Basic Energy Sciences
Funding Profile by Subprogram

	(Dollars in Thousands)		
	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
Materials Sciences and Engineering			
Scattering and Instrumentation Sciences Research	68,254	64,721	73,721
Condensed Matter and Materials Physics Research	127,236	123,723	148,723
Materials Discovery, Design, and Synthesis Research	80,289	76,585	84,585
Experimental Program to Stimulate Competitive Research (EPSCoR)	8,520	8,520	8,520
Energy Frontier Research Centers (EFRCs)	58,000	58,000	68,000
Energy Innovation Hubs	0	19,410	24,237
SBIR/STTR	0	10,668	12,829
Total, Materials Sciences and Engineering	342,299	361,627	420,615
Chemical Sciences, Geosciences, and Biosciences			
Fundamental Interactions Research	71,394	67,562	71,562
Chemical Transformations Research	108,512	100,875	110,875
Photochemistry and Biochemistry Research	74,603	71,822	77,822
Energy Frontier Research Centers (EFRCs)	42,000	42,000	52,000
Energy Innovation Hubs	22,000	24,263	24,237
General Plant Projects (GPP)	6,615	200	2,315
SBIR/STTR	0	9,317	10,586
Total, Chemical Sciences, Geosciences, and Biosciences	325,124	316,039	349,397
Scientific User Facilities			
Synchrotron Radiation Light Sources	404,225	379,000	438,800
High-Flux Neutron Sources	255,850	249,068	257,694
Nanoscale Science Research Centers (NSRCs)	107,888	102,500	113,500
Other Project Costs	1,500	7,700	24,400
Major Items of Equipment	19,400	73,500	32,000
Research	30,928	24,545	27,000
SBIR/STTR	0	22,714	25,483
Total, Scientific User Facilities	819,791	859,027	918,877
Subtotal, Basic Energy Sciences	1,487,214	1,536,693	1,688,889

	(Dollars in Thousands)		
	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
Construction			
National Synchrotron Light Source-II (NSLS-II), BNL	151,297	151,400	47,203
Linac Coherent Light Source-II (LCLS-II), SLAC	0	0	63,500
Total, Construction	151,297	151,400	110,703
Total, Basic Energy Sciences	1,638,511[a]	1,688,093[b]	1,799,592

[a] Total is reduced by $39,684,000: $35,432,000 of which was transferred to the Small Business Innovation Research (SBIR) program and $4,252,000 of which was transferred to the Small Business Technology Transfer (STTR) program.
[b] The FY 2012 appropriation is reduced by $5,907,000 for the Basic Energy Sciences share of the DOE-wide $73,300,000 rescission for contractor pay freeze savings. The FY 2013 budget request reflects the FY 2013 impact of the contractor pay freeze.

Public Law Authorizations

Public Law 95-91, "Department of Energy Organization Act", 1977
Public Law 108-153, "21st Century Nanotechnology Research and Development Act 2003"
Public Law 109-58, "Energy Policy Act of 2005"
Public Law 110-69, "America COMPETES Act of 2007
Public Law 111-358, "America COMPETES Act of 2010"

Overview and Benefits

The mission of the BES program 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.

The research disciplines that the BES program supports—condensed matter and materials physics, chemistry, geosciences, and aspects of physical biosciences—are those that discover new materials and design new chemical processes that touch virtually every aspect of energy resources, production, conversion, transmission, storage, efficiency, and waste mitigation. BES research provides a knowledge base to help understand, predict, and ultimately control the natural world and serves as an agent of change in achieving the vision of a secure and sustainable energy future. The BES program also supports world-class open-access scientific 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. BES facilities probe materials in space, time, and energy with the appropriate resolutions that can interrogate the inner workings of matter—transport, reactivity, fields, excitations, and motion—to answer some of the most challenging grand science questions. BES-supported activities stand at the dawn of an age in which materials can be built with atom-by-atom precision and computational models can predict the behavior of materials before they exist. These capabilities, unthinkable only a few decades ago, create unprecedented opportunities to revolutionize the discovery and design of advanced materials and novel chemical processes for advanced energy technologies, resulting in broad economic and societal impacts.

Major breakthroughs in clean energy technologies will arise from innovations built on a deep foundation of basic research advances. Solar photovoltaic technology has its roots in Einstein's early twentieth-century paper on the photoelectric effect. The electronics used to render today's internal combustion engine more efficient have their root in the transistor, whose development was critically dependent on the concept of quantum mechanics. At the core of such advances is the ability to create new materials using sophisticated synthesis and processing techniques, precisely define the atomic arrangements in matter, and control physical and chemical transformations. The energy systems of the future—whether they tap sunlight, store electricity, or make fuel from splitting water or reducing carbon dioxide—will revolve around materials and chemical changes that convert energy from one form to another. Such materials will need to be more functional than today's energy materials. To control chemical reactions or to convert a solar photon to an electron requires coordination of multiple steps, each carried out by customized materials with designed nanoscale structures. Such advanced materials are not found in nature; they must be designed and fabricated to exacting standards using principles revealed by basic science.

Basic and Applied R&D Coordination

For longer-term basic research to be relevant to the DOE technology programs that fund R&D toward specific near-to-mid-term needs, it is important to maintain strong, continual coordination activities between BES and other DOE program offices. R&D coordination is an integral characteristic of BES, which was formed in 1977 to link federally-funded fundamental research to energy technologies. Coordination between DOE R&D programs is achieved through a variety of departmental activities, including joint participation in research workshops, strategic planning activities, solicitation development, and program review meetings. For example, the DOE Hub Working Group meets regularly to coordinate programmatic oversight and promote commonality across the DOE Energy Innovation Hubs. BES also coordinates with DOE technology offices on the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) program, including the topical area planning, solicitations, reviews, and award selections.

BES program managers regularly participate in intra-departmental meetings for information exchange and coordination on solicitations, program reviews and project selections in the research areas of biofuels derived from biomass; solar energy utilization; hydrogen production, storage, and use; building technologies, including solid-state lighting; advanced nuclear energy systems and advanced fuel cycle technologies; vehicle technologies; improving efficiencies in industrial processes; and superconductivity for grid applications. These activities facilitate cooperation and coordination between BES and the DOE technology offices and defense programs. DOE program managers have also established formal technical coordination working groups that meet on a regular basis to discuss R&D programs with wide applications for basic and applied programs. Additionally, DOE technology office staff participates in reviews of BES research, and BES staff participates in reviews of research funded by the technology offices and ARPA-E.

Co-funding and co-siting of research by BES and DOE 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 of resources, expertise, and knowledge of research breakthroughs and program needs. The Department's national laboratory system plays a particularly important role in this regard.

New collaborative efforts with the Office of Energy Efficiency and Renewable Energy (EERE) will also be initiated through jointly funded R&D aimed at accelerating the transition of novel scientific discoveries into innovative, prototype clean energy technologies.

Program Accomplishments and Milestones

The following descriptions of recent accomplishments resulting from BES-supported research represent selected outcomes of the broad range of studies supported in the BES program. These few examples build on a large collection of BES accomplishments over the past few decades that in total portray remarkable discoveries of new knowledge, the rapidity with which scientific knowledge can often be incorporated into other research disciplines and into the commercial sector, and the great potential of basic research for future impacts on energy production and use.

New X-ray Sources Provide Unprecedented Probes of Matter. The Linac Coherent Light Source (LCLS) (the world's first x-ray free electron laser) provides capabilities that are revolutionizing our ability to image matter at the atomic scale. The intensity and ultrashort duration of LCLS x-ray pulses allow researchers to develop a new approach for determining the three dimensional structures of proteins. The laser's brilliant pulses of x-ray light pull structural data from tiny protein nanocrystals, avoiding the need to use large protein crystals that can be difficult or impossible to prepare. This technique will accelerate the structural analysis of some proteins by several years and will allow scientists to decipher tens of thousands of other macromolecules that are out of reach today, including many involved in energy technologies and biopharmaceutical applications.

Dynamic Solar Cells Capable of Self-repair. An artificial solar cell that mimics the self-repair process used by plants while they convert light into energy has been demonstrated for the first time. Long-term exposure to sunlight can damage solar cells leading to reductions in efficiency. Previously, only natural photosynthetic systems had shown the ability to disintegrate and then precisely reassemble complex light-harvesting machinery to repair photo-damage. An artificial system, made up of an ordered structure of carbon nanotubes, protein lipids, and bacterial photosynthetic reaction centers, was recently generated by directed self-assembly. The photoconversion efficiency of the artificial solar cell increased by over 300% through “self-repair” or regeneration over 168 hours of operation. These results provide a bioinspired design route to more robust, fault-tolerant solar energy conversion schemes that have the potential for indefinite extension of their lifetimes.

Superconductivity Better Understood. Important clues have been discovered to help unlock one of the long-standing mysteries of high-temperature superconductors—materials that conduct electricity at 100% efficiencies. An unanswered question centers on the origin and electronic behavior of the pseudogap phase, which is a non-superconducting state observed in a superconductor’s electronic spectrum at temperatures above the superconducting state. Is the pseudogap phase a static state with a stable electronic structure or a dynamic state whose electronic structure fluctuates in time? Two new sets of measurements provide data that the pseudogap may display both features simultaneously. The results of these experiments provide very significant information toward understanding and identifying exactly what the pseudogap state is and how it affects superconductivity.

Magnetism Seen at an Atomic Scale. For the first time, the “spin” of atoms—the atomic behavior that controls the magnetic properties critical for computer hard drives and permanent magnets used in many technologies—has been imaged in an electron microscope. Being able to map spin at an atomic scale will provide the understanding to resolve many of the mysteries of magnetism. These experiments took advantage of new imaging techniques using our most advanced electron microscopes and focused on cobalt, a technologically important material found in batteries, magnets, and structural materials. This new imaging technique, coupled with predictive modeling, offers the potential to design and control the spin structure, enabling fine-tuning of the properties of materials.

Smart Microparticles Perform Robotic Functions. BES researchers recently demonstrated an innovative approach for the directed formation and manipulation of microparticle assemblies that can perform elaborate mechanical functions such as grasping, transporting, and releasing cargo. The ability to manipulate these structures is crucial for further development of dynamically responsive systems such as microrobots. They are made of magnetic microparticles confined between two non-mixing liquids which self-assemble into miniature star-like structures—asters—when energized by a magnetic field. By manipulating the magnetic field, individual asters and aster arrays can be directed to open and close around a target particle, swim, and then release the captured particle at a desired location. This discovery demonstrates control of functionality and opens new opportunities for design and fabrication of materials with self-repair, multi-tasking, and reconfiguring capabilities.

Breaking the Strongest Chemical Bonds Catalytically. Nitrogen (N_2) is converted to ammonia (NH_3) using catalysis through the Haber-Bosch process. It is arguably one of the most important chemical processes ever devised by man—approximately 50% of the world’s population relies on the fertilizer derived from this process to grow their food supply. Unfortunately, it is also one of the most energy-intensive and heaviest carbon-dioxide-producing processes practiced by the chemical industry. Fundamental research in catalysis has resulted in new synthetic methods now promote these challenging chemical transformations under much milder conditions. For example, a hafnium metal complex has been discovered that uses carbon monoxide (CO) to break the N_2 bond, while making new carbon–carbon and carbon–nitrogen bonds. Adding some hydrogen creates oxamide, an important agrochemical that is currently made from fossil fuels. The whole process operates at ambient temperature, which is remarkable because it catalytically ruptures two of the strongest chemical bonds found in nature, those in N_2 and CO. This research begins to establish low-energy pathways to a broad variety of everyday products, such as fertilizers, pesticides and herbicides, polymers and polymer fibers, and pharmaceuticals.

