron Light Source II	**128,100**	**128,100**	**142,208**	**164,851**	**+36,751**
Number of Users	1,500	1,885	1,584	1,755	+255
Achieved Operating Hours	–	4,601	–	–	–
Planned Operating Hours	4,800	–	4,400	4,500	-300
Stanford Synchrotron Radiation Light Source	**48,242**	**48,679**	**64,752**	**80,982**	**+32,740**
Number of Users	1,100	599	1,980	1,710	+610
Achieved Operating Hours	–	1,756	–	–	–
Planned Operating Hours	3,316	–	4,970	4,590	+1,274
Linac Coherent Light Source	**175,080**	**177,080**	**202,400**	**224,317**	**+49,237**
Number of Users	600	322	880	990	+390
Achieved Operating Hours	–	1,526	–	–	–

	(dollars in thousands)				
	FY 2023 Enacted	**FY 2023 Current**	**FY 2024 Annualized CR**	**FY 2025 Request**	**FY 2025 Request vs FY 2023 Enacted**
Planned Operating Hours	3,200	–	5,720	6,750	+3,550
Spallation Neutron Source	**189,727**	**189,737**	**178,908**	**222,066**	**+32,339**
Number of Users	450	701	255	736	+286
Achieved Operating Hours	–	2,790	–	–	–
Planned Operating Hours	2,700	–	1,408	3,780	+1,080
High Flux Isotope Reactor	**126,013**	**126,013**	**193,016**	**142,626**	**+16,613**
Number of Users	290	474	352	382	+92
Achieved Operating Hours	–	2,935	–	–	–
Planned Operating Hours	2,700	–	2,904	2,548	-152
Scientific User Facilities - Type B					
Center for Nanoscale Materials	**30,519**	**30,519**	**28,737**	**33,881**	**+3,362**
Number of Users	730	850	682	702	-28
Center for Functional Nanomaterials	**27,114**	**27,614**	**25,760**	**28,419**	**+1,305**
Number of Users	630	655	616	639	+9
Molecular Foundry	**38,051**	**38,051**	**36,571**	**41,063**	**+3,012**
Number of Users	950	1,090	1,144	1,215	+265
Center for Nanophase Materials Sciences	**30,404**	**30,984**	**28,629**	**31,913**	**+1,509**
Number of Users	730	753	686	711	-19
Center for Integrated Nanotechnologies	**27,321**	**27,821**	**27,104**	**29,146**	**+1,825**
Number of Users	870	926	832	855	-15
Total, Facilities	**1,068,647**	**1,073,674**	**1,198,669**	**1,319,461**	**+250,814**
Number of Users	12,790	13,789	12,267	12,764	-26
Achieved Operating Hours	–	20,438	–	–	–
Planned Operating Hours	23,748	–	24,330	26,958	+3,210

Note:

- *Percent optimal operations defines what is achieved at this funding level. This includes staffing, up-to-date equipment and software, operations and maintenance, and appropriate investments to maintain world leadership.*

Scientific Employment

	FY 2023 Enacted	FY 2024 Annualized CR	FY 2025 Request	FY 2025 Request vs FY 2023 Enacted
Number of Permanent Ph.Ds (FTEs)	5,840	5,590	5,650	-190
Number of Postdoctoral Associates (FTEs)	1,670	1,540	1,540	-130
Number of Graduate Students (FTEs)	2,620	2,400	2,400	-220
Number of Other Scientific Employment (FTEs)	3,550	3,520	3,600	+50
Total Scientific Employment (FTEs)	**13,680**	**13,050**	**13,190**	**-490**

Note:

- Other Scientific Employment (FTEs) includes technicians, engineers, computer professionals and other support staff.

24-SC-10, HFIR Pressure Vessel Replacement (PVR), ORNL
Oak Ridge National Laboratory, ORNL
Project is for Design and Construction

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

Summary

The HFIR PVR project replaces the aging HFIR pressure vessel to extend facility lifetime, enable resumption of 100 MW operations, and enhance isotope production and scattering research. These upgrades will maintain a domestic high-flux, steady-state neutron source for diverse and critical missions. The FY 2025 Request for the HFIR Pressure Vessel Replacement (PVR), ORNL is $6,000,000 of Total Estimated Cost (TEC) funding and $5,000,000 of Other Project Costs (OPC) funding. The preliminary total project cost (TPC) range is estimated to be $300,000,000 to $740,000,000. This preliminary cost range encompassed the most feasible preliminary alternatives at CD-0, updated by preliminary planning for the project. Pending CD-1 reviews, the project's current preliminary TPC is $729,000,000.

Significant Changes

This project was initiated in the FY 2024 Request. The most recent DOE Order 413.3B approved Critical Decision (CD) is CD-0, Approve Mission Need, which was approved on October 28, 2020. A combined CD-1, Approve Alternative Selection and Cost Range, and CD-3A, Approve Long Lead Procurements, is expected 4Q FY 2026. This Construction Project Data Sheet (CPDS) is an update of the FY 2024 CPDS and does not include a new start for FY 2025.

During the initial design activities, the project's preliminary TPC range originally established at CD-0 was increased from $300,000,000 to $550,000,000, to $300,000,000 to $740,000,000. To ensure U.S. competitiveness and maintain world leading capabilities for HFIR's diverse and critical missions, the replacement pressure vessel will be redesigned to maximize neutron scattering and isotope production and will be constructed for the latest pressure vessel materials, increasing the initial estimated cost. The redesign of the pressure vessel coupled with DOE regulatory reviews and supply chain delays will require replacement of the beryllium reflector, further adding to the cost and required schedule.

FY 2023 funding initiated the alternatives analysis and preconceptual design activities. The FY 2024 Request will support planning, design, R&D, analysis, engineering, and potentially prototyping to advance the conceptual design with emphasis on design optimization, and material studies. The FY 2025 Request will continue FY 2024 activities with emphasis on the highest priority activities needed to advance the conceptual design toward readiness for CD-1 and potential long lead procurements in FY 2026.

A Federal Project Director with the appropriate level of certification will be assigned to this project prior to CD-1.

Critical Milestone History

Fiscal Year	CD-0	Conceptual Design Complete	CD-1	CD-2	Final Design Complete	CD-3	CD-4
FY 2025	10/28/20	4Q FY 2025	4Q FY 2026	4Q FY 2027	4Q FY 2030	4Q FY 2028	4Q FY 2036

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

Fiscal Year	Performance Baseline Validation	CD-3A
FY 2025	4Q FY 2027	4Q FY 2026

CD-3A – Approve Long-Lead Procurements, to reduce schedule and technical risk by procuring specialty materials and components early in the project lifecycle that can have a long-lead time from procurement to receipt.

Project Cost History

(dollars in thousands)

Fiscal Year	TEC, Design	TEC, Construction	TEC, Total	OPC, Except D&D	OPC, Total	TPC
FY 2024	177,000	346,000	523,000	27,000	27,000	550,000
FY 2025	153,000	526,000	679,000	50,000	50,000	729,000

2. Project Scope and Justification

Scope

The HFIR-PVR project will replace the existing HFIR reactor pressure vessel with a modern, redesigned pressure vessel, enabling HFIR to continue providing world-class brightness and flux for a variety of critical mission objectives for decades to come.

Justification

HFIR provides state-of-the-art facilities for neutron scattering, isotope production, materials irradiation, and neutron activation analysis. HFIR, completed in 1965, is the world's most intense source of thermal neutrons for research. Due to its age, HFIR is at risk of falling behind reactors recently completed and in construction in Russia. The HFIR-PVR project will reduce the risk of potential reliance on foreign reactors for isotope production and for scientific research.

HFIR started operation in 1965 at 100 megawatts (MW), however its power was reduced to 85 MW in 1990 to extend the lifetime of the reactor pressure vessel. In 2019, the BES Advisory Committee (BESAC) was charged with assessing the long-term strategy for HFIR and the scientific justification for a U.S. reactor-based research facility. A key recommendation from the resulting July 2020 report, *The Scientific Justification for a U.S. Domestic High-Performance Reactor-Based Research Facility,*[l] is to replace the pressure vessel with enhanced capabilities for both in-reactor and beamline research.

The HFIR-PVR project will replace the aging HFIR pressure vessel to extend facility lifetime, resume 100 MW operations, and address the need for long-term availability of a high-flux, steady-state neutron source to maintain world-leading capabilities for its missions. HFIR-PVR will enable next-generation instrumentation for the neutron scattering user community; enhance isotope production for research, clinical and medical uses, and federal and industrial applications, including NASA deep space missions; and improve materials irradiation and neutron activation analysis capabilities.

Potential capability and capacity enhancements include: a ~20 percent increase in neutron flux for all missions resulting from the power ramp up from 85 MW to 100 MW operations, a further increase in the thermal neutron flux at beamlines by factors of two or more through optimization of the layout to improve the performance, and an increase in the overall number of beamlines for users. The 100 MW operations will increase isotope production and enhance throughput in instrumented materials irradiation experiments.

The project is being conducted in accordance with the project management requirements in DOE Order 413.3B, *Program and Project Management for the Acquisition of Capital Assets*.

[l] The Scientific Justification for a U.S. Domestic High-Performance Reactor-Based Research Facility, October 2020.

Key Performance Parameters (KPPs)

The KPPs are preliminary and may change as the project continues towards CD-2. At CD-2 approval, the KPPs will be baselined. The Threshold KPPs represent the minimum acceptable performance that the project must achieve. Achievement of the Threshold KPPs will be a prerequisite for approval of CD-4, Project Completion. The Objective KPPs represent the desired project performance.

Performance Measure	Threshold	Objective
Pressure Vessel Power Level Capability	85 MW	100 MW

3. Financial Schedule

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs
Total Estimated Cost (TEC)			
Design (TEC)			
FY 2024	4,000	4,000	—
FY 2025	6,000	6,000	—
Outyears	143,000	143,000	153,000
Total, Design (TEC)	**153,000**	**153,000**	**153,000**
Construction (TEC)			
Outyears	526,000	526,000	526,000
Total, Construction (TEC)	**526,000**	**526,000**	**526,000**
Total Estimated Cost (TEC)			
FY 2024	4,000	4,000	—
FY 2025	6,000	6,000	—
Outyears	669,000	669,000	679,000
Total, Total Estimated Cost (TEC)	**679,000**	**679,000**	**679,000**

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs
Other Project Cost (OPC)			
FY 2023	3,000	3,000	392
FY 2024	9,000	9,000	8,000
FY 2025	5,000	5,000	6,000
Outyears	33,000	33,000	35,608
Total, Other Project Cost (OPC)	**50,000**	**50,000**	**50,000**

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs
Total Project Cost (TPC)			
FY 2023	3,000	3,000	392
FY 2024	13,000	13,000	8,000
FY 2025	11,000	11,000	6,000
Outyears	702,000	702,000	714,608
Total, TPC	**729,000**	**729,000**	**729,000**

4. Details of Project Cost Estimate

(dollars in thousands)

	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
Total Estimated Cost (TEC)			
Design	117,000	137,000	**N/A**
Design - Contingency	36,000	40,000	**N/A**
Total, Design (TEC)	**153,000**	**177,000**	**N/A**
Construction	376,000	247,500	**N/A**
Construction - Contingency	150,000	98,500	**N/A**
Total, Construction (TEC)	**526,000**	**346,000**	**N/A**
Total, TEC	**679,000**	**523,000**	**N/A**
Contingency, TEC	*186,000*	*138,500*	***N/A***
Other Project Cost (OPC)			
Total, D&D	**6,400**	**5,600**	**N/A**
Conceptual Design	13,600	14,000	**N/A**
Start-up	20,000	2,400	**N/A**
OPC - Contingency	10,000	5,000	**N/A**
Total, Except D&D (OPC)	**43,600**	**21,400**	**N/A**
Total, OPC	**50,000**	**27,000**	**N/A**
Contingency, OPC	*10,000*	*5,000*	***N/A***
Total, TPC	**729,000**	**550,000**	**N/A**
Total, Contingency (TEC+OPC)	***196,000***	***143,500***	***N/A***

5. Schedule of Appropriations Requests

(dollars in thousands)

Fiscal Year	Type	Prior Years	FY 2023	FY 2024	FY 2025	Outyears	Total
FY 2024	TEC	—	—	4,000	—	519,000	523,000
	OPC	—	3,000	9,000	—	15,000	27,000
	TPC	—	3,000	13,000	—	534,000	550,000
FY 2025	TEC	—	—	4,000	6,000	669,000	679,000
	OPC	—	3,000	9,000	5,000	33,000	50,000
	TPC	—	3,000	13,000	11,000	702,000	729,000

6. Related Operations and Maintenance Funding Requirements

Start of Operation or Beneficial Occupancy	4Q FY 2036
Expected Useful Life	50 years
Expected Future Start of D&D of this capital asset	4Q FY 2086

Related Funding Requirements
(dollars in thousands)

	Annual Costs		Life Cycle Costs	
	Previous Total Estimate	Current Total Estimate	Previous Total Estimate	Current Total Estimate
Operations	N/A	TBD	N/A	TBD
Utilities	N/A	TBD	N/A	TBD
Maintenance and Repair	N/A	TBD	N/A	TBD
Total, Operations and Maintenance	N/A	TBD	N/A	TBD

7. D&D Information

At this stage of project planning and development, SC anticipates that there will be no new area being constructed in the construction project.

8. Acquisition Approach

The acquisition approach will be developed and matured as part of the acquisition strategy and alternatives analysis required for CD-1. DOE has determined that ORNL will acquire the HFIR-PVR project under the existing DOE Management and Operations (M&O) contract.

A Conceptual Design Report for the project will identify key design activities, requirements, and high-risk subsystem components to reduce cost and schedule risk to the project and expedite the startup. Project management systems are fully up to date, operating, and are maintained as an ORNL-wide resource.

ORNL will design and procure the key technical subsystem components. Some technical system designs may require research and development activities. Preliminary cost estimates for these components and systems will likely be based on operating experience of HFIR and vendor estimates, while some first-of-a-kind components may be based on expert judgement. Vendors and/or partner labs with the necessary capabilities will fabricate the technical equipment. ORNL will competitively bid and award all subcontracts based on best value to the government. The M&O contractor's performance will be evaluated through the annual laboratory performance appraisal process.

Lessons learned from other SC projects and other similar facilities will be exploited fully in planning and executing the HFIR-PVR project.

24-SC-12, NSLS-II Experimental Tools - III (NEXT-III), BNL
Brookhaven National Laboratory, BNL
Project is for Design and Construction

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

Summary
The NEXT-III project will provide a pathway for the construction of an additional suite of up to 12 beamlines that will be optimized to enhance the capability of NSLS-II. The FY 2025 Request for the NSLS-II Experimental Tools - III (NEXT-III) Project is $5,500,000 of Total Estimated Cost (TEC) funding and $4,500,000 of Other Project Cost (OPC) funding. The current preliminary total project cost (TPC) range is $350,000,000 to $500,000,000. The preliminary cost range encompasses the most feasible preliminary alternatives at this time. The current preliminary TPC for this project is $500,000,000.

Significant Changes
This project was initiated in the FY 2024 Request. The most recent DOE Order 413.3B approved Critical Decision (CD) is CD-0, Approve Mission Need, was approved on September 30, 2022. CD-1, Approve Alternative Selection and Cost Range, is expected in 4Q FY 2024. This Construction Project Data Sheet (CPDS) is an update of the FY 2024 CPDS and does not include a new start for FY 2025.

FY 2023 funding supported planning activities for this project. The FY 2024 Request will continue planning activities including development of plans for CD-1, any required R&D and the future CD-3A package, and initiates conceptual design activities, building on the activities planned in FY 2023. The FY 2025 Request will enable securing CD-3A approval to start long lead procurements of the first group of beamlines and continued design of the second group of beamlines. The project is considering a phased approach of subprojects with roughly three beamlines scoped under each subproject. Final execution plans for the project will be established at CD-1.

A Level III certified Federal Project Director will be assigned to this project prior to CD-1.

Critical Milestone History

Fiscal Year	CD-0	Conceptual Design Complete	CD-1	CD-2	Final Design Complete	CD-3	CD-4
FY 2025	9/30/22	3Q FY 2024	4Q FY 2024	3Q FY 2026	3Q FY 2028	4Q FY 2028	1Q FY 2036

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

Fiscal Year	Performance Baseline Validation	CD-3A	CD-3B
FY 2025	2Q FY 2026	3Q FY 2025	3Q FY 2026

CD-3A – Approve Long-Lead Procurements, plan to acquire long lead items and assembly for the 1st group of instruments.
CD-3B – Approve Long-Lead Procurements, plan to acquire long lead items and assembly for the 2nd group of instruments.

Project Cost History

(dollars in thousands)

Fiscal Year	TEC, Design	TEC, Construction	TEC, Total	OPC, Except D&D	OPC, Total	TPC
FY 2024	38,000	442,000	480,000	20,000	20,000	500,000
FY 2025	38,000	442,000	480,000	20,000	20,000	500,000

2. Project Scope and Justification

Scope

The NEXT-III project will provide for the construction of up to 12 performance and enterprise beamlines that will be optimized to enhance the capability of NSLS-II to support multimodal research. Performance beamlines will be designed to push a given technique to or beyond the current state-of-the-art, offering extraordinary capabilities. These beamlines, together with complementary results from the enterprise beamlines, will enable cutting-edge research in clean sustainable energy, sustainable manufacturing, carbon sequestration and storage, materials for environmental remediation, automated structure-analysis of biological macromolecules, drug discovery, bio-preparedness, quantum material and quantum information science, as well as developing novel instrumentation and tools required to maintain the global competitiveness of the U.S. light sources such as adaptive x-ray optics and ultrafast detectors.

The enterprise beamlines will be designed to provide capabilities and techniques that are mature and have strong, well-established user communities. These beamlines will carry out more routine measurements and are typically highly automatable with a high throughput of experiments. These beamlines are also very useful for providing supporting information for projects which would also take data on a performance beamline. The enterprise beamlines will enable multimodal research for a larger more diverse community including researchers from under-represented communities.

Justification

The mission of BES is to support fundamental research to understand, predict, and ultimately control matter and energy at the electronic, atomic, and molecular levels to provide the foundations for new energy technologies and to support DOE's missions in energy, environment, and national security. To accomplish its mission, BES continually strives to enhance the ability to observe, measure, and understand the structure and properties of materials and the evolution of chemical and physical processes, including providing world-class user facilities with these capabilities. International competition in these research areas is fierce and scientific breakthroughs are often driven by the availability of novel tools and techniques.

A significant fraction of researchers world-wide who use x-ray storage-ring sources use low- and medium-energy x-rays. Low- and medium-energy x-rays are used to determine the structure of materials at atomic resolution, provide images at nanometer spatial resolution, are sensitive to features on the surface and in the bulk, and can operate in extremes of temperature, pressure, and applied magnetic field. The BES program constructed the NSLS-II storage ring light source to provide one of the world's brightest storage ring synchrotron sources of low- and medium-energy x-rays. Completed in FY 2015, NSLS-II has a total capacity of 60 beamlines, with only 28 beamlines (about 47 percent of the capacity) constructed and in current operation.

Because of the importance of development of new materials and other national priorities, failure to acquire the suite of new advanced tools made possible by the NEXT-III project would have serious repercussions on U.S. competitiveness.

The project is being conducted in accordance with the project management requirements in DOE Order 413.3B, *Program and Project Management for the Acquisition of Capital Assets.*

Key Performance Parameters (KPPs)
The KPPs listed are conceptual and will be revised for CD-1 (as preliminary) and finalized at CD-2.

Performance Measure	Threshold	Objective
Performance beamlines	At least 3 or more beamlines capable of operating in the range of 0.1 to 20 KeV Energy Range with tunable spatial resolutions.	At least 5 or more beamlines capable of delivering 0.1-30 KeV energy range with tunable spatial resolutions.
Enterprise beamlines	At least 5 or more beamlines capable of micron to submicron spatial resolution for tomography and high-resolution diffraction and crystallography, all with multi-modal capabilities.	At least 7 or more beamlines capable of micron to submicron spatial resolution for tomography, high-resolution diffraction and crystallography, full-field x-ray imaging, high-energy x-ray scattering and imaging, all with multi-modal capabilities.

3. Financial Schedule

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs
Total Estimated Cost (TEC)			
Design (TEC)			
FY 2024	2,556	2,556	1,500
FY 2025	3,000	3,000	2,500
Outyears	32,444	32,444	34,000
Total, Design (TEC)	**38,000**	**38,000**	**38,000**
Construction (TEC)			
FY 2025	2,500	2,500	2,100
Outyears	439,500	439,500	439,900
Total, Construction (TEC)	**442,000**	**442,000**	**442,000**
Total Estimated Cost (TEC)			
FY 2024	2,556	2,556	1,500
FY 2025	5,500	5,500	4,600
Outyears	471,944	471,944	473,900
Total, Total Estimated Cost (TEC)	**480,000**	**480,000**	**480,000**

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs
Other Project Cost (OPC)			
FY 2023	1,500	1,500	361
FY 2024	4,000	4,000	3,800
FY 2025	4,500	4,500	4,300
Outyears	10,000	10,000	11,539
Total, Other Project Cost (OPC)	**20,000**	**20,000**	**20,000**

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs
Total Project Cost (TPC)			
FY 2023	1,500	1,500	361
FY 2024	6,556	6,556	5,300
FY 2025	10,000	10,000	8,900
Outyears	481,944	481,944	485,439
Total, TPC	**500,000**	**500,000**	**500,000**

4. Details of Project Cost Estimate

(dollars in thousands)

	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
Total Estimated Cost (TEC)			
Design	28,500	28,500	**N/A**
Design - Contingency	9,500	9,500	**N/A**
Total, Design (TEC)	**38,000**	**38,000**	**N/A**
Construction	115,200	115,200	**N/A**
Equipment	172,800	172,800	**N/A**
Construction - Contingency	154,000	154,000	**N/A**
Total, Construction (TEC)	**442,000**	**442,000**	**N/A**
Total, TEC	**480,000**	**480,000**	**N/A**
Contingency, TEC	*163,500*	*163,500*	***N/A***
Other Project Cost (OPC)			
R&D	4,000	4,000	**N/A**
Conceptual Planning	3,000	3,000	**N/A**
Conceptual Design	10,000	10,000	**N/A**

(dollars in thousands)

	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
OPC - Contingency	3,000	3,000	**N/A**
Total, Except D&D (OPC)	**20,000**	**20,000**	**N/A**
Total, OPC	**20,000**	**20,000**	**N/A**
Contingency, OPC	*3,000*	*3,000*	***N/A***
Total, TPC	**500,000**	**500,000**	**N/A**
Total, Contingency (TEC+OPC)	***166,500***	***166,500***	***N/A***

5. **Schedule of Appropriations Requests**

(dollars in thousands)

Fiscal Year	Type	Prior Years	FY 2023	FY 2024	FY 2025	Outyears	Total
FY 2024	TEC	—	—	2,556	—	477,444	480,000
	OPC	—	1,500	4,000	—	14,500	20,000
	TPC	—	1,500	6,556	—	491,944	500,000
FY 2025	TEC	—	—	2,556	5,500	471,944	480,000
	OPC	—	1,500	4,000	4,500	10,000	20,000
	TPC	—	1,500	6,556	10,000	481,944	500,000

6. **Related Operations and Maintenance Funding Requirements**

Start of Operation or Beneficial Occupancy	1Q FY 2036
Expected Useful Life	15 years
Expected Future Start of D&D of this capital asset	1Q FY 2051

Related Funding Requirements
(dollars in thousands)

	Annual Costs		Life Cycle Costs	
	Previous Total Estimate	**Current Total Estimate**	**Previous Total Estimate**	**Current Total Estimate**
Operations	N/A	TBD	N/A	TBD
Utilities	N/A	TBD	N/A	TBD
Maintenance and Repair	N/A	TBD	N/A	TBD
Total, Operations and Maintenance	N/A	TBD	N/A	TBD

7. D&D Information

At this stage of project planning and development, SC anticipates no new area will be constructed for this project.

8. Acquisition Approach

NEXT-III will be acquired by BNL under the existing M&O contract managed by the Brookhaven Science Associates. Since completion of the NSLS-II User Facility in 2015, the BNL team has constructed many beamlines at the facility and has the requisite expertise and experience to deliver the project. The project will potentially be structured into several subprojects with about three beamlines scoped under each subproject. The phased acquisition of subprojects would be implemented through a combination of sub-contracts for purchase of turn-key systems, and specific instruments and components. Installations will be accomplished by utilizing in-house labor as well as subcontractors.

Lessons learned from other SC projects and other similar facilities are being exploited fully in planning and executing NEXT-III. The M&O contractor’s performance will be evaluated through the annual laboratory performance appraisal process.

21-SC-10, Cryomodule Repair & Maintenance Facility (CRMF), SLAC
SLAC National Accelerator Laboratory, SLAC
Project is for Design and Construction

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

Summary

The CRMF project will provide a much-needed capability to maintain, repair, and test superconducting radiofrequency (SRF) accelerator components. The FY 2025 Request for the Cryomodule Repair and Maintenance Facility (CRMF) project at SLAC National Accelerator Laboratory is $20,000,000 of Total Estimated Cost (TEC) funding. This project has a preliminary Total Project Cost (TPC) range of $70,000,000 to $98,000,000. These cost ranges encompass the most feasible preliminary alternatives at this time. As the conceptual design of this project has matured, the current preliminary TPC estimate for this project is $94,500,000.

Significant Changes

CRMF was initiated in FY 2021. The most recent DOE Order 413.3B approved Critical Decision (CD) is CD-1, Approve Cost Range and Analysis of Alternatives, which was approved on October 11, 2023. The initial plan for a CD-3A is no longer being pursued as the approach to the cryogenic delivery system has changed and the project is planning for a combined CD-2/3 in 1Q FY 2026. This Construction Project Data Sheet (CPDS) is an update of the FY 2024 CPDS and does not include a new start for FY 2025.

FY 2023 funding supported the design of building infrastructure and technical systems and finalizing the design guidelines and specifications for cryogenics capabilities. The FY 2024 Request will support completion of the preliminary design of the facility and technical specifications for the cryogenic systems/equipment. The FY 2025 Request will support finalizing the design for the CRMF including the building, infrastructure, cryogenic system, and all the activities required to establish the performance baseline.

A Federal Project Director, certified to Level II, has been assigned to this project.

Critical Milestone History

Fiscal Year	CD-0	Conceptual Design Complete	CD-1	CD-2	Final Design Complete	CD-3	CD-4
FY 2025	12/6/19	8/24/23	10/11/23	1Q FY 2026	4Q FY 2025	1Q FY 2026	1Q FY 2030

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

Fiscal Year	Performance Baseline Validation
FY 2025	1Q FY 2026

Project Cost History

(dollars in thousands)

Fiscal Year	TEC, Design	TEC, Construction	TEC, Total	OPC, Except D&D	OPC, Total	TPC
FY 2024	5,600	83,200	88,800	5,700	5,700	94,500
FY 2025	16,400	72,400	88,800	5,700	5,700	94,500

Note:
- *This project has not received CD-2 approval; therefore, funding estimates are preliminary.*

2. Project Scope and Justification

Scope
The preliminary scope of the CRMF project is to construct a building equipped with clean rooms, handling tools, and fixtures to support the repair, maintenance, and testing of superconducting radiofrequency (SRF) accelerator components. These components may include but are not limited to, SRF cavities and cryomodules, future capabilities for high brightness electron injectors, and superconducting undulators. The requirements will be refined as the project matures.

Justification
Through two current BES construction projects, LCLS-II and LCLS-II-HE, SC is making over a $1,800,000,000 capital investment in an SRF linac at SLAC to support the science mission of DOE. The LCLS-II project is providing a 4 GeV SRF-based linear accelerator containing 35 SRF cryomodules to accelerate the electrons. The LCLS-II-HE project will increase the energy of the superconducting linac to 8 GeV by providing an additional 20-23 SRF cryomodules of a similar design to those installed by the LCLS-II project, but operating at a higher accelerating gradient. SLAC has partnered with Fermi National Accelerator Laboratory (FNAL) and the Thomas Jefferson National Accelerator Facility (TJNAF) to provide the accelerating cryomodules. FNAL and TJNAF produce the cryomodules making use of specialized fabrication, assembly, and test capabilities available there. To make any repairs, SLAC must currently send the cryomodules cross country back to either FNAL or TJNAF at an increased risk of damage, cost, and schedule delays. This approach also assumes that either FNAL or TJNAF would have the maintenance capacity available when needed, typically requiring 6 to 12 months of advance notice to schedule maintenance or repairs.

The proposed CRMF is designed to meet these challenges and will provide the capability to repair, maintain, and test SRF accelerator components, primarily the SRF cryomodules that make up the new superconducting linac being constructed by the LCLS-II and LCLS-II-HE construction projects.

The project is being conducted in accordance with the project management requirements in DOE Order 413.3B, *Program and Project Management for the Acquisition of Capital Assets*.

Key Performance Parameters (KPPs)
The KPPs are preliminary and may change as the project continues towards CD-2. At CD-2 approval, the KPPs will be part of the approved performance baseline. The Threshold KPPs represent the minimum acceptable performance that the project must achieve. The Objective KPPs represent the desired project performance. Achievement of the Threshold KPPs will be a prerequisite for approval of CD-4, Project Completion.

Subsystem	Threshold	Objective
Building	~ 16,000 sq-ft building ready for occupancy	~ 24,000 sq-ft building ready for occupancy
Cleanrooms	ISO 4 cleanroom	ISO 4 and ISO 6 cleanrooms

Subsystem	Threshold	Objective
Cryomodule assembly capability	Infrastructure and equipment for cryomodule and cavity string disassembly and reassembly	Infrastructure and equipment for cryomodule and cavity string disassembly and reassembly
Cryogenic cooling capability	Infrastructure and cryogenic equipment to sustain the single cavity heat load during CM testing (2.3 g/s of liquid helium delivered to the Dewar at CRMF, as measured by liquid accumulation)	Infrastructure and cryogenic equipment to sustain the 8-cavity heat load during CM testing (11 g/s of liquid helium delivered to the Dewar at CRMF, as measured by liquid accumulation)
Cryomodule RF testing capability	Power amplifier capable to reach the power level needed to measure a cavity up to 21 MV/m in CM (with Q=2.7e10)	Power amplifier capable to reach the power level needed to measure a cavity up to 26 MV/m in CM (with Q=2.7e10)

3. Financial Schedule

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs	IRA Supp. Costs
Total Estimated Cost (TEC)				
Design (TEC)				
Prior Years	2,000	2,000	—	—
Prior Years - IRA Supp.	300	300	—	—
FY 2023	1,600	1,600	—	—
FY 2024	7,800	7,800	9,200	300
FY 2025	4,700	4,700	4,700	—
Outyears	—	—	2,200	—
Total, Design (TEC)	**16,400**	**16,400**	**16,100**	**300**
Construction (TEC)				
Prior Years - IRA Supp.	19,700	19,700	—	—
FY 2023	8,400	8,400	—	—
FY 2024	1,200	1,200	—	11,000
FY 2025	15,300	15,300	21,000	8,700
Outyears	27,800	27,800	31,700	—
Total, Construction (TEC)	**72,400**	**72,400**	**52,700**	**19,700**
Total Estimated Cost (TEC)				
Prior Years	2,000	2,000	—	—
Prior Years - IRA Supp.	20,000	20,000	—	—
FY 2023	10,000	10,000	—	—
FY 2024	9,000	9,000	9,200	11,300
FY 2025	20,000	20,000	25,700	8,700
Outyears	27,800	27,800	33,900	—
Total, Total Estimated Cost (TEC)	**88,800**	**88,800**	**68,800**	**20,000**

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs	IRA Supp. Costs
Other Project Cost (OPC)				
Prior Years	3,000	3,000	1,457	–
Prior Years - IRA Supp.	700	700	–	–
FY 2023	1,000	1,000	1,504	700
FY 2024	1,000	1,000	150	–
FY 2025	–	–	896	–
Outyears	–	–	993	–
Total, Other Project Cost (OPC)	**5,700**	**5,700**	**5,000**	**700**

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs	IRA Supp. Costs
Total Project Cost (TPC)				
Prior Years	5,000	5,000	1,457	–
Prior Years - IRA Supp.	20,700	20,700	–	–
FY 2023	11,000	11,000	1,504	700
FY 2024	10,000	10,000	9,350	11,300
FY 2025	20,000	20,000	26,596	8,700
Outyears	27,800	27,800	34,893	–
Total, TPC	**94,500**	**94,500**	**73,800**	**20,700**

4. Details of Project Cost Estimate

(dollars in thousands)

	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
Total Estimated Cost (TEC)			
Design	12,500	4,000	**N/A**
Design - Contingency	3,900	1,600	**N/A**
Total, Design (TEC)	**16,400**	**5,600**	**N/A**
Construction	31,700	28,700	**N/A**
Site Preparation	N/A	5,800	**N/A**
Equipment	24,200	24,400	**N/A**
Construction - Contingency	16,500	24,300	**N/A**
Total, Construction (TEC)	**72,400**	**83,200**	**N/A**
Total, TEC	**88,800**	**88,800**	**N/A**

(dollars in thousands)

	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
Contingency, TEC	*20,400*	*25,900*	***N/A***
Other Project Cost (OPC)			
Conceptual Planning	500	500	**N/A**
Conceptual Design	2,800	3,100	**N/A**
Start-up	1,200	1,100	**N/A**
OPC - Contingency	1,200	1,000	**N/A**
Total, Except D&D (OPC)	**5,700**	**5,700**	**N/A**
Total, OPC	**5,700**	**5,700**	**N/A**
Contingency, OPC	*1,200*	*1,000*	***N/A***
Total, TPC	**94,500**	**94,500**	**N/A**
Total, Contingency (TEC+OPC)	***21,600***	***26,900***	***N/A***

5. Schedule of Appropriations Requests

(dollars in thousands)

Fiscal Year	Type	Prior Years	FY 2023	FY 2024	FY 2025	Outyears	Total
FY 2024	TEC	22,000	10,000	9,000	—	47,800	88,800
	OPC	3,700	1,000	1,000	—	—	5,700
	TPC	25,700	11,000	10,000	—	47,800	94,500
FY 2025	TEC	22,000	10,000	9,000	20,000	27,800	88,800
	OPC	3,700	1,000	1,000	—	—	5,700
	TPC	25,700	11,000	10,000	20,000	27,800	94,500

Note:

- *This project has not received CD-2 approval; therefore, funding estimates are preliminary.*

6. Related Operations and Maintenance Funding Requirements

Start of Operation or Beneficial Occupancy	1Q FY 2030
Expected Useful Life	25 years
Expected Future Start of D&D of this capital asset	1Q FY 2055

Related Funding Requirements
(dollars in thousands)

	Annual Costs		Life Cycle Costs	
	Previous Total Estimate	Current Total Estimate	Previous Total Estimate	Current Total Estimate
Operations, Maintenance and Repair	5,500	5,500	137,500	137,500

The estimate will be updated and additional details will be provided after CD-1, Approve Alternative Selection and Cost Range.

7. D&D Information

At this stage of project planning and development, SC is planning to construct a new building up to 24,000 gross square feet as part of this project.

	Square Feet
New area being constructed by this project at SLAC	16,000 – 24,000
Area of D&D in this project at SLAC	—
Area at SLAC to be transferred, sold, and/or D&D outside the project, including area previously "banked"	16,000 – 24,000
Area of D&D in this project at other sites	—
Area at other sites to be transferred, sold, and/or D&D outside the project, including area previously "banked"	—
Total area eliminated	—

8. Acquisition Approach

The CRMF Project will be sited at SLAC and is being acquired under the existing DOE M&O contract with Stanford University. SLAC has delivered several large construction projects and research facilities and has the requisite expertise to successfully deliver CRMF. SLAC, with support from partner laboratory expert staff, will complete the design of the technical systems. The acquisition of the CRMF building will be based on the design-build or design-bid-build methodology currently under evaluation. Selected subcontracted vendors, pre-qualified with the necessary capabilities, will fabricate the technical equipment. All contracts will be competitively bid and awarded based on best value to the government.

Lessons learned from other SC projects and other similar facilities will be exploited fully in planning and executing CRMF. The M&O contractor's performance will be evaluated through the annual laboratory performance appraisal process.

19-SC-14, Second Target Station (STS), ORNL
Oak Ridge National Laboratory, ORNL
Project is for Design and Construction

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

Summary

The STS project will design and build a new, very high brightness cold[m] neutron scattering capability to maintain U.S. competitiveness in providing world-leading neutron scattering user facilities. STS will offer unique beamlines to advance our understanding of the fundamental aspects of the natural world. The FY 2025 Request for the STS project is $52,000,000 of Total Estimated Cost (TEC) funding. This project has a preliminary Total Project Cost (TPC) range of $1,800,000,000 to $3,000,000,000. This cost range encompasses the most feasible preliminary alternatives. The current preliminary TPC estimate is $2,242,000,000.

Significant Changes

STS was initiated in FY 2019. The most recent DOE Order 413.3B approved Critical Decision (CD) is CD-1, Approve Alternative Selection and Cost Range, which was approved on November 23, 2020. CD-3A, Approve Long Lead Procurements, is expected in 4Q FY 2025. This Construction Project Data Sheet (CPDS) is an update of the FY 2024 CPDS and does not include a new start for FY 2025.

FY 2023 funding supported the planning, R&D, design, engineering, prototyping, and testing to mature the preliminary design, formalize the design interfaces between systems, and advance the selection and award of the construction manager/general contractor for the conventional facilities construction. FY 2023 efforts continued to focus on reduction of the TPC, including elimination of an office building from the project. The FY 2024 Request will support continued efforts to advance the highest priority activities with an emphasis on the accelerator optics, target assembly, moderator reflector assembly, and civil engineering. The FY 2025 Request will support continued planning, R&D, design, engineering, prototyping, and testing to advance the highest priority activities with emphasis on key project scope for the target vessel, shielding, moderator, and conventional facilities. A potential long lead procurement for civil construction site preparation depends on available funding.

A Federal Project Director, certified to level III, has been assigned to this project.

Critical Milestone History

Fiscal Year	CD-0	Conceptual Design Complete	CD-1	CD-2	Final Design Complete	CD-3	CD-4
FY 2025	1/7/09	4/30/21	11/23/20	4Q FY 2026	4Q FY 2029	4Q FY 2027	2Q FY 2037

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

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[m] Neutrons can be described based on their wavelength and energy. Cold neutrons have lower energy (below 25 meV) and longer wavelengths (>0.2 nm) than thermal neutrons. Cold neutrons are best for characterizing materials with large atomic/molecular structures, such as polymers, biological materials, and magnetic materials. The wavelength of cold neutrons is similar to the activation energies for many solid-state excitations, molecular relaxations, and dynamic processes.

Fiscal Year	Performance Baseline Validation	CD-3A
FY 2025	4Q FY 2026	4Q FY 2025

CD-3A – Approve Long-Lead Procurements for the Construction Management/General Contractor (CM/GC) to perform site preparation for conventional civil construction.

Project Cost History

(dollars in thousands)

Fiscal Year	TEC, Design	TEC, Construction	TEC, Total	OPC, Except D&D	OPC, Total	TPC
FY 2024	294,250	1,850,750	2,145,000	97,000	97,000	2,242,000
FY 2025	290,700	1,854,300	2,145,000	97,000	97,000	2,242,000

Note:
- *This project has not received CD-2 approval; therefore, funding estimates are preliminary.*

2. Project Scope and Justification

Scope

The STS project will design and build the new cold neutron scattering facility that comprises four primary elements: the neutron target and moderators; the accelerator systems; the instruments; and the conventional facilities. Costs for acceptance testing, integrated testing, and initial commissioning to demonstrate achievement of the KPPs are included in the STS scope. STS will be located in unoccupied space east of the existing SNS First Target Station (FTS). The project requires approximately 275,000 square feet of new buildings, making conventional facility construction a major contributor to project costs.

Justification

BES supports a diverse portfolio of large-scale user facilities including two neutron scattering facilities, the HFIR and the SNS, with the SNS FTS providing the world's brightest pulsed neutron scattering capability for thermal neutrons.[n] Currently, the U.S. lacks domestic capacity for research with lower energy, longer wavelength cold neutrons. Filling this gap is critical to maintaining U.S. competitiveness in world-leading neutron scattering research. The STS project will design and build a new, very high brightness, cold neutron scattering capability. The STS will provide unique beamlines to probe matter in space, time, and energy to advance understanding of the fundamental aspects of the natural world. Cold neutrons are best for characterizing materials with large atomic/molecular structures, enabling important scientific results across basic and applied research in chemistry, physics, materials and environmental science, advanced manufacturing, biology, and biomedical science. The research will support design of novel complex materials for energy systems, understanding of foundational phenomena for quantum materials, and enhanced biopreparedness.

STS will feature a very high-density proton beam that strikes a rotating solid tungsten target. The produced neutron beam illuminates compact moderators that will feed experimental beamlines. The neutron moderator system is geometrically optimized to deliver higher peak brightness of cold neutrons. The STS project will exploit 0.7 MW of the 2.8 MW accelerator proton beam power enabled by the PPU project. STS is designed to operate at 15 pulses/second simultaneously with FTS by using one out of every four proton pulses to produce cold neutron beams. FTS will operate at 45 pulses/second. An initial set of eight world-class instruments will feature advanced neutron optics, optimized geometry, and high resolution, advanced detectors, enabling new research opportunities and unprecedented levels of performance.

[n] Thermal neutrons have higher energy (at and above 25 meV) and shorter wavelengths (<0.2 nm) than cold neutrons. The wavelength of thermal neutrons is similar to the interatomic distances in materials, making them ideal for engineering materials, imaging, and determination of crystal structures.

The project is being conducted in accordance with the project management requirements in DOE Order 413.3B, *Program and Project Management for the Acquisition of Capital Assets*.

Key Performance Parameters (KPPs)
The KPPs are preliminary and may change as the project continues towards CD-2. At CD-2 approval, the KPPs will be baselined. The Threshold KPPs represent the minimum acceptable performance that the project must achieve. The Objective KPPs represent the desired project performance. Achievement of the Threshold KPPs will be a prerequisite for approval of CD-4, Project Completion.

Performance Measure	Threshold	Objective
Demonstrate independent control of the proton beam on the two target stations	Operate beam to FTS at 45 pulses/s, with no beam to STS. Operate beam to STS at 15 pulses/s, with no beam to FTS. Operate with beam to both target stations 45 pulses/s at FTS and 15 pulses/s at STS.	Operate beam to FTS at 45 pulses/s, with no beam to STS. Operate beam to STS at 15 pulses/s, with no beam to FTS. Operate with beam to both target stations 45 pulses/s at FTS and 15 pulses/s at STS.
Demonstrate proton beam power on STS at 15 Hz	100 kW beam power	700 kW beam power
Measure STS neutron brightness	peak brightness of 2×10^{13}n/cm^2/sr/Å/s at 5 Å	peak brightness of 2×10^{14}n/cm^2/sr/Å/s at 5 Å
Beamlines transitioned to operations	8 beamlines successfully passed the integrated functional testing per the transition to operations parameters acceptance criteria.	≥ 8 beamlines successfully passed the integrated functional testing per the transition to operations parameters acceptance criteria.

3. Financial Schedule

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs	IRA Supp. Costs
Total Estimated Cost (TEC)				
Design (TEC)				
Prior Years	82,000	82,000	50,442	—
Prior Years - IRA Supp.	42,700	42,700	—	—
FY 2023	32,000	32,000	—	31,728
FY 2024	37,000	37,000	50,000	10,972
FY 2025	17,000	17,000	51,000	—
Outyears	80,000	80,000	96,558	—
Total, Design (TEC)	**290,700**	**290,700**	**248,000**	**42,700**
Construction (TEC)				
FY 2024	15,000	15,000	—	—
FY 2025	35,000	35,000	36,000	—
Outyears	1,804,300	1,804,300	1,818,300	—
Total, Construction (TEC)	**1,854,300**	**1,854,300**	**1,854,300**	**—**
Total Estimated Cost (TEC)				

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs	IRA Supp. Costs
Total Estimated Cost (TEC)				
Prior Years	82,000	82,000	50,442	—
Prior Years - IRA Supp.	42,700	42,700	—	—
FY 2023	32,000	32,000	—	31,728
FY 2024	52,000	52,000	50,000	10,972
FY 2025	52,000	52,000	87,000	—
Outyears	1,884,300	1,884,300	1,914,858	—
Total, Total Estimated Cost (TEC)	**2,145,000**	**2,145,000**	**2,102,300**	**42,700**

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs
Other Project Cost (OPC)			
Prior Years	45,805	45,805	32,772
FY 2023	7,040	7,040	14,500
FY 2024	–	–	2,500
FY 2025	–	–	3,806
Outyears	44,155	44,155	43,422
Total, Other Project Cost (OPC)	**97,000**	**97,000**	**97,000**

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs	IRA Supp. Costs
Total Project Cost (TPC)				
Prior Years	127,805	127,805	83,214	–
Prior Years - IRA Supp.	42,700	42,700	–	–
FY 2023	39,040	39,040	14,500	31,728
FY 2024	52,000	52,000	52,500	10,972
FY 2025	52,000	52,000	90,806	–
Outyears	1,928,455	1,928,455	1,958,280	–
Total, TPC	**2,242,000**	**2,242,000**	**2,199,300**	**42,700**

4. Details of Project Cost Estimate

(dollars in thousands)

	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
Total Estimated Cost (TEC)			
Design	250,700	256,000	**N/A**
Design - Contingency	40,000	38,250	**N/A**
Total, Design (TEC)	**290,700**	**294,250**	**N/A**
Construction	1,299,300	1,477,000	**N/A**
Construction - Contingency	555,000	373,750	**N/A**
Total, Construction (TEC)	**1,854,300**	**1,850,750**	**N/A**
Total, TEC	**2,145,000**	**2,145,000**	**N/A**
Contingency, TEC	*595,000*	*412,000*	***N/A***
Other Project Cost (OPC)			
R&D	20,000	29,546	**N/A**
Conceptual Design	26,000	26,454	**N/A**
Start-up	32,000	22,000	**N/A**
OPC - Contingency	19,000	19,000	**N/A**
Total, Except D&D (OPC)	**97,000**	**97,000**	**N/A**
Total, OPC	**97,000**	**97,000**	**N/A**
Contingency, OPC	*19,000*	*19,000*	***N/A***
Total, TPC	**2,242,000**	**2,242,000**	**N/A**
Total, Contingency (TEC+OPC)	***614,000***	***431,000***	***N/A***

5. Schedule of Appropriations Requests

(dollars in thousands)

Fiscal Year	Type	Prior Years	FY 2023	FY 2024	FY 2025	Outyears	Total
FY 2024	TEC	124,700	32,000	52,000	—	1,936,300	2,145,000
	OPC	45,805	5,000	—	—	46,195	97,000
	TPC	170,505	37,000	52,000	—	1,982,495	2,242,000
FY 2025	TEC	124,700	32,000	52,000	52,000	1,884,300	2,145,000
	OPC	45,805	7,040	—	—	44,155	97,000
	TPC	170,505	39,040	52,000	52,000	1,928,455	2,242,000

Note:
- *This project has not received CD-2 approval; therefore, funding estimates are preliminary.*

6. Related Operations and Maintenance Funding Requirements

Start of Operation or Beneficial Occupancy	2Q FY 2037
Expected Useful Life	25 years
Expected Future Start of D&D of this capital asset	2Q FY 2062

Related Funding Requirements
(dollars in thousands)

	Annual Costs		Life Cycle Costs	
	Previous Total Estimate	**Current Total Estimate**	**Previous Total Estimate**	**Current Total Estimate**
Operations, Maintenance and Repair	59,000	59,000	1,475,000	1,475,000

The numbers presented are the incremental operations and maintenance costs above the existing SNS facility without escalation. The estimate will be updated and additional details will be provided after CD-2, Approve Performance Baseline.

7. D&D Information

The new area being constructed in this project will not replace existing facilities.

	Square Feet
New area being constructed by this project at ORNL	~275,000
Area of D&D in this project at ORNL	—
Area at ORNL to be transferred, sold, and/or D&D outside the project, including area previously "banked"	~275,000
Area of D&D in this project at other sites	—
Area at other sites to be transferred, sold, and/or D&D outside the project, including area previously "banked"	—
Total area eliminated	—

8. Acquisition Approach

Based on the DOE determination at CD-1, ORNL is acquiring the STS project under the existing DOE M&O contract.

The M&O contractor prepared a Conceptual Design Report for the STS project and identified key design activities, requirements, and high-risk subsystem components to reduce cost and schedule risk to the project and expedite the startup. The necessary project management systems are fully up to date, operating, and are maintained as an ORNL-wide resource.

ORNL will design and procure the key technical subsystem components. Some technical system designs will require research and development activities. Preliminary cost estimates for most of these systems are based on SNS operating experience and vendor estimates, while some first-of-a-kind systems are based on expert judgement. Vendors and/or partner labs with the necessary capabilities will fabricate the technical equipment. ORNL will competitively bid and award all subcontracts based on best value to the government. The M&O contractor's performance will be evaluated through the annual laboratory performance appraisal process.

Lessons learned from other SC projects and other similar facilities are being exploited fully in planning and executing the STS.

18-SC-13, Linac Coherent Light Source-II-High Energy (LCLS-II-HE), SLAC
SLAC National Accelerator Laboratory, SLAC
Project is for Design and Construction

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

Summary

The LCLS-II-HE project will expand the capabilities of the LCLS to maintain U.S. leadership in ultrafast and ultrabright x-ray science. The project will increase the energy of the superconducting linac from 4 GeV to 8 GeV and thereby expand the high repetition rate operation (one million pulses per second) into the hard x-ray regime (5-12 keV). The FY 2025 Request for the LCLS-II-HE project is $100,000,000 of Total Estimated Cost (TEC) funding. At CD-1, this project established a preliminary Total Project Cost (TPC) range of $290,000,000 to $480,000,000. This cost range encompassed the most feasible preliminary alternatives. For the pending CD-2 reviews, the project's TPC estimate has exceeded the prior point estimate of $660,000,000 and now has reached $710,000,000, based on COVID-driven cost and schedule growth and additional risks.

Significant Changes

The LCLS-II-HE project was initiated in FY 2019. The most recent DOE Order 413.3B approved Critical Decision (CD) is CD-3B, Approve Long-Lead Procurements, which was approved on January 27, 2023, and was enabled by the investment of the IRA funds. The LCLS-II-HE project continues to be impacted by inflation and supply chain delays, impacting the initial cost, schedule, and project milestones assumptions. A combined CD-2/3 approval is projected for 3Q FY 2024; CD-4 is projected for 2Q FY 2030. This Construction Project Data Sheet (CPDS) is an update of the FY 2024 CPDS and does not include a new start for FY 2025.

FY 2023 funding supported finalizing the design and the performance baseline; continued with engineering, R&D, and injector gun prototyping; and initiated CD-3B long-lead procurements of cryogenic system components and transfer lines for the new superconducting electron gun and cryomodule production at the partner labs. The FY 2024 Request will continue support of the production of cryomodules, continue CD-3B procurements and begin the procurement of vendor-supported design efforts for the cryogenic distribution system, controls systems, and the low emittance injector beamline and related infrastructure; continue the R&D for the superconducting radiofrequency electron gun; and initiate construction/installation contracts. The FY 2025 Request will continue the construction and installation contracts, including the infrastructure systems for cryogenic transfer lines, water, mechanical and electrical, and pre-staging activities for start of the year-long LCLS Dark Time.

A Federal Project Director, certified to Level IV, has been assigned to this project.

Critical Milestone History

Fiscal Year	CD-0	Conceptual Design Complete	CD-1	CD-2	Final Design Complete	CD-3	CD-4
FY 2025	12/15/16	3/23/18	9/21/18	3Q FY 2024	2Q FY 2025	3Q FY 2024	2Q FY 2030

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

Fiscal Year	Performance Baseline Validation	CD-3A	CD-3B
FY 2025	3Q FY 2024	5/12/20	1/27/23

CD-3A – Approve Long-Lead Procurements for cryomodule associated parts and equipment.
CD-3B – Approve Long-Lead Procurements for SRF Injector cryogenic systems, Cryo Distribution Box, Optics for Experimental Systems, Controls Systems.

Project Cost History

(dollars in thousands)

Fiscal Year	TEC, Design	TEC, Construction	TEC, Total	OPC, Except D&D	OPC, Total	TPC
FY 2024	80,400	597,600	678,000	32,000	32,000	710,000
FY 2025	59,000	619,000	678,000	32,000	32,000	710,000

2. Project Scope and Justification

Scope

The LCLS-II-HE project's scope increases the superconducting linac energy from 4 GeV to 8 GeV by installing additional cryomodules in the first kilometer of the existing linac tunnel. The electron beam, generated by a superconducting electron source, will be transported to the existing undulator hall to extend the x-ray energy to 12 keV and beyond. The project will also modify or upgrade existing infrastructure (process cooling water, power, electrical) in the last sector of the linac tunnel and the x-ray transport, optics, and diagnostics system. It will provide new or upgraded instrumentation to augment existing and planned capabilities.

Justification

International developments in X-ray facilities will challenge LCLS's world leadership position. The Shanghai Advanced Research Institute (SARI)XFEL in Shanghai, China, called SHINE, will match the high pulse rate for continuous operation and have double the electron energy enabled by the LCLS-II project, which allows production of shorter (i.e., harder) x-ray wavelength pulses compared to LCLS-II. The European X-ray Free Electron Laser (XFEL) at DESY in Hamburg, Germany has a higher electron energy than LCLS, and recent plans could extend the European XFEL from a pulsed operation mode to continuous operation. The continuous operation improves the stability of the electron beam and provides uniformly spaced pulses of x-rays or, if desired, the ability to customize the sequence of x-ray pulses provided to experiments to optimize the measurements being made. The European XFEL began operations in 2017, and SHINE is expected to begin in 2025. Both of these create a profound capability gap compared to LCLS.

In the face of this challenge to U.S. scientific leadership, extending the energy reach of x-rays beyond the upper limit of LCLS (5 keV) is a high priority. This expanded range to 12 keV will allow U.S. researchers to access x-ray wavelengths as short as one Ångstrom and probe earth-abundant elements that will be needed for large-scale deployment of photo-catalysts for electricity and fuel production. It also allows the study of strong spin-orbit coupling that underpins many aspects of quantum materials, and it reaches the biologically important selenium k-edge, used for protein crystallography.

The ability to observe and understand the structural dynamics of complex matter at the atomic scale, at ultrafast time scales, and in operational environments is critical to the nation's R&D enterprise and ability to develop the new advanced materials for new energy technologies. To achieve this objective, DOE needs a hard x-ray source capable of producing high energy ultrafast bursts with full spatial and temporal coherence at high repetition rates. This capability cannot be provided by any existing or planned light source.

The LCLS-II project was completed successfully in October 2023 and began operation in November 2023. LCLS-II is the first step to address this capability gap. With this upgrade, LCLS is currently the premier XFEL facility in the world at photon energies ranging from 200 eV up to approximately 5 keV. The cryomodule technology is a major advancement from prior designs that will allow continuous operation up to 1 MHz.

Over the past few years, the cryomodule design for the LCLS-II project has performed beyond expectations, providing the technical basis to double the electron beam energy. It is therefore possible to add additional acceleration capacity to double the electron beam energy from 4 GeV to 8 GeV in the LCLS-II-HE project. Calculations indicate that an 8 GeV linac will deliver a hard x-ray photon beam with peak energy of 12.8 keV, which will meet the mission need.

The LCLS-II-HE upgrade will provide world leading experimental capabilities for the U.S. research community by extending the x-ray energy from 5 keV to 12 keV and beyond.

The project is being conducted in accordance with the project management requirements in DOE Order 413.3B, *Program and Project Management for the Acquisition of Capital Assets*.

Key Performance Parameters (KPPs)

The KPPs are preliminary and may change as the project continues towards CD-2. At CD-2 approval, the KPPs will be baselined.

Performance Measure	Threshold	Objective
Superconducting linac electron beam energy	≥ 7 GeV	≥ 8 GeV
Electron bunch repetition rate	93 kHz	929 kHz
Superconducting linac charge per bunch	0.02 nC	0.1 nC
Photon beam energy range	250 to ≥ 8,000 eV	250 to ≥ 20,000 eV
High repetition rate capable, hard X-ray end stations	≥ 1	≥ 4
FEL photon quantity (10^{-3} BW)	$5x10^8$ (50x spontaneous @ 8 keV)	> 10^{11} @ 8 keV (200 mJ) or > $6x10^9$ @ 20.0 keV (20 mJ)

3. Financial Schedule

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs	IRA Supp. Costs
Total Estimated Cost (TEC)				
Design (TEC)				
Prior Years	39,000	39,000	24,037	—
FY 2023	13,000	13,000	15,654	—
FY 2024	7,000	7,000	16,000	—
FY 2025	—	—	3,309	—
Total, Design (TEC)	**59,000**	**59,000**	**59,000**	**—**
Construction (TEC)				
Prior Years	139,657	139,657	99,472	—

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs	IRA Supp. Costs
Total Estimated Cost (TEC)				
Prior Years - IRA Supp.	90,000	90,000	—	—
FY 2023	77,000	77,000	43,118	11,171
FY 2024	113,000	113,000	36,171	78,829
FY 2025	100,000	100,000	188,000	—
Outyears	99,343	99,343	162,239	—
Total, Construction (TEC)	**619,000**	**619,000**	**529,000**	**90,000**
Total Estimated Cost (TEC)				
Prior Years	178,657	178,657	123,509	—
Prior Years - IRA Supp.	90,000	90,000	—	—
FY 2023	90,000	90,000	58,772	11,171
FY 2024	120,000	120,000	52,171	78,829
FY 2025	100,000	100,000	191,309	—
Outyears	99,343	99,343	162,239	—
Total, Total Estimated Cost (TEC)	**678,000**	**678,000**	**588,000**	**90,000**

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs	IRA Supp. Costs
Other Project Cost (OPC)				
Prior Years	17,000	17,000	11,946	–
Prior Years - IRA Supp.	6,000	6,000	–	–
FY 2023	4,000	4,000	4,158	–
FY 2024	–	–	–	2,200
FY 2025	–	–	–	900
Outyears	5,000	5,000	9,896	2,900
Total, Other Project Cost (OPC)	**32,000**	**32,000**	**26,000**	**6,000**

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs	IRA Supp. Costs
Total Project Cost (TPC)				
Prior Years	195,657	195,657	135,455	–
Prior Years - IRA Supp.	96,000	96,000	–	–

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs	IRA Supp. Costs
Total Project Cost (TPC)				
FY 2023	94,000	94,000	62,930	11,171
FY 2024	120,000	120,000	52,171	81,029
FY 2025	100,000	100,000	191,309	900
Outyears	104,343	104,343	172,135	2,900
Total, TPC	**710,000**	**710,000**	**614,000**	**96,000**

Note:

– *In FY 2021, the Office of Science reprogrammed $19,343,211.24 of prior year funds from this project to support the LCLS-II project at SLAC. The Prior Year Budget Authority in the table above reflects this reprogramming. Also in FY 2021, a total of $10,000,000 in current year and prior year funding was reprogrammed to the LCLS-II-HE project and additional funds are included in the outyears to maintain the project profile.*

4. Details of Project Cost Estimate

(dollars in thousands)

	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
Total Estimated Cost (TEC)			
Design	55,500	73,400	**N/A**
Design - Contingency	3,500	7,000	**N/A**
Total, Design (TEC)	**59,000**	**80,400**	**N/A**
Construction	262,000	240,400	**N/A**
Site Preparation	2,000	2,000	**N/A**
Equipment	236,000	220,000	**N/A**
Construction - Contingency	119,000	135,200	**N/A**
Total, Construction (TEC)	**619,000**	**597,600**	**N/A**
Total, TEC	**678,000**	**678,000**	**N/A**
Contingency, TEC	*122,500*	*142,200*	***N/A***
Other Project Cost (OPC)			
R&D	10,000	9,000	**N/A**
Conceptual Planning	1,000	1,000	**N/A**
Conceptual Design	8,000	8,000	**N/A**
Start-up	7,000	6,700	**N/A**
OPC - Contingency	6,000	7,300	**N/A**
Total, Except D&D (OPC)	**32,000**	**32,000**	**N/A**
Total, OPC	**32,000**	**32,000**	**N/A**
Contingency, OPC	*6,000*	*7,300*	***N/A***
Total, TPC	**710,000**	**710,000**	**N/A**

(dollars in thousands)

	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
Total, Contingency (TEC+OPC)	***128,500***	***149,500***	***N/A***

5. Schedule of Appropriations Requests

(dollars in thousands)

Fiscal Year	Type	Prior Years	FY 2023	FY 2024	FY 2025	Outyears	Total
FY 2024	TEC	268,657	90,000	120,000	—	199,343	678,000
	OPC	23,000	4,000	—	—	5,000	32,000
	TPC	291,657	94,000	120,000	—	204,343	710,000
FY 2025	TEC	268,657	90,000	120,000	100,000	99,343	678,000
	OPC	23,000	4,000	—	—	5,000	32,000
	TPC	291,657	94,000	120,000	100,000	104,343	710,000

Note:

– *In FY 2021, the Office of Science reprogrammed $19,343,211.24 of prior year funds from this project to support the LCLS-II project at SLAC. The Prior Year Budget Authority in the table above reflects this reprogramming. Also in FY 2021, a total of $10,000,000 in current year and prior year funding was reprogrammed to the LCLS-II-HE project and additional funds are included in the outyears to maintain the project profile.*

6. Related Operations and Maintenance Funding Requirements

Start of Operation or Beneficial Occupancy	2Q FY 2030
Expected Useful Life	25 years
Expected Future Start of D&D of this capital asset	2Q FY 2055

Related Funding Requirements
(dollars in thousands)

	Annual Costs		Life Cycle Costs	
	Previous Total Estimate	**Current Total Estimate**	**Previous Total Estimate**	**Current Total Estimate**
Operations, Maintenance and Repair	21,500	21,500	537,500	537,500

The numbers presented are the incremental operations and maintenance costs above the LCLS-II facility without escalation. The estimate will be updated and additional details will be provided after CD-2, Approve Project Performance Baseline.

7. D&D Information

At this stage of project planning and development, SC anticipates no new area will be constructed for this project.

8. Acquisition Approach

Based on the DOE determination at CD-1, SLAC is acquiring the LCLS-II-HE project under the existing DOE M&O contract.

SLAC has completed a Conceptual Design Report for the LCLS-II-HE and is completing the design and preparing for CD-2/3 approval. The necessary project management systems are fully operating and are maintained as a SLAC-wide resource.

SLAC is partnering with other laboratories for design and procurement of key technical subsystem components. Technical system designs require research and development activities. Preliminary cost estimates for these systems are based on actual costs from the LCLS-II project and other similar facilities, to the extent practicable. The M&O contractor is fully exploiting recent cost data in planning and budgeting for the project. SLAC or partner laboratory staff will complete the design of the technical systems. SLAC or subcontracted vendors with the necessary capabilities will fabricate the technical equipment. All subcontracts will be competitively bid and awarded based on best value to the government. The M&O contractor's performance will be evaluated through the annual laboratory performance appraisal process.

Lessons learned from the LCLS-II project and other similar facilities are exploited fully in planning and executing LCLS-II-HE.