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 Basic Energy Sciences 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, topical in-depth community workshops and reports, and rigorous program reviews. BES balances its research investments among discovery-oriented basic research, use-inspired basic research as exemplified by the Energy Frontier Research Centers (EFRCs), and research in support of Federal priorities and technological innovation such as the Energy Earthshot Research Centers (EERCs).

BES scientific user facilities consist of a complementary set of intense 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, fields, excitations, and motion—to answer some of the most challenging science questions and to provide insights on the scientific basis for energy technologies. The above-noted BESAC report recounts the central role of these shared resources in U.S. scientific and industrial leadership; a 2021 BESAC report on international benchmarking[b] outlines strategies to maintain and enhance this competitive position for facilities and key BES scientific areas. In response to the COVID-19 pandemic, BES facilities were at the forefront of the research to understand the virus, to provide therapeutics to combat it, and to combat supply chain issues for personal protective and medical equipment. 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 begins with rigorous community-based processes for conceptualization, planning, and execution in construction of facilities that continues in performance assessment for operating facilities.

Key to exploiting scientific discoveries for future clean energy technological 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. Robust materials need improved functionality relative to today's energy materials, and new chemical processes require ever-increasing control at the level of electronic structure and dynamics. 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 technologies including hydrogen and solar generation of fuels and electricity, long-term energy storage, geothermal energy, nuclear energy, carbon capture, and clean, lower carbon manufacturing. Working closely with the DOE technology offices, innovations and insights from BES research will evolve with awareness of technology challenges and will be disseminated to the broader research community to accelerate applied research and translate federal investments to industrial impact.

To reach the full potential of these tools and capabilities for clean energy, it is critical that the Nation bring to bear the strengths of all of its human resources, including students and institutions not currently well represented in the scientific ecosystem, and underserved and environmental justice regions. Collectively, with fully broadened participation, these new tools and capabilities convey a significant strategic advantage for the Nation to advance the scientific frontiers while laying the foundation for future clean energy innovations and economic prosperity.

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[a] https://science.osti.gov/~/media/bes/pdf/BESat40/BES_at_40.pdf
[b] https://science.osti.gov/-/media/bes/pdf/reports/2021/International_Benchmarking-Report.pdf

Highlights of the FY 2024 Request
The BES FY 2024 Request of $2,692.9 million is an increase of $158.9 million, or 6.3 percent, above the FY 2023 Enacted.

Research
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). Through continued funding for the Established Program to Stimulate Competitive Research (EPSCoR) and the Reaching a New Energy Sciences Workforce (RENEW) and Funding for Accelerated, Inclusive Research (FAIR) initiatives, BES will build stronger programs with underrepresented institutions and regions, including investing in a more diverse and inclusive workforce to address environmental justice issues.

- Clean Energy and SC Energy Earthshots Initiatives: BES will increase support for research to provide understanding and foundations for clean energy, with investments across the entire portfolio to accelerate innovation to reduce impacts resulting from climate change while advancing clean energy technologies and infrastructure. Current DOE Energy Earthshots focus on aggressive goals for direct air capture of CO_2, carbon-neutral hydrogen, energy storage for the grid, geothermal systems, floating offshore wind, and industrial heat decarbonization, with additional topics under development. BES funding will also advance understanding of the fundamental properties of Critical Materials/Minerals and identify methodologies to reduce their use and discover substitutes, and to enhance their domestic supply.
- There are other initiatives with continued BES funding including: Fundamental Science to Transform Advanced Manufacturing, emphasizing low-carbon processes and transformative chemistry, materials, and biology for next-generation industries; and Microelectronics, focusing on a multi-disciplinary co-design innovation ecosystem in which materials, chemistries, devices, systems, architectures, algorithms, and software are developed in a closely integrated fashion including new Microelectronics Science Research Centers as authorized under the CHIPS and Science Act (Section 10731, Micro Act). Additionally, BES funding will support Accelerate Innovation in Emerging Technologies (Accelerate), to drive scientific discovery to sustainable production of new technologies across the innovation continuum, including relevant experiences for the future workforce; and Artificial Intelligence and Machine Learning (AI/ML), data science to accelerate fundamental discoveries and to apply these techniques for effective user facility operations and interpretation of massive data sets.
- BES will also support: QIS, a robust core research portfolio to complement the NQISRCs; Biopreparedness Research Virtual Environment (BRaVE), developing and expanding capabilities at user facilities for responsiveness to biological threats; Accelerator Science and Technology Initiative, to provide the world's most comprehensive and advanced accelerator-based facilities for scientific research; and Advanced Computing, with Advanced Scientific Computing Research (ASCR), including computational materials and chemical sciences to deliver shared software infrastructure, and support for efforts toward integration of computing, networking, and data storage with experimental user facilities and instruments at national labs. BES will prioritize transitioning Exascale Computing Project (ECP) researchers, software, and technologies into core research efforts and DOE priority research areas as ECP concludes.
- BES will support RENEW, expanding targeted efforts, including a RENEW graduate fellowship, to broaden participation and advance belonging, accessibility, justice, equity, diversity, and inclusion in SC-sponsored research; and FAIR, improving underrepresented institutions' capability to perform and propose competitive research and building beneficial relationships with DOE national laboratories and facilities.

Facility Operations
The five BES-supported x-ray light sources, two neutron sources, and five Nanoscale Science Research Centers (NSRCs) are supported at approximately 90 percent of the funding required for re-baselined, normal operations—balancing safe operations with user access.

Projects
Support continues for the Advanced Light Source Upgrade (ALS-U), Linac Coherent Light Source-II High Energy (LCLS-II-HE), Proton Power Upgrade (PPU), Second Target Station (STS), and Cryomodule Repair and Maintenance Facility (CRMF) line-item projects and two Major Items of Equipment (MIE) projects: NSLS-II Experimental Tools-II (NEXT-II) and NSRC Recapitalization. The Request initiates design funding for the NSLS-II Experimental Tools-III (NEXT-III) and High Flux Isotope Reactor Pressure Vessel Replacement (HFIR-PVR) line-item projects. In addition, the Request initiates preliminary planning for Advanced Photon Source (APS) and Advanced Light Source (ALS) Beamline MIE projects.

Basic Energy Sciences
Funding

(dollars in thousands)

	FY 2022 Enacted	FY 2023 Enacted	FY 2024 Request	FY 2024 Request vs FY 2023 Enacted
Basic Energy Sciences				
Scattering and Instrumentation Sciences Research	85,675	105,971	107,713	+1,742
Condensed Matter and Materials Physics Research	192,569	203,807	221,214	+17,407
Materials Discovery, Design, and Synthesis Research	88,047	97,097	101,297	+4,200
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	12,500	–
Energy Innovation Hubs - Materials	25,000	25,913	25,913	–
Computational Materials Sciences	13,492	13,492	13,492	–
Total, Materials Sciences and Engineering	**494,783**	**548,780**	**572,129**	**+23,349**
Fundamental Interactions Research	124,842	127,985	141,339	+13,354
Chemical Transformations Research	119,725	129,651	140,158	+10,507
Photochemistry and Biochemistry Research	106,871	130,877	139,714	+8,837
Energy Frontier Research Centers - Chemical	65,000	65,000	65,000	–
Energy Earthshot Research Centers - Chemical	–	12,500	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	**451,688**	**501,263**	**533,961**	**+32,698**
X-Ray Light Sources	538,282	599,498	704,134	+104,636
High-Flux Neutron Sources	294,000	315,740	373,163	+57,423
Nanoscale Science Research Centers	142,744	153,409	150,880	-2,529
Other Project Costs	14,300	19,500	14,000	-5,500
Major Items of Equipment	30,000	50,000	25,000	-25,000

(dollars in thousands)

	FY 2022 Enacted	FY 2023 Enacted	FY 2024 Request	FY 2024 Request vs FY 2023 Enacted
Scientific User Facilities, Research	38,003	52,610	58,966	+6,356
Total, Scientific User Facilities (SUF)	**1,057,329**	**1,190,757**	**1,326,143**	**+135,386**
Subtotal, Basic Energy Sciences	**2,003,800**	**2,240,800**	**2,432,233**	**+191,433**
Construction				
24-SC-10 HFIR Pressure Vessel Replacement (PVR), ORNL	–	–	4,000	+4,000
24-SC-12 NSLS-II Experimental Tools - III (NEXT-III), BNL	–	–	2,556	+2,556
21-SC-10 Cryomodule Repair & Maintenance Facility (CRMF), SLAC	1,000	10,000	9,000	-1,000
19-SC-14 Second Target Station (STS), ORNL	32,000	32,000	52,000	+20,000
18-SC-10 Advanced Photon Source Upgrade (APS-U), ANL	101,000	9,200	–	-9,200
18-SC-11 Spallation Neutron Source Proton Power Upgrade (PPU), ORNL	17,000	17,000	15,769	-1,231
18-SC-12 Advanced Light Source Upgrade (ALS-U), LBNL	75,100	135,000	57,300	-77,700
18-SC-13 Linac Coherent Light Source-II-High Energy (LCLS-II-HE), SLAC	50,000	90,000	120,000	+30,000
13-SC-10 Linac Coherent Light Source-II (LCLS-II), SLAC	28,100	–	–	–
Subtotal, Construction	**304,200**	**293,200**	**260,625**	**-32,575**
Total, Basic Energy Sciences	**2,308,000**	**2,534,000**	**2,692,858**	**+158,858**

SBIR/STTR funding:

- FY 2022 Enacted: SBIR $61,375,000 and STTR $8,643,000
- FY 2023 Enacted: SBIR $35,557,000 and STTR $5,000,000
- FY 2024 Request: SBIR $36,306,000 and STTR $5,105,000

Basic Energy Sciences
Explanation of Major Changes

	(dollars in thousands) FY 2024 Request vs FY 2023 Enacted
Materials Sciences and Engineering Research will continue to support fundamental scientific opportunities for materials innovations, including those identified in recent BESAC and Basic Research Needs workshop reports. Research priorities include clean energy (e.g., hydrogen, direct air capture of CO_2, energy storage, and wind), advanced manufacturing (e.g., reductions in carbon-intensive heat), microelectronics research centers, data science and AI/ML, Accelerate, critical materials, computational materials sciences, advanced computing, 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 program, the NQISRCs, EPSCoR, and the EERCs.	**+$23,349**
Chemical Sciences, Geosciences, and Biosciences Research will continue to support fundamental scientific opportunities for innovations in chemistry, geosciences, and biosciences, including those identified in recent BESAC, Basic Research Needs, and Roundtable workshop reports. Research priorities include clean energy (e.g., energy-efficient, sustainable cycles for carbon and hydrogen, geothermal, and direct air capture of CO_2), advanced manufacturing, microelectronics research centers, Accelerate, critical materials/minerals, computational chemical sciences, QIS, FAIR, and RENEW. The Request also includes funding for continued support of the EFRCs, the Fuels from Sunlight Hub awards, the NQISRCs, and the EERCs.	**+$32,698**
Scientific User Facilities (SUF) Five BES-supported x-ray light sources, two neutron sources, five NSRCs are supported at approximately 90 percent of the re-baselined funding level, balancing safe operation and user access. These facilities will continue to support the BRaVE initiative to maintain and enhance capabilities to tackle biological threats and the advanced computing initiative to augment integration of computing, networking, and data storage with user facilities and national labs. Continued facilities research priorities include accelerator science and technology, data science and AI/ML, and RENEW. The Request continues two MIEs: the NEXT-II beamline project for NSLS-II and the NSRC recapitalization project and initiates preliminary planning for APS and ALS Beamline MIE projects. The Request also provides Other Project Costs (OPC) to support the CRMF, HFIR-PVR, and NEXT-III projects.	**+$135,386**
Construction The Request provides continuing support for the LCLS-II-HE, the STS, and the CRMF projects and provides final funding for the PPU and the ALS-U projects. The Request also initiates design funding for the NEXT-III project at Brookhaven National Laboratory (BNL) and the HFIR-PVR project at Oak Ridge National Laboratory (ORNL).	**-$32,575**
Total, Basic Energy Sciences	**+$158,858**

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 joint participation in research workshops, strategic planning activities, solicitation development, and program review meetings, 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. For example, BES participates in the newly formed Hydrogen JST (previously a SETT), engaging in activities to advance the Hydrogen Energy Earthshot aimed at accelerating breakthroughs of more abundant, affordable, and reliable clean energy solutions within the decade.[c] BES also contributes to the Carbon Dioxide Removal SETT and the Carbon Negative Earthshot to address the challenge of long-term removal of carbon dioxide from the atmosphere using a variety of approaches including direct air capture, and the Energy Storage JST and Long Duration Storage Earthshot to accelerate the development, commercialization, and utilization of next-generation energy storage technologies. In addition, BES is also participating in recently established Earthshots focused on floating offshore wind, decarbonization of heating used in manufacturing, and enhanced geothermal systems. Other coordination activities focus on fusion energy and sustainable fuels. Collectively, these BES activities impact the energy-use sectors: transportation, buildings, industrial, and electricity. Historically, co-siting of research by BES and DOE energy technology programs at the same institutions has proven to be a valuable approach to facilitate close integration of basic and applied research. In these cases, teams of researchers benefit by sharing expertise and knowledge of research breakthroughs and program needs. The DOE national laboratory system plays a crucial role in achieving this integration of basic and applied research.

Informal coordination includes participation of BES program managers in regularly scheduled intra-departmental meetings for information exchange and coordination on solicitations, program reviews, and project selections. These interactions cover a broad range of topics including biofuels derived from biomass; solar energy utilization, including solar fuels; critical minerals/materials; advanced nuclear energy systems; vehicle technologies; biotechnology; and fundamental science to transform advanced manufacturing and industrial processes. These activities facilitate cooperation and coordination between BES and the DOE energy technology offices and defense programs. Additionally, DOE technology office personnel participate in reviews of BES research, and BES personnel participate in reviews of research funded by the technology offices.

Program Accomplishments
BES user facilities continue to combat the COVID-19 pandemic and to prepare for biological threats, including monkeypox.

- Pfizer scientists used x-ray facility capabilities to determine certain structural properties of their vaccine Comirnaty, and to develop their antiviral, Paxlovid. Following on their approved therapeutic Sotrovimab, GlaxoSmithKline and Vir Biotechnology used x-ray facilities to help produce an antibody that neutralizes all known strains of SARS-CoV-2. More than 750 unique users (including most major Pharma companies), using more than 55 different beamlines at x-ray facilities, determined more than 490 structures of SARS CoV-2 proteins with/without potential antivirals or antibodies.
- X-ray light source users are also at the forefront of investigations of monkeypox, including structural biology research related to how poxviruses (including monkeypox virus) evade the host anti-viral immune response. Research includes characterization of poxvirus protein structures and interactions with antigenic proteins and antibodies, as well as therapeutics developments to combat monkeypox and related poxviridae.

BES research and facilities advance understanding of catalysts and of key components of chemical and energy conversions for value-added chemicals and clean fuels.

- X-ray, nanoscale science, and computational facilities were used to study a catalyst under different reaction conditions to track methanol formation. The tools helped to identify the active catalyst sites and model the kinetics of different reaction pathways. The data show that the reaction proceeds on two different pathways using two different sites of

[c] https://www.energy.gov/eere/fuelcells/hydrogen-shot.

the catalyst, yielding insights into conversion of waste methane greenhouse gases into methanol, a liquid fuel and chemical.

- Pursuing highly efficient transformations of renewable feedstocks, researchers developed molecular catalysts that are highly active and selective at low temperature for ethanol upgrading to butanol, that demonstrated a prolonged lifetime, and that could couple ethanol in tandem reactions to produce high-value industrial chemical intermediates. Conversion of ethanol to higher-order alcohols has the potential to supplement the transportation sector; higher-order alcohols feature more desirable fuel characteristics, such as higher energy densities and lower water solubility.
- Researchers developed a non-thermal plasma-excited pathway that achieved the desired conversion of the waste gas CO_2 and ethane to value-added oxygenated chemicals and fuels at atmospheric pressure and temperature in an energy-efficient single step. Plasma-activated reactions are more easily adaptable to renewable electricity than are large-scale thermally activated processes.
- Scientists used ultrafast attosecond-duration pulses of x-rays to map the coherent motion of electrons in a molecule, with the potential to provide a precise understanding of the fundamental role of coherent charge transfer in chemical and biological processes and energy conversions. The measurement provides a testbed for exploring the effect of electronic coherence in the photoexcitation dynamics and subsequent photochemical behavior of molecular systems.

BES research and facilities improve materials assembly processes for advanced manufacturing.

- Neutron scattering has been used for real-time monitoring and evaluation of residual strain during post-production heat treatment to improve 3D printing processes for metal parts. Comparison to computer simulation allows prediction of the residual stress distributions as a function of the process parameters. The results are being used to validate computer models and adjust component designs to reduce residual strain formation during additive manufacturing.
- Scientists have advanced the use of DNA for assembling new nanoscale materials into complex and prearranged structures for next-generation applications, such as nano-robots for manufacturing or innovative materials to harvest light. A hollow DNA cuboid nanochamber is formed, and the encoded DNA strands that extend from it allow precise control of the assembly pathway. Complex arrays of nanocargoes were fabricated with controlled architectures.

BES research contributes to the potential for reduced use and increased supply of critical materials for energy storage.

- Scientists have demonstrated that partially substituting iron for nickel in rare earth nickelates produces a change in electron transfer that makes it easier for the material to accept and donate electrons during catalysis, boosting the oxygen evolution reaction (OER). OER is a crucial process for energy conversion and storage, especially for water electrolysis to produce hydrogen. Current OER catalysts are based on precious metals. This work offers new insights into design strategies for developing low-cost, earth-abundant, and robust electrocatalysts for OER.
- Researchers developed AI/ML methods to assist the computational design of ligands for more selective and efficient solvent extraction and separation of rare-earth elements, to predict accurate distribution coefficients, and to enable higher-throughput screening of viable candidates, resulting in an extensive and shareable ligand property database for rare-earth separations.

Scientists advance AI/ML techniques for BES science applications and develop novel materials with potential to advance quantum computation.

- An AI/ML transfer learning approach using data from laboratory experiments is helping scientists understand and predict how natural faults respond, a critical factor in the design and control of geologic energy storage and waste sequestration reservoirs for CO_2 sequestration, hydrogen storage, and geothermal energy extraction.
- Researchers incorporated physics-based descriptions (quantum chemistry) directly in a deep neural network to develop chemical models that are simultaneously accurate, transferable, and interpretable for large or new chemical systems and for predicting molecular properties.
- Molecular spins are a promising class of chemically tunable quantum bits (qubits) for emerging quantum technologies; scientists addressed practical challenges by developing molecular color-center qubits with optically addressable spin. In topological materials for electronics, researchers showed that Weyl and Dirac semimetals with a topological “laser-pulse switch” can control electron motion at high speed with low energy. Researchers directly observed electrons forming a 2D Wigner crystal, in which they move collectively as a coherent system. All of these findings could be exploited for quantum computation.

Basic Energy Sciences
Materials Sciences and Engineering

Description

Materials are critical to nearly every aspect of energy generation, storage, transmission, and end-use. 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 and to tackle climate change. The BESAC report on transformative opportunities for discovery science, coupled with the Basic Research Needs workshop reports on energy technologies and roundtable reports, provide further documentation of the importance of materials sciences in forefront research for next-generation scientific and technological advances. 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 design and discovery 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, thermal, optical, and mechanical properties that result from material composition (including rare earths and other critical materials); understanding the impact of extreme environments on material properties and performance; and exploring materials whose properties arise from the effects of quantum mechanics.
- **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 use of rare earth and other critical materials, enable more effective polymer chemistries, and/or 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 (femtoseconds to seconds) and length (nanoscale to mesoscale and beyond) 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 manufacturing processes, including extremes in temperature, pressure, stress, photon and radiation flux, electromagnetic fields, and chemical exposures. To maintain leadership in materials discovery, 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. This research includes investigation of the interfaces between physical, chemical, and biological sciences to explore new approaches to novel materials design and advanced sustainable manufacturing. In clean energy-related research, there is a growing emphasis on carbon dioxide removal, including direct capture of carbon dioxide from the air. Other topics in clean energy include a focus on low-carbon hydrogen research and energy storage for both transportation and the electricity grid. Also, critical materials and minerals 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 for QIS. 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, NQISRCs, in partnership with other SC programs, and EERCs (in partnership with ASCR, Biological and Environmental Research [BER], and with DOE energy technology offices). These research modalities support multi-investigator, multi-disciplinary research focused on forefront scientific challenges in support of the DOE clean energy mission. This subprogram supports the Accelerate initiative to ensure that science advances are rapidly transitioned to energy technologies.

This subprogram also includes the DOE EPSCoR program. The DOE EPSCoR program will strengthen 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 expands targeted efforts, including a RENEW graduate fellowship, to broaden participation and advance belonging, accessibility, justice, equity, diversity, and inclusion in SC-sponsored research. The FAIR initiative focuses investment on enhancing research on clean energy, climate, and related topics at minority serving and under-served institutions.

<u>Scattering and Instrumentation Sciences Research</u>
Advanced characterization tools with very high precision in space and time are essential to understand, predict, and ultimately control matter and energy at the electronic, atomic, and nanoscale levels. 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, generating scientific knowledge that is foundational to the BES mission. The major advances in materials sciences from DOE’s world-leading electron, neutron, and x-ray scattering facilities provide continuing evidence of the importance of this research field. In addition, the BESAC report on transformative opportunities for discovery science identified imaging as one of the pillars for future transformational advances. The importance of multimodal platforms to reveal the most critical features of a material has been a finding in several of the Basic Research Needs 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, supporting the work of NQISRCs. This program is focused on open questions in materials science and physics, but these characterization tools 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 at length- and time-scales spanning many orders of magnitude. A distinct aspect of this activity is the development of innovative instrumentation and techniques for scattering, spectroscopy, and imaging needed to link the microscopic and macroscopic properties of materials relevant to technologies for clean energy and mitigation of climate change. Included is the use of cryogenic environments to evaluate properties only occurring at these temperatures and to learn about processes and interfaces in materials that are damaged by the probes used to characterize them. The use of multiscale and multimodal techniques to extract heretofore unattainable information on multiple length and time scales is a growing aspect of this research, as is the development and application of cryogenic electron microscopy for challenges in physical sciences. For 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 (temperature, pressure, stress, radiation, magnetic fields, and electrochemical potentials). Advances in cryogenic microscopy will support the BRaVE initiative since this instrumentation is heavily used to characterize biological threats. Information from these characterization tools is the foundation for the creation of new materials that have extraordinary tolerance and can function in extreme environments without property degradation.

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. Also supported is research to understand the role of rare earth and other 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. Investigations include bulk materials as well as nanostructures and layered structures such as graphene, multilayered structures of two-dimensional materials, and studies of the electronic properties of materials at ultra-low temperatures and in high magnetic fields. The research advances the fundamental understanding of electronic, magnetic, thermal, and optical properties relevant to energy-efficient microelectronics and QIS. The focus on QIS research couples experimental and theoretical expertise in quantum materials with prototypes of quantum structures that can be used to study the science of device functionality and performance.

Activities also emphasize research to understand how materials respond to temperature, light, radiation, corrosive chemicals, and other environmental conditions. This includes electrical and optical properties of materials related to solar energy as well as the effects of defects on electronic properties, strength, deformation, and failure over a wide range of length and time scales. In FY 2024, these activities will continue to support the SC Energy Earthshots initiative. A recent focus is on extending knowledge of radiation effects to enable predictive capabilities for the extreme environments expected in future nuclear reactors and accelerators for SC facilities.

In FY 2024, BES will continue to partner with other SC programs to support the NQISRCs initiated in FY 2020. These centers focus on a set of QIS applications and cross-cutting topics that span the development space that will impact SC programs, including sensors, communication, quantum emulators/simulators, and enabling technologies that will pave the path to exploit quantum computing in the longer term. 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 the ASCR, High Energy Physics (HEP), Fusion Energy Sciences (FES), and Nuclear Physics (NP) programs, BES will continue activities begun in FY 2021 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] Among the challenges is discovery science that can lead to low-power microelectronics for edge computing as well as for exascale computers and beyond. Such computing capabilities will be necessary to analyze the vast volumes of data that will be generated by future SC facilities. Similarly, transforming power electronics and the electricity grid into a modern, agile, resilient, and energy-efficient system requires improvements in advanced microelectronics materials, and their integration within a co-design framework.

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

Materials Discovery, Design, and Synthesis Research

The discovery and development of new materials has long been recognized as the engine that drives science frontiers, technology innovations, and advanced manufacturing. Predictive design and discovery of new forms of matter with desired properties continues to be a significant challenge for materials sciences. A strong, vibrant research enterprise in the discovery and design of new materials is critical to world leadership—scientifically, technologically, and economically. One of the goals of this activity is 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. In FY 2024, these activities will support the SC Energy Earthshots initiative.

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. In FY 2024, this program will continue to apply materials discovery and synthesis research to understand the unique properties of rare earth and other critical materials and minerals, with the goal of reducing their use. New research directions will be inspired by BES reports related to advanced manufacturing, as well as 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. Emphasis will include advancing the basic science of advanced manufacturing through innovative approaches for scalable assembly and integration of predictive modeling with characterization tools tuned to advanced manufacturing scale, complexity, and speed.

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. Major research directions include the controlled synthesis and assembly of nanoscale materials into functional materials with desired properties; mimicking the low-energy synthesis approaches of biology to produce materials; bio-inspired materials that assemble autonomously and, in response to external stimuli, dynamically assemble and disassemble to form non-equilibrium structures; and adaptive and resilient materials that also possess self-repairing and self-regulating capabilities. The portfolio also 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. An important element of this activity is research to understand the progression of structure and properties as a material is formed, in order to understand the underlying physical mechanisms and to gain atomic level control of material synthesis and processing, including the extraordinary challenges for synthesis of quantum materials.

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 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 energy-related research; jumpstart research capabilities in designated states and territories through training scientists and engineers in energy-related areas; and build beneficial relationships between scientists and engineers in the designated jurisdictions and world-class national laboratories managed by the DOE. This research leverages DOE national user facilities and takes advantage of opportunities for intellectual collaboration across the DOE system. Through broadened participation, DOE EPSCoR seeks to augment the network of energy-related research performers across the Nation.

Annual EPSCoR funding opportunities alternate between a focus on research performed in collaboration with the DOE national laboratories and a focus on implementation awards that facilitate larger team awards for the development of research infrastructure in the EPSCoR jurisdictions. The FY 2024 program will focus on EPSCoR State-National Laboratory Partnership awards promoting single-investigator and small-group interactions with the unique capabilities of the DOE national laboratory system. The technical scope will include a focus on clean energy research to tackle climate science, expanding these important research communities and supporting the SC Energy Earthshots initiative. The program will continue to support early career scientists from EPSCoR jurisdictions on an annual basis and complementary support for research grants to eligible institutions, including participation in the RENEW and FAIR initiatives.

<u>Energy Frontier Research Centers</u>
The EFRC program is a unique research modality, bringing together the skills and talents of teams of investigators to perform energy-relevant, basic research with a scope and complexity beyond what is possible in standard single-investigator or small-group awards. These multi-investigator, multi-disciplinary centers foster, encourage, and enable transformative scientific advances. They allow experts from a variety of disciplines to collaborate on shared challenges, combining their strengths to uncover new and innovative solutions to the most difficult problems in materials sciences. The EFRCs also support numerous graduate students and postdoctoral researchers, educating and training a scientific workforce for the 21st century economy. The EFRCs supported in this subprogram focus on the following topics: 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 and gas separation; quantum materials and QIS; microelectronics; and materials for future nuclear energy and waste storage. After thirteen years of research activity, the program has produced an impressive breadth of scientific accomplishments, including over 15,000 peer-reviewed journal publications.

BES uses a variety of methods to regularly assess the progress of the EFRCs, including annual progress reports, monthly phone calls with the EFRC Directors, periodic Directors' meetings, and on-site visits by program managers. Each EFRC undergoes a review of its management structure and approach in the first year of the award and a midterm assessment of scientific progress compared to its scientific goals. To facilitate communication of results to other EFRCs and DOE, BES holds scientific meetings of the EFRC researchers biennially.

In FY 2024, BES plans to issue a Funding Opportunity Announcement (FOA) to recompete the four-year EFRC awards that were made in FY 2020. Emphasis will be placed on topical areas of the highest priority to the Department, including QIS, microelectronics, transformative manufacturing, and other program priorities.

<u>Energy Earthshot Research Centers</u>
The EERC program was launched in FY 2023, building on the success of the EFRCs. Like the EFRCs, EERCs will 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, EERCs will address the gap between basic research and the applied research and development activities to facilitate the exchange of knowledge between SC and the DOE energy technology offices, which is key to realizing the stretch goals of the Energy Earthshots. EERCs will support team awards involving academic, national lab, and industrial researchers with joint planning by SC and energy technology offices, establishing a new era of cross-office research cooperation. The funding will focus efforts directly at the interface, ensuring that directed fundamental research and capabilities at SC user facilities tackle the most challenging barriers identified in the applied research and development activities.

Existing DOE Energy Earthshots include the Hydrogen Shot, the Long Duration Storage Shot, the Carbon Negative Shot, the Enhanced Geothermal Shot, the Floating Offshore Wind Shot, and the Industrial Heat Shot. Additional topics are under consideration for future announcements. From a science perspective, many research gaps for the Energy Earthshots crosscut all topics and will provide a foundation for other clean energy technology challenges, including biotechnology, critical minerals/materials, energy-water, subsurface science (including geothermal research), 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 development of the scientific base to co-design processes and systems rather than individual materials, chemistries, and components. EERCs will leverage individual Center research to cross-fertilize the ideas that emerge in one topical area to benefit others with similar challenges accelerating the science, as well as the technologies.

The FY 2024 Request continues support for the EERCs established in FY 2023 and provides additional support for Centers associated with new Energy Earthshots.

Energy Innovation Hubs

The Batteries and Energy Storage Energy Innovation Hub program was initiated by BES in 2012 and supported the Joint Center for Energy Storage Research (JCESR) for ten years. JCESR was a multi-institutional research team led by Argonne National Laboratory (ANL) in collaboration with multiple other national laboratories and universities, as well as the Army Research Laboratory and industry. JCESR focused on early-stage research to tackle forefront, basic scientific challenges for next-generation electrochemical energy storage. In FY 2024, BES will continue to support Batteries and Energy Storage Energy Innovation Hub awards initiated in FY 2023 as a result of an open recompetition of the program. Based on established best practices for managing large awards, BES will continue to require quarterly reports, frequent teleconferences, and annual progress reports and peer reviews to communicate progress, provide input on the technical directions, and ensure high-quality, impactful research.

Computational Materials Sciences

Major strides in materials synthesis, processing, and characterization, combined with concurrent advances in computational science enabled by enormous improvements in high-performance computing capabilities; also, have opened an unprecedented opportunity to design new materials with specific functions and physical properties. The opportunity is to leap beyond simple extensions of current theory and models of materials towards a paradigm shift in which specialized computational codes and software enable the design, discovery, and development of new materials or functionalities, and in turn, create new advanced, innovative technologies.

Awards in this program focus on the creation of computational codes and associated experimental/computational databases for the design of materials with new 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 validate the computational predictions. It uses the unique world-leading tools and instruments at DOE’s user facilities. The computational codes will use DOE’s leadership computational facilities and be positioned to take advantage of today’s petascale and 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. These codes and generated data will be disseminated for use by the broader research community and by industry to accelerate the design of new functional materials.

BES manages the computational materials science research activities using the approaches developed for similar small and large team modalities. Management reviews by a peer review panel are held in the first year of the award for large teams. Mid-term peer reviews are held to assess scientific progress, with regular teleconferences, annual progress reports, and active oversight by BES throughout the performance period. In FY 2024, the funding associated with the four-year awards in FY 2020 will be recompeted. Within available resources, BES will prioritize transitioning ECP researchers, software, and technologies into core research efforts and DOE priority research areas as ECP concludes.

Basic Energy Sciences
Materials Sciences and Engineering

Activities and Explanation of Changes

(dollars in thousands)

FY 2023 Enacted		FY 2024 Request	Explanation of Changes FY 2024 Request vs FY 2023 Enacted
Materials Sciences and Engineering	**$548,780**	**$572,129**	**+$23,349**
Scattering and Instrumentation Sciences Research	$105,971	$107,713	+$1,742
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 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, tackling climate change, advanced manufacturing, and preparedness for biological threats. The RENEW initiative expands targeted efforts to increase participation and retention of individuals from underrepresented groups in SC research activities. The Request supports the FAIR and Accelerate initiatives.	Expanded investments will broaden RENEW activities, including a RENEW graduate fellowship. Investments will emphasize basic research related to clean energy and advanced manufacturing and will provide research and training opportunities for underrepresented communities and institutions.

(dollars in thousands)

FY 2023 Enacted	FY 2024 Request	Explanation of Changes FY 2024 Request vs FY 2023 Enacted
Condensed Matter and Materials Physics Research $203,807	$221,214	+$17,407
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 such as solar 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 will continue to partner with other SC program offices to support the NQISRCs that were initiated in FY 2020. Additional investments will 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. New Microelectronics Science Research Centers are established, as authorized under the CHIPS and Science Act (Section 10731, Micro Act).	Expanded investments will include support for the SC Energy Earthshots initiative including robust materials for energy/infrastructure and thermal processing innovation and new microelectronics research centers. Investments will emphasize basic research related to clean energy and advanced manufacturing, and AI/ML, and will provide research and training opportunities for underrepresented communities and institutions.

(dollars in thousands)

FY 2023 Enacted	FY 2024 Request	Explanation of Changes FY 2024 Request vs FY 2023 Enacted
Materials Discovery, Design, and Synthesis Research $97,097	$101,297	+$4,200
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 biology-inspired 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 manufacturing and clean energy technologies, including innovative approaches to scalable assembly and integration of characterization and predictive modeling. Research will continue to explore science-based solutions to materials criticality. 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. Additional investments in these topical areas will focus on support for the SC Energy Earthshots initiative.	Expanded investments will support the SC Energy Earthshots initiative, including robust materials for energy/infrastructure. Investments will emphasize basic research related to clean energy and advanced manufacturing and will provide research and training opportunities for underrepresented communities and institutions.

(dollars in thousands)

FY 2023 Enacted	FY 2024 Request	Explanation of Changes FY 2024 Request vs FY 2023 Enacted
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 co-investment 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 Implementation awards, FY 2024 will emphasize State-National Laboratory Partnership awards, single investigator and small group grants that promote interactions with the unique capabilities and expertise at the DOE national labs. The FY 2024 funding opportunity will consider only new proposals. Investment will continue in early career research faculty from EPSCoR-designated jurisdictions and in co-investment with other programs for awards to eligible institutions.	Funding will focus on State-National Laboratory Partnership awards promoting interactions between EPSCoR institutions and the DOE national laboratory system, with expanded investments in clean energy, climate science, and low-carbon manufacturing research as well as connections to the SC Energy Earthshots initiative. Teams will be encouraged to include institutions serving underrepresented and minority communities. EPSCoR will continue to participate in the SC-wide RENEW and FAIR initiatives to provide training and research opportunities for students and academic institutions not currently well represented in the U.S. S&T ecosystem.
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 third year of support for four-year EFRC awards that were made in FY 2022 in a broad range of topical areas relevant to clean energy, advanced manufacturing, and other national priorities such as QIS and microelectronics. In addition, BES plans to issue a solicitation in FY 2024 to recompete the EFRC awards made in FY 2020, with emphasis on QIS, microelectronics, transformative manufacturing, and other high-priority topics.	Technical emphasis for the EFRC program will continue to include research directions identified in recent strategic planning activities and aligned with program priorities, including research related to QIS, microelectronics, and low-carbon manufacturing.

(dollars in thousands)

FY 2023 Enacted	FY 2024 Request	Explanation of Changes FY 2024 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 Energy Earthshot topics and those announced by DOE prior to release of the FOA.	The Request will provide the second year of support for the initial cohort of EERCs that were initiated in FY 2023 and will support new EERCs for topics announced prior to FY 2024.	Technical emphasis for the EERC program will be on Energy Earthshot topics, including low-carbon hydrogen, long-duration energy storage, carbon dioxide removal, geothermal energy, offshore wind, industrial heat decarbonization, and new topics announced prior to FY 2024.
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 second year of funding for one or more new Batteries and Energy Storage Hub awards initiated in FY 2023 as a result of an open competition.	Funding will continue to support next-generation batteries and energy storage research.

(dollars in thousands)

FY 2023 Enacted	FY 2024 Request	Explanation of Changes FY 2024 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 second year of funding for awards made in FY 2023. The Request will continue to support research aimed at the development of open source, validated software that takes advantage of DOE's leadership computational facilities. BES plans to issue a FOA in FY 2024 to recompete awards made in FY 2020. BES will prioritize transitioning ECP researchers, software, and technologies into core research efforts and DOE priority research areas as ECP concludes.	Funding will continue to support research focused on the development of computational codes and associated experimental and computational databases for the predictive design of functional materials.

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 that is the foundation for 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. At the most fundamental level, research to understand quantum mechanical behavior is rapidly evolving into the ability to control and direct such behavior to achieve desired outcomes. 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 in gas and condensed phases, and at interfaces, based on understanding quantum interactions among photons, electrons, atoms, and molecules.
- **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 a focus on scientific understanding to accelerate innovation that can reduce impacts of climate change 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 to advanced manufacturing. Related research emphasizes the chemistry, separations, and substitutions important for reducing dependence on critical materials and minerals and for promoting innovative and robust manufacturing supply chains. Fundamental biochemistry will discover principles that can enable biomimetic and biohybrid clean energy systems and guide new approaches in biotechnology. 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, bringing simulation and experiments together, will provide tools and infrastructure needed for shared data repositories.

Five synergistic, foundational research themes are at the intersections of multiple research focus areas in this portfolio. Ultrafast Chemistry probes electron and atom dynamics to understand energy and chemical conversions. Chemistry at Complex Interfaces advances understanding of how interfacial dynamics and structural and functional disorder influence chemical phenomena. Charge Transport and Reactivity explores how charge dynamics contribute to energy flow and chemical conversions. Reaction Pathways in Diverse Environments discovers the influence of nonequilibrium, heterogeneous, nanoscale, and extreme environments on complex reaction mechanisms. Chemistry in Aqueous Environments addresses water's unique properties and the role it plays in energy and chemical conversions.

The subprogram supports a diverse portfolio of research efforts including single investigators, small groups, and larger multi-investigator, cross-disciplinary teams through EFRCs, the Fuels from Sunlight Energy Innovation Hub program, Computational Chemical Sciences, data science, and QIS to advance foundational science that can enable critical clean energy technologies. The subprogram also partners across SC to support the NQISRCs that were established in FY 2020 and, new in FY 2023, EERCs (in partnership with ASCR, BER, and with DOE energy technology offices). This subprogram also supports the RENEW initiative, expanding targeted efforts, including a RENEW graduate fellowship, to broaden participation and advance belonging, accessibility, justice, equity, diversity, and inclusion in SC-sponsored research; the FAIR initiative focused investment on enhancing research on clean energy, climate, and related topics at minority serving and underserved institutions; and the Accelerate initiative for scientific research to accelerate the transition of science advances to energy technologies.

Fundamental Interactions Research

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 also supports theory and computation for accurate descriptions of molecular reactions and chemical dynamics. These efforts provide the foundational knowledge and the 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.

The principal research thrusts in this activity are atomic, molecular, and optical sciences (AMOS), gas phase chemical physics (GPCP), condensed phase and interfacial molecular science (CPIMS), and computational and theoretical chemistry (CTC). AMOS research emphasizes the fundamental interactions of atoms and molecules with electrons and photons, to characterize and control their behavior. Novel attosecond sources, x-ray free electron laser sources such as the LCLS-II, and ultrafast electron diffraction are used to image the ultrafast dynamics of electrons and charge transport. CPIMS research emphasizes foundational research at the boundary of chemistry and physics, pursuing a molecular-level understanding of chemical, physical, and electron- and photon-driven processes in liquids and at interfaces. Experimental, theoretical, and computational investigations in the condensed phase and at interfaces elucidate the molecular-scale chemical and physical properties and interactions that govern condensed phase structure and dynamics. The GPCP program supports research on fundamental gas-phase chemical processes important in energy applications. Research in this program explores chemical reactivity, kinetics, and dynamics in the gas phase at the level of electrons, atoms, molecules, and nanoparticles. The CTC program supports development, improvement, and integration of new and existing theoretical and massively parallel computational or data-driven strategies for the accurate and efficient prediction or simulation of processes and mechanisms. Research in this area is crucial to utilize emerging exascale computing facilities and to optimize use of existing leadership class computers, leveraging U.S. leadership in the development of open-source computational chemistry codes and databases. In the context of the NQISRCs, this research also lays the groundwork for applications of future quantum computers to computational quantum chemistry.

In FY 2024, BES, in partnership with other SC programs, will continue support for the multi-disciplinary multi-institutional QIS centers, initiated in FY 2020. The NQISRCs will focus on a set of QIS applications or cross-cutting topics including innovative research on sensors, quantum emulators/simulators, and enabling technologies that will pave the path to exploit quantum computing in the longer term. Research initiated in FY 2021 in microelectronics will continue with a focus on unraveling complex mechanisms of chemical reactions at interfaces to inform the design and synthesis of new materials.[e] Research in clean energy and low-carbon manufacturing will continue to address science that is foundational to novel synthesis, processing, modeling, *operando* characterization, and validation approaches for manufacturing. The Fundamental Interactions activity will continue to advance data science and computational approaches for chemical sciences with a focus on integration of databases and computational chemistry tools for the generation of scientific knowledge that is foundational to the BES mission.

Chemical Transformations Research

This activity seeks fundamental knowledge of chemical reactivity, matter and charge transport, and chemical separation and stabilization processes that are foundational for developing future clean energy and advanced manufacturing technologies, and for innovations to mitigate or adapt to climate change. Core research areas include catalysis science, separation science, heavy element chemistry, and geosciences. The research entails use of ultrafast spectroscopy to follow transient species during reactions; advances the understanding of charge transport and reactivity, which determine the kinetics of electrocatalytic, separations, and geochemical processes; explores the influence of complex interfaces on chemical transformations; develops the mechanistic insight 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.

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

Catalysis science research is focused on understanding reaction mechanisms, precise synthesis, *operando* characterization, manipulation of catalytic active sites and their environments, and control of reaction conditions for efficiency and selectivity. A primary goal is the molecular-level control of chemical transformations relevant to the sustainable conversion of energy resources, with emphasis on thermal and electrochemical conversions. Separation science research seeks to understand and ultimately predict and control the atomic and molecular interactions and energy exchanges determining the efficiency and viability of chemical separations, with emphasis on critical elements and atmospheric CO_2. The major focus is to advance discovery of principles and predictive design of future chemical separation approaches with improved efficiencies. Heavy element chemistry provides foundational knowledge on the influence of complex environments, such as multiple phases and extreme conditions of temperature and radiation, on the dynamic behavior of actinide compounds. A primary goal is to advance understanding of the unique chemistry of f-electron systems that is required to design new ligands for actinide and rare-earth separations processes, to predict the chemical evolution of actinides in nuclear wastes and next-generation reactors, and to improve models of actinide environmental transport. Geosciences research provides the fundamental science underlying the subsurface chemistry and physics of natural substances under extreme conditions of pressure or confined environments. Areas of emphasis include the molecular-level understanding of phase equilibria, reaction mechanisms and rates associated with aqueous geochemical processes, the distribution and accumulation of elements in the earth upper mantle, and a mechanistic understanding of the origins of subsurface physical properties and the response of earth materials subject to chemo-mechanical stress.

In FY 2024, this activity will continue to support efforts central to transformative approaches to advanced manufacturing,[f] including predictive design of catalytic and separations processes for circular use of natural and synthetic resources with atom and energy efficiency, as exemplified by polymer upcycling.[g] In support of the Energy Earthshot initiative, this activity will increase focus on discovery and design of sustainable cycles for carbon and hydrogen, by means of enhanced carbon separation from both dilute and concentrated sources and clean energy cycles of hydrogen generation, storage, and use. Also supporting the Energy Earthshot initiative, research will increase the fundamental knowledge of subsurface processes across spatial and temporal scales—such as mineralization, crack propagation, and rock fracture—that is critical for developing innovative clean energy technologies for the subsurface. Support will also continue for research to address challenges in critical materials with focus on novel approaches for resource identification and extraction, selective separation, and substitution and use of critical elements. Research will continue to investigate the unique quantum phenomena enabled by f-electron elements, including rare earth elements and actinides. The use of data science and AI/ML approaches will continue to be emphasized in research across the portfolio to accelerate the generation and propagation of scientific knowledge that is foundational to the BES mission.

Photochemistry and Biochemistry Research

This activity supports research on the molecular mechanisms that capture light energy and convert it into electrical and chemical energy in both natural and man-made systems. This mechanistic understanding can inspire new strategies to control reaction pathways critical for clean energy conversions and for innovations to tackle climate change. An important component of the Photochemistry and Biochemistry activity is its 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 that advances understanding of absorption, transfer, and conversion of energy across spatial and temporal scales and on redox interconversion of small molecules (e.g., carbon dioxide/methane, nitrogen/ammonia, and protons/hydrogen) important for clean fuels (e.g., solar fuels). Studies of ultrafast chemistry and photo-driven quantum coherence probe the short time-scales critical in natural photosynthesis and artificial molecular systems and can provide insights into the role of quantum phenomena in chemical and biochemical reactions. Research expands understanding of the influence of complex interfaces and aqueous environments on the dynamics and function of enzymes, natural and artificial membranes, and nano- to meso-scale structures.

This activity integrates multidisciplinary research at the interface of chemistry, physics, and biology. Research of biological systems provides insights for understanding and enhancing man-made chemical systems. In a reciprocal manner, studies of chemical (non-biological) systems provide insights on the dynamics and reactivity underlying biochemical processes.

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

Research in natural photosynthesis advances knowledge of biological mechanisms of solar energy capture and conversion and can inspire development of bio-hybrid, biomimetic, and artificial photosynthetic systems for clean energy production and biotechnology. Studies of complex multielectron redox reactions, electron bifurcation, and quantum phenomena in biological systems can suggest innovative approaches to energy conversion and storage strategies for clean energy, biotechnology approaches, and climate change mitigation technologies. Complementary research on the elementary steps of light absorption, charge separation, and charge transport of solar energy conversion in man-made systems provides foundational knowledge for the use of solar energy for carbon-neutral fuel production and electricity generation. Research also addresses fundamental effects of ionizing radiation to understand chemical reactions in extreme environments and to provide insights for remediation, fuel-cycle separation, and design of nuclear reactors.

In FY 2024, research will continue to establish a molecular-level understanding of biochemical and photochemical processes. Efforts will build on BES biochemistry and biophysics research to discover and design chemical processes and complex structures that can enable innovations for clean energy technologies, advanced manufacturing and microelectronics, and climate change mitigation, such as bio-inspired, biohybrid, and biomimetic systems with desired functions and properties. Studies of photo-driven quantum coherence in natural photosynthesis and artificial molecular systems will continue with the goal of developing new strategies for efficient solar energy use. Research will also address challenges of reducing the use of critical and rare earth elements in light absorbers and catalysts for clean energy. In support of the Energy Earthshot initiative, this activity will increase support for research to identify new approaches for harnessing solar energy for chemical conversions, providing knowledge that could enable carbon-neutral hydrogen technologies and advance strategies for other solar fuels. This activity supports the Accelerate initiative that targets scientific research to accelerate the transition of science advances to energy technologies. This activity provides support for the ongoing SC-wide RENEW initiative and for the new FAIR initiative to build stronger programs at underrepresented institutions, including those in underserved and environmental justice communities, with a focus on enhancing research on clean energy, climate, and related topics.

Energy Frontier Research Centers

The EFRC program is a unique research modality, bringing together the skills and talents of teams of investigators to perform energy-relevant, basic research with a scope and complexity 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. They allow experts from a variety of disciplines to collaborate on shared challenges, combining their strengths to uncover new and innovative solutions to the most difficult problems in chemical sciences, geosciences, and biosciences. The EFRCs also support numerous graduate students and postdoctoral researchers, educating and training a scientific workforce for the 21st-century. The EFRCs supported in this subprogram focus on the following topics: the design, discovery, characterization, and control of the 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 polymer upcycling; interdependent energy-water issues; QIS; future nuclear energy and the chemistry of waste processing; and advanced interrogation and characterization of the earth's subsurface. After thirteen years of research activity, the program has produced an impressive range of scientific accomplishments, including over 15,000 peer-reviewed journal publications.

BES uses a variety of methods to regularly assess the progress of the EFRCs, including annual progress reports, monthly phone calls with the EFRC Directors, periodic Directors' meetings, and on-site visits by program managers. Each EFRC undergoes a review of its management structure and approach in the first year of the award and a mid-term assessment by outside experts of scientific progress compared to its scientific goals. To facilitate communication of results to other EFRCs and DOE, BES holds meetings of the EFRC researchers biennially.

In FY 2024, BES plans to issue a FOA to recompete the four-year EFRC awards that were made in FY 2020. Emphasis will be placed on topical areas of the highest priority to the Department, including QIS, microelectronics, transformative manufacturing, and other program priorities.

Energy Earthshot Research Centers

The EERC program was launched in FY 2023, building on the success of the EFRCs. Like the EFRCs, EERCs will 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, EERCs will address the gap between basic research and the applied research and development activities to facilitate the exchange of knowledge between SC and the DOE energy technology offices, which is key to realizing the stretch goals of the Energy Earthshots. EERCs will support team awards involving academic, national lab, and industrial researchers with joint planning by SC and energy technology offices, establishing a new era of cross-office research cooperation. The funding will focus efforts directly at the interface, ensuring that directed fundamental research and capabilities at SC user facilities tackle the most challenging barriers identified in the applied research and development activities.

Existing DOE Energy Earthshots include the Hydrogen Shot, the Long Duration Storage Shot, the Carbon Negative Shot, the Enhanced Geothermal Shot, the Floating Offshore Wind Shot, and the Industrial Heat Shot. Additional topics are under consideration for future announcements. From a science perspective, many research gaps for the Energy Earthshots crosscut all topics and will provide a foundation for other clean energy technology challenges, including biotechnology, critical minerals/materials, energy-water, subsurface science (including geothermal research), 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 development of the scientific base to co-design processes and systems rather than individual materials, chemistries, and components. EERCs will leverage individual Center research to cross-fertilize the ideas that emerge in one topical area to benefit others with similar challenges—accelerating the science, as well as the technologies.

The FY 2024 Request continues support for the EERCs established in FY 2023 and provides additional support for Centers associated with new Energy Earthshots.

Energy Innovation Hubs

The two multi-investigator, cross-disciplinary solar fuels research awards for the Fuels from Sunlight Hub program build on the unique accomplishments of the first Fuels from Sunlight Hub and address both new directions and long-standing challenges in the use of solar energy, water, and carbon dioxide as the only inputs for fuels production for clean energy and climate change mitigation. The FY 2024 Request will continue support for these fundamental research efforts that target innovative solutions to key scientific challenges for solar fuels (as identified in the strategic planning report from the Roundtable on Liquid Solar Fuels), including how to overcome degradation mechanisms to increase durability of solar fuel-generating components and systems, design catalytic microenvironments to selectively produce energy-rich solar fuels, take advantage of the direct coupling of light-driven phenomena and chemical processes to improve component and system performance, and tailor complex phenomena that interact and affect function of integrated multicomponent assemblies for solar fuels production.[h]

BES uses a variety of methods to regularly assess the progress of the awards, including annual progress reports, regular phone calls with the Directors, periodic Directors' meetings to ensure coordination and communication, and on-site visits and reviews. Each award undergoes a review of its management structure and approach in the first year and beginning in the second year will have an annual peer review of research progress against its scientific goals.

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

Computational Chemical Sciences

The computational chemical sciences program (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 that allow full use of current and future planned DOE leadership-class computing capabilities. This research supports a publicly accessible website[i] 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.

BES uses a variety of methods to regularly assess the progress of the CCS awards, including annual progress reports, regular phone calls with the Directors, and periodic meetings of funded activities to ensure coordination and communication. Large team awards undergo a review of management structure and approach in the first year and a mid-term review by outside experts to evaluate scientific progress compared to the project's scientific goals. The FY 2024 support will continue awards from FY 2021 and FY 2022.

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.

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

Basic Energy Sciences
Chemical Sciences, Geosciences, and Biosciences

Activities and Explanation of Changes

(dollars in thousands)

FY 2023 Enacted		FY 2024 Request	Explanation of Changes FY 2024 Request vs FY 2023 Enacted
Chemical Sciences, Geosciences, and Biosciences	**$501,263**	**$533,961**	**+$32,698**
Fundamental Interactions Research	$127,985	$141,339	+$13,354
Funding continues to develop forefront ultrafast approaches, with emphasis on the use of x-ray free electron lasers, including LCLS and its upgrades. Gas-phase 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 target the understanding and control of interfacial chemical conversion mechanisms and quantum phenomena at the molecular level to advance clean energy technologies, climate mitigation technologies (e.g., emissions mitigation), and design of materials relevant to microelectronics. This activity will continue generation and use of advanced theoretical and computational approaches that can take full advantage of exascale computing capabilities and the development of data science methods that enhance approaches for knowledge discovery. This activity provides continued support for the NQISRCs established in FY 2020. New Microelectronics Science Research Centers are established, as authorized under the CHIPS and Science Act (Section 10731, Micro Act).	Expanded investments will include support for new microelectronics research centers. Investments will emphasize basic research related to clean energy, climate, microelectronics, AI/ML, and advanced manufacturing. Funding will also provide research and training opportunities for underrepresented communities and institutions.

(dollars in thousands)

FY 2023 Enacted		FY 2024 Request	Explanation of Changes FY 2024 Request vs FY 2023 Enacted
Chemical Transformations Research	$129,651	$140,158	+$10,507
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, climate change mitigation, and advanced manufacturing technologies. Separation science research 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 fundamental theories of f-electron systems. Geosciences research will continue to reveal subsurface phenomena, such as mineralization and rock fracture propagation under extreme subsurface conditions, 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. The Request supports the SC Energy Earthshots initiative.	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, microelectronics, and advanced manufacturing. Funding will also provide research and training opportunities for underrepresented communities and institutions.

(dollars in thousands)

FY 2023 Enacted	FY 2024 Request	Explanation of Changes FY 2024 Request vs FY 2023 Enacted
Photochemistry and Biochemistry Research $130,877	$139,714	+$8,837
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. Studies of light absorption, energy transfer, photocatalysis, and charge separation can lead to innovations for clean energy and climate change mitigation. Study of biochemical processes and structures will provide a foundation for bio-inspired, biohybrid, and biomimetic systems with desired functions and properties, impacting strategies for artificial photosynthesis, carbon dioxide removal, and biotechnology. Solar fuels research will address molecular mechanisms of photon capture, charge transport, product selectivity, and the reduction of critical element use in photoabsorbers and catalysts. Biological and chemical studies will examine the role of quantum phenomena in energy conversion. The RENEW initiative expands targeted efforts to increase participation and retention of individuals from underrepresented groups in SC research activities. The Request supports the SC Energy Earthshots, FAIR, and Accelerate initiatives.	Expanded investments will include support for the SC Energy Earthshots initiative including innovations in solar and bio-based fuels. Expanded investments will broaden RENEW activities, including a RENEW graduate fellowship. Investments will emphasize basic research related to clean energy, climate, and advanced manufacturing, and will provide research and training opportunities for underrepresented communities and institutions.

(dollars in thousands)

FY 2023 Enacted		FY 2024 Request	Explanation of Changes FY 2024 Request vs FY 2023 Enacted
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 third year of support for four-year EFRC awards that were made in FY 2022 in a broad range of topical areas relevant to clean energy, advanced manufacturing, and other national priorities such as QIS and microelectronics. In addition, BES plans to issue a solicitation in FY 2024 to recompete the EFRC awards made in FY 2020, with emphasis on QIS, microelectronics, transformative manufacturing, and other high-priority topics.	Technical emphasis for the EFRC program will continue to include research directions identified in recent strategic planning activities and aligned with program priorities, including research related to QIS, microelectronics, and low-carbon manufacturing.
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 the second year of support for the initial cohort of EERCs that were initiated in FY 2023 and will support new Energy Earthshot topics announced prior to FY 2024.	Technical emphasis for the EERC program will be on Energy Earthshot topics, including low-carbon hydrogen, long-duration energy storage, carbon dioxide removal, enhanced geothermal systems, offshore wind, industrial heat decarbonization, and new topics announced prior to FY 2024.

(dollars in thousands)

FY 2023 Enacted		FY 2024 Request	Explanation of Changes FY 2024 Request vs FY 2023 Enacted
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 Request will continue support of fundamental research to address both long-standing and emerging new scientific challenges for solar fuels generation. Research will continue to focus on innovative artificial photosynthesis approaches to generate liquid fuels using only sunlight, carbon dioxide, and water as inputs. Integration of experiment and theory will advance the design of processes, components, and systems for selective, stable, and efficient liquid solar fuels production for clean energy, climate change mitigation, and sustainability.	Funding will continue support for prior year awards in priority research areas.
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 will continue CCS awards made in FY 2021 and FY 2022, with ongoing research to develop public, validated, open-source software that takes advantage of DOE's leadership computing facilities.	Funding will continue support for prior year awards in priority research areas.
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 changes.

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
Scientific User Facilities (SUF)

Description

The Scientific User Facilities subprogram supports the 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. These user facilities are operated on an open access, competitive, merit review basis, enabling scientists from every state and many disciplines from academia, national laboratories, and industry to utilize the facilities' unique capabilities and sophisticated instrumentation.

Studying matter at the level of atoms and molecules requires instruments that can probe structures that are one thousand times smaller than those detectable by the most advanced light microscopes. Thus, to characterize structures with atomic detail, researchers must use probes such as electrons, x-rays, and neutrons with wavelengths at least as small as the structures being investigated. 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 appropriate resolutions that can interrogate the inner workings of matter to answer some of the most challenging grand science questions. By taking advantage of the intrinsic charge, mass, and magnetic characteristics of x-rays, neutrons, and electrons, these tools offer unique capabilities to help understand the fundamental aspects of the natural world.

The 12 BES scientific user facilities provide unique capabilities to the scientific community and industry. Critically for U.S. scientific leadership, they provide comprehensive and advanced tools that enable fundamental discovery science and research to tackle critical challenges for national priorities in energy and other strategic areas. Collectively, they contribute to important research results that span the continuum from basic to applied research and embrace the full range of scientific and technological endeavors, including chemistry, physics, geology, materials science, environmental science, biology, and biomedical science. These capabilities enable scientific insights that can lead to the discovery and design of advanced materials and novel chemical processes with broad societal impacts, from energy applications to information technologies and biopharmaceutical discoveries.

Before the COVID-19 pandemic, more than 16,000 scientists and engineers in many fields of science and technology used BES scientific facilities annually. During the pandemic, user facilities were under curtailed user operations, available mainly through remote access for many instruments. The BES facilities supported over 15,000 users in FY 2022. Light sources and neutron sources were able to provide critical support to the development of potential therapeutic drugs and vaccines through structural studies of the proteins of the SARS-CoV-2 virus, which causes COVID-19. All BES user facilities contributed to other COVID-19 activities, including research on masks, characterization of novel manufacturing for medical equipment, and delivery of therapeutics. The BES facilities will continue to support ongoing research efforts to combat COVID-19 and evolve the tools and expertise needed for future public health challenges. In FY 2024, continued support to enhance user capabilities for research on biological threats is included in the BRaVE initiative.

At these facilities, hundreds of experiments are conducted simultaneously around the clock, generating vast quantities of raw experimental data that must be stored, transported, and then analyzed to convert the raw data into information to unlock the answers to important scientific questions. Management of the collection, transport, and analysis of data presents new and growing challenges as new capabilities and advanced detector technologies come online. Data science, artificial intelligence, and machine learning methods and advanced computing hardware are being implemented to help address these data and information challenges and needs. Challenges include speeding up high-fidelity simulations for online models, fast tuning in high-dimensional space, anomaly/breakout detection, 'virtual diagnostics' that can operate at high repetition rates, and sophisticated compression/rejection data pipelines operating at the 'edge' (next to the instrument) to save the highest-value data from user experiments.

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 instrumental capabilities such as new x-ray and neutron experimental stations with improved computational and data analysis infrastructure 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 technology.

The FY 2024 Request supports user facilities at 90 percent of the operational budget requirements determined by the user facilities that have redefined the meaning of optimum operations. These assessments considered funding requirements from growth in the cost of operations, evolution of the user needs for remote use, and transitioning of new capabilities from facility upgrades to operations. Funding at the 90 percent level will balance safe operations with user access.

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. However, remote operations require more facility staff and expansion of computational and experimental tools. This translates to increased necessary staffing levels and staff with different expertise to support both in-person and continued growth of remote users and capabilities. In addition, increases in costs due to inflation and supply chain issues have resulted in an increase in the funding levels to ensure safe and continued operation of capabilities needed to address the challenges facing the Nation in clean energy, climate, QIS, microelectronics, and biopreparedness.

X-Ray Light Sources

X-rays are an essential tool for studying the structure of matter and have long been used to peer into material through which visible light cannot penetrate. Today's light source facilities produce x-rays that are billions of times brighter than medical x-rays. Scientists use these highly focused, intense beams of x-rays to reveal the identity and arrangement of atoms in a wide range of materials. The tiny wavelength of x-rays allows us 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.

From their first systematic use as an experimental tool in the 1960s, large-scale light source facilities have vastly enhanced the utility of pre-existing and contemporary techniques, such as x-ray diffraction, x-ray spectroscopy, and imaging and have given rise to scores of new ways to do experiments that would not otherwise be feasible with conventional x-ray machines. Moreover, the wavelength can be selected over a broad range (from the infrared to hard x-rays) to match the needs of particular experiments. Together with additional features, such as controllable polarization, coherence, and ultrafast pulsed time structure, these characteristics make x-ray light sources an important tool for a wide range of research. The wavelengths of the emitted photons span a range of dimensions from the atom to biological cells, thereby providing incisive probes for advanced research in a wide range of areas, including materials science, physical and chemical sciences, metrology, geosciences, environmental sciences, biosciences, medical sciences, and pharmaceutical sciences. BES operates a suite of five light sources, including a free electron laser, the LCLS at SLAC, and four storage ring-based light sources—the ALS at LBNL, the APS at ANL, the Stanford Synchrotron Radiation Lightsource (SSRL) at SLAC, and the National Synchrotron Light Source-II (NSLS-II) at BNL. BES provides funding to support facility operations, technical support, 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.

Investments at the BES light sources continue support and development of new tools for biopreparedness (under the BRaVE initiative) and to advance data science, artificial intelligence, and machine learning, as well as computing hardware, required to plan experiments, analyze data, and efficiently operate the accelerators and beamlines.

Facility upgrade projects are underway for the APS, ALS, and LCLS to ensure ongoing world leadership for these facilities. In addition, since completing construction of NSLS-II in FY 2015, the initial suite of seven beamlines has expanded to the current 28 beamlines with room for at least 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 are requested for NEXT-III, a line-item construction project to deliver the next cadre of beamlines.

High-Flux Neutron Sources

One of the goals of modern materials science is to understand the factors that determine the properties of matter on the atomic scale and to use this knowledge to optimize those properties or to develop new materials and functionality. This process regularly involves the discovery of fascinating new physics, which itself may lead to previously unexpected applications. Among the different probes used to investigate atomic-scale structure and dynamics, thermal neutrons have unique advantages:

- they have a wavelength similar to the spacing between atoms, allowing atomic-resolution studies of structure, and have an energy similar to the elementary excitations of atoms and magnetic spins in materials, thus allowing an investigation of material dynamics;
- they have no charge, allowing deep penetration into a bulk material;
- they are scattered to a similar extent by both light and heavy atoms but differently by different isotopes of the same element, so that different chemical sites can be uniquely distinguished via isotope substitution experiments, for example substitution of deuterium for hydrogen in organic and biological materials;
- they have a magnetic moment, and thus can probe magnetism in condensed matter systems; and
- their scattering cross-section is precisely measurable on an absolute scale, facilitating straightforward comparison with theory and computer modeling.

The High Flux Isotope Reactor (HFIR) at ORNL generates neutrons via fission in a research reactor. 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 instruments in the user program at HFIR and the adjacent cold neutron beam guide hall, which include world-class instruments for inelastic scattering, small angle scattering, powder and single crystal diffraction, neutron imaging, and engineering diffraction. In FY 2024, operations funding will support preparation work 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 Spallation Neutron Source (SNS) at ORNL uses a different approach for generating neutron beams, where an accelerator generates protons that strike a heavy-metal target such as mercury. As a result of the impact, cascades of neutrons are produced in a process known as spallation. The SNS is the world's brightest pulsed neutron facility, and presently includes 19 instruments. These world-leading instruments include very high-resolution inelastic and quasi-elastic scattering capabilities, powder and single crystal diffraction, polarized and unpolarized beam reflectometry, and spin echo and small angle scattering spectrometers. A large suite of capabilities for high and low temperature, high magnetic field, and high-pressure sample environment equipment is available for the instruments. All the SNS instruments are in high demand by researchers world-wide in a range of disciplines from biology to materials sciences and condensed matter physics. Current construction projects at SNS focus on maintaining world-leadership for neutron scattering.

Investments continue support and development of new tools for biopreparedness (under the BRaVE initiative) and to advance data science, artificial intelligence, and machine learning, as well as computing hardware, to plan experiments, analyze data, and efficiently operate the accelerator and beamlines.

Nanoscale Science Research Centers

Since the launching of the National Nanotechnology Initiative in 2000, nanoscale science has become foundational in many scientific and technology research areas. Nanoscience focuses on phenomena that occur at the nanometer scale—probing and assembling single atoms, clusters of atoms, and molecular structures. One aspect is discovery of new nanoscale materials and structures not found in nature. However, the ability to observe and understand functionality at this length scale, including interactions with physical and chemical environments, is key to many science and engineering challenges for energy, QIS, next-generation semiconductors, and biopreparedness. Developments at the nanoscale and mesoscale have the potential to make major contributions to delivering remarkable scientific discoveries that transform our understanding of energy and matter and advance national, economic, and energy security.

The NSRCs focus on interdisciplinary discovery research at the nanoscale, providing a foundation for research that encompasses technology innovations, discovery science, new tools, and new computing capabilities. Distinct from the x-ray and neutron sources, NSRCs comprise a suite of smaller unique tools and expert scientific staff. The five NSRCs are the Center for Nanoscale Materials at ANL, the Center for Functional Nanomaterials at BNL, the Molecular Foundry at LBNL, the Center for Nanophase Materials Sciences at ORNL, and the Center for Integrated Nanotechnologies at SNL and LANL. Each center has particular expertise and capabilities, such as nanomaterials 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 catalysis, electronic materials, nanoscale photonics, and soft and biological materials. Four of the centers are near or adjoining BES facilities for x-rays, neutrons, and/or SC-supported computation facilities, which complement and leverage these capabilities for the user communities. These custom-designed laboratories contain clean rooms, nanofabrication resources (crucial for semiconductor and quantum information science research), one-of-a-kind signature instruments, and other instruments generally available only at major user facilities. The NSRC electron and scanning probe microscopy capabilities provide superior atomic-scale spatial resolution and simultaneously obtain structural, chemical, and other types of information from sub-nanometer regions at short time scales. They house electron microscopes that are among the highest resolution in the world and bring unique analytical capabilities for users. Data science approaches are enabling large and fast data acquisition, real-time analysis, and autonomous experiments. Operating funds provide capabilities for cutting-edge research, technical support, and administration of the user program at these facilities, which serve academic, government, and industry researchers with access determined through external peer review of user proposals.

Since their inception, the NSRCs have played a foundational role in establishing nanoscience characterization and associated approaches as a key endeavor for energy and other national priority research areas. Going forward, the NSRCs will continue to develop infrastructure and capabilities for materials synthesis, device fabrication, metrology, modeling, and simulation. Future investments will recognize the transition from development of nanoscience as a field of research to a new phase focused on evolving these capabilities to address the most pressing national needs in clean energy and technological competitiveness. The goal is to develop a flexible and enabling infrastructure so that U.S. institutions and industry can rapidly develop and commercialize the new discoveries and innovations.

<u>Other Project Costs</u>
The total project cost (TPC) of DOE’s construction projects comprises two major components: the total estimated cost (TEC) and OPC. The TEC includes project costs incurred after Critical Decision (CD)-1, such as costs associated with all engineering design and inspection; the acquisition of land and land rights; direct and indirect construction/fabrication; the initial equipment necessary to place the facility or installation in operation; and facility construction costs and other costs specifically related to those construction efforts. OPC represents all other costs related to the projects that are not included in the TEC, such as costs that are incurred during the project’s initiation and definition phase for planning, conceptual design, research, and development, and those incurred during the execution phase for R&D, startup, and commissioning. OPC is always funded via operating funds.

<u>Major Items of Equipment</u>
BES supports MIE projects to ensure the continual development and upgrade of major scientific instrument capabilities, including fabricating new x-ray and neutron experimental stations, improving NSRC core facilities, additional beamlines for the NSLS-II, and providing new stand-alone instruments and capabilities. In FY 2024, preliminary planning support is requested for new MIEs for additional beamlines for the APS and ALS.

<u>Research</u>
This activity supports research from initial studies of accelerator physics and instrumentation to their translation into innovative components or techniques that improve existing or supported concepts of future BES user facilities. Production of beams with increased average flux and brightness and the detection tools capable of responding to the high beam intensity are the two major components for the advancement of light and neutron sources. The first component requires higher-repetition-rate photocathode guns and radiofrequency (RF) systems, and photon beams of enhanced temporal coherence, such as produced by improved seeding techniques or x-ray oscillators for free electron lasers (FELs). Areas of interest are techniques leading to Terawatt-power radiation, source-generated THz beams, and research on “beam on demand” techniques to support multiple beamlines simultaneously. The second component—detectors—requires 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 high-intensity H– currents, requiring tight control of

beam losses, and detectors designed for advanced neutron imaging with very high throughput. A focus is on research that will maintain the competitiveness of BES user facilities to their counterparts in Europe and Japan. BES coordinates with the SC Office of Accelerator R&D and Production on crosscutting research and technology areas.

Investments will continue to support development of data science methods and tools to address data and information challenges at the BES user facilities, including accelerator optimization, control, prognostics, and experiment automation and real-time data analysis. Funding continues for the RENEW initiative that provides undergraduate and graduate training opportunities 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 and development of advanced instrumentation to address these research challenges.

Basic Energy Sciences
Scientific User Facilities (SUF)

Activities and Explanation of Changes

(dollars in thousands)

FY 2023 Enacted		FY 2024 Request	Explanation of Changes FY 2024 Request vs FY 2023 Enacted
Scientific User Facilities (SUF)	**$1,190,757**	**$1,326,143**	**+$135,386**
X-Ray Light Sources	$599,498	$704,134	+$104,636
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-II, APS, ALS, NSLS-II, and SSRL). Funding supports LCLS transition to LCLS-II operations, APS activities in anticipation of APS-U completion, and increased beamline support for ALS in preparation for ALS-U.	Funding will support LCLS-II, APS, ALS, NSLS-II and SSRL operations at 90 percent of optimal funding, re-baselined to account for inflation, supply chain costs, staffing support, COVID-19 and remote operations, and other costs. Development of capabilities for biopreparedness, computational techniques, and data will continue.
High-Flux Neutron Sources	$315,740	$373,163	+$57,423
Funding supports operations at SNS and HFIR.		The Request will support operations at SNS and HFIR (including partial funding for the HFIR beryllium reflector replacement procurements and planning).	Funding will support operations for SNS and HFIR at approximately 90 percent of optimal funding, re-baselined to account for inflation, supply chain costs, staffing support, COVID-19 and remote operations, and other costs. Development of capabilities for biopreparedness, computational techniques, and data will continue.
Nanoscale Science Research Centers	$153,409	$150,880	-$2,529
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 nanoscience and QIS-related research infrastructure and capabilities for materials synthesis, device fabrication, metrology, modeling and simulation.	Funding will support operations for the five NSRCs at approximately 90 percent of optimal funding, re-baselined to account for inflation, supply chain costs, staffing support, COVID-19 and remote operations, and other costs.

(dollars in thousands)

FY 2023 Enacted		FY 2024 Request	Explanation of Changes FY 2024 Request vs FY 2023 Enacted
Other Project Costs	$19,500	$14,000	-$5,500
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 CRMF project at SLAC, the HFIR-PVR project at ORNL, and the NEXT-III project at BNL.	Funding will support planning for the CRMF project at SLAC, the HFIR-PVR project at ORNL, and the NEXT-III project at BNL. OPC will support preliminary project plans for these activities.
Major Items of Equipment	$50,000	$25,000	-$25,000
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.		The Request will provide final funding for the beamline project for NEXT-II at BNL and the recapitalization project for the NSRCs.	Funding will support the approved funding profiles for the NEXT-II and NSRC Recapitalization MIE projects.

(dollars in thousands)

FY 2023 Enacted	FY 2024 Request	Explanation of Changes FY 2024 Request vs FY 2023 Enacted
Research $52,610	$58,966	+$6,356
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 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 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 response to biological threats and to increase the diversity of the research performers.	Funding will support investment in future accelerator technologies to continue to provide the world's most comprehensive and advanced accelerator-based facilities for scientific research. Funding will also continue the development of data science methods and tools to address data and information challenges at the BES user facilities, including accelerator optimization, control, prognostics, and experiment automation and real time data analysis. Funding will support the BRaVE initiative to enable facility capabilities for responsiveness to biological threats. Investment will include research in underrepresented communities and institutions. Funding will support the RENEW initiative for user facility internships from HBCUs and MSIs.

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
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, as well as research in response to national priorities such as the COVID-19 pandemic. 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 address two capability gaps. First, HFIR is no longer operating at the 100 MW design power due to the discovery of embrittlement issues and a subsequent derating of the reactor to 85 MW. Second, the design of the current pressure vessel limits the addition of new mission-driven scattering instrumentation, enhanced isotope production, and potential flexibilities such as adding a second cold source and guide hall to enhance the key missions of the reactor. Replacement of the pressure vessel and resumption of 100 MW operations meets the need for continued availability of a high-flux, steady-state neutron source that will accommodate future advances and maintain world-leading capabilities for diverse and critical missions that include: production of thermal and cold neutrons and neutrinos for the scientific user community; isotope production for research, medicine, and federal and industrial applications including NASA deep space missions; and materials irradiation and neutron activation analysis for federal and industrial partners. The project received CD-0, Approve Mission Need, on October 28, 2020, with a current Total Project Cost (TPC) range of $300,000,000–$550,000,000 and CD-1, Approve Alternative Selection and Cost Range, is expected 4Q FY 2025.

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 approximately 12 beamlines that will be optimized to enhance the capability of NSLS-II. NEXT-III will deliver a combination of performance and enterprise beamlines. Performance beamlines will be designed to push a given technique to or beyond the current state-of-the-art, offering extraordinary capabilities. 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 from crystals to atomic structures, 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. 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 can also provide a first step to gather data for complex experiments that would be fine-tuned to subsequently acquire data on a performance beamline. Enterprise beamlines will enable multimodal (remote as well as on-site) 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 and CD-1, Approve Alternative Selection and Cost Range, is expected 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 is envisioned to require a building up to 25,000 gross square feet to contain the necessary equipment. The building will need a concrete shielded enclosure for cryomodule testing, a control room, a vertical test stand area for testing SRF cavities and

components, supplied with cryogenic refrigeration and a distribution box which is connected to a source of liquid helium and will distribute liquid helium within the CRMF building, cryomodule fixtures used to insert and remove the cold mass from the cryomodule vacuum vessel, a cleanroom partitioned into class 10 and class 1000 areas, a loading and cryomodule preparation area, storage areas, and a 15 ton bridge crane for moving equipment from one area to another within the building. The project received CD-0, Approve Mission Need, on December 6, 2019, with a current TPC range of $70,000,000–$98,000,000, and CD-1, Approve Alternative Selection and Cost Range, is expected 4Q FY 2023.

<u>19-SC-14, Second Target Station (STS), ORNL</u>
The STS project will expand SNS capabilities for neutron scattering research by exploiting part of the higher SNS accelerator proton beam power (2.8 MW) enabled by the PPU project. The STS will be a complementary pulsed source with a narrow proton beam which increases the proton beam power density compared to the first target station (FTS). This dense beam of protons, when deposited on a compact, rotating, water-cooled tungsten target, will create neutrons through spallation and direct them to high efficiency coupled moderators to produce an order of magnitude higher brightness cold neutrons than were previously achievable. By optimizing the design of the instruments with advanced neutron optics, optimized geometry for 15 Hz operation, and advanced detectors, the detection resolution will be up to two orders of magnitude higher, enabling new research opportunities. The project received CD-1, Approve Alternative Selection and Cost Range, on November 23, 2020, which established the approved TPC range of $1,800,000,000–$3,000,000,000 and CD-3A, Approve Long Lead Procurements, is expected 4Q FY 2024.

<u>18-SC-11, Spallation Neutron Source Proton Power Upgrade (PPU), ORNL</u>
The PPU project will double the proton beam power capability of the SNS from 1.4 megawatts (MW) to 2.8 MW by fabricating and installing seven new superconducting radio frequency (SRF) cryomodules and supporting RF equipment, upgrade the first target station to accommodate beam power up to 2 MW, and deliver a 2 MW-qualified target. The high voltage converter modulators and klystrons for some of the existing installed RF equipment will be upgraded to handle the higher beam current. The accumulator ring will be upgraded with minor modifications to the injection and extraction areas. The improved target performance at the increased beam power of 2 MW is enabled by the addition of a new gas injection system and a redesigned mercury target vessel. The project received a combined CD-2, Approve Performance Baseline, and CD-3, Approve Start of Construction, on October 6, 2020, with a TPC of $271,567,000 and CD-4, Approve Project Completion, is expected 4Q FY 2028.

<u>18-SC-12, Advanced Light Source Upgrade (ALS-U), LBNL</u>
The ALS-U project will upgrade the existing ALS facility by replacing the existing electron storage ring with a new electron storage ring based on a multi-bend achromat lattice design, which will provide a soft x-ray source that is up to 1000 times brighter and with a significantly higher coherent flux fraction. ALS-U will leverage two decades of investments in scientific tools at the ALS by making use of the existing beamlines and infrastructure. ALS-U will ensure that the ALS facility remains a world leader in soft x-ray science. The project received CD-3, Approve Start of Construction, on November 10, 2022, with a TPC of $590,000,000 and CD-4, Approve Project Completion, is expected 4Q of FY 2029.

<u>18-SC-13, Linac Coherent Light Source-II-High Energy (LCLS-II-HE), SLAC</u>
The LCLS-II-HE project will increase the energy of the superconducting linac currently under construction as part of the LCLS-II project from 4 giga-electronvolts (GeV) to 8 GeV and thereby expand the high repetition rate operation (1 million pulses per second) of this unique facility into the hard x-ray regime (5-12 keV). LCLS-II-HE will add new and upgraded instrumentation to augment existing capabilities and upgrade the facility infrastructure as needed. The LCLS-II-HE project will upgrade and expand the capabilities of the LCLS-II to maintain U.S. leadership in ultrafast x-ray science. 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, added scope for a new superconducting electron source, and increased the project's contingency to address several future risks, the TPC estimate has increased to $710,000,000. The LCLS-II-HE project continues to assess the impact of COVID-19 on the project's cost and schedule. A combined CD-2/3, Approve Performance Baseline and Approve Start of Construction, is expected in 2Q FY 2024.

Activities and Explanation of Changes

(dollars in thousands)

FY 2023 Enacted		FY 2024 Request		Explanation of Changes FY 2024 Request vs FY 2023 Enacted
Construction	**$293,200**		**$260,625**	**-$32,575**
24-SC-10, HFIR Pressure Vessel Replacement (PVR), ORNL	$ —		$4,000	+$4,000
No funding is requested in FY 2023.		The Request will initiate planning, design, R&D, analysis, engineering, and prototyping to advance design.		Funding will initiate the HFIR PVR project.
24-SC-12, NSLS-II Experimental Tools - III (NEXT-III), BNL	$ —		$2,556	+$2,556
No funding is requested in FY 2023.		The Request will initiate conceptual design activities, building on the planning activities supported in FY 2023.		Funding will initiate the NEXT-III project.
21-SC-10, Cryomodule Repair & Maintenance Facility (CRMF), SLAC	$10,000		$9,000	-$1,000
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 completion of the detailed design of the facility and technical specifications of the cryogenic plant and initiate long-lead procurements upon associated CD approvals. CD-1 is expected for 4Q FY 2023 and CD-3A is expected for 1Q FY 2024.		Funding will advance progress on the CRMF project.

(dollars in thousands)

FY 2023 Enacted	FY 2024 Request	Explanation of Changes FY 2024 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 2024.	Final funding for this project is provided in FY 2023.
18-SC-11, Spallation Neutron Source Proton Power Upgrade (PPU), ORNL $17,000	$15,769	-$1,231
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.	The Request will support construction of the tunnel stub that will facilitate connection to the future STS, install the final additional cryomodules and related radiofrequency systems, begin first target station upgrades to support high-flow target gas injection, upgrade the ring magnets, and operate the first PPU production target at increased power levels.	Final funding for this project is requested in FY 2024.
18-SC-12, Advanced Light Source Upgrade (ALS-U), LBNL $135,000	$57,300	-$77,700
The project continues to advance construction activities.	The Request will continue to advance construction activities upon associated CD approvals.	Final funding for this project is requested in FY 2024.

(dollars in thousands)

FY 2023 Enacted	FY 2024 Request	Explanation of Changes FY 2024 Request vs FY 2023 Enacted
18-SC-13, Linac Coherent Light Source-II-High Energy (LCLS-II-HE), SLAC $90,000	$120,000	+$30,000
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 2Q FY 2024.	Funding will advance progress on the LCLS-II-HE project.

Basic Energy Sciences
Capital Summary

(dollars in thousands)

	Total	Prior Years	FY 2022 Enacted	FY 2022 IRA Supp.	FY 2023 Enacted	FY 2024 Request	FY 2024 Request vs FY 2023 Enacted
Capital Operating Expenses							
Capital Equipment	N/A	N/A	55,740	38,500	80,698	57,394	-23,304
Minor Construction Activities							
General Plant Projects	N/A	N/A	1,740	–	3,400	22,040	+18,640
Accelerator Improvement Projects	N/A	N/A	23,431	–	14,010	81,169	+67,159
Total, Capital Operating Expenses	**N/A**	**N/A**	**80,911**	**38,500**	**98,108**	**160,603**	**+62,495**

Capital Equipment

(dollars in thousands)

	Total	Prior Years	FY 2022 Enacted	FY 2022 IRA Supp.	FY 2023 Enacted	FY 2024 Request	FY 2024 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	13,783	15,000	18,500	25,000	20,000	-5,000
NSRC Recapitalization	79,150	14,150	15,000	20,000	25,000	5,000	-20,000
Total, MIEs	N/A	N/A	30,000	38,500	50,000	25,000	-25,000
Total, Non-MIE Capital Equipment	N/A	N/A	25,740	–	30,698	32,394	+1,696
Total, Capital Equipment	**N/A**	**N/A**	**55,740**	**38,500**	**80,698**	**57,394**	**-23,304**

Note:

- *The Capital Equipment table includes MIEs located at a DOE facility with a Total Estimated Cost (TEC) > $5M and MIEs not located at a DOE facility with a TEC >$2M.*

Minor Construction Activities

(dollars in thousands)

	Total	Prior Years	FY 2022 Enacted	FY 2023 Enacted	FY 2024 Request	FY 2024 Request vs FY 2023 Enacted
General Plant Projects (GPP)						
GPPs (greater than or equal to $5M and less than $30M)						
HFIR Guide Hall Extension	20,640	–	740	1,400	18,500	+17,100
HFIR Fabrication, Alignment & Manufacturing (FAM) Bldg., ORNL	1,540	–	–	–	1,540	+1,540
Total GPPs (greater than or equal to $5M and less than $30M)	N/A	N/A	740	1,400	20,040	+18,640
Total GPPs less than $5M	N/A	N/A	1,000	2,000	2,000	–
Total, General Plant Projects (GPP)	**N/A**	**N/A**	**1,740**	**3,400**	**22,040**	**+18,640**
Accelerator Improvement Projects (AIP)						
AIPs (greater than or equal to $5M and less than $30M)						
3rd Harmonic Cavity, National Synchrotron Light Source-II	4,720	–	–	–	4,720	+4,720
Spallation Neutron Source Cold Box-Engineering	10,500	–	–	–	10,500	+10,500
Cold Source Helium Refrigerator System	21,939	9,339	–	–	12,600	+12,600
Moderator Test Stand (SNS)	6,250	–	6,250	–	–	–
160kW Solid State Amplifier Hardware and Utilities - Phase 2 (APS)	11,934	–	–	5,967	5,967	–
Flexon 2nd Endstation, LBNL	8,500	–	–	–	8,500	+8,500
New SAX/WAX Beamline, LBNL	17,750	–	–	–	17,750	+17,750
Total AIPs (greater than or equal to $5M and less than $30M)	N/A	N/A	6,250	5,967	60,037	+54,070
Total AIPs less than $5M	N/A	N/A	17,181	8,043	21,132	+13,089
Total, Accelerator Improvement Projects (AIP)	**N/A**	**N/A**	**23,431**	**14,010**	**81,169**	**+67,159**

(dollars in thousands)

	Total	Prior Years	FY 2022 Enacted	FY 2023 Enacted	FY 2024 Request	FY 2024 Request vs FY 2023 Enacted
Total, Minor Construction Activities	**N/A**	**N/A**	**25,171**	**17,410**	**103,209**	**+85,799**

Notes:
- *GPP activities less than $5M include design and construction for additions and/or improvements to land, buildings, replacements or addition to roads, and general area improvements. AIP activities less than $5M 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.*

Basic Energy Sciences
Major Items of Equipment Description(s)

Scientific User Facilities (SUF) MIEs:
In FY 2024, preliminary planning support is requested for new MIEs for additional beamlines for the APS and ALS user facilities.

NSLS-II Experimental Tools-II (NEXT-II) Project
The NEXT-II project will add three world-class beamlines to the NSLS-II Facility as part of a phased buildout of beamlines to provide advances in scientific capabilities for the soft x-ray user community. These beamlines will focus on the techniques of coherent diffraction imaging, soft x-ray spectromicroscopy, and nanoscale probes of electronic excitations. The project received CD-2, Approve Performance Baseline, and CD-3, Approve Start of Construction, on October 13, 2021. The approved total project cost is $94,500,000. The FY 2024 Request of $20,000,000 provides final funding for the project and will continue R&D, prototyping, other supporting activities, and construction/equipment procurements. The project is planning for CD-4 approval early in FY 2027.

Nanoscale Science Research Center (NSRC) Recapitalization Project
The NSRCs started early operations in 2006-2007 and now, over a decade later, instrumentation recapitalization is needed to continue to perform cutting edge science to support and accelerate advances in the fields of nanoscience, materials, chemistry, and biology. The recapitalization will also provide essential support for quantum information science and systems. The project received a combined CD-2, Approve Performance Baseline, and CD-3, Approve Start of Construction, on March 31, 2022. The approved total cost is $80,000,000. The FY 2024 Request of $5,000,000 provides final funding for the project and will continue R&D, design, engineering, prototyping, other supporting activities, and construction/equipment procurements. The project is planning for CD-4 approval early in FY 2028.

Basic Energy Sciences
Construction Projects Summary

(dollars in thousands)

	Total	Prior Years	FY 2022 Enacted	FY 2022 IRA Supp.	FY 2023 Enacted	FY 2024 Request	FY 2024 Request vs FY 2023 Enacted
24-SC-10, HFIR Pressure Vessel Replacement (PVR)							
Total Estimated Cost (TEC)	523,000	–	–	–	–	4,000	+4,000
Other Project Cost (OPC)	27,000	–	–	–	3,000	9,000	+6,000
Total Project Cost (TPC)	**550,000**	**–**	**–**	**–**	**3,000**	**13,000**	**+10,000**
24-SC-12, NSLS-II Experimental Tools-III (NEXT-III)							
Total Estimated Cost (TEC)	480,000	–	–	–	–	2,556	+2,556
Other Project Cost (OPC)	20,000	–	–	–	1,500	4,000	+2,500
Total Project Cost (TPC)	**500,000**	**–**	**–**	**–**	**1,500**	**6,556**	**+5,056**
21-SC-10, Cryomodule Repair & Maintenance Facility (CRMF), SLAC							
Total Estimated Cost (TEC)	88,800	1,000	1,000	20,000	10,000	9,000	-1,000
Other Project Cost (OPC)	5,700	1,000	2,000	700	1,000	1,000	–
Total Project Cost (TPC)	**94,500**	**2,000**	**3,000**	**20,700**	**11,000**	**10,000**	**-1,000**
19-SC-14, Spallation Neutron Source Second Target Station (STS), ORNL							
Total Estimated Cost (TEC)	2,145,000	50,000	32,000	42,700	32,000	52,000	+20,000
Other Project Cost (OPC)	97,000	45,805	–	–	5,000	–	-5,000
Total Project Cost (TPC)	**2,242,000**	**95,805**	**32,000**	**42,700**	**37,000**	**52,000**	**+15,000**
18-SC-10, Advanced Photon Source Upgrade (APS-U), ANL							
Total Estimated Cost (TEC)	796,500	686,300	101,000	–	9,200	–	-9,200
Other Project Cost (OPC)	18,500	8,500	5,000	–	5,000	–	-5,000
Total Project Cost (TPC)	**815,000**	**694,800**	**106,000**	**–**	**14,200**	**–**	**-14,200**

(dollars in thousands)

	Total	Prior Years	FY 2022 Enacted	FY 2022 IRA Supp.	FY 2023 Enacted	FY 2024 Request	FY 2024 Request vs FY 2023 Enacted
18-SC-11, Spallation Neutron Source Proton Power Upgrade (PPU), ORNL							
Total Estimated Cost (TEC)	257,769	208,000	17,000	–	17,000	15,769	-1,231
Other Project Cost (OPC)	13,798	13,798	–	–	–	–	–
Total Project Cost (TPC)	**271,567**	**221,798**	**17,000**	**–**	**17,000**	**15,769**	**-1,231**
18-SC-12, Advanced Light Source Upgrade (ALS-U), LBNL							
Total Estimated Cost (TEC)	562,000	198,000	75,100	96,600	135,000	57,300	-77,700
Other Project Cost (OPC)	28,000	28,000	–	–	–	–	–
Total Project Cost (TPC)	**590,000**	**226,000**	**75,100**	**96,600**	**135,000**	**57,300**	**-77,700**
18-SC-13, Linac Coherent Light Source-II-High Energy (LCLS-II-HE), SLAC							
Total Estimated Cost (TEC)	678,000	128,657	50,000	90,000	90,000	120,000	+30,000
Other Project Cost (OPC)	32,000	14,000	3,000	6,000	4,000	–	-4,000
Total Project Cost (TPC)	**710,000**	**142,657**	**53,000**	**96,000**	**94,000**	**120,000**	**+26,000**
13-SC-10, Linac Coherent Light Source II (LCLS-II), SLAC							
Total Estimated Cost (TEC)	1,080,200	1,052,100	28,100	–	–	–	–
Other Project Cost (OPC)	56,200	51,900	4,300	–	–	–	–
Total Project Cost (TPC)	**1,136,400**	**1,104,000**	**32,400**	**–**	**–**	**–**	**–**
Total, Construction							
Total Estimated Cost (TEC)	**N/A**	**N/A**	**304,200**	**249,300**	**293,200**	**260,625**	**-32,575**
Other Project Cost (OPC)	**N/A**	**N/A**	**14,300**	**6,700**	**19,500**	**14,000**	**-5,500**
Total Project Cost (TPC)	**N/A**	**N/A**	**318,500**	**256,000**	**312,700**	**274,625**	**-38,075**

Note:

- *The Prior Year amounts in the table above include reprogramming of funds from the APS-U project (-$3,500,000) to the LCLS-II-HE project (+$3,500,000) and the LCLS-II project (+$2,801,000) in FY 2021.*

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 2022 Enacted	FY 2022 Current	FY 2023 Enacted	FY 2024 Request	FY 2024 Request vs FY 2023 Enacted
Scientific User Facilities - Type A					
Advanced Light Source	**70,704**	**68,672**	**74,934**	**105,289**	**+30,355**
Number of Users	1,400	1,663	1,500	1,545	+45
Achieved Operating Hours	–	3,957	–	–	–
Planned Operating Hours	3,885	3,885	3,880	3,010	-870
Advanced Photon Source	**146,226**	**141,638**	**173,142**	**174,920**	**+1,778**
Number of Users	4,000	4,582	3,440	1,810	-1,630
Achieved Operating Hours	–	4,820	–	–	–
Planned Operating Hours	4,550	4,550	3,152	2,071	-1,081
National Synchrotron Light Source II	**121,243**	**117,759**	**128,100**	**147,240**	**+19,140**
Number of Users	1,600	1,380	1,500	1,620	+120
Achieved Operating Hours	–	4,610	–	–	–
Planned Operating Hours	4,656	4,656	4,800	4,506	-294
Stanford Synchrotron Radiation Light Source	**45,825**	**44,989**	**48,242**	**67,035**	**+18,793**
Number of Users	1,350	1,601	1,100	1,800	+700
Achieved Operating Hours	–	4,833	–	–	–
Planned Operating Hours	4,850	4,850	3,316	4,537	+1,221
Linac Coherent Light Source	**154,284**	**155,273**	**175,080**	**209,650**	**+34,570**
Number of Users	800	869	600	900	+300
Achieved Operating Hours	–	4,598	–	–	–
Planned Operating Hours	4,655	4,655	3,200	5,850	+2,650

	(dollars in thousands)				
	FY 2022 Enacted	**FY 2022 Current**	**FY 2023 Enacted**	**FY 2024 Request**	**FY 2024 Request vs FY 2023 Enacted**
Spallation Neutron Source	**185,081**	**172,409**	**189,727**	**180,147**	**-9,580**
Number of Users	800	577	450	260	-190
Achieved Operating Hours	–	3,275	–	–	–
Planned Operating Hours	3,040	3,040	2,700	1,444	-1,256
High Flux Isotope Reactor	**108,919**	**111,452**	**126,013**	**193,016**	**+67,003**
Number of Users	560	254	290	290	–
Achieved Operating Hours	–	2,322	–	–	–
Planned Operating Hours	3,025	3,025	2,700	2,970	+270
Scientific User Facilities - Type B					
Center for Nanoscale Materials	**30,666**	**29,652**	**30,519**	**29,558**	**-961**
Number of Users	480	756	730	700	-30
Center for Functional Nanomaterials	**25,690**	**25,601**	**27,114**	**26,483**	**-631**
Number of Users	520	640	630	630	–
Molecular Foundry	**32,226**	**31,166**	**38,051**	**37,494**	**-557**
Number of Users	750	968	950	1,170	+220
Center for Nanophase Materials Sciences	**28,691**	**28,497**	**30,404**	**29,441**	**-963**
Number of Users	580	811	730	700	-30
Center for Integrated Nanotechnologies	**25,471**	**24,636**	**27,321**	**27,904**	**+583**
Number of Users	660	906	870	850	-20
Total, Facilities	**975,026**	**951,744**	**1,068,647**	**1,228,177**	**+159,530**
Number of Users	13,500	15,007	12,790	12,275	-515
Achieved Operating Hours	–	28,415	–	–	–
Planned Operating Hours	28,661	28,661	23,748	24,388	+640

Note:

- *Achieved Operating Hours and Unscheduled Downtime Hours will only be reflected in the Congressional budget cycle which provides actuals.*

Basic Energy Sciences
Scientific Employment

	FY 2022 Enacted	FY 2023 Enacted	FY 2024 Request	FY 2024 Request vs FY 2023 Enacted
Number of Permanent Ph.Ds (FTEs)	5,280	5,840	6,190	+350
Number of Postdoctoral Associates (FTEs)	1,520	1,670	1,740	+70
Number of Graduate Students (FTEs)	2,380	2,620	2,730	+110
Number of Other Scientific Employment (FTEs)	3,190	3,550	3,810	+260
Total Scientific Employment (FTEs)	**12,370**	**13,680**	**14,470**	**+790**

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 FY 2024 Request for the HFIR Pressure Vessel Replacement (PVR), ORNL is $4,000,000 of Total Estimated Cost (TEC) funding and $9,000,000 of Other Project Costs (OPC) funding. The preliminary total project cost (TPC) range is $300,000,000 to $550,000,000. This preliminary cost range encompasses the most feasible preliminary alternatives at this time. The current preliminary TPC is $550,000,000.

Significant Changes

This is a new Construction Project Data Sheet (CPDS) and this project is a new start in FY 2024.

The HFIR started initial operations in 1965 at 100 Mega Watts (MW) but has been operating since 1990 at 85 MW to extend the lifetime of the reactor pressure vessel by slowing radiation-induced embrittlement. In 2019, the Basic Energy Sciences Advisory Committee (BESAC) was charged with assessing the long-term strategy for HFIR and the scientific justification for a U.S. domestic high-performance 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,* is to replace the pressure vessel with one made with modern materials better able to withstand the harsh radiation environment. After the PVR upgrade, HFIR can resume operations at 100 MW, maintaining reliable access to the world's most intense source of neutrons and ensuring continued support for a variety of high-impact missions in science, isotope production, energy, environment, and national security.

The most recent DOE Order 413.3B approved Critical Decision (CD) is CD-0, Approve Mission Need, approved on October 28, 2020. The FY 2023 Enacted Appropriations include $3,000,000 in OPC funding to initiate the alternatives analysis and conceptual design activities required for CD-1. The FY 2024 Request will support planning, design, R&D, analysis, engineering, and prototyping to advance the design.

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	D&D Complete	CD-4
FY 2024	10/28/20	4Q FY 2025	4Q FY 2025	4Q FY 2026	4Q FY 2029	4Q FY 2027	4Q FY 2034	4Q FY 2034

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 2024	4Q FY 2026	4Q FY 2025

CD-3A – Approve Long-Lead Procurements, to reduce schedule and technical risk by procuring specialty radiation and corrosion resistant nuclear reactor materials 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

2. Project Scope and Justification

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

Justification
The BES mission 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 missions in energy, environment, and national security. BES accomplishes its mission in part by operation of large-scale user facilities consisting of a complementary set of intense x-rays sources, neutron scattering centers, electron beam characterization capabilities, and research centers for nanoscale science.

Maintaining world-class user facilities for neutron scattering research and other national priorities requiring neutron sources are an important component of the user facility portfolio enabled by the Spallation Neutron Source (SNS) for pulsed neutrons and the HFIR for reactor-based high-flux neutrons. The HFIR, completed in 1965, has the highest thermal neutron flux in the western world but is at risk of falling behind the 100 MW PIK reactor in Gatchina, Russia (completed in 2021) and the 150 MW MBIR reactor in Dmitrovgrad, Russia (planned for completion in 2027). The HFIR-PVR project reduces the risk of needing to rely on foreign research reactors for critical isotope production and scientific research needs in the long term.

The HFIR-PVR project will address two capability gaps. First, HFIR is no longer operating at the 100 MW design power due to the discovery of embrittlement issues and a subsequent derating of the reactor to 85 MW. Second, the design of the current pressure vessel limits the addition of new mission-driven scattering instrumentation, enhanced isotope production, and potential flexibilities such as adding a second cold source and guide hall to enhance the key missions of the reactor. Replacement of the pressure vessel and resumption of 100 MW operations meets the need for continued availability of a high-flux, steady-state neutron source that will accommodate future advances and maintain world leading capabilities for diverse and critical missions that include: production of thermal and cold neutrons and neutrinos for the scientific user community, isotope production for research, medicine, and federal and industrial applications including NASA deep space missions; and materials irradiation and neutron activation analysis for federal and industrial partners.

The July 2020 BESAC subcommittee report, *The Scientific Justification for a U.S. Domestic High-Performance Reactor-Based Research Facility,* recommends fabricating and replacing the pressure vessel with one made with modern materials better able to withstand the harsh radiation environment. This upgrade will resume operations at 100 MW, maintaining reliable access to HFIR, the world's most intense source of neutrons, ensuring continued support for a variety of high-impact missions including neutron science, materials irradiation, neutron activation analysis, neutrino research, and radioisotope production for research, medicine, and federal and industrial applications. Potential capability and capacity enhancements benefiting the scientific community include: an immediate ~20 percent increase in neutron flux from 100 MW operations; flexibility for a second guide providing the opportunity to increase the number of instruments from the current 12 to 20; the option for a new cold source that provides a ~50 percent boost to cold neutron brightness; and improved beam systems that increase the available flux at cold and thermal instruments by factors of two or more. Additionally, an improved reactor vessel head that allows introduction and removal of capsules during reactor operations will increase isotope production and enable a significant increase 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*.

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
Instrument ports available for future expansion beyond the current facility	2	8

3. Financial Schedule

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs
Total Estimated Cost (TEC)			
Design (TEC)			
FY 2024	4,000	4,000	–
Outyears	173,000	173,000	177,000
Total, Design (TEC)	**177,000**	**177,000**	**177,000**
Construction (TEC)			
Outyears	346,000	346,000	346,000
Total, Construction (TEC)	**346,000**	**346,000**	**346,000**
Total Estimated Cost (TEC)			
FY 2024	4,000	4,000	–
Outyears	519,000	519,000	523,000
Total, TEC	**523,000**	**523,000**	**523,000**

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs
Other Project Cost (OPC)			
FY 2023	3,000	3,000	2,400
FY 2024	9,000	9,000	8,000
Outyears	15,000	15,000	16,600
Total, OPC	**27,000**	**27,000**	**27,000**

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs
Total Project Cost (TPC)			
FY 2023	3,000	3,000	2,400
FY 2024	13,000	13,000	8,000
Outyears	534,000	534,000	539,600
Total, TPC	**550,000**	**550,000**	**550,000**

4. Details of Project Cost Estimate

(dollars in thousands)

	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
Total Estimated Cost (TEC)			
Design	137,000	N/A	**N/A**
Design - Contingency	40,000	N/A	**N/A**
Total, Design (TEC)	**177,000**	**N/A**	**N/A**
Construction	247,500	N/A	**N/A**
Construction - Contingency	98,500	N/A	**N/A**
Total, Construction (TEC)	**346,000**	**N/A**	**N/A**
Total, TEC	**523,000**	**N/A**	**N/A**
Contingency, TEC	*138,500*	***N/A***	***N/A***
Other Project Cost (OPC)			
Total, D&D	**5,600**	**N/A**	**N/A**
Conceptual Design	14,000	N/A	**N/A**
Start-up	2,400	N/A	**N/A**
OPC - Contingency	5,000	N/A	**N/A**
Total, Except D&D (OPC)	**21,400**	**N/A**	**N/A**
Total, OPC	**27,000**	**N/A**	**N/A**
Contingency, OPC	*5,000*	*N/A*	***N/A***
Total, TPC	**550,000**	**N/A**	**N/A**
Total, Contingency (TEC+OPC)	***143,500***	***N/A***	***N/A***

5. Schedule of Appropriations Requests

(dollars in thousands)

Fiscal Year	Type	Prior Years	FY 2022	FY 2023	FY 2024	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

6. Related Operations and Maintenance Funding Requirements

Start of Operation or Beneficial Occupancy	4Q FY 2034
Expected Useful Life	50 years
Expected Future Start of D&D of this capital asset	4Q FY 2084

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 Office of Science 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 FY 2024 Request for the NSLS-II Experimental Tools - III (NEXT-III) Project is $2,556,000 of Total Estimated Cost (TEC) funding and $4,000,000 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 is a new Construction Project Data Sheet (CPDS) and this project is a new start in FY 2024.

The most recent DOE Order 413.3B approved Critical Decision (CD) is CD-0, Approve Mission Need, approved on September 30, 2022. The FY 2023 Enacted Appropriations included $1,500,000 in OPC funding for planning activities for this project. The FY 2024 Request continues 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.

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 2024	9/30/22	3Q FY 2024	4Q FY 2024	2Q FY 2026	3Q FY 2027	4Q FY 2027	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 2024	2Q FY 2026	3Q FY 2025	2Q 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

2. Project Scope and Justification

Scope

The NEXT-III project will provide for the construction of approximately 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, 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 from crystals to atomic structures, 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 (remote as well as on-site) research for a larger more diverse community including researchers from under-represented communities.

Justification

SC has a mission to deliver the scientific discoveries and major scientific tools that transform our understanding of nature and advance the energy, economic, and national security of the United States. SC accomplishes this mission through direct support of research, construction, and operation of national scientific user facilities, and the stewardship of ten world-class national laboratories. The SC national laboratories collectively comprise a preeminent federal research system that develops unique, often multidisciplinary, scientific capabilities beyond the scope of academic and industrial institutions, to benefit the nation's researchers and national strategic priorities.

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 our ability to observe, measure, and understand the structure and properties of materials and the evolution of chemical and physical processes within them. 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 storage-ring sources use low- and medium-energy x-rays in their research because of their great importance in characterization for the fields of energy, the environment, new or improved materials, and biological studies. Low- and medium-energy x-rays can be used to determine the structure of materials at the atomic resolution scales, can provide images at the 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. However, performance limitations of the U.S. low- and medium-energy x-ray sources had prevented measurements with the necessary resolution and sensitivity in space, energy, and time. Those types of measurements are essential for understanding and controlling energy conversion in materials used in alternative energy technologies. To address these limitations and to further the accomplishment of its mission, the BES program constructed the NSLS-II storage ring light source at Brookhaven National Laboratory to provide one of the world's brightest storage ring synchrotron sources of low- and medium-energy x-rays. NSLS-II has a total capacity of 60 beamlines, with only 28 beamlines (about 47 percent of the capacity) constructed and in current operation.

The NEXT-III project will significantly close the current capability gap by constructing an additional suite of state-of-the-art beamlines. These capabilities are at the core of the NSLS-II User Facility mission to support identified needs of the U.S. research community and the DOE mission to tackle the discoveries and transformational solutions needed for the next generation of sustainable energy technologies. Implementation of this state-of-the-art suite of instrumentation will significantly improve the scientific quality and productivity from the U.S. research community. The remaining open beamlines will allow future opportunities for as yet unforeseen science needs and technology developments.

Because of the importance of the development of new materials and sustainable manufacturing processes, failure to acquire the suite of new advanced tools made possible by the NEXT-III project would have serious repercussions on the competitiveness of U.S. science and engineering. Constructing major scientific user facilities and tools that lead the world in cutting edge research is one of the most important strategic activities of SC. As a result, BES has made the design and fabrication of synchrotron light source beamlines a high priority in order to keep the U.S. at the forefront of energy research.

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. 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
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
Outyears	35,444	35,444	36,500
Total, Design (TEC)	**38,000**	**38,000**	**38,000**
Construction (TEC)			
Outyears	442,000	442,000	442,000
Total, Construction (TEC)	**442,000**	**442,000**	**442,000**
Total Estimated Cost (TEC)			
FY 2024	2,556	2,556	1,500
Outyears	477,444	477,444	478,500
Total, 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	1,300
FY 2024	4,000	4,000	3,800
Outyears	14,500	14,500	14,900
Total, 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	1,300
FY 2024	6,556	6,556	5,300
Outyears	491,944	491,944	493,400
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	N/A	**N/A**
Design - Contingency	9,500	N/A	**N/A**
Total, Design (TEC)	**38,000**	**N/A**	**N/A**
Construction	115,200	N/A	**N/A**
Equipment	172,800	N/A	**N/A**
Construction - Contingency	154,000	N/A	**N/A**
Total, Construction (TEC)	**442,000**	**N/A**	**N/A**
Total, TEC	**480,000**	**N/A**	**N/A**
Contingency, TEC	*163,500*	***N/A***	***N/A***
Other Project Cost (OPC)			
R&D	4,000	N/A	**N/A**
Conceptual Planning	3,000	N/A	**N/A**
Conceptual Design	10,000	N/A	**N/A**
OPC - Contingency	3,000	N/A	**N/A**
Total, Except D&D (OPC)	**20,000**	**N/A**	**N/A**
Total, OPC	**20,000**	**N/A**	**N/A**
Contingency, OPC	*3,000*	*N/A*	***N/A***
Total, TPC	**500,000**	**N/A**	**N/A**
Total, Contingency (TEC+OPC)	***166,500***	***N/A***	***N/A***

5. Schedule of Appropriations Requests

(dollars in thousands)

Fiscal Year	Type	Prior Years	FY 2022	FY 2023	FY 2024	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

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 that there will be no new area being constructed in the construction project.

8. Acquisition Approach

NEXT-III will be acquired by the BNL under the existing M&O contract managed by the Brookhaven Science Associates. Since completion of NSLS-II User Facility in 2015, the BNL team has constructed many beamlines at the facility and have all the requisite expertise and experience to deliver the project. Project acquisition will 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.

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 FY 2024 Request for the Cryomodule Repair and Maintenance Facility (CRMF) project at SLAC National Accelerator Laboratory is $9,000,000 of Total Estimated Cost (TEC) funding and $1,000,000 of Other Project Costs (OPC) 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 has increased from $94,000,000 to $94,500,000.

Significant Changes

CRMF was initiated in FY 2021. The most recent DOE Order 413.3B approved Critical Decision (CD) is CD-0, Approve Mission Need, approved on December 6, 2019. This Construction Project Data Sheet (CPDS) is an update of the FY 2023 CPDS and does not include a new start for FY 2024.

In FY 2022, funding supported analysis of alternatives and matures the conceptual design with expertise from an architectural and engineering (AE) firm in preparation for the CD-1 planned in FY 2023. Also in FY 2022, CRMF received $20,700,000 in Inflation Reduction Act (IRA) supplemental funding that will enable the project to accelerate the procurement of the AE design services and will expedite the design. FY 2023 funding supports the design of building infrastructure and technical systems and finalizing the design guidelines and specifications for cryogenics capabilities as part of the proposed CD-3A, approval of long lead procurements. The FY 2024 Request will support completion of the detailed design of the facility, and technical specifications for the procurement of cryogenic systems/equipment.

A Federal Project Director, certified to Level I, 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 2024	12/6/19	4Q FY 2023	4Q FY 2023	1Q FY 2025	4Q FY 2024	1Q FY 2025	4Q FY 2029

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 2024	1Q FY 2025	1Q FY 2024

CD-3A – Approve Long-Lead Procurements

As the project planning and design matures, long lead procurement may be requested to mitigate cost and schedule risk to the project. Pending the final design, the long lead items may include the components for CRMF cryogen capabilities.

Project Cost History

(dollars in thousands)

Fiscal Year	TEC, Design	TEC, Construction	TEC, Total	OPC, Except D&D	OPC, Total	TPC
FY 2023	5,600	84,700	90,300	3,700	3,700	94,000
FY 2024	5,600	83,200	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 to support the repair, maintenance, and testing of superconducting radiofrequency (SRF) LCLS-II and LCLS-II-HE 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. The initial concept includes a building with a concrete shielded enclosure for cryomodule testing, a control room, a vertical test stand area for testing SRF cavities and components, supplied with cryogenic refrigeration and a distribution box, cryomodules handling tools and fixtures used to insert and remove the cold mass from the cryomodule vacuum vessel, a cleanroom partitioned into class 10 and class 1000 areas, a loading and cryomodule preparation area, storage areas, and a 15 ton bridge crane for moving equipment from one area to another within the building.

The building is sized to enable future upgrades of capabilities including installation of a dedicated SRF electron injector development and test area, a 40 mega-electronvolt (MeV) SRF linac to provide the equipment and diagnostics necessary for an integrated injector test stand, and equipment to refurbish and test the niobium SRF cavities. The project is pre-CD-2; the scope included in the alternative selection and cost range will be refined at CD-1.

Justification
SC, through the two current BES construction projects, LCLS-II and LCLS-II-HE, 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 capable of providing 1 megahertz (MHz) electron pulses to create a free electron, x-ray laser. This machine contains 35 SRF cryomodules to accelerate the electrons to 4 GeV. The LCLS-II-HE will increase the energy of the LCLS-II linac to 8 GeV by providing an additional 20-23 SRF cryomodules of a similar design to the LCLS-II ones 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, the facilities must currently send the cryomodules back to either FNAL or TJNAF at an increased risk of damage, cost, and schedule delays.

The initial assumption was that cryomodules could be shipped back to the partner laboratories as needed for maintenance at a rate of 1 to 2 cryomodules per year. However, during construction of the LCLS-II facility it was determined that multi-million dollar cryomodules could be damaged during transportation; transportation of cryomodules for repairs during operations would pose a risk to reliable facility operations and scientific productivity. This approach also assumed that either FNAL or TJNAF would have the maintenance capabilities available when needed. At this time, the two partner laboratories have informed SLAC that they will need 6 to 12 months of advance notice to schedule maintenance or repairs to the SLAC hardware.

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 accelerator being constructed by the LCLS-II and LCLS-II-HE construction projects. 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.

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.

Performance Measure	Threshold	Objective
Conventional Facilities Building Area	19,000 gross square feet	25,000 gross square feet
Electron Beam Energy	50 MeV	128 MeV
Cryogenic Cooling Capacity at 2K	100 Watts	250 Watts

3. Financial Schedule

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs	IRA Supp. Costs
Total Estimated Cost (TEC)				
Design (TEC)				
Prior Years	1,000	1,000	–	–
FY 2022	1,000	1,000	–	–
FY 2022 - IRA Supp.	300	300	–	–
FY 2023	1,600	1,600	–	–
FY 2024	1,000	1,000	4,600	300
Outyears	700	700	700	–
Total, Design (TEC)	**5,600**	**5,600**	**5,300**	**300**
Construction (TEC)				
FY 2022 - IRA Supp.	19,700	19,700	–	–
FY 2023	8,400	8,400	–	–
FY 2024	8,000	8,000	–	11,000
Outyears	47,100	47,100	63,500	8,700
Total, Construction (TEC)	**83,200**	**83,200**	**63,500**	**19,700**
Total Estimated Cost (TEC)				
Prior Years	1,000	1,000	–	–
FY 2022	1,000	1,000	–	–
FY 2022 - IRA Supp.	20,000	20,000	–	–
FY 2023	10,000	10,000	–	–
FY 2024	9,000	9,000	4,600	11,300
Outyears	47,800	47,800	64,200	8,700
Total, 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	1,000	1,000	59	–
FY 2022	2,000	2,000	1,398	–
FY 2022 - IRA Supp.	700	700	–	–
FY 2023	1,000	1,000	2,400	700
FY 2024	1,000	1,000	193	–
Outyears	–	–	950	–
Total, 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	2,000	2,000	59	–
FY 2022	3,000	3,000	1,398	–
FY 2022 - IRA Supp.	20,700	20,700	–	–
FY 2023	11,000	11,000	2,400	700
FY 2024	10,000	10,000	4,793	11,300
Outyears	47,800	47,800	65,150	8,700
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	4,000	4,000	**N/A**
Design - Contingency	1,600	1,600	**N/A**
Total, Design (TEC)	**5,600**	**5,600**	**N/A**
Construction	28,700	N/A	**N/A**
Site Preparation	5,800	8,800	**N/A**
Equipment	24,400	26,160	**N/A**
Other Construction	N/A	25,500	**N/A**
Construction - Contingency	24,300	24,240	**N/A**
Total, Construction (TEC)	**83,200**	**84,700**	**N/A**
Total, TEC	**88,800**	**90,300**	**N/A**
Contingency, TEC	*25,900*	*25,840*	***N/A***
Other Project Cost (OPC)			
Conceptual Planning	500	500	**N/A**
Conceptual Design	3,100	1,700	**N/A**
Start-up	1,100	500	**N/A**
OPC - Contingency	1,000	1,000	**N/A**
Total, Except D&D (OPC)	**5,700**	**3,700**	**N/A**
Total, OPC	**5,700**	**3,700**	**N/A**
Contingency, OPC	*1,000*	*1,000*	***N/A***
Total, TPC	**94,500**	**94,000**	**N/A**
Total, Contingency (TEC+OPC)	***26,900***	***26,840***	***N/A***

5. Schedule of Appropriations Requests

(dollars in thousands)

Fiscal Year	Type	Prior Years	FY 2022	FY 2022 IRA Supp.	FY 2023	FY 2024	Outyears	Total
FY 2023	TEC	1,000	1,000	—	10,000	—	78,300	90,300
	OPC	1,000	2,000	—	—	—	700	3,700
	TPC	2,000	3,000	—	10,000	—	79,000	94,000
FY 2024	TEC	1,000	1,000	20,000	10,000	9,000	47,800	88,800
	OPC	1,000	2,000	700	1,000	1,000	—	5,700
	TPC	2,000	3,000	20,700	11,000	10,000	47,800	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	4Q FY 2029
Expected Useful Life	25 years
Expected Future Start of D&D of this capital asset	4Q FY 2054

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 25,000 gross square feet as part of this project.

	Square Feet
New area being constructed by this project at SLAC	19,000 – 25,000
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"	19,000 – 25,000
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 the SLAC and is being acquired by Stanford University under the existing DOE Management and Operations contract.

SLAC is preparing a Conceptual Design Report for the CRMF project and has the requisite construction and project management systems and expertise to execute the project.

Preliminary cost estimates are based on similar facilities at other national laboratories, to the extent practicable. The project will fully exploit recent cost data from similar operating facilities in planning and budgeting. SLAC or partner laboratory staff may assist with completing the design of the technical systems. The selected contractor and/or subcontracted vendors with the necessary capabilities will fabricate technical equipment. All subcontracts 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.

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 FY 2024 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, approved on November 23, 2020. This Construction Project Data Sheet (CPDS) is an update of the FY 2023 CPDS and does not include a new start for FY 2024.

In FY 2022, funding supported continued planning, R&D, design, engineering, prototyping, and testing to assist in maturing the project design, scope, cost, schedule, and key performance parameters with emphasis on advancing the preliminary design, incorporating the eight selected instruments into the project plan, and evaluating proposals for the construction manager/general contractor. FY 2022 Inflation Reduction Act (IRA) funds of $42,700,000 will help address inflation-driven concerns of increasing labor, materials, and supply costs, and sustain forward momentum and reduce project risks. FY 2023 funds will continue planning, R&D, design, engineering, prototyping, and testing to advance the highest priority R&D and design activities. Emphasis will be on advancing the neutron detectors and velocity selectors, proton beam optics, target assemblies, instrument optics and choppers, integrated controls systems, safety systems, target material characterization and site characterization in preparation for civil construction. FY 2024 funding will support continued planning, R&D, design, engineering, prototyping, and testing to advance the highest priority activities. Emphasis will be on advancing the instrument prototypes, target preliminary designs and material characterization, proton beam delivery magnets, neutron beam optics and choppers, neutron moderator, and accelerator designs and controls. A potential long lead procurement for civil construction site preparation to bring in new roads and perform site grading depends on progress of the conventional facility design and DOE review and approval of the plans and use of 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 2024	1/7/09	4/30/21	11/23/20	4Q FY 2026	4Q FY 2029	4Q FY 2026	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.

Fiscal Year	Performance Baseline Validation	CD-3A
FY 2024	4Q FY 2026	4Q FY 2024

CD-3A – Approve Long-Lead Procurements for the Construction Management/General Contractor (CM/GC) to create roads for site access and perform site grading and 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 2023	332,757	1,810,243	2,143,000	99,000	99,000	2,242,000
FY 2024	294,250	1,850,750	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
To address the gap in advanced neutron sources and instrumentation, the STS project will design, build, install, and test the equipment necessary to provide the four primary elements of the new facility: 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. The STS will be located in unoccupied space east of the existing First Target Station (FTS). The project requires approximately 375,000 ft^2 of new buildings, making conventional facility construction a major contributor to project costs.

Justification
The BES mission is to support fundamental research to understand, predict, and ultimately control matter and energy at the electronic, atomic, and molecular levels in order to provide the foundations for new energy technologies and to support DOE missions in energy, environment, and national security. BES accomplishes its mission in part by operation of large-scale user facilities consisting of a complementary set of intense x-rays sources, neutron scattering centers, electron beam characterization capabilities, and research centers for nanoscale science.

In the area of neutron science, the scientific community conducted numerous studies since the 1970's that have established the scientific justification and need for a very high-intensity pulsed neutron source in the U.S. Since 2007, when it began its user program at ORNL, the FTS at the SNS has been fulfilling this need. In accordance with the 1996 BESAC (Russell Panel) Report recommendation, SNS has many technical margins built into its systems to facilitate a power upgrade into the 2-4 megawatt (MW) range to maintain its position of scientific leadership in the future.

The STS would enable many advances in the opportunities described in the 2015 BESAC report "Challenges at the Frontiers of Matter and Energy: Transformative Opportunities for Discovery Science." ORNL held four workshops to assess the neutron scattering needs in quantum condensed matter, soft matter, biology, and the frontiers in materials discovery. These four areas encompass and directly map to the transformative opportunities identified in the BES Grand Challenges update. Quantum materials map most directly to harnessing coherence in light and matter, while soft matter and biology are aligned primarily with mastering hierarchical architectures and beyond-equilibrium matter, and frontiers in materials discovery explored many of the topics in beyond ideal materials and systems: understanding the critical roles of heterogeneity, interfaces, and disorder. As an example, while neutrons already play an important role in the areas of biology and soft matter, step change improvements in capability will be required to make full use of the unique properties of neutrons to meet challenges in mastering hierarchical architectures and beyond-equilibrium matter and understanding the critical roles of heterogeneity and interfaces. The uniform conclusion from all workshops was that in the areas of science covered, neutrons play a unique and pivotal role in understanding structure and dynamics in materials required to develop future technologies.

The STS will feature a very high-density beam of protons that strikes a rotating solid tungsten target. The produced neutron beam illuminates moderators located above and below the target that will feed experimental beamlines (eight within the

STS project scope) with neutron beams conditioned for specific instruments. The small-volume cold neutron moderator system is geometrically optimized to deliver higher peak brightness neutrons.

The SNS PPU project, requested separately, will double the power of the SNS accelerator complex to 2.8 MW so that the STS can use one out of every four proton pulses to produce cold neutron beams with the highest peak brightness of any current or projected neutron sources. The high-brightness pulsed source optimized for cold neutron production will operate at 15 Hz (as compared to FTS, which currently operates at 60 Hz, but will operate at 45 pulses/second when the STS is operating) to provide the large time-of-flight intervals corresponding to the broad time and length scales required to characterize complex materials. The project will provide a series of kicker magnets to divert every fourth proton pulse away from the FTS to a new line feeding the STS. Additional magnets will further deflect the beam into the transport line to the new target. A final set of quadrupole magnets will tailor the proton beam shape and distribution to match the compact source design.

An initial set of eight best-in-class instruments, developed with input from the user community, are largely built on known and demonstrated technologies but will need some research and development to deliver unprecedented levels of performance. Advanced neutron optics designs are needed for high alignment and stability requirements. The lower repetition rate of the STS pushes the chopper design to larger diameter rotating elements with tighter limits on allowed mechanical vibration. The higher peak neutron production of the STS will put a greater demand on neutron detector technology.

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 Hz, with no beam to FTS. Operate with beam to both target stations 45 pulses/s at FTS and 15 Hz at STS.	Operate beam to FTS at 45 pulses/s, with no beam to STS. Operate beam to STS at 15 Hz, with no beam to FTS. Operate with beam to both target stations 45 pulses/s at FTS and 15 Hz 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	50,000	50,000	20,360	–
FY 2022	32,000	32,000	30,082	–
FY 2022 - IRA Supp.	42,700	42,700	–	–
FY 2023	32,000	32,000	22,300	32,700
FY 2024	37,000	37,000	62,000	10,000
Outyears	100,550	100,550	116,808	–
Total, Design (TEC)	**294,250**	**294,250**	**251,550**	**42,700**
Construction (TEC)				
FY 2024	15,000	15,000	10,000	–
Outyears	1,835,750	1,835,750	1,840,750	–
Total, Construction (TEC)	**1,850,750**	**1,850,750**	**1,850,750**	**–**
Total Estimated Cost (TEC)				
Prior Years	50,000	50,000	20,360	–
FY 2022	32,000	32,000	30,082	–
FY 2022 - IRA Supp.	42,700	42,700	–	–
FY 2023	32,000	32,000	22,300	32,700
FY 2024	52,000	52,000	72,000	10,000
Outyears	1,936,300	1,936,300	1,957,558	–
Total, TEC	**2,145,000**	**2,145,000**	**2,102,300**	**42,700**

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs	IRA Supp. Costs
Other Project Cost (OPC)				
Prior Years	45,805	45,805	29,232	–
FY 2022	–	–	3,540	–
FY 2023	5,000	5,000	14,500	–
FY 2024	–	–	2,500	–
Outyears	46,195	46,195	47,228	–
Total, OPC	**97,000**	**97,000**	**97,000**	**–**

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs	IRA Supp. Costs
Total Project Cost (TPC)				
Prior Years	95,805	95,805	49,592	–
FY 2022	32,000	32,000	33,622	–
FY 2022 - IRA Supp.	42,700	42,700	–	–
FY 2023	37,000	37,000	36,800	32,700
FY 2024	52,000	52,000	74,500	10,000
Outyears	1,982,495	1,982,495	2,004,786	–
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	256,000	258,000	**N/A**
Design - Contingency	38,250	74,757	**N/A**
Total, Design (TEC)	**294,250**	**332,757**	**N/A**
Construction	1,477,000	1,290,000	**N/A**
Construction - Contingency	373,750	520,243	**N/A**
Total, Construction (TEC)	**1,850,750**	**1,810,243**	**N/A**
Total, TEC	**2,145,000**	**2,143,000**	**N/A**
Contingency, TEC	*412,000*	*595,000*	***N/A***
Other Project Cost (OPC)			
R&D	29,546	22,875	**N/A**
Conceptual Design	26,454	24,750	**N/A**
Start-up	22,000	20,250	**N/A**
OPC - Contingency	19,000	31,125	**N/A**
Total, Except D&D (OPC)	**97,000**	**99,000**	**N/A**
Total, OPC	**97,000**	**99,000**	**N/A**
Contingency, OPC	*19,000*	*31,125*	***N/A***
Total, TPC	**2,242,000**	**2,242,000**	**N/A**
Total, Contingency (TEC+OPC)	***431,000***	***626,125***	***N/A***

5. Schedule of Appropriations Requests

(dollars in thousands)

Fiscal Year	Type	Prior Years	FY 2022	FY 2022 IRA Supp.	FY 2023	FY 2024	Outyears	Total
FY 2023	TEC	50,000	32,000	—	32,000	—	2,029,000	2,143,000
	OPC	45,805	—	—	5,000	—	48,195	99,000
	TPC	95,805	32,000	—	37,000	—	2,077,195	2,242,000
FY 2024	TEC	50,000	32,000	42,700	32,000	52,000	1,936,300	2,145,000
	OPC	45,805	—	—	5,000	—	46,195	97,000
	TPC	95,805	32,000	42,700	37,000	52,000	1,982,495	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 is not replacing existing facilities.

	Square Feet
New area being constructed by this project at ORNL	~375,000
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"	~375,000
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 Management and Operations (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 Office of Science projects and other similar facilities are being exploited fully in planning and executing the STS.

18-SC-11, Spallation Neutron Source Proton Power Upgrade (PPU), ORNL
Oak Ridge National Laboratory, ORNL
Project is for Design and Construction

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

Summary
The FY 2024 Request for the PPU project is $15,769,000 of Total Estimated Cost (TEC) funding. The Total Project Cost (TPC) is $271,567,000.

Significant Changes
PPU was initiated in FY 2018. The most recent DOE Order 413.3B Critical Decision (CD) is a combined CD-2, Approve Performance Baseline, and CD-3, Approve Start of Construction, approved on October 6, 2020. CD-4, Approve Project Completion, is anticipated in 4Q FY 2028. This Construction Project Data Sheet (CPDS) is an update of the FY 2023 CPDS and does not include a new start for FY 2024.

In FY 2022, the project continued R&D, engineering, prototyping, preliminary and final design, testing, fabrication, procurement of baseline and spare hardware, and component integration and installation and civil construction, focused on completion of initial cryomodules, advancing the target knowledge base by running the first PPU target during Spallation Neutron Source (SNS) operations, and continued radiofrequency (RF) equipment procurement, and initial equipment installation in the klystron gallery. In FY 2023, funding supports remaining R&D, engineering, final design, testing, fabrication, procurement of baseline and spare hardware, component integration and installation, and civil construction site activities, with priority on continuing RF equipment installation in the klystron gallery, assembly, installation, and use of new cryomodules, magnet fabrication, and operation of the second PPU test target at increased power levels. The FY 2024 Request reflects the final year of funding for the project and will start construction of the tunnel stub that will facilitate connection to the future Second Target Station, install the final additional cryomodules and related radiofrequency systems, begin first target station upgrades to support high-flow target gas injection, upgrade the ring magnets, and operate the first PPU production target at increased power levels.

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 2024	1/7/09	8/1/17	4/4/18	10/6/20	2/9/22	10/6/20	4Q FY 2028

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 2024	10/6/20	10/5/18	9/3/19

CD-3A – Approve Long-Lead Procurements for niobium material, cryomodule cavities, and related cryomodule procurements to reduce project technical and schedule risk.

CD-3B – Approve Long-Lead Procurements for klystron gallery buildout, RF procurements, and cryomodule hardware to reduce project technical and schedule risk.

Project Cost History

(dollars in thousands)

Fiscal Year	TEC, Design	TEC, Construction	TEC, Total	OPC, Except D&D	OPC, Total	TPC
FY 2023	45,300	212,469	257,769	13,798	13,798	271,567
FY 2024	47,800	209,969	257,769	13,798	13,798	271,567

2. Project Scope and Justification

Scope

The PPU project will design, build, install, and test the equipment necessary to double the accelerator power from 1.4 megawatts (MW) to 2.8 MW, upgrade the existing SNS target system to accommodate beam power up to 2 MW, and deliver a 2 MW qualified target. PPU includes the provision for a stub-out in the SNS transport line to the existing target to facilitate rapid connection to a new proton beamline. The project also includes utility infrastructure upgrades in the klystron gallery building needed for the new accelerator equipment.

Justification

The BES mission is to “support fundamental research to understand, predict, and ultimately control matter and energy at the electronic, atomic, and molecular levels in order to provide the foundations for new energy technologies and to support DOE missions in energy, environment, and national security.” BES accomplishes its mission in part by operating large-scale user facilities consisting of a complementary set of intense x-ray sources, neutron scattering centers, electron beam characterization capabilities, and research centers for nanoscale science.

In the area of neutron science, numerous studies by the scientific community since the 1970s have established the scientific justification and need for a very high-intensity pulsed neutron source in the U.S. The SNS, which began its user program at ORNL in 2007, currently fulfills the need. The SNS was designed to be upgradeable so as to maintain its position of scientific leadership in the future, in accordance with the 1996 BESAC (Russell Panel) Report recommendation, and many technical margins were built into the SNS systems to facilitate a power upgrade into the 2 - 4 MW range with the ability to extract some of that power to a second target station.

An upgraded SNS will enable many advances in the opportunities described in the 2015 BESAC report “Challenges at the Frontiers of Matter and Energy: Transformative Opportunities for Discovery Science.” Four workshops were held by ORNL to assess the neutron scattering needs in quantum condensed matter, soft matter, biology, and the frontiers in materials discovery. These four areas encompass and directly map to the transformative opportunities identified in the BES Grand Challenges update. Quantum materials map most directly to harnessing coherence in light and matter, while soft matter and biology align primarily with mastering hierarchical architectures and beyond-equilibrium matter, and frontiers in materials discovery explored many of the topics in beyond ideal materials and systems: understanding the critical roles of heterogeneity, interfaces, and disorder. As an example, while neutrons already play an important role in the areas of biology and soft matter, step change improvements in capability will be required to make full use of the unique properties of neutrons to meet challenges in mastering hierarchical architectures and beyond-equilibrium matter and understanding the critical roles of heterogeneity and interfaces. The uniform conclusion from all of the workshops was that, in the areas of science covered, neutrons play a unique and pivotal role in understanding structure and dynamics in materials required to develop future technologies.

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 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
Beam power on target	1.7 MW at 1.25 giga-electron volts (GeV)	2.0 MW at 1.3 GeV
Beam energy	1.25 GeV	1.3 GeV
Target reliability lifetime without target failure	1,250 hours at 1.7 MW	1,250 hours at 2.0 MW
Stored beam intensity in ring	$\geq 1.6 \times 10^{14}$ protons at 1.25 GeV	$\geq 2.24 \times 10^{14}$ protons at 1.3 GeV

3. Financial Schedule

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs
Total Estimated Cost (TEC)			
Design (TEC)			
Prior Years	45,300	45,300	40,020
FY 2022	2,500	2,500	7,668
FY 2023	–	–	112
Total, Design (TEC)	**47,800**	**47,800**	**47,800**
Construction (TEC)			
Prior Years	162,700	162,700	79,625
FY 2022	14,500	14,500	36,137
FY 2023	17,000	17,000	36,050
FY 2024	15,769	15,769	21,815
Outyears	–	–	36,342
Total, Construction (TEC)	**209,969**	**209,969**	**209,969**
Total Estimated Cost (TEC)			
Prior Years	208,000	208,000	119,645
FY 2022	17,000	17,000	43,805
FY 2023	17,000	17,000	36,162
FY 2024	15,769	15,769	21,815
Outyears	–	–	36,342
Total, TEC	**257,769**	**257,769**	**257,769**

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs
Other Project Cost (OPC)			
Prior Years	13,798	13,798	9,814
FY 2023	–	–	501
FY 2024	–	–	555
Outyears	–	–	2,928
Total, OPC	**13,798**	**13,798**	**13,798**

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs
Total Project Cost (TPC)			
Prior Years	221,798	221,798	129,459
FY 2022	17,000	17,000	43,805
FY 2023	17,000	17,000	36,663
FY 2024	15,769	15,769	22,370
Outyears	–	–	39,270
Total, TPC	**271,567**	**271,567**	**271,567**

4. Details of Project Cost Estimate

(dollars in thousands)

	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
Total Estimated Cost (TEC)			
Design	47,800	36,960	32,000
Design - Contingency	N/A	8,340	8,000
Total, Design (TEC)	**47,800**	**45,300**	**40,000**
Construction	173,242	168,502	163,466
Construction - Contingency	36,727	43,967	54,303
Total, Construction (TEC)	**209,969**	**212,469**	**217,769**
Total, TEC	**257,769**	**257,769**	**257,769**
Contingency, TEC	*36,727*	*52,307*	*62,303*
Other Project Cost (OPC)			
R&D	2,500	2,408	2,408
Conceptual Design	7,220	7,250	7,250
Other OPC Costs	1,150	3,480	3,480
OPC - Contingency	2,928	660	660
Total, Except D&D (OPC)	**13,798**	**13,798**	**13,798**
Total, OPC	**13,798**	**13,798**	**13,798**
Contingency, OPC	*2,928*	*660*	*660*
Total, TPC	**271,567**	**271,567**	**271,567**
Total, Contingency (TEC+OPC)	***39,655***	***52,967***	***62,963***

5. Schedule of Appropriations Requests

(dollars in thousands)

Fiscal Year	Type	Prior Years	FY 2022	FY 2023	FY 2024	Outyears	Total
FY 2023	TEC	208,000	17,000	17,000	—	15,769	257,769
	OPC	13,798	—	—	—	—	13,798
	TPC	221,798	17,000	17,000	—	15,769	271,567
FY 2024	TEC	208,000	17,000	17,000	15,769	—	257,769
	OPC	13,798	—	—	—	—	13,798
	TPC	221,798	17,000	17,000	15,769	—	271,567

6. Related Operations and Maintenance Funding Requirements

Start of Operation or Beneficial Occupancy	4Q FY 2028
Expected Useful Life	40 years
Expected Future Start of D&D of this capital asset	4Q FY 2068

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	9,325	9,325	373,000	373,000

7. D&D Information

The new area being constructed in this project is not replacing existing facilities.

	Square Feet
New area being constructed by this project at ORNL	3,000-4,000
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"	3,000-4,000
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, the PPU project is being acquired by ORNL under the existing DOE Management and Operations (M&O) contract.

The M&O contractor has completed a Conceptual Design Report for the PPU 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 is partnering with other laboratories for design and procurement of key technical subsystem components. Some technical system designs will require research and development activities. Cost estimates for these systems are based on operating experience of SNS and vendor quotes. ORNL, partner laboratory staff, and/or vendors will complete the design of the technical systems. Vendors and/or partner labs with the necessary capabilities will fabricate technical equipment. All subcontracts will be competitively bid and awarded based on best value to the government.

Lessons learned from other Office of Science projects and other similar facilities have been sought and are being applied as appropriate in planning and executing PPU. The M&O contractor's performance will be evaluated through the annual laboratory performance appraisal process.

18-SC-12, Advanced Light Source Upgrade (ALS-U), LBNL
Lawrence Berkeley National Laboratory, LBNL
Project is for Design and Construction

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

Summary

The FY 2024 Request for the ALS-U project is $57,300,000 of Total Estimated Cost (TEC) funding. The project has a Total Project Cost (TPC) of $590,000,000.

Significant Changes

The ALS-U was initiated in FY 2018. The most recent DOE Order 413.3B approved Critical Decision (CD) is CD-3, Approve Start of Construction, approved on November 10, 2022. This Construction Project Data Sheet (CPDS) is an update of the FY 2023 CPDS and does not include a new start for FY 2024.

In FY 2022, the project continued planning, engineering, design, R&D, prototyping, and procurements of both long-lead components for the accumulator ring installation as well as start of major procurements for the storage ring systems and components. In addition, the ALS-U received $96,600,000 in FY 2022 Inflation Reduction Act (IRA) supplemental funding that will enable the project to significantly expedite procurements taking advantage of lower pricing and mitigate inflation uncertainties as well as schedule and technical risks, accelerating the funding profile resulting in reduced funding in the outyears. FY 2023 funding supports post CD-3 procurements and continuation of the Accumulator Ring installation. The FY 2024 Request reflects the final year of funding for the project and will continue to advance the remaining procurements for the Accumulator Ring and the Storage Ring, advance installation of the Accumulator Ring in the tunnel, start pre-staging and assembly of the Storage Ring rafts and components, as the vacuum systems, magnets and diagnostics instruments are received, in preparation for the year-long dark time during which the new Storage Ring will be installed in FY 2026.

With the departure of the previous Federal Project Director (FPD), a new FPD certified to Level II has been assigned to this project, with Level III certification in progress.

Critical Milestone History

Fiscal Year	CD-0	Conceptual Design Complete	CD-1	CD-2	Final Design Complete	CD-3	CD-4
FY 2024	9/27/16	4/30/18	9/21/18	4/2/21	11/10/22	11/10/22	4Q FY 2029

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 2024	4/2/21	12/19/19

CD-3A – Approve Long-Lead Procurements scope included the equipment required for the electron accumulator ring. CD-3A, approved in December of 2019, enables completion of the new Accumulator Ring installation, which is on the ALS-U critical path, ahead of the year-long down time (the period during which the new storage ring will be installed) thereby, accelerating project completion by more than a year.

Project Cost History

(dollars in thousands)

Fiscal Year	TEC, Design	TEC, Construction	TEC, Total	OPC, Except D&D	OPC, Total	TPC
FY 2023	134,340	427,660	562,000	28,000	28,000	590,000
FY 2024	134,340	427,660	562,000	28,000	28,000	590,000

2. Project Scope and Justification

Scope

The ALS-U project will upgrade the existing ALS facility by replacing the existing electron storage ring with a new electron storage ring based on a multi-bend achromat (MBA) lattice design to provide a soft x-ray source that is orders of magnitude brighter—a 10-1000 times increase in brightness over the current ALS—and to provide a significantly higher fraction of coherent light in the soft x-ray region (approximately 50-2,000 electronvolts [eV]) than is currently available at ALS. The project will replace the existing triple-bend achromat storage ring with a new, high-performance storage ring based on a nine-bend achromat design. In addition, the project will add a low-emittance, full-energy accumulator ring to the existing tunnel inner shield wall to enable on- and off-axis, swap-out injection and extraction into and from the new storage ring using fast kicker magnets. The new source will require upgrading x-ray optics on existing beamlines with some beamlines being realigned or relocated. The project adds two new undulator beamlines that are optimized for the novel science made possible by the beam's new high coherent flux. The project intends to reuse the existing building, utilities, electron gun, linac, and booster synchrotron equipment currently at ALS. Prior to CD-2, the scope was increased to include radiation shielding and safety-mandated seismic structural upgrades to the ALS facility. With an aggressive accelerator design, ALS-U will provide the highest coherent flux of any existing or planned storage ring facility worldwide, up to a photon energy of about 3.5 keV. This range covers the entire soft x-ray regime.

Justification

At this time, our ability to observe and understand materials and material phenomena in real-time and as they emerge and evolve is limited. Soft x-rays (approximately 50 to 2,000 eV) are ideally suited for revealing the chemical, electronic, and magnetic properties of materials, as well as the chemical reactions that underpin these properties. This knowledge is crucial for the design and control of new advanced materials that address the challenges of new energy technologies.

Existing storage ring light sources lack a key attribute that would revolutionize x-ray science: stable, nearly continuous soft x-rays with high brightness and high coherent flux—that is, smooth, well organized soft x-ray wave fronts. Such a stable, high brightness, high coherent flux source would enable 3D imaging with nanometer resolution and the measurement of spontaneous nanoscale motion with nanosecond resolution—all with electronic structure sensitivity.

Currently, BES operates advanced ring-based light sources that produce soft x-rays. The NSLS-II, commissioned in 2015, is the brightest soft x-ray source in the U.S. The ALS, completed in 1993, is competitive with NSLS-II for x-rays below 200 eV but not above that. NSLS-II is somewhat lower in brightness than the new Swedish light source, MAX-IV, which began user operations in 2017 and represents the first use of a MBA lattice design in a light source facility. Neither NSLS-II nor ALS make use of the newer MBA lattice design. Switzerland's SLS-2 (an MBA-based design in the planning stage) will be a brighter soft x-ray light source than both NSLS-II and MAX-IV when it is built and brought into operation. These international light sources, and those that follow, will present a significant challenge to the U.S. light source community to provide competitive x-ray sources to domestic users. Neither NSLS-II nor ALS soft x-ray light sources possess sufficient brightness or coherent flux to provide the capability to meet the mission need in their current configurations.

BES is currently supporting two major light source upgrade projects, the APS-U and LCLS-II. These two projects will upgrade existing x-ray facilities in the U.S. and will provide significant increases in brightness and coherent flux. These upgrades will not address the specific research needs that demand stable, nearly continuous soft x-rays with high brightness and high coherence.

APS-U, which is under construction at ANL, will deploy the MBA lattice design optimized for its higher 6 GeV electron energy and to produce higher energy (hard) x-rays in the range of 10-100 keV. Because the ring will be optimized for high energy, the soft x-ray light it produces will not be sufficiently bright to meet the research needs described above.

LCLS-II, which is under construction at SLAC, is a high repetition rate (up to 1 MHz) free electron laser (FEL) designed to produce high brightness, coherent x-rays, but in extremely short bursts rather than as a nearly continuous beam. Storage rings offer higher stability than FELs. In addition, there is a need for a facility that can support a larger number of concurrent experiments than is possible with LCLS-II in its current configuration. This is critical for serving the large and expanding soft x-ray research community. LCLS-II will not meet this mission need.

The existing ALS is a 1.9 GeV storage ring operating at 500 milliamps (mA) of beam current. It is optimized to produce intense beams of soft x-rays, which offer spectroscopic contrast, nanometer-scale resolution, and broad temporal sensitivity. The ALS facility includes an accelerator complex and photon delivery system that can provide the foundations for an upgrade that will achieve world-leading soft x-ray coherent flux. The existing ALS provides a ready-made foundation, including conventional facilities, a $500,000,000 scientific infrastructure investment and a vibrant user community of over 2,500 users per year already attuned to the potential scientific opportunities an upgrade offers. The facility also includes extensive (up to 40) simultaneously operating beamlines and instrumentation, an experimental hall, computing resources, ancillary laboratories, offices, and related infrastructure that will be heavily utilized in an upgrade scenario. Furthermore, the upgrade leverages the ALS staff, who are experts in the scientific and technical aspects of the proposed upgrade.

In summary, the capabilities at our existing x-ray light source facilities are insufficient to develop the next generation of tools that combine high resolution spatial imaging together with precise energy resolving spectroscopic techniques in the soft x-ray range. To enable these cutting-edge experimental techniques, ALS-U is designed and being constructed to be a world-leading facility in soft x-ray science by delivering ultra-bright source of light in soft x-ray regime with high coherent x-ray flux required to resolve nanometer-scale features and interactions, and to allow the real-time observation and understanding of materials and phenomena as they emerge and evolve. Developing such a light source will ensure the U.S. has the tools to maintain its leadership in soft x-ray science and will significantly accelerate the advancement of the fundamental sciences that underlie a broad range of emerging and future energy applications.

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 Threshold KPPs approved at CD-2 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
Storage Ring Energy	≥ 1.9 GeV	2.0 GeV
Beam Current	> 25 mA	500 mA
Horizontal Emittance	< 150 pm-rad	< 85 pm-rad
Brightness @ 1 keV[a]	> 2 x 10^{19}	≥ 2 x 10^{21}
New MBA Beamlines	2	≥ 2

[a]Units = photons/sec/0.1% BW/mm2/mrad2

3. Financial Schedule

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs	IRA Supp. Costs
Total Estimated Cost (TEC)				
Design (TEC)				
Prior Years	114,340	114,340	85,215	–
FY 2022	20,000	20,000	28,947	–
FY 2023	–	–	14,681	–
FY 2024	–	–	2,132	–
Outyears	–	–	3,365	–
Total, Design (TEC)	**134,340**	**134,340**	**134,340**	**–**
Construction (TEC)				
Prior Years	83,660	83,660	18,675	–
FY 2022	55,100	55,100	25,076	–
FY 2022 - IRA Supp.	96,600	96,600	–	4
FY 2023	135,000	135,000	12,464	72,450
FY 2024	57,300	57,300	108,121	24,146
Outyears	–	–	166,724	–
Total, Construction (TEC)	**427,660**	**427,660**	**331,060**	**96,600**
Total Estimated Cost (TEC)				
Prior Years	198,000	198,000	103,890	–
FY 2022	75,100	75,100	54,023	–
FY 2022 - IRA Supp.	96,600	96,600	–	4
FY 2023	135,000	135,000	27,145	72,450
FY 2024	57,300	57,300	110,253	24,146
Outyears	–	–	170,089	–
Total, TEC	**562,000**	**562,000**	**465,400**	**96,600**

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs	IRA Supp. Costs
Other Project Cost (OPC)				
Prior Years	28,000	28,000	23,560	–
Outyears	–	–	4,440	–
Total, OPC	**28,000**	**28,000**	**28,000**	**–**

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs	IRA Supp. Costs
Total Project Cost (TPC)				
Prior Years	226,000	226,000	127,450	–
FY 2022	75,100	75,100	54,023	–
FY 2022 - IRA Supp.	96,600	96,600	–	4
FY 2023	135,000	135,000	27,145	72,450
FY 2024	57,300	57,300	110,253	24,146
Outyears	–	–	174,529	–
Total, TPC	**590,000**	**590,000**	**493,400**	**96,600**

4. Details of Project Cost Estimate

(dollars in thousands)

	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
Total Estimated Cost (TEC)			
Design	117,778	101,098	92,967
Design - Contingency	16,562	33,242	38,778
Total, Design (TEC)	**134,340**	**134,340**	**131,745**
Construction	159,338	150,093	142,165
Equipment	172,938	171,743	161,449
Construction - Contingency	95,384	105,824	126,641
Total, Construction (TEC)	**427,660**	**427,660**	**430,255**
Total, TEC	**562,000**	**562,000**	**562,000**
Contingency, TEC	*111,946*	*139,066*	*165,419*
Other Project Cost (OPC)			
R&D	N/A	4,971	8,241
Conceptual Planning	10,261	2,000	2,000
Conceptual Design	14,100	12,100	12,100
Start-up	1,000	2,000	2,000
OPC - Contingency	2,639	6,929	3,659
Total, Except D&D (OPC)	**28,000**	**28,000**	**28,000**
Total, OPC	**28,000**	**28,000**	**28,000**
Contingency, OPC	*2,639*	*6,929*	*3,659*
Total, TPC	**590,000**	**590,000**	**590,000**
Total, Contingency (TEC+OPC)	***114,585***	***145,995***	***169,078***

5. Schedule of Appropriations Requests

(dollars in thousands)

Fiscal Year	Type	Prior Years	FY 2022	FY 2022 IRA Supp.	FY 2023	FY 2024	Outyears	Total
FY 2023	TEC	198,000	75,100	—	135,000	—	153,900	562,000
	OPC	28,000	—	—	—	—	—	28,000
	TPC	226,000	75,100	—	135,000	—	153,900	590,000
FY 2024	TEC	198,000	75,100	96,600	135,000	57,300	—	562,000
	OPC	28,000	—	—	—	—	—	28,000
	TPC	226,000	75,100	96,600	135,000	57,300	—	590,000

6. Related Operations and Maintenance Funding Requirements

Start of Operation or Beneficial Occupancy	4Q FY 2029
Expected Useful Life	25 years
Expected Future Start of D&D of this capital asset	4Q FY 2054

Related Funding Requirements
(dollars in thousands)

	Annual Costs		Life Cycle Costs	
FY 2018 Estimates	**Previous Total Estimate**	**Current Total Estimate**	**Previous Total Estimate**	**Current Total Estimate**
Operations, Maintenance and Repair	—	71,500	—	2,597,500

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

Based on the DOE determination at CD-1, LBNL is acquiring the ALS-U project under the existing DOE Management and Operations (M&O) contract.

The ALS-U project 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 a LBNL-wide resource.

LBNL has partnered with BNL for design and procurement of all required power supplies. Technical system designs required research and development and prototyping activities that are now near completion. Cost estimates for the remaining work have been updated by acquiring recent vendor quotes as part of CD-3 approval. All subcontracts are being competitively bid and awarded based on best value to the government. The M&O contractor's performance is being 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 ALS-U.

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 FY 2024 Request for the LCLS-II-HE project is $120,000,000 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 at that time. 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. The LCLS-II-HE project is continuing to assess the impact of COVID-19 on the project's cost, schedule, and project milestones. A combined CD-2/3 approval is projected for 2Q FY 2024; CD-4 is now projected for 2Q FY 2030. This Construction Project Data Sheet (CPDS) is an update of the FY 2023 CPDS and does not include a new start for FY 2024.

FY 2022 funding supported engineering, design, R&D, prototyping, continuing CD-3A long-lead procurements, and advancing the preliminary and final designs. LCLS-II-HE received $96,000,000 in FY 2022 Inflation Reduction Act (IRA) supplemental funding that will enable the project to expedite the design and long-lead procurements, by more than a year, significantly reducing the inflation uncertainties as well as schedule and technical risks. FY 2023 funding supports finalizing the design and the performance baseline, continues with engineering, R&D, injector gun prototyping, initiates 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 support the production of cryomodules, continue with CD-3B procurements and begin the procurement of remaining scope including vendor supported completion of design efforts associated with the cryogenic distribution system, controls systems, and the low emittance injector beamline, and continue the R&D of the superconducting radiofrequency electron gun and initiating construction/installation contracts.

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 2024	12/15/16	3/23/18	9/21/18	2Q FY 2024	2Q FY 2026	2Q 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 2024	2Q 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 2023	39,000	589,000	628,000	32,000	32,000	660,000
FY 2024	80,400	597,600	678,000	32,000	32,000	710,000

2. Project Scope and Justification

Scope
The LCLS-II-HE project's scope includes increasing the superconducting linac energy from 4 giga-electronvolts (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 x-ray transport, optics, and diagnostics system, and provide new or upgraded instrumentation to augment existing and planned capabilities. Additional scope is being considered to address several risks associated with the linac performance, operation reliability and scientific mission capability.

Justification
The leadership position of LCLS-II will be challenged by the European x-ray free electron laser (XFEL) at DESY in Hamburg, Germany, which began operations in 2017. The European XFEL has a higher electron energy, which allows production of shorter (i.e., harder) x-ray wavelength pulses compared to LCLS-II. More recent plans emerging from DESY have revealed how the European XFEL could be extended from a pulsed operation mode to continuous operation, which would create a profound capability gap compared to LCLS-II. 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.

In the face of this challenge to U.S. scientific leadership, extending the energy reach of x-rays beyond the upper limit of LCLS-II (5 keV) is a high priority. 12 keV x-rays correspond to an x-ray wavelength of approximately 1 Ångstrom, which is particularly important for high resolution structural determination experiments since this is the characteristic distance between bound atoms in matter. Expanding the photon energy range beyond 5 keV will allow U.S. researchers to probe earth-abundant elements that will be needed for large-scale deployment of photo-catalysts for electricity and fuel production; it 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.

There is also a limited ability to observe and understand the structural dynamics of complex matter at the atomic scale with hard x-rays, at ultrafast time scales, and in operational environments. Overcoming this capability gap is crucial for the design, control and understanding of new advanced materials necessary to develop new energy technologies. To achieve this objective, the Department needs a hard x-ray source capable of producing high energy ultrafast bursts, with full spatial and temporal coherence, at high repetition rates. Possession of a hard x-ray source with a photon energy range from 5- 12 keV and beyond would enable spectroscopic analysis of additional key elements in the periodic table, deeper penetration into materials, and enhanced resolution. This capability cannot be provided by any existing or planned light source.

The LCLS-II project at SLAC, which is currently under construction and will begin operations in 2022–2024 is the first step to address this capability gap. LCLS-II will be the premier XFEL facility in the world at energies ranging from 200 eV up to approximately 5 keV. The cryomodule technology that underpins LCLS-II is a major advance from prior designs that will allow continuous operation up to 1 megahertz (MHz).

When completed, LCLS-II will be powered by SLAC's 4 GeV superconducting electron linear accelerator (linac). Over the past years, the cryomodule design for LCLS-II has performed beyond expectations, providing the technical basis to double the electron beam energy. It is therefore conceivable to add additional acceleration capacity at SLAC to double the electron beam energy from 4 GeV to 8 GeV. 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 project will upgrade the LCLS-II to fully address the capability gaps and maintain U.S. leadership in XFEL science. The upgrade will provide world leading experimental capabilities for the U.S. research community by extending the x-ray energy of LCLS-II from 5 keV to 12 keV and beyond. The flexibility and detailed pulse structure associated with the proposed LCLS-II-HE facility will not be matched by other facilities under development worldwide.

Based on the factors described above, the most effective and timely approach for DOE to meet the Mission Need and realize the full potential of the facility is by upgrading the LCLS-II, currently under construction at SLAC, by increasing the energy of the superconducting accelerator and upgrading the existing infrastructure and instrumentation.

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*.

<u>Key Performance Parameters (KPPs)</u>
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
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	200 to ≥ 8,000 eV	200 to ≥ 12,000 eV
High repetition rate capable, hard X-ray end stations	≥ 3	≥ 5
FEL photon quantity (10^{-3} BW)	$5x10^8$ (50x spontaneous @ 8 keV)	> 10^{11} @ 8 keV (200 μJ) or > 10^{10} @ 12.8 keV (20 μJ)

3. Financial Schedule

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs	IRA Supp. Costs
Total Estimated Cost (TEC)				
Design (TEC)				
Prior Years	28,000	28,000	12,568	–
FY 2022	11,000	11,000	17,700	–
FY 2023	17,000	17,000	24,700	–
FY 2024	15,000	15,000	14,000	–
Outyears	9,400	9,400	11,432	–
Total, Design (TEC)	**80,400**	**80,400**	**80,400**	**–**
Construction (TEC)				
Prior Years	100,657	100,657	65,387	–
FY 2022	39,000	39,000	34,085	–
FY 2022 - IRA Supp.	90,000	90,000	–	–
FY 2023	73,000	73,000	15,000	70,000
FY 2024	105,000	105,000	80,000	20,000
Outyears	189,943	189,943	313,128	–
Total, Construction (TEC)	**597,600**	**597,600**	**507,600**	**90,000**
Total Estimated Cost (TEC)				
Prior Years	128,657	128,657	77,955	–
FY 2022	50,000	50,000	51,785	–
FY 2022 - IRA Supp.	90,000	90,000	–	–
FY 2023	90,000	90,000	39,700	70,000
FY 2024	120,000	120,000	94,000	20,000
Outyears	199,343	199,343	324,560	–
Total, 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	14,000	14,000	8,820	–
FY 2022	3,000	3,000	3,126	–
FY 2022 - IRA Supp.	6,000	6,000	–	–
FY 2023	4,000	4,000	–	3,800
FY 2024	–	–	–	2,200
Outyears	5,000	5,000	14,054	–
Total, 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	142,657	142,657	86,775	–
FY 2022	53,000	53,000	54,911	–
FY 2022 - IRA Supp.	96,000	96,000	–	–
FY 2023	94,000	94,000	39,700	73,800
FY 2024	120,000	120,000	94,000	22,200
Outyears	204,343	204,343	338,614	–
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	73,400	35,000	**N/A**
Design - Contingency	7,000	4,000	**N/A**
Total, Design (TEC)	**80,400**	**39,000**	**N/A**
Construction	240,400	33,000	**N/A**
Site Preparation	2,000	9,000	**N/A**
Equipment	220,000	468,000	**N/A**
Construction - Contingency	135,200	79,000	**N/A**
Total, Construction (TEC)	**597,600**	**589,000**	**N/A**
Total, TEC	**678,000**	**628,000**	**N/A**
Contingency, TEC	*142,200*	*83,000*	***N/A***
Other Project Cost (OPC)			
R&D	9,000	15,000	**N/A**
Conceptual Planning	1,000	2,000	**N/A**
Conceptual Design	8,000	2,000	**N/A**
Start-up	6,700	8,000	**N/A**
OPC - Contingency	7,300	5,000	**N/A**
Total, Except D&D (OPC)	**32,000**	**32,000**	**N/A**
Total, OPC	**32,000**	**32,000**	**N/A**
Contingency, OPC	*7,300*	*5,000*	***N/A***
Total, TPC	**710,000**	**660,000**	**N/A**
Total, Contingency (TEC+OPC)	***149,500***	***88,000***	***N/A***

5. Schedule of Appropriations Requests

(dollars in thousands)

Fiscal Year	Type	Prior Years	FY 2022	FY 2022 IRA Supp.	FY 2023	FY 2024	Outyears	Total
FY 2023	TEC	128,657	50,000	—	90,000	—	359,343	628,000
	OPC	14,000	3,000	—	4,000	—	11,000	32,000
	TPC	142,657	53,000	—	94,000	—	370,343	660,000
FY 2024	TEC	128,657	50,000	90,000	90,000	120,000	199,343	678,000
	OPC	14,000	3,000	6,000	4,000	—	5,000	32,000
	TPC	142,657	53,000	96,000	94,000	120,000	204,343	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 that there will be no new area being constructed in the construction project.

8. Acquisition Approach

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

SLAC has completed a Conceptual Design Report for the LCLS-II-HE project and is in the preliminary design phase, identifying 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 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 LCLS-II 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.