Catalyst Mimics and Beats Nature. The conversion of electrical energy from intermittent energy sources, such as solar and wind, into chemical bonds is a proven and effective means of energy storage. The reverse conversion, from chemical to electrical energy, is equally effective at delivering the energy when it is needed. Catalysts are a critical component of the electrochemistry required for efficient inter-conversion between electrical and chemical energy. Researchers at the Center for Molecular Electrocatalysis, an Energy Frontier Research Center, have used a naturally occurring enzyme to guide the design of a remarkable new catalyst for producing hydrogen from electricity. The synthetic catalyst works a record-breaking 10 times faster than the original enzyme. The new synthetic catalyst and the natural enzyme both use the inexpensive, abundant metals nickel or iron in their design—a significant benefit over traditional electro-catalysts that use expensive metals like platinum or gold. The synthetic catalyst is readily produced in bulk and more likely to stand up to industrial conditions than the natural enzyme. This is an important breakthrough in electro-catalyst design that could enable the effective inter-conversion of electrical and chemical energy.

Splitting Water without the Bubbles. Researchers at the Joint Center for Artificial Photosynthesis (JCAP), which is the Fuels from Sunlight DOE Energy Innovation Hub, have created a proton exchange membrane (PEM) electrolyzer that splits water vapor to create hydrogen and oxygen. The new approach displays electrolysis rates higher than the current systems using liquid water. A key reaction in the pursuit of an artificial photosynthetic system is photo-electrolysis, or the splitting of water by sunlight. This process is usually run in liquid water and starts with a light absorber that captures energy from sunlight and utilizes a catalyst to drive the reaction. The products are gases, however, and their formation generates copious quantities of bubbles that inhibit the reaction by attenuating the amount of sunlight reaching the absorber and by slowing the transport of liquid water reactant to the catalyst. The PEM electrolysis of water vapor by the JCAP researchers involves no interference from bubbles. The fundamental insights gained from this discovery may lead to a whole new approach to photo-electrolysis, which, in turn, could alter the strategy for building a commercially viable solar fuels generation system.

Revolutionary Industrial Battery Technology Developed using Light Source Facilities. Battery experiments at the National Synchrotron Light Source and the Advanced Photon Source have provided the breakthroughs necessary to help launch a new line of heavy duty batteries and a new U.S. manufacturing facility. General Electric (GE) researchers used these facilities to measure the detailed chemical fluctuations of a commercial battery during charging and discharging in real time. Additional studies of cathode cross-sections helped the engineers further understand the evolution of battery chemistry at the interfaces within the system. The resulting new batteries—based on sodium metal halide technology—boast three times the energy density and charging power of lead-acid batteries, the current battery of choice for heavy duty applications. They also have expected lifetimes of up to twenty years and can operate in a wide range of temperature environments.

Milestone	Date
Complete a comprehensive peer review of all 46 Energy Frontier Research Centers.	3rd Qtr, FY 2012
Complete a Committee of Visitor's review of the Materials Sciences and Engineering subprogram.	3rd Qtr, FY 2012
Complete the pre-Critical Decision-2/3A review for the Linac Coherent Light Source-II (LCLS-II)	1st Qtr, FY 2013
Complete the LCLS Ultrafast Science Instruments (LUSI) project	4th Qtr, FY 2012
Complete the pre-Critical Decision-2/3A review for the Advanced Photon Source Upgrade (APS-U)	1st Qtr, FY 2013

Explanation of Changes

In FY 2013, BES will support the 46 Energy Frontier Research Centers, two Energy Innovation Hubs (*Fuels from Sunlight* and the *Batteries and Energy Storage)*, National Synchrotron Light Source-II (NSLS-II) construction and early operations, Linac Coherent Light Source-II (LCLS-II) construction, and the operations of the BES user facilities at near optimal levels. BES core research activities are flat funded with FY 2012. Major item of equipment (MIE) projects for the Advanced Photon Source Upgrade (APS-U) and the NSLS-II Experimental Tools (NEXT) are also continued in FY 2013.

In FY 2013, BES will also begin new research to enhance the role of science in supporting a clean energy agenda. The goal of this research is to develop the next generation of materials, chemicals, and game-changing processes based on a deeper scientific understanding of structure and properties across many scales: from atomic and molecular scales, through the nanoscale, and into the mesoscale. This research will enable science-based chemical and materials design and manufacturing through an understanding of the correlations between material structure, chemistry, and function. In the realm of energy, this means innovations in direct conversion of solar energy to fuels, in effective storage and transmission of electrical energy, in carbon capture and sequestration, and in the efficient use of energy.

Additional research efforts will be initiated to design materials with targeted properties and tailored chemical processes through theory, computation, and modeling, as validated by precise experimental characterization. Discovery of new materials and chemical assemblies with totally new properties and accurate predictions of their interactions with the environment are crucial to advances in energy technologies, as well as to virtually all industries that use materials in their products and manufacturing. The ultimate goal is to provide the Nation with a science-based computational tool set to rationally predict and design materials and chemical processes to gain a global competitive edge in scientific discovery and innovation.

New collaborative efforts with EERE will also be initiated through jointly funded R&D aimed at accelerating the transition of novel scientific discoveries into innovative prototype clean energy technologies. The joint efforts will ensure improved coordination of energy-related research across the Department and be focused on R&D activities aimed at overcoming the underlying physical challenges related to clean energy technology and designing and testing next-generation clean energy devices.

Program Planning and Management

The factors that are considered in the planning and management of research activities in BES include:

- new scientific opportunities as determined by recent scientific discoveries and by new ideas submitted in proposals;
- results of external program reviews and international benchmarking activities of entire fields or sub-fields, such as those performed by the National Academy of Sciences;
- reports from the federally chartered Basic Energy Sciences Advisory Committee (BESAC);
- in-depth topical workshops, conferences, and principle investigators' meetings of scientists, engineers, and technologists from universities, federal laboratories, and the private sector;
- coordination and planning activities between DOE programs including informal day-to-day contacts among program managers;
- interagency coordinating activities;
- evolving mission needs as described by Presidential priorities and DOE and Office of Science (SC) mission statements and strategic plans; and
- Congressional direction.

All research projects supported by BES undergo regular peer review and merit evaluation based on procedures set down in the Title 10 of the Code of Federal Regulations Part 605, for the extramural grant program and in an analogous process for the laboratory programs and scientific user facilities. The BES peer review process evaluates the following four criteria, in order of decreasing importance: scientific and/or technical merit of the project, appropriateness of the proposed method or approach, competency of the personnel and adequacy of proposed resources, and reasonableness and appropriateness of the proposed budget. The criteria for review may also include other appropriate factors established and announced by BES.

Typically, every BES research project receives external peer review and merit evaluation once every three years to determine whether the research is continued or terminated. Success rates vary, but approximately 10-20% of all BES research projects are terminated over the three-year review cycle, which creates a very dynamic program. The termination of work that has reached its conclusion, is past its fruition, or has underperformed provides funding to renew or increase support for outstanding performers and initiate promising new research work by scientific investigators with fresh ideas.

Facilities are also reviewed using external, independent review committees operating according to the procedures established for peer review of BES laboratory programs and facilities. Important aspects of the reviews include assessments of the quality of research performed at the facility, the reliability and availability of the facility, user access policies and procedures, user satisfaction, facility staffing levels, R&D activities to advance the facility, management of the facility, long-range goals of the facility, and that all activities are conducted safely and in an environmentally conscientious manner. The outcomes of these reviews help improve operations and develop new models of operation for all BES scientific user facilities.

Facilities that are in design or construction are reviewed according to procedures in DOE Order 413.3B, Program and Project Management for Capital Assets and in the Office of Science's Independent Review Handbook. In general, once a project has entered the construction phase, it is reviewed with external, independent committees approximately biannually. These Office of Science construction project reviews enlist experts in the technical scope of the facility under construction and focus on its costing, scheduling, and construction management.

Many long-range planning exercises for elements of the BES program are performed under the auspices of BESAC. Of particular note is the BESAC report, *Basic Research Needs to Assure a Secure Energy Future* (2003), which was the foundation for ten follow-on Basic Research Needs workshops (2003–2007) supported by BES in the areas of the hydrogen economy, solar energy utilization, superconductivity, solid-state lighting, advanced nuclear energy systems, combustion of 21st century transportation fuels, electrical-energy storage, geosciences as it relates to the storage of energy wastes (the long-term storage of both nuclear waste and carbon dioxide), materials under extreme environments, and catalysis for energy applications. Together, these workshops help create a basic research portfolio in the BES program that underpins a national decades-to-century energy strategy.

Building on the series of Basic Research Needs workshops, BESAC wrote four subsequent reports. *Directing Matter and Energy: Five Challenges for Science and the Imagination* (2007) identifies the most important scientific questions and science-driven technical challenges facing BES and describes the importance of these challenges to advances in disciplinary science, to technology development, and to energy and other societal needs. *New Science for a Secure and Sustainable Energy Future* (2008) assimilates the scientific research directions that emerged from the BES Basic Research Needs workshop reports into a comprehensive set of science themes, and identifies implementation strategies and tools required to accomplish the science. *Next-Generation Photon Sources for Grand Challenges in Science and Energy* (2008) identifies connections between major new research opportunities and the capabilities of the next generation of light sources. *Science for Energy Technology: Strengthening the Link between Basic Research and Industry* (2010) identifies the scientific priority research directions needed to address the roadblocks and accelerate the innovation of clean energy technologies.

Together these reports describe a continuum of research spanning the most fundamental questions of how nature works to the questions that address technological show-stoppers in the applied research programs supported by the DOE technology offices as well as by industry. Dealing with these issues requires breakthrough advances with new understanding, new materials, and new phenomena that will come from fundamental science. These reports will continue to inform the BES research agenda to bring frontier research to bear on addressing the Department's mission in science and energy. BESAC also reviews the major elements of the BES program annually using Committees of Visitors (COVs). The first COV review of BES was conducted in 2002, and all elements of the BES program have been reviewed once every three years on a rotating schedule. COVs assess the efficacy and quality of the processes used to solicit, review, recommend, monitor, and document proposal actions; and the quality of the resulting portfolio, specifically the breadth and depth of portfolio elements and the national and international standing of the elements. The latest COV was held on April 6–8, 2011, on the Chemical Sciences, Geosciences, and Biosciences subprogram, and the next COV will be in April 2012 on the Materials Sciences and Engineering subprogram. All COV reports and BES responses to COV recommendations are available on the BES website at http://science.energy.gov/bes/besac/bes-cov.

Program Goals and Funding

Basic Energy Sciences performance expectations are focused on four areas:

- Research: Advance fundamental research to understand, predict, and ultimately control matter and energy at the electronic, atomic, and molecular levels to provide foundations for new energy technologies.
- Facility Operations: Sustain a diverse suite of major scientific to provide critical insights to the electronic,

atomic, and molecular configurations, often at ultrasmall length and ultrafast time scales.

- Future Facilities: Progress towards completion of the next generation of user facilities that will provide research communities with tools to fabricate, characterize, and develop new materials and chemical processes to advance research across the full range of scientific disciplines and technological research areas.
- Scientific Workforce: Contribute to the effort aimed at ensuring that DOE and the Nation have a sustained pipeline of highly skilled and diverse science, technology, engineering, and mathematics (STEM) workers.

Goal Areas by Subprogram

	Research	Facilities Operations	Future Facilities	Scientific Workforce
Materials Sciences and Engineering	100%	0%	0%	0%
Chemical Sciences, Geosciences, and Biosciences	100%	0%	0%	0%
Scientific User Facilities	6%	86%	8%	0%
Construction	0%	0%	100%	0%
Total, Basic Energy Sciences	46%	44%	10%	0%

Explanation of Funding Changes

(Dollar in Thousands)

	FY 2012 Enacted	FY 2013 Request	FY 2013 vs. FY 2012
Materials Sciences and Engineering	361,627	420,615	+58,988
Core research activities and EFRCs continue at the FY 2012 level. The Batteries and Energy Storage Innovation Hub continues. New research will be initiated for science supporting a clean energy agenda, materials and chemistry by design, and jointly funded R&D with EERE.			
Chemical Sciences, Geosciences, and Biosciences	316,039	349,397	+33,358
Core research activities and EFRCs continue at the FY 2012 level. The Fuels from Sunlight Innovation Hub continues. New research will be initiated for science supporting a clean energy agenda, materials and chemistry by design, and jointly funded R&D with EERE.			
Scientific User Facilities	859,027	918,877	+59,850
Increases in operations funding of the BES user facilities—five light sources, five Nanoscale Science Research Centers, and three neutron sources—allow for near optimal hours delivered to users. Early operations of the National Synchrotron Light Source-II at Brookhaven National Laboratory start in FY 2013. The APS Upgrade and NEXT MIE projects are also continued. New activities will be initiated at the facilities through jointly funded R&D with EERE.			

	(Dollar in Thousands)		
	FY 2012 Enacted	FY 2013 Request	FY 2013 vs. FY 2012
Construction	151,400	110,703	-40,697
Construction of the National Synchrotron Light Source-II (NSLS-II) will be ramped down, as scheduled (-$104,197,000) and the Linac Coherent Light Source-II (LCLS-II) begins funding as a construction project with PED and civil construction (+$63,500,000). The LCLS-II was funded as an MIE in FY 2012.			
Total, Basic Energy Sciences	1,688,093	1,799,592	+111,499

Materials Sciences and Engineering
Funding Profile by Activity

	(Dollars in Thousands)		
	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
Scattering and Instrumentation Sciences Research	68,254	64,721	73,721
Condensed Matter and Materials Physics Research	127,236	123,723	148,723
Materials Discovery, Design, and Synthesis Research	80,289	76,585	84,585
Experimental Program to Stimulate Competitive Research (EPSCoR)	8,520	8,520	8,520
Energy Frontier Research Centers (EFRCs)	58,000	58,000	68,000
Energy Innovation Hubs	0	19,410	24,237
SBIR/STTR	0	10,668	12,829
Total, Materials Sciences and Engineering	342,299	361,627	420,615

Overview

Materials are critical to nearly every aspect of energy generation and end-use. Materials limitations are often the barrier to improved energy efficiencies, longer lifetimes of infrastructure and devices, or the introduction of new energy technologies. The *Materials Sciences and Engineering* subprogram supports research to provide the understanding of materials synthesis, behavior and performance that will enable solutions to these wide ranging challenges as well as opening new directions that are not foreseen based on the existing knowledge base. The research explores the origin of macroscopic material behaviors and their fundamental connections to atomic, molecular, and electronic structures. At the core of the subprogram is the quest for a paradigm shift to enable the deterministic design and discovery of new materials with novel structures, functions, and properties. Such understanding and control are critical to science-guided design of highly efficient energy conversion processes, such as the conversion of sunlight to electricity, new electromagnetic pathways for enhanced light emission in solid-state lighting and multi-functional nanoporous structures for optimum electronic transport in batteries and fuel cells.

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

- **Scattering and Instrumentation Sciences**—The development of the new tools and techniques to characterize and correlate materials performance, structure, and dynamics on multiple time and length scales and in the environments in which materials are used;
- **Condensed Matter and Materials Physics**—Understanding the foundations of material functionality and behavior; and
- **Materials Discovery, Design, and Synthesis**—How to design and precisely assemble structures in order to control materials properties and enable discovery of new materials with unprecedented functionalities.

The portfolio emphasizes understanding how to direct and control energy flow in materials systems over multiple time and length scales. The research will enable prediction of materials behavior, transformations, and processes in challenging real-world systems—for example, for materials with many atomic constituents, complex structures, and a broad range of defects that are exposed to extreme environments. To maintain leadership in materials discovery, the research explores new frontiers and unpredicted, emergent materials behavior in materials systems (e.g., magnetism, superconductors), utilization of nanoscale control, and systems that are metastable or far from equilibrium. Finally, the subprogram exploits the interfaces between physical and biological sciences to explore bio-mimetic processes as new approaches to novel materials design. This subprogram is also the home of the DOE **Experimental Program to Stimulate Competitive Research (EPSCoR)** supporting basic research spanning the broad range of DOE's science and technology programs in states that have historically received relatively less Federal research funding.

In addition to single-investigator and small-group research, the subprogram supports a core group of **Energy Frontier Research Centers** that were established in FY 2009 and the **Batteries and Energy Storage Energy Innovation Hub** that is initiated in FY 2012. These research modalities support multi-investigator, multidisciplinary research and focus on forefront energy technology challenges. The Hub supports a large, tightly integrated team and research that spans basic and applied regimes with the goal of providing the scientific understanding that will enable the next generation of electrochemical energy storage for vehicles and the electrical grid.

Explanation of Funding Changes

(Dollars in Thousands)

	FY 2012 Enacted	FY 2013 Request	FY 2013 vs. FY 2012
Scattering and Instrumentation Sciences Research	64,721	73,721	+9,000
Research increased for materials and chemistry by design to enhance experimental validation techniques (+$2,000,000) and for clean energy to advance scattering research to characterize relevant functionality in materials (+$7,000,000).			
Condensed Matter and Materials Physics Research	123,723	148,723	+25,000
Research increased for materials and chemistry by design to develop experimentally validated software including new theoretical tools (+$10,000,000) and for clean energy to explore mesoscale phenomena to advance new materials and functionalities for energy (+$15,000,000).			
Materials Discovery, Design, and Synthesis Research	76,585	84,585	+8,000
Research increased for materials and chemistry by design to develop experimentally validated computational tools for predictive materials synthesis (+$2,000,000) and for clean energy to explore related mesoscale phenomena to extend the lifetime and self-repair of materials and novel materials for carbon capture and storage (+$6,000,000).			
Experimental Program to Stimulate Competitive Research (EPSCoR)	8,520	8,520	0
Research continues at the FY 2012 level.			
Energy Frontier Research Centers (EFRCs)	58,000	68,000	+10,000
As part of the jointly funded R&D with EERE, increased funding will accelerate the transition of EFRC scientific discoveries into innovative, prototype clean energy technologies and enhance coordination between fundamental EFRC research and applied research and engineering development supported by EERE.			
Energy Innovation Hubs	19,410	24,237	+4,827
In FY 2013, Batteries and Energy Storage Hub operations are supported at the planned, annual level.			

	(Dollars in Thousands)		
	FY 2012 Enacted	FY 2013 Request	FY 2013 vs. FY 2012
SBIR/STTR	10,668	12,829	+2,161
In FY 2011, $8,331,000 and $1,000,000 were transferred to the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs, respectively. SBIR/STTR funding is set at 2.95% of non-capital funding in FY 2012 and 3.05% in FY 2013.			
Total, Materials Sciences and Engineering	361,627	420,615	+58,988

Scattering and Instrumentation Sciences Research

Overview

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 molecular levels. These capabilities provide the foundation for research central to DOE missions in energy, environment, and national security. Research in Scattering and Instrumentation Science supports innovative techniques and instrumentation for scattering, spectroscopy, and imaging using electrons, neutrons, and x-rays. These tools provide precise information on the atomic structure and dynamics in materials. DOE's longstanding investments in world-leading electron, neutron, and synchrotron x-ray scattering facilities at the DOE national laboratories are a testament to the importance of this activity to the DOE mission. Revolutionary advances in these techniques will enable transformational research on advanced materials to address energy challenges.

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 several orders of magnitude. Furthermore, recent advances in investigations of dynamic phenomena in real-time and relevant conditions provide a window into material functions under operational conditions. New instrumentation in the ultrafast regime will investigate dynamics at very fast timescales related to electronic, catalytic, magnetic, and other transport processes. A distinct aspect of this activity is the development of innovative neutron optics and techniques with polarized neutrons to probe the properties of materials.

Funding and Activity Schedule

Fiscal Year	Activity	Funding ($000)
FY 2011 Current	Development of new instrumentation and techniques for ultrafast diffraction and imaging with x-rays and electrons for forefront materials research at these timescales continued to be emphasized. Spectroscopy and imaging research with neutron and x-ray scattering highlighted understanding material behavior at extreme conditions such as high pressures and temperatures. A new direction in scanning probe research was imaging functionality to understand properties of materials, including electrochemical reactions and transport.	68,254
FY 2012 Enacted	In FY 2012 research supports scattering research, including continued enhancement of ultrafast research and development of techniques to observe, control and understand material dynamics through the use of electron, optical, neutron, and x-ray techniques and sources.	64,721
FY 2013 Request	The research will emphasize timely exploitation of the tremendous enhancements in intensities at DOE's world-leading facilities and new technologies in optics, detectors, and electronics to develop new techniques not previously possible. New research will initiate development of in situ analysis capabilities for materials and chemistry by design and development and application of forefront scattering capabilities, including ultrafast techniques, to address key issues for clean energy. This research will advance the development and utilization of new capabilities with increasing physical, chemical, structural, and temporal precision by the broader clean energy research community, opening new avenues for mesoscale research. These capabilities will open new regimes for materials research, especially to understand complex, use-inspired functionalities. Research in soft and hybrid materials will also be emphasized.	73,721

	(Dollars in Thousands)		
	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
Electron and Scanning Probe Microscopes	29,315	26,955	28,955
Neutron and X-Ray Scattering	38,939	37,766	44,766
Total, Scattering and Instrumentation Sciences Research	68,254	64,721	73,721

Condensed Matter and Materials Physics Research

Overview

Understanding the foundations of how to control and change the properties of materials is critical to improving their functionality on every level and is essential to fulfilling DOE's energy mission. The Condensed Matter and Materials Physics activity supports experimental and theoretical research to advance our current understanding of phenomena in condensed matter—the solids, liquids, and mesoscale materials that make up the infrastructure for energy technologies at every level, including electronics, magnetic, optical, thermal, and structural materials.

A central focus is characterizing and understanding materials whose properties are driven by strong interactions of the electrons in their structure, such as superconductors and magnetic materials. An emphasis is placed on investigating low-dimensional systems, including nanostructures, and studies of electronic properties under extreme conditions such as ultra-low temperatures and extremely high magnetic fields. Research relevant to energy technologies includes understanding the elementary energy conversion steps in photovoltaics, the energetics of hydrogen storage, and electron spin-phenomena and basic semiconductor physics relevant to next generation information technologies and electronics. Fundamental studies of the interactions of atomic particles and energy (quantum physics) will lead to an improved understanding of electrical and thermal conduction in a wide range of material systems. There is a critical need to couple theories that describe properties at the atomic scale to properties at the macroscale where the connection between the properties of materials and their size, shape, and composition are poorly understood.

The activity also emphasizes understanding how materials respond to their environment, such as temperature, electromagnetic fields, radiation, and chemical environments. The influence of defects in materials and their effects on strength, structure, deformation, and failure over a wide range of length and time scales will enable the design of materials having superior mechanical properties and resistance to change under the influence of radiation.

Funding and Activity Schedule

Fiscal Year	Activity	Funding ($000)
FY 2011 Current	Experimental and theoretical research continued to focus on understanding, designing, and controlling electronic and physical properties of materials through studies of the relationship of atomic-level structure to the electrical, optical, magnetic, surface reactivity, and mechanical properties of materials. Included were investigations of the ways in which materials respond to external stimuli such as stress, chemical and electrochemical environments, and radiation, as well as the proximity of materials to surfaces and interfaces.	127,236
FY 2012 Enacted	In FY 2012, combined computational and experimental research to develop validated theoretical models is enhanced. Research supports further advances in our understanding of approaches to control materials properties and to push the frontiers and scientific foundations for new materials such as topological insulators, graphene, and metamaterials. Research continues on materials that underpin the evolution of energy technologies such as superconductors, radiation resistant materials, and photovoltaic, optical, and electronic applications. Research will be reduced in granular materials, surface diffusion and reconstruction, liquid crystals, and heat transfer in nanofluidics.	123,723
FY 2013 Request	The FY 2013 request continues to emphasize experimental and theoretical research in newly discovered systems that exhibit correlation effects including graphene and topological insulators. Research on ultra-cold atom clusters will be supported to provide new insights into the evolution of condensed matter behavior.	148,723

Fiscal Year	Activity	Funding ($000)

New research in materials and chemistry by design will emphasize development of validated software that can be used by the broader community, including the development of new theoretical tools that relate directly to clean energy technologies. Additional research will explore mesoscale phenomena and enhance use-inspired clean energy research relevant to solar energy utilization, mechanical properties and radiation effects, and correlated electron behavior in materials, such as superconductivity and magnetism that are important to a number of energy technologies. The new research will focus advancing our fundamental understanding of defects in materials that is needed to extend lifetimes and enhance performance of materials used in energy generation and use.

Research will continue to support fundamental insights to the understanding of structure-property relationships, including the influence of reduced dimensionality and defects on physical, optical, and electrical properties, and controlling material functionality in response to multiple external stimuli such as temperature, pressure, magnetic and electric fields, and radiation.

	(Dollars in Thousands)		
	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
Experimental Condensed Matter Physics	47,610	46,781	51,281
Theoretical Condensed Matter Physics	29,623	31,623	41,623
Mechanical Behavior and Radiation Effects	18,953	17,582	23,082
Physical Behavior of Materials	31,050	27,737	32,737
Total, Condensed Mater and Materials Physics Research	127,236	123,723	148,723

Materials Discovery, Design, and Synthesis Research

Overview

The discovery and development of new materials has long been recognized as the engine that drives science frontiers and technology innovations. Understanding how materials form is central to predictive discovery of new forms of matter with tailored properties. A strong, vibrant research enterprise in the discovery 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.

A key part of the portfolio is biomimetic materials research—translating biological processes into impactful approaches to the design and synthesis of materials with the remarkable properties found only in nature, e.g., self-repair and adaptability to the changing environment. Research in Materials Discovery, Design, and Synthesis includes activities in Materials Chemistry and Biomolecular Materials, and Synthesis and Processing Science. This research underpins many energy-related technological areas such as batteries and fuel cells, catalysis, solar energy conversion and storage, friction and lubrication, and membranes for advanced separations.

In Materials Chemistry and Biomolecular Materials, the emphasis is on chemistry- and biology-based approaches to materials synthesis and assembly. Major research directions include the controlled synthesis of nanoscale materials and their assembly into functional materials with desired properties; mimicking the energy-efficient synthesis approaches of biology to generate new, advanced materials for use under harsher, non-biological conditions; bio-inspired materials that assemble autonomously and dynamically; adaptive and resilient materials that also possess self-repairing capabilities. Synthesis and Processing Science supports fundamental research on the development of new methods and techniques to synthesize materials with desired structure and tailored properties. An important element of this activity is the development of real-time monitoring tools, diagnostic techniques and instrumentation to provide information on 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.

Funding and Activity Schedule

Fiscal Year	Activity	Funding ($000)
FY 2011 Current	In FY 2011, continuing scientific core research activities included: development of advanced methods to direct and control the assembly, symmetry, dimensionality, and functionality of materials; design and control of interfaces between dissimilar materials, including biological and non-biological systems in search of new materials and new phenomena; integration of theory, computation, and experiment to elucidate the mechanisms controlling synthesis and to further capabilities for materials discovery; and novel synthesis methods using extreme environments of field and flux.	80,289
FY 2012 Enacted	FY 2012 continues research to enhance the scientific foundations for understanding the fundamentals of synthesis, fabrication and processing for physical, chemical, and biomimetic materials. Additional emphasis will be included on integration of theory, computation, and experiment to enhance capabilities for materials discovery. Research will be reduced in activities that focus on ion beam assisted growth techniques, artificial enzymes, and synthesis of individual nanowires, particles, etc.	76,585

Fiscal Year	Activity	Funding ($000)
FY 2013 Request	Research will continue to emphasize integration of experimental and theory activities to accelerate progress in understanding synthesis and discovery of new materials; bio-inspired synthesis toward more efficient processes that will scale to larger quantities and result in resilient materials, porous materials modeled after biological membranes and related features. New directions in use-inspired clean energy research will consider opportunities related to mesoscale science, including self-healing materials to extend the lifetimes of materials in solar devices and for solar energy conversion. New research underpinning carbon capture will take advantage of novel chemistries and approaches for gas storage and release, including innovative biomolecular materials research. Research will focus on obtaining a deeper understanding of the role of interfaces in the processes underpinning energy storage and catalytic technologies. Experimental research will also support materials and chemistry by design, including predictive design of materials synthesis through development of validated software for physical and chemical synthesis and processing techniques. Research will continue to emphasize the development of new strategies and methods to direct and control the assembly of materials structures across a range of length scales.	84,585

(Dollars in Thousands)

	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
Materials Chemistry and Biomolecular Materials	57,270	54,237	59,237
Synthesis and Processing Science	23,019	22,348	25,348
Total, Materials Discovery, Design, and Synthesis Research	80,289	76,585	84,585

Experimental Program to Stimulate Competitive Research (EPSCoR)

Overview

The U.S. Department of Energy's Experimental Program to Stimulate Competitive Research (DOE EPSCoR) is a federal-state partnership program designed to enhance the capabilities and research infrastructure of designated states and territories to conduct sustainable and nationally competitive research. This activity supports basic research spanning the broad range of science and technology related to DOE mission areas in states and territories that have historically received relatively less Federal research funding than other states. The EPSCoR states/territories are listed below. The intent of EPSCoR is to help these states develop their infrastructure and research capabilities so that they can successfully compete for research funding. The research supported by EPSCoR includes materials sciences, chemical sciences, physics, energy-relevant biological sciences, geological and environmental sciences, high energy physics, nuclear physics, fusion energy sciences, advanced computing, and the basic sciences underpinning fossil energy, nuclear energy, and energy efficiency and renewable energy.

EPSCoR places a high priority on promoting strong research collaboration between scientists and engineers in the designated states and territories with the world-class national laboratories, leveraging national user facilities, and taking advantage of opportunities for intellectual collaboration across the DOE system. This program is science-driven and supports the most meritorious proposals based on peer review and programmatic priorities.

Funding and Activity Schedule

Fiscal Year	Activity	Funding ($000)
FY 2011 Current	Research supported a diversity of science and energy-related research topics. New research projects were initiated on conversion of solar and residual thermal energy to electricity and hydrogen and on chemical and mechanical degradation of battery materials.	8,520
FY 2012 Enacted	Continued support of basic research related to DOE mission areas. Collaborative efforts with DOE laboratories and user facilities will be enhanced.	8,520
FY 2013 Request	Efforts will continue to span science in support of the DOE mission, with emphasis on science underpinning the DOE energy technology programs broadly. Infrastructure-driven implementation grants will be enhanced.	8,520

EPSCoR Distribution of Funds by State

(Dollars in Thousands)

	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
Alabama	585	0	0
Alaska	0	0	446
Arkansas	0	0	0
Delaware	780	829	180
Hawaii	0	0	0
Idaho	0	0	0
Iowa	0	0	0
Kansas	0	0	0
Kentucky	590	590	590

(Dollars in Thousands)

	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
Louisiana	0	0	0
Maine	600	600	600
Mississippi	0	0	0
Montana	505	125	140
Nebraska	0	0	0
Nevada	0	0	0
New Hampshire	700	700	0
New Mexico	480	0	0
North Dakota	600	0	0
Oklahoma	0	0	422
Puerto Rico	770	770	770
Rhode Island	2,355	1,932	2,137
South Carolina	0	0	0
South Dakota	0	0	496
Tennessee	0	0	0
U.S. Virgin Islands	0	0	0
Utah	0	0	0
Vermont	0	0	0
West Virginia	300	300	0
Wyoming	0	0	407
Technical Support	255	260	275
Other[a]	0	2,414	2,057
Total, EPSCoR	8,520	8,520	8,520

[a] Uncommitted funds in FY 2012 and FY 2013 will be competed among all EPSCoR states.

Energy Frontier Research Centers

Overview

The Basic Research Needs workshops in 2003-2009 established the foundational basic research challenges that would enable major advances in energy technologies and retain U.S. leadership in innovations, inspired by research on grand science challenges. One of the recommendations was the need for assembling "multidisciplinary teams" of scientists and engineers to focus on these challenges. In response, the Energy Frontier Research Centers (EFRCs) were established in late FY 2009. These multi-investigator, multi-disciplinary centers foster, encourage, and accelerate basic research to provide the basis for transformative energy technologies of the future. There were 46 EFRC awards, 16 with full 5-year support from the American Recovery and Reinvestment Act of 2009. The remaining 30 are funded on an annual basis through this subprogram and the Chemical Sciences, Geosciences, and Biosciences subprogram. The initial 5-year initial award period will end in FY 2014.

The EFRCs are an important research modality, bringing together the skills and talents of a team of investigators to perform energy-relevant, basic research with a scope and complexity beyond that found in standard single-investigator or small-group awards. To help ensure their success, BES provides proactive oversight through regular and frequent interactions with the EFRCs, including meetings with the EFRCs as a group, and formal reviews, highlighted by an early management peer review (FY 2010) and the upcoming mid-term scientific peer reviews in FY 2012. To ensure communication of scientific research advances, technology needs, and program directions (to avoid duplication), management of the EFRC research includes coordination with other BES research activities and with the DOE technology offices.

In this activity, individual EFRCs perform a wide breadth of research in materials science and engineering that are focused on: the design, discovery, synthesis, and characterization of novel, solid-state materials that improve the conversion of solar energy and heat into electricity and fuels; improving the conversion of electricity to light; improving electrical energy storage; enhancing materials resistance to corrosion, decay, or failure in extreme conditions of temperature, pressure, radiation, or chemical exposures; taking advantage of emergent phenomena, such as superconductivity, to improve energy transmission; optimizing energy flow to improve energy efficiency; and tailoring materials and processes at the atomic level to maximize catalytic activity. Efforts to bridge disciplines, generate new avenues of inquiry, and accelerate research within the broader community include periodic all-hands meetings, joint symposia and workshops, summer schools, tool development, and principal investigators' meetings.

Funding and Activity Schedule

Fiscal Year	Activity	Funding ($000)
FY 2011 Current	The EFRCs continued their planned research activities and addressed Center specific guidance on areas that needed improvement based on the management review held in 2010. To communicate early research progress, the EFRC Summit and Forum was held and attended by over 1,000 people.	58,000
FY 2012 Enacted	The EFRCs complete their third year of operation in late FY 2012. To date, the 46 EFRCs have produced more than 1,000 peer reviewed publications and more than 90 invention disclosures or patent applications. In January-April 2012, a panel-based peer-review will assess the scientific progress of each EFRC. These reviews will also identify deficiencies and extraordinary performance.	58,000
FY 2013 Request	Research will incorporate modifications to research activities and directions resulting from the FY 2012 peer review. Additional funding will be provided to accelerate the transition of novel scientific discoveries from the EFRCs into innovative, prototype clean energy technologies and to improve coordination between fundamental research conducted in the EFRCs and applied research and engineering development supported by EERE.	68,000

Energy Innovation Hubs

Overview

Energy Innovation Hubs are composed of a large, multidisciplinary team of investigators whose research integrates basic to applied research and focuses on a single critical national energy need. They are funded as five-year, potentially renewable projects. Advanced energy storage solutions have become increasingly critical to the Nation with the expanded deployment of renewable energy sources coupled with growth in the numbers of hybrid and electric vehicles. For the electrical grid, new approaches to electrochemical energy storage can enable inherently intermittent renewable energy sources to meet continuous electricity demand. For vehicles, new batteries with improved lifetimes and storage capacities are needed to expand range of electric vehicles' for a single charge while simultaneously decreasing the manufacturing cost and weight. Today's electrical energy storage approaches suffer from limited energy and power capacities, lower-than-desired rates of charge and discharge, cycle life limitations, low abuse tolerance, high cost, and poor performance at high or low temperatures. The Batteries and Energy Storage Hub focuses on understanding the fundamental performance limitations for electrochemical energy storage to enable the next generation of electrochemical energy storage technologies.

The Batteries and Energy Storage Hub will accelerate the development of energy storage solutions that are well beyond current capabilities and approach theoretical limits. This development will be enabled by cross-disciplinary R&D focused on the barriers to transforming electrochemical energy storage, including the exploration of new materials, devices, systems, and novel approaches for transportation and utility-scale storage. Outside of the Hub, battery research is typically focused on one particular problem or research challenge and thus lacks the resources and the diverse breadth of talent to consider holistic solutions. The Hub will provide this critical mass directed on research to overcome the current technical limits for electrochemical energy storage to the point that the risk level will be low enough for industry to further develop the innovations discovered by the Hub and deploy these new technologies into the marketplace.

The Hub's goal is to deliver revolutionary research that will result in new technologies and approaches, rather than focusing on a single technology or incremental improvements to current technologies. The Hub's ultimate technological impact should go well beyond current research and development activities. While advancing the current understanding and underpinning science for energy storage, the Hub will include the development of working bench-top prototype devices that demonstrate radically new approaches for electrochemical storage and are scalable. These should have the potential to be produced at low manufacturing cost from earth-abundant materials and possess greatly improved properties compared to present commercially available energy storage technologies.

Funding and Activity Schedule

Fiscal Year	Activity	Funding ($000)
FY 2011 Current	No funding was provided for the Hub.	0
FY 2012 Enacted	The Hub will be awarded through peer-review selection. The early stages of Hub research will be initiated. The Hub proposal and management plan will provide specific performance objectives and milestones. These will provide the baseline for future assessments of Hub progress.	19,410
FY 2013 Request	Hub research will follow the plan established in the proposal. A management peer review will take place to evaluate the Hub's progress in fulfilling the research plan. It is expected that the first scientific publications would appear, advisory groups would be operational (including industrial input), and a communications network would be established by the Hub.	24,237

Chemical Sciences, Geosciences, and Biosciences
Funding Profile by Activity

	(Dollars in Thousands)		
	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
Fundamental Interactions Research	71,394	67,562	71,562
Chemical Transformations Research	108,512	100,875	110,875
Photochemistry and Biochemistry Research	74,603	71,822	77,822
Energy Frontier Research Centers (EFRCs)	42,000	42,000	52,000
Energy Innovation Hubs	22,000	24,263	24,237
GPP	6,615	200	2,315
SBIR/STTR	0	9,317	10,586
Total, Chemical Sciences, Geosciences, and Biosciences	325,124	316,039	349,397

Overview

The transformation of energy between types (optical, electrical, chemical, heat, etc.) and the rearrangement of matter at the atomic, molecular, and nano-scales are critically important in every energy technology. The *Chemical Sciences, Geosciences, and Biosciences* subprogram supports research that explores fundamental aspects of chemical reactivity and energy transduction in order to develop a broad spectrum of new chemical processes, such as catalysis, that can contribute significantly to the advancement of new energy technologies. Research addresses the challenge of understanding physical and chemical phenomena over a tremendous range of spatial and temporal scales and at multiple levels of complexity.

At the heart of this research lies the quest to understand and control chemical reactions and the transformation of energy at the molecular scale in systems ranging from simple atoms and molecules, to active catalysts, to larger biochemical or geochemical systems. At the most fundamental level, the development and understanding of the quantum mechanical behavior of electrons, atoms, and molecules is rapidly evolving into the ability to control and direct such behavior to achieve desired results in macro scale energy conversion systems.

This subprogram seeks to extend this new era of control science to include the capability to tailor chemical transformations with atomic and molecular precision. Here, the challenge is to achieve fully predictive assembly and manipulation of larger, more complex chemical, geochemical, and biochemical systems at the same level of detail now known for simple molecular systems.

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

- **Fundamental Interactions**—Structural and dynamical studies of atoms, molecules, and nanostructures with the aim of providing a complete understanding of atomic and molecular interactions in the gas phase, condensed phase, and at interfaces.
- **Chemical Transformations**—Design, synthesis, characterization, and optimization of chemical processes that underpin advanced energy technologies, including catalytic production of fuels, nuclear energy, and geological sequestration of carbon dioxide.
- **Photochemistry and Biochemistry**—Research on the molecular mechanisms involved in the capture of light energy and its conversion into chemical and electrical energy through biological and chemical pathways.

The portfolio of this subprogram includes several unique efforts that enable these overall research themes. Novel sources of photons, electrons, and ions are developed to probe and control atomic, molecular, and nanoscale matter, particularly ultrafast optical and x-ray techniques to study and direct molecular, dynamics, and chemical reactions. This subprogram supports the nation’s largest federal effort in catalysis science for the design of new catalytic methods and materials for the clean and efficient production of fuels and chemicals. It also contains a unique effort in the fundamental chemistry of the heavy elements, with complementary research on chemical separations and analysis. Research in geosciences emphasizes analytical and physical geochemistry, rock-fluid interactions, and flow/transport phenomena that are critical to a scientific understanding of carbon sequestration. Natural photosynthetic systems are studied to create robust artificial and bio-hybrid systems that exhibit the biological traits of self assembly, regulation, and self repair. Complementary research on man-made systems includes organic and inorganic photochemistry, photo-induced electron and energy transfer, photoelectrochemistry, and molecular assemblies for artificial photosynthesis.

In addition to single-investigator and small-group research, the subprogram supports a core group of Energy Frontier Research Centers that were established in FY 2009 and the Fuels from Sunlight Energy Innovation Hub that was awarded in FY 2010. These research modalities support multi-investigator, multidisciplinary research and focus on forefront energy technology challenges. The Hub supports a large, tightly integrated team and research that spans basic and applied regimes with the goal of providing the scientific understanding that will enable the next generation of technologies for the direct conversion of sunlight to chemical fuels.

Explanation of Funding Changes

(Dollars in Thousands)

	FY 2012 Enacted	FY 2013 Request	FY 2013 vs. FY 2012
Fundamental Interactions Research	67,562	71,562	+4,000
Research increased for materials and chemistry by design for the use of optical fields to control and design quantum mechanical systems and new computational chemistry approaches to electronically excited states in molecules and extended systems (+$3,000,000). In science supporting the clean energy agenda, an increase for advanced combustion research to accelerate the predictive simulation of internal combustion engines (+$1,000,000).			
Chemical Transformations Research	100,875	110,875	+10,000
Research increased for materials and chemistry by design for the development of computational methods for the simulation of photo-catalytic, fuel-forming reactions and for complementary efforts in synthesis and characterization (+$2,000,000). In science supporting the clean energy agenda, increases for advanced catalytic approaches to the conversion of biomass to fuels and other chemical products, novel approaches to the separation of carbon dioxide from post-combustion gas streams and oxygen from air prior to oxy-combustion, actinide research in support of advanced nuclear energy systems, and research on the multi-scale dynamics of flow and plume migration in carbon sequestration (+$8,000,000).			

	(Dollars in Thousands)		
	FY 2012 Enacted	FY 2013 Request	FY 2013 vs. FY 2012
Photochemistry and Biochemistry Research	71,822	77,822	+6,000
Research increased for materials and chemistry by design for computational methods to simulate light harvesting and solar energy conversion to fuels and electricity (+$1,000,000). In science supporting the clean energy agenda, increases for studies or self-protection and repair of natural photosynthetic systems, research on the molecular level structure of the plant cell wall in order to elucidate catalytic routes for biomass conversion, and photocatalytic fuel generation (+$5,000,000).			
Energy Frontier Research Collaborations	42,000	52,000	+10,000
As part of the jointly funded R&D with EERE, an increase to accelerate the transition of EFRC scientific discoveries into innovative, prototype clean energy technologies and to improve coordination between fundamental EFRC research and applied research and engineering development supported by EERE (+$10,000,000).			
Energy Innovation Hubs	24,263	24,237	-26
In FY 2013, Hub operations are supported at the planned, annual level.			
GPP	200	2,315	+2,115
Funds are provided for facility improvements and upgrades at Ames Laboratory.			
SBIR/STTR	9,317	10,586	+1,269
In FY 2011, $7,684,000 and $922,000 were transferred to the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs, respectively. SBIR/STTR funding is set at 2.95% of non-capital funding in FY 2012 and 3.05% in FY 2013.			
Total, Chemical Sciences, Geosciences, and Biosciences	316,039	349,397	+33,358

Fundamental Interactions Research

Overview

This activity builds the fundamental science basis essential for technological advances in a diverse range of energy processes. Research encompasses structural and dynamical studies of atoms, molecules, and nanostructures, and the description of their interactions in full quantum detail. The ultimate objective, often gained through studies of model systems, is a complete understanding of reactive chemistry in the gas phase, condensed phase, and at interfaces. In complement, this activity supports development of novel experimental and theoretical tools. New sources of photons, electrons, and ions are used to probe and control atomic, molecular, and nanoscale matter and processes on ultrafast time scales. New algorithms for computational chemistry are developed and applied in close coordination with experiment. Areas of emphasis are use-inspired, with relevance for example to combustion and catalysis, but the knowledge and techniques produced by this activity form a science base to underpin numerous aspects of the DOE mission.

This activity's principle research thrusts are in atomic, molecular, and optical (AMO) sciences and chemical physics. AMO research emphasizes the interactions of atoms, molecules, and nanostructures with photons, particularly those from BES light sources, to characterize and control their behavior. AMO research examines energy transfer within isolated molecules that provides the foundation for understanding the making and breaking of chemical bonds. Chemical physics research builds from this foundation by examining reactive chemistry of molecules that are not isolated, but whose chemistry is profoundly affected by the environment. It confronts the transition from molecular-scale chemistry to collective phenomena in complex systems, such as the effects of solvation or interfaces on chemical structure and reactivity. Understanding such collective behavior is critical in a wide range of energy and environmental applications, from solar energy conversion to improved methods for handling radiolytic effects in context of advanced nuclear fuel or waste remediation. Gas-phase chemical physics emphasizes the incredibly rich chemistry of combustion—a full description of the burning of diesel fuel requires thousands of chemical reactions. Combustion simulation and diagnostic studies address the subtle interplay between combustion chemistry and the turbulent flow that characterizes all real combustion devices. This activity includes support for the Combustion Research Facility (CRF), a multi-investigator research laboratory for the study of combustion science.

Funding and Activity Schedule

Fiscal Year	Activity	Funding ($000)
FY 2011 Current	Current topics in AMO science included interactions of atoms and molecules with intense electromagnetic fields; collisions and highly correlated interactions of atomic and molecular systems; and the development and application of novel, ultrafast optical probes of matter, particularly x-ray sources. In chemical physics research, current topics included studies of the dynamics and rates of gas-phase chemical reactions at energies characteristic of combustion, identification key combustion intermediates, and understanding their chemical and physical properties, as well as development of new experimental and theoretical techniques. These underpin the development of robust and fully predictive simulation capabilities for turbulent combustion, which is critical to enable efficient and clean use of renewable and fossil fuels.	71,394

Fiscal Year	Activity	Funding ($000)
FY 2012 Enacted	Core research activities continue with emphasis on the development and application of new ultrafast x-ray and optical probes of matter. Additional new research emphasizes the chemistry associated with stochastic combustion processes and the fundamental science of liquid fuel injection, both of which are required to further enable the predictive simulation of internal combustion engines.	67,562
FY 2013 Request	AMO sciences research will emphasize the development and application of new ultrafast x-ray and optical probes of matter, including experiments at the Linac Coherent Light Source and BES synchrotron light sources and theoretical and computational methods for the interpretation of ultrafast measurements. Chemical physics research will emphasize development of new theoretical and simulation techniques relevant to a wide variety of potential applications. As part of the effort on materials and chemistry by design, increases are provided for the use of optical fields to control and design quantum mechanical systems and for new computational chemistry approaches to electronically excited states in molecules and extended mesoscale systems, which are critically important in solar energy conversion. As part of science in supporting a clean energy agenda, an increase is provided for advanced combustion research to accelerate the predictive simulation of internal combustion engines.	71,562

	(Dollars in Thousands)		
	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
Chemical Physics Research	48,264	46,492	49,492
Atomic, Molecular, and Optical Science	23,130	21,070	22,070
Total, Fundamental Interactions Research	71,394	67,562	71,562

Chemical Transformations Research

Overview

This activity emphasizes the design, synthesis, characterization, and optimization of chemical processes that underpin advanced energy technologies including the catalytic production of fuels, nuclear energy, and geological sequestration of carbon dioxide. A tremendous breadth of novel chemistry is covered: inorganic, organic, and hybrid molecular complexes; nanostructured surfaces; electrochemistry; nanoscale membranes; bio-inspired chemistry; and analytical and physical geochemistry. This activity develops unique tools for chemical analysis, using laser-based and ionization techniques for molecular detection, with an emphasis on imaging chemically distinct species.

This activity has a leadership role in the application of basic science to unravel the principles that define how catalysts work—how they accelerate and direct chemistry. Such knowledge enables the rational synthesis of novel nanoscale catalysts that will lead to increased energy efficiency and chemical selectivity. Because so many processes for the production of fuels and chemicals rely on catalysts, improving catalytic efficiency and selectivity has enormous economic and energy consequences. Advanced gas separation schemes for the removal of carbon dioxide from post-combustion streams are explored—these are essential to making carbon capture an economic reality. Fundamental studies of the structure and reactivity of actinide-containing molecules provides the basis for their potential use in advanced nuclear energy systems. Geosciences research emphasizes a greater understanding of the consequences of deliberate storage, or accidental discharges, of energy related products (carbon dioxide or waste effluents), which require ever more refined knowledge of how such species react and move in the subsurface environment.

Funding and Activity Schedule

Fiscal Year	Activity	Funding ($000)
FY 2011 Current	Current topics in catalysis science include the chemistry of inorganic, organic, and hybrid porous materials and their self-assembly into functional catalytic systems. Emphasis was placed on elucidating the elementary steps of catalytic reaction mechanisms and their kinetics, the construction of catalytic sites at the atomic level, and synthesis of molecular catalysts that are often inspired by natural systems. Breakthroughs in directed chemical synthesis enabled the design of membranes and filters that can distinguish and sort even very similar molecules, such as nitrogen and oxygen, or carbon dioxide and methane. SC synchrotron light sources and leadership class computational facilities were used to advance our understanding of new actinide-ligand complexes whose basic chemistry is not well understood, but that hold great potential as next-generation nuclear fuels. Nanoscale geochemistry and biogeochemistry studies provided measurement and monitoring techniques, and understanding to validate predictive models for subsurface transport.	108,512
FY 2012 Enacted	Core research activities continue and include emphasis on the combination of computational design, directed synthesis, and molecular-scale characterization to create and optimize novel catalysts. Other areas of research emphasis include fluid flow in nanoscale membranes, fundamental actinide chemistry, and the translation of interfacial chemistry into the geosciences arena in order to improve our understanding of subsurface geochemistry.	100,875

Fiscal Year	Activity	Funding ($000)
FY 2013 Request	As part of the materials and chemistry by design effort, an increase is provided for the development of computational methods and software tools for the simulation of photo-catalytic, fuel-forming reactions and for complementary efforts in synthesis and characterization of new catalytic materials that are designed at the nanoscale to function on the mesoscale. As part of science in supporting a clean energy agenda, increases are provided for novel approaches to the separation of carbon dioxide from post-combustion gas streams and oxygen from air prior to oxy-combustion and for research on the multi-scale dynamics of flow and plume migration in carbon sequestration, which can lead to improved models and risk assessment for carbon sequestration. Additional clean energy increases are provided for actinide research in support of advanced nuclear energy systems, with emphasis on complex separation chemistry addressing the multiplicity of chemical forms and oxidation states in actinides for nuclear fuels and waste forms, and for advanced catalytic approaches to the conversion of biomass to fuels and other chemical products.	110,875

	(Dollars in Thousands)		
	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
Catalysis Science	49,656	49,650	53,650
Separations and Analysis	15,415	14,193	16,193
Heavy Element Chemistry	15,108	14,751	16,751
Geosciences Research	28,333	22,281	24,281
Total, Chemical Transformations Research	108,512	100,875	110,875

Photochemistry and Biochemistry Research

Overview

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. The work is of critical importance for the effective use of our most abundant and durable energy source—the sun. More energy from the sun strikes the Earth in one hour than is used by its entire human population in a year.

Natural photosynthesis is studied to provide roadmaps for the creation of robust artificial as well as bio-hybrid systems that exhibit the biological traits of self assembly, regulation, and self repair. Physical science tools are extensively utilized to elucidate the molecular and chemical mechanisms of biological energy transduction, including processes beyond primary photosynthesis such as carbon dioxide reduction and subsequent deposition of the reduced carbon into energy-dense carbohydrates and lipids. Complementary research on man-made systems encompasses organic and inorganic photochemistry, light-driven energy and electron transfer processes, as well as photo-electrochemical mechanisms and molecular assemblies for artificial photosynthetic fuel production.

Funding and Activity Schedule

Fiscal Year	Activity	Funding ($000)
FY 2011 Current	An area of significant focus was the biological machinery involved in light-driven water splitting (photolysis), arguably the most demanding reaction in nature. The bonds between hydrogen and oxygen atoms in water must first be broken, before the atoms can be reformed into a fuel. Drawing from the natural blueprint, a new class of metal-based complexes that are a thousand times more active than previous generations have recently been synthesized. This significant advancement results from the ability of a single metal atom to complex with organic ligands in far more configurations than previous designs. Other current topics included advances in photo-electrochemistry, which is an alternative to semiconductor photovoltaic cells for electricity generation from sunlight using closed, renewable cycles. The plant cell wall is where biology stores solar energy in the form of complex macromolecules. Therefore a current focus was on understanding of cell wall architecture at the molecular level, which is required for catalytic conversion of biomass into chemical fuels.	74,603
FY 2012 Enacted	The continuation of ongoing research activities includes efforts to define molecular-level structure-function relationships of the natural photosynthetic apparatus and apply that knowledge to synthetic solar fuel systems, including the design of ligands that further increase the reactivity of metal-based catalytic complexes. Efforts will continue to understand the biophysical and biochemical parameters that make the plant cell wall recalcitrant to catalytic conversion into fuels and other value-added products.	71,822

Fiscal Year	Activity	Funding ($000)
FY 2013 Request	As part of the materials and chemistry by design effort, an increase is provided for the development of computational methods and software tools for the simulation of light harvesting and conversion of solar energy into electricity and fuels (in coordination with the *Chemical Transformations* activity). As part of science in supporting a clean energy agenda, increases are provided for experimental research on direct conversion of solar energy to fuels and for advancing the catalytic conversion of biomass to fuels, both of which require translation from the nano to the mesoscale. These include: studies of the mechanisms that protect and self-repair the natural photosynthetic apparatus; photocatalytic generation of fuels in synthetic systems, via semiconductor/polymer interfaces, dye-sensitized solar cells, inorganic-organic molecular complexes, and nano-scale water splitting assemblies; and advanced analysis of the structure of plant cell walls to elucidate catalytic routes for the conversion of biomass to fuels and other chemical products (in coordination with the *Chemical Transformations* activity).	77,822

	(Dollars in Thousands)		
	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
Photosynthetic Systems	17,424	17,424	19,424
Physical Biosciences	17,112	16,147	18,147
Solar Photochemistry	40,067	38,251	40,251
Total, Photochemistry and Biochemistry Research	74,603	71,822	77,822

Energy Frontier Research Centers

Overview

The Basic Research Needs workshops in 2003-2009 established the foundational basic research challenges that would enable major advances in energy technologies and retain U.S. leadership in innovations, inspired by research on grand science challenges. One of the recommendations was the need for assembling multidisciplinary teams of scientists and engineers to focus on these challenges. In response, the Energy Frontier Research Centers (EFRCs) were established in late FY 2009. These multi-investigator, multi-disciplinary centers foster, encourage, and accelerate basic research to provide the basis for transformative energy technologies of the future. There were 46 EFRC awards, 16 with full 5-year support from the American Recovery and Reinvestment Act of 2009. The remaining 30 are funded on an annual basis through this subprogram and the Materials Sciences and Engineering subprogram. The initial 5-year initial award period will end in FY 2014.

The EFRCs are an important research modality, bringing together the skills and talents of a team of investigators to perform energy-relevant, basic research with a scope and complexity beyond that found in standard single-investigator or small-group awards. To help ensure their success, BES provides proactive oversight through regular and frequent interactions with the EFRCs, including meetings with the EFRCs as a group, and formal reviews, highlighted by an early management peer review (FY 2010) and the upcoming mid-term scientific peer reviews in FY 2012. To ensure communication of scientific research advances, technology needs and program directions (to avoid duplication), management of the EFRC research includes coordination with other BES research activities and with the DOE technology offices.

The EFRCs in this activity are focused on the design, discovery, control, and characterization of chemical, biochemical, and geological moieties and processes for the advanced conversion of solar energy into chemical fuels; for improved electrochemical storage of energy; for the creation of next-generation biofuels via catalytic chemistry and biochemistry; for the clean and efficient combustion of advanced transportation fuels; and for science-based carbon capture and geological sequestration. Unifying themes in the research include the fundamental understanding of interfacial phenomena underlying the transport of electrons, atoms, molecules, and energy at the nanoscale and the development and application of new experimental and theoretical tools for molecular-scale understanding of complex chemical, biochemical, and geological processes. Efforts to bridge disciplines, generate new avenues of inquiry, and accelerate research within the broader community include periodic all-hands meetings, joint symposia and workshops, summer schools, tool development, and principal investigators' meetings.

Funding and Activity Schedule

Fiscal Year	Activity	Funding ($000)
FY 2011 Current	The EFRCs continued their planned research activities and addressed Center specific guidance on areas that needed improvement based on the management review held in 2010. To communicate early research progress, the EFRC Summit and Forum was held and attended by over 1,000 people.	42,000
FY 2012 Enacted	Continued support of ongoing research activities. The EFRCs complete their third year of operation in late FY 2012. To date, the 46 EFRCs have produced more than 1,000 peer reviewed publication and more than 90 invention disclosures or patent applications. In January-April 2012, a panel-based peer-review will assess the scientific progress of each EFRC. These reviews will also identify deficiencies and extraordinary performance.	42,000

Fiscal Year	Activity	Funding ($000)
FY 2013 Request	Research will incorporate modifications to research activities and directions resulting from the FY 2012 peer review. Additional funding will be provided to accelerate the transition of novel scientific discoveries from the EFRCs into innovative, prototype clean energy technologies and to improve coordination between fundamental research conducted in the EFRCs and applied research and engineering development supported by EERE.	52,000

Energy Innovation Hubs

Overview

Established in September 2010, the Fuels from Sunlight Hub is designed as a potentially renewable five-year project to bring together a multi-disciplinary, multi-investigator, multi-institutional team to create transformative advances in the development of artificial photosynthetic systems that convert sunlight, water, and carbon dioxide into a range of commercially useful fuels. This Hub, the Joint Center for Artificial Photosynthesis (JCAP), is lead by the California Institute of Technology (Caltech) in primary partnership with Lawrence Berkeley National Laboratory (LBNL). Other partners include the SLAC National Accelerator Laboratory and several University of California institutions. JCAP is composed of internationally-renowned scientists and engineers that seek to integrate decades of community effort in light harvesting and conversion, homogeneous and heterogeneous catalysis, interfacing, membrane and mesoscale assembly, and computational modeling and simulation, with more current research efforts using powerful new tools to examine, understand, and manipulate matter at the nanoscale. By studying the science of scale-up and benchmarking both components (catalysts) and systems (device prototypes), JCAP seeks to accelerate the transition from laboratory discovery to industrial use. As there is currently no direct solar-to-fuels industry in the world, JCAP has the potential for profound environmental and economic impact—establishing U.S. global leadership in renewable energy, reducing our dependence on imported oil, decreasing greenhouse gas emissions, and providing new jobs in an emerging energy technology.

Funding and Activity Schedule

Fiscal Year	Activity	Funding ($000)
FY 2011 Current	JCAP's first year of operation was devoted to project development: establishing research facilities, hiring personnel, setting-up collaborative agreements, and instituting an overall business model. DOE oversight included monthly teleconferences between JCAP management and DOE staff, quarterly and annual written reports, informal site visits, and a reverse-site review accessing JCAP's management and early operations (April 2011). Notably, the DOE external review panel unanimously commented on the imperative need for a Fuels From Sunlight Hub to integrate the various constituents of the solar fuels community and found that JCAP has an ambitious vision and an aggressive strategy to achieve its very challenging goal. All operations at LBNL are housed in a newly renovated, 14,000 square foot laboratory and the renovations of laboratory space for JCAP on the Caltech campus are on schedule. Initial research supported through JCAP includes the synthesis and characterization of earth-abundant semiconductor materials with suitable band gaps for water splitting and carbon dioxide activation; the design of a new high throughput screening system for the preparation and testing up to one million semiconductor formulations per day; and the establishment of parameters for catalyst benchmarking for water splitting and carbon dioxide activation studies that will compare the reactivity and selectivity of catalysts from around the world in the same prototype devices, under the same experimental conditions. Early JCAP research has resulted in several invention disclosures and scientific manuscripts.	22,000

Fiscal Year	Activity	Funding ($000)
FY 2012 Enacted	In FY 2012, renovations of the permanent facility for JCAP on the Caltech campus will be completed and ready for occupancy by all JCAP staff from Caltech and the University of California partners. JCAP staffing will continue to grow toward a steady state of 150–180 scientists and engineers, with an additional 30–50 visitors from the Energy Frontier Research Centers, other DOE Programs, and other countries. The Hub will increase efforts to integrate the solar fuels community through symposia and workshops, tool development, and principal investigators' meetings. In April 2012, an external peer review will assess the scientific and technical progress of the Hub. These reviews will identify any deficiencies as well as areas of extraordinary performance.	24,263
FY 2013 Request	In FY 2013, areas of increased emphasis will include: extensive use of SC leadership class computational facilities and synchrotron light sources for materials design and characterization, the development of scientific scale-up procedures for nanoscale device components, and the establishment of a number of prototype solar-to-fuels devices for component (light harvesters, catalysts, membranes, etc.) testing and optimization. It is expected that FY 2013 will bring extensive collaboration between the external scientific and technical communities and JCAP in order to test and redesign light absorbers and catalysts. It is also expected that there will be significantly increased interactions with and/or licensing to industry in order to develop targeted direct solar fuels technologies.	24,237

General Plant Projects (GPP)

Overview

GPP funding is provided for minor new construction, for other capital alterations and additions, and for improvements to land, buildings, and utility systems principally at the Ames Laboratory and the Combustion Research Facility (CRF) at Sandia National Laboratories. Funding of this type is essential for maintaining the productivity and usefulness of Department-owned facilities and in meeting requirements for safe and reliable facilities operation. The total estimated cost of each GPP project will not exceed $10,000,000.

Funding and Activity Schedule

Fiscal Year	Activity	Funding ($000)
FY 2011 Current	In addition to minor facility improvements at Ames Laboratory, the CRF, and the Notre Dame Radiation Laboratory, funding was provided to Ames for planning of infrastructure upgrades. Funding was also provided for the seismic retrofit of the CRF office building to ensure safe office conditions for the BES-supported researchers.	6,615
FY 2012 Enacted	FY 2012 funding will support minor facility improvements at Ames Laboratory.	200
FY 2013 Request	Funding will support minor infrastructure improvements and upgrades at Ames Laboratory.	2,315

Scientific User Facilities
Funding Profile by Activity

	(Dollars in Thousands)		
	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
Synchrotron Radiation Light Sources	404,225	379,000	438,800
High-Flux Neutron Sources	255,850	249,068	257,694
Nanoscale Science Research Centers (NSRCs)	107,888	102,500	113,500
Other Project Costs	1,500	7,700	24,400
Major Items of Equipment	19,400	73,500	32,000
Research	30,928	24,545	27,000
SBIR/STTR	0	22,714	25,483
Total, Scientific User Facilities	819,791	859,027	918,877

Overview

The Scientific User Facilities subprogram supports the operation of a geographically diverse suite of major facilities that provide thousands of researchers from universities, industry, and government laboratories unique tools to advance a wide range of sciences. These user facilities are operated on an open access, competitive merit review, basis, enabling scientists from every state and of 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 measure structures that are one thousand times smaller than those detectable by the most advanced light microscopes. Thus, to characterize structures with atomic detail, we must use probes such as x-rays, electrons, and neutrons that are at least as small as the atoms being investigated. These large-scale user facilities consist of a complementary set of intense x-ray sources, neutron scattering centers, electron beam characterization capabilities, 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.

Advances in tools and instruments often drive scientific discovery. The continual development and upgrade of the instrumental capabilities include new x-ray and neutron experimental stations, improved core facilities, and new stand-alone instruments. The subprogram also supports research in accelerator and detector development to explore technology options for the next generations of x-ray and neutron sources.

Annually, the BES user facilities are visited by more than 11,000 scientists and engineers in many fields of science and technology. These facilities provide unique capabilities to the scientific community and are a critical component of maintaining U.S. leadership in the physical sciences. Collectively, these user facilities and enabling tools produce 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 offer critical scientific insights for the discovery and design of advanced materials and novel chemical processes with broad societal impacts, from energy applications to information technologies and biopharmaceutical discoveries. The impacts extend from energy-efficient catalysts for clean energy production to spin-based electronics and new drugs for cancer therapy. For approved, peer-reviewed projects, operating time is available without charge to researchers who intend to publish their results in the open literature.

Explanation of Funding Changes

The overarching strategy for this subprogram focuses on maintaining U.S. scientific leadership by ensuring that the BES-supported scientific tools and instrumentation stay at the technological forefront and continue to charter new paths for revolutionary discoveries. The U.S. is a global leader in the photon sciences as reflected in the stellar performance and impacts of the suite of five synchrotron radiation light source facilities supported by BES. These facilities are critical to maintaining the Nation's base of scientific innovations and require sustained support.

The FY 2013 budget request fulfills stewardship responsibilities to ensure the optimal operations and continual upgrades in capabilities. The budget request supports the upgrade of the Advanced Photon Source. FY 2013 will also see the early operations of the National Synchrotron Light Source-II (NSLS-II) in preparation for full operations in FY 2015. Funding will be provided to continue the NSLS-II Experimental Tools (NEXT) project, which will add additional best-in-class beamlines to NSLS-II. The FY 2013 request provides near optimal operations of all facilities.

New collaborative efforts with EERE will also be initiated at BES scientific user facilities to accelerate the transition of novel scientific discoveries into innovative, prototype clean energy technologies. The joint efforts will ensure improved coordination of energy-related research across the Department and be focused on characterization activities aimed at overcoming the underlying physical challenges related to clean energy technology and designing and testing next-generation clean energy devices. Within the user facilities, these efforts will focus on expanding the available experimental toolkit to enable research in this area.

(Dollars in Thousands)

	FY 2012 Enacted	FY 2013 Request	FY 2013 vs. FY 2012
Synchrotron Radiation Light Sources	379,000	438,800	+59,800
Increases in operations funding allow for near optimal hours delivered to users. The National Synchrotron Light Source-II at Brookhaven National Laboratory begins early operations in FY 2013. New activities will be initiated at the facilities through jointly funded R&D with EERE.			
High-Flux Neutron Sources	249,068	257,694	+8,626
Increases in operating funding allow for near optimal hours delivered to users. New capabilities and user capacity will be added at the Spallation Neutron Source at Oak Ridge National Laboratory.			
Nanoscale Science Research Centers (NSRCs)	102,500	113,500	+11,000
Increases in operations funding allow for near optimal hours delivered to users. New activities will be initiated at the facilities through jointly funded R&D with EERE.			
Other Project Costs	7,700	24,400	+16,700
Funding is provided to support other project costs related to NSLS-II construction according to the project profile. The increase supports the preparation for the startup of NSLS-II.			
Major Items of Equipment	73,500	32,000	-41,500
Funding will be provided to ensure continual upgrade of light source capabilities and instruments. The SING-II project final year of funding is FY 2012 (-$11,500,000) and the LCLS-II is included as a construction project in the FY 2013 request (-$30,000,000).			

	(Dollars in Thousands)		
	FY 2012 Enacted	FY 2013 Request	FY 2013 vs. FY 2012
Research	24,545	27,000	+2,455
Increased funding to support accelerator and detector research and the electron beam microcharacterization centers.			
SBIR/STTR	22,714	25,483	+2,769
In FY 2011, $19,417,000 and $2,330,000 were transferred to the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs, respectively. SBIR/STTR funding is set at 2.95% of non-capital funding in FY 2012 and 3.05% in FY 2013.			
Total, Scientific User Facilities	859,027	918,877	+59,850

Synchrotron Radiation Light Sources

Overview

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 synchrotron 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, ceramics, polymers, catalysts, plastics, and biological molecules. The fundamental tenet of materials research is that structure determines function. The practical corollary that converts materials research from an intellectual exercise into a foundation of our modern technology-driven economy is that structure can be manipulated to construct materials with particular desired behaviors. To this end, synchrotron radiation has transformed the role of x-rays as a mainline tool for probing the atomic and electronic structure of materials internally and on their surfaces.

From its first systematic use as an experimental tool in the early 1960s, synchrotron radiation has vastly enhanced the utility of pre-existing and contemporary techniques, such as x-ray diffraction, x-ray spectroscopy, and imaging, and has given rise to scores of new ways to do experiments that would not otherwise be feasible with conventional x-ray machines. Synchrotron radiation is, in the newest facilities, billions of times brighter than the light from conventional x-ray sources. 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 synchrotron radiation the x-ray source of choice for a wide range of materials 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 synchrotron radiation light sources, including four storage ring based light sources—the Advanced Light Source (ALS) at Lawrence Berkeley National Laboratory (LBNL), Advanced Photon Source (APS) at Argonne National Laboratory (ANL), National Synchrotron Light Source (NSLS) at Brookhaven National Laboratory (BNL), Stanford Synchrotron Radiation Lightsource (SSRL), and a Free Electron Laser, the Linac Coherent Light Source (LCLS) at SLAC National Accelerator Laboratory (SLAC). Funds are provided to support facility operations, enable cutting-edge research and technical support and to administer a robust user program at these facilities, which are made available to all researchers with access determined via peer review of user proposals.

Funding and Activity Schedule

Fiscal Year	Activity	Funding ($000)
FY 2011 Current	Funds have been provided to operate the BES synchrotron radiation light sources that are available to thousands of users yearly. Funding is also included for the first full year of operations of the newly completed LCLS.	404,225
FY 2012 Enacted	Funds are provided to support the continued operations of the BES synchrotron radiation light sources. The FY 2012 funding is below the optimal level and will likely impact machine maintenance and user support.	379,000
FY 2013 Request	In FY 2013, funding is requested for the National Synchrotron Light Source-II (NSLS-II) early operations in addition to supporting the operations of the five BES synchrotron radiation light source facilities at near optimal levels.	438,800

Fiscal Year	Activity	Funding ($000)
	New collaborative efforts with EERE will also be initiated at BES light sources to accelerate the transition of novel scientific discoveries into innovative, prototype clean energy technologies. Funding will support procurement of instrumentation dedicated to clean energy research.	

	(Dollars in Thousands)		
	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
Advanced Light Source, LBNL	59,600	62,000	70,000
Advanced Photon Source, ANL	137,175	123,000	134,800
National Synchrotron Light Source, BNL	41,500	36,000	39,500
National Synchrotron Light Source-II, BNL	0	0	22,000
Stanford Synchrotron Radiation Lightsource, SLAC	34,950	34,000	42,000
Linac Coherent Light Source (LCLS), SLAC	131,000	124,000	130,500
Total, Synchrotron Radiation Light Sources	404,225	379,000	438,800

High-Flux Neutron Sources

Overview

The goal of modern materials science is to understand the factors that determine the properties of matter on the atomic scale, and then 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 unthought-of capabilities. Among the different probes used to investigate atomic-scale structure and dynamics in scattering experiments, thermalized neutrons have several unique advantages: they have a wavelength similar to the spacing between atoms for studying structure with atomic resolution, and an energy similar to that of atoms in materials for investigating their 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, so that different chemical sites can be distinguished in isotope substitution experiments, for example in organic and biological materials. They have a suitable magnetic moment for probing magnetism in condensed matter. Finally, their scattering cross-section is precisely measurable on an absolute scale, facilitating straightforward comparison with theory and computer modeling.

One way of generating neutrons is via fission in a research reactor—the High Flux Isotope Reactor (HFIR) at Oak Ridge National Laboratory (ORNL) is this type of neutron source. Another approach is to use an accelerator to generate protons that strike a target made of a heavy metal. As a result of the impact, neutrons are produced in a process known as spallation. Since accelerators are naturally pulsed, the resulting neutron source is also pulsed, enabling a highly efficient use of the neutrons produced in time-of-flight experiments.

The Spallation Neutron Source (SNS) at ORNL is the world's brightest pulsed neutron facility. SNS is in the process of building out the full suite of 18 beamlines to enable scientists to make neutron measurements of greater sensitivity, higher speed, higher resolution, and in more complex sample environments than ever before. HFIR operates at 85 megawatts to provide state-of-the-art facilities for neutron scattering, materials irradiation, and neutron activation analysis and is the world's leading source of elements heavier than plutonium for medical, industrial and research applications. Two of the triple-axis spectrometers for studying the dynamics of a wide range of materials, and two small-angle scattering spectrometers at the recently installed liquid-hydrogen cold source for measuring structures of condensed matter and biological materials on nm-µm length scales provides are best in their class world-wide. The Lujan Center, a pulsed spallation source operating at about 100 kW, supports a target hall constructed by SC and instruments fabricated by SC and NNSA that address the needs of both the basic research community and the NNSA mission of science-based stockpile stewardship.

Funding and Activity Schedule

Fiscal Year	Activity	Funding ($000)
FY 2011 Current	Funding was provided to support the operations of the three BES neutron scattering facilities. All three have seen a continuing growth in scientific productivity and users. FY 2011 was the first full year of operation of the diffractometer for studying the structure of nanoscale-disordered materials (built at SNS under the SING-I project).	255,850
FY 2012 Enacted	Funding is provided to support the operations of the three BES neutron scattering facilities. The funding will support the operations of additional instruments that are coming online at the SNS. FY 2012 will be the first full year of operation of a new chemical spectrometer for measuring excitations in single crystals, the last instrument built at SNS under the SING-I project. The FY 2012 funding is below the optimal level and will likely impact machine maintenance and user support.	249,068

Fiscal Year	Activity	Funding ($000)
FY 2013 Request	Additional funding is requested to provide near optimal support for user operations. This will be the first full year of operation of the new chemical spectrometer instrument at SNS.	257,694

	(Dollars in Thousands)		
	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
Spallation Neutron Source, ORNL	181,300	180,568	187,194
High Flux Isotope Reactor, ORNL	60,200	58,000	60,000
Intense Pulsed Neutron Source, ANL	3,000	0	0
Lujan Neutron Scattering Center, LANL	11,350	10,500	10,500
Total, High-Flux Neutron Sources	255,850	249,068	257,694

Nanoscale Science Research Centers (NSRCs)

Overview

Nanoscience is the study of materials and their behaviors at the nanometer (nm) scale—probing single atoms, clusters of atoms, and molecular structures. The scientific quest is to design, observe, and understand how these systems function, including how they interact with their environment. Developments at the nanoscale have the potential to make major contributions to delivering remarkable scientific discoveries that transform our understanding of energy and matter and advance the national, economic, and energy security.

The NSRCs are DOE's premier user centers for interdisciplinary research at the nanoscale, serving as the basis for a national program that encompasses new science, new tools, and new computing capabilities. The five NSRCs are: Center for Nanoscale Materials at Argonne National Laboratory (ANL), Center for Functional Nanomaterials at Brookhaven National Laboratory (BNL), Molecular Foundry at Lawrence Berkeley National Laboratory (LBNL), Center for Nanophase Materials Sciences at Oak Ridge National Laboratory (ORNL), and Center for Integrated Nanotechnologies at Sandia National Laboratories and Los Alamos National Laboratory (SNL/LANL). Each center has particular expertise and capabilities in selected theme areas, such as synthesis and characterization of nanomaterials; catalysis; theory, modeling and simulation; electronic materials; nanoscale photonics; soft and biological materials; imaging and spectroscopy; and nanoscale integration. The centers are housed in custom-designed laboratory buildings near one or more other major BES facilities for x-ray, neutron, or electron scattering, which complement and leverage the capabilities of the NSRCs. These laboratories contain clean rooms, nanofabrication resources, one-of-a-kind signature instruments, and other instruments not generally available except at major user facilities. Operating funds are provided to enable cutting-edge research and technical support and to administer a robust user program at these facilities, which are made available to all researchers with access determined via external peer review of user proposals.

Funding and Activity Schedule

Fiscal Year	Activity	Funding ($000)
FY 2011 Current	Funding supported continued operations of the five NSRCs, which are routinely available to users during normal operating hours. Funding also supported capital equipment for nanofabrication and characterization, and computer modeling.	107,888
FY 2012 Enacted	In FY 2012, funding is provided to support the user operations and new synthesis and characterization capabilities through techniques development and procurement of new equipment. The goal is to sustain and further develop a robust user program with high scientific and technological impacts at each of the NSRCs. The FY 2012 funding is below the optimal level and will likely impact maintenance and user support.	102,500
FY 2013 Request	An increase in funding is requested to support near optimal operations of the five NSRCs. Continued emphasis will be on developing world leadership in key nanoscale science thrust areas via advancing the state-of-the-art in nanoscale synthesis and characterization tools and in corresponding theory, modeling, and simulation research. The NSRCs will continue to cultivate and expand its user base from universities, national laboratories, and industry. New collaborative efforts with EERE will also be initiated at the NSRCs to accelerate the transition of novel scientific discoveries into innovative, prototype clean energy technologies. Funding will support procurement of instrumentation dedicated to clean energy research.	113,500

	(Dollars in Thousands)		
	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
Center for Nanoscale Materials, ANL	22,047	20,500	22,700
Center for Functional Nanomaterials, BNL	20,471	20,000	22,700
Molecular Foundry, LBNL	22,313	20,500	22,700
Center for Nanophase Materials Sciences, ORNL	21,758	20,500	22,700
Center for Integrated Nanotechnologies, SNL/LANL	21,299	21,000	22,700
Total, Nanoscale Science Research Centers (NSRCs)	107,888	102,500	113,500

Other Project Costs

Overview

The Total Project Cost (TPC) of DOE's construction or major instrumentation projects comprises two major components—the Total Estimated Cost (TEC) and the Other Project Cost (OPC). The TEC includes project costs incurred after Critical Decision-1, such as costs associated with all engineering design and inspection, the acquisition of land and land rights; direct and indirect construction/fabrication; and 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. OPCs are all other costs related to the projects that are not included in the TEC. Generally, OPC are costs incurred during the project's initiation and definition phase for planning, conceptual design, research, and development, and during the execution phase for research and development, startup, and commissioning. OPC are always funded via operating funds.

Funding and Activity Schedule

Fiscal Year	Activity	Funding ($000)
FY 2011 Current	Funds were provided in FY 2011 for other project costs associated with the National Synchrotron Light Source-II (NSLS-II) at BNL.	1,500
FY 2012 Enacted	Funds are provided in FY 2012 for other project costs associated with the NSLS-II at BNL.	7,700
FY 2013 Request	Funds are requested in FY 2013 for other project costs associated with the NSLS-II at BNL according to the project plan. The increase supports the preparation for the startup of NSLS-II.	24,400

Major Items of Equipment

Overview

BES supports major item of equipment (MIE) projects to ensure the continual development and upgrade of major scientific instrument capabilities, including new x-ray and neutron experimental stations, improve core facilities, and provide new stand-alone instruments. In general, each MIE greater than $5,000,000 in total project cost and all line item construction projects are required to follow the DOE Project Management Order 413.3B, which requires formal reviews to obtain critical decisions that advance the development stages of a project. Additional reviews may be required depending on the complexity and needs of the projects in question. BES MIE projects are in two main categories:

Synchrotron Radiation Light Sources

The Advanced Photon Source Upgrade (APS-U) MIE supports activities to design, build, install, and test the equipment necessary to upgrade an existing third-generation synchrotron light source facility, the Advanced Photon Source (APS). The APS is one of the Nation's most productive x-ray light source facilities, serving over 3,500 users annually and providing key capabilities to enable forefront scientific research in a broad range of fields of physical and biological sciences. The APS is the only hard x-ray GeV source in the U.S. and, along with the ESRF in France and Spring-8 in Japan, is only one of three in the world. The high energy penetrating x-ray is especially critical for probing materials under real working environments, such as a battery or fuel cell in action. Both foreign facilities, commissioned at about the same time as the APS, are well into campaigns of major upgrades due to aging of beamlines as well as technological advancements in accelerator science. With the ever increasing demand for higher penetration power for probing real-world materials and applications, the higher energy hard x-rays (20 keV and above) produced at APS provide unique capabilities in the U.S. arsenal needed for tackling the grand science and energy challenges of the 21st century. The APS-U Project will upgrade the existing APS to provide an unprecedented combination of high-energy, high-average-brilliance, high flux, and short-pulse hard x-rays together with state-of-the-art x-ray beamline instrumentation. The APS-U's high-energy penetrating x-rays will provide a unique scientific capability directly relevant to problems in energy, the environment, new or improved materials, and biological studies. The upgraded APS will complement the capabilities of the 4th generation light sources (e.g., Linac Coherent Light Source (LCLS)), which occupy different spectral, flux, and temporal range of technical specifications. The project is managed by Argonne National Laboratory. The LCLS facility, commissioned in April 2009, has been a success, from conception to construction, and into operation. This success has prompted the LCLS-II Project, which is to expand the x-ray spectral operating range and the user capacity. The LCLS-II is supported as an MIE in FY 2012 and will be funded as a construction project starting in FY 2013. The change in funding mode was informed and validated by a pre-CD-1 Lehman review in FY 2011. The NSLS-II Experimental Tools (NEXT) MIE supports activities to add beamlines to the National Synchrotron Light Source-II (NSLS-II) Project. The NEXT project will provide NSLS-II with complementary "best-in-class" beamlines that support the identified needs of the U.S. research community and the DOE energy mission. Implementation of this state-of-the-art instrumentation will significantly increase the scientific quality and productivity of NSLS-II. In addition, the NEXT project will enable and enhance more efficient operations of NSLS-II. The project is managed by Brookhaven National Laboratory.

High Flux Neutron Sources

The Spallation Neutron Source Instrumentation Next Generation-II (SING-II) MIE provides funding to fabricate four instruments, competitively selected using a peer review process, to be installed at the SNS. The project has an approved CD-2 Performance Baseline Total Project Cost of $60,000,000 and will complete the installation of these instruments on a phased schedule between FY 2012 and FY 2014. The SING-II instruments are in addition to the five instruments to be provided by the SING-I project.

Funding and Activity Schedule

Fiscal Year	Activity	Funding ($000)
FY 2011 Current	After receiving Critical Decision-0 (CD-0) Approve Mission Need in FY 2010, the APS-U completed conceptual design and received CD-1 approval during the 4th quarter of FY 2011. Similarly, the LCLS-II and the NEXT projects also achieved CD-0 in FY 2010. The SNS PUP was placed on indefinite hold after a Critical Decision-2 (CD-2) readiness review, which showed significant projected growth in cost and schedule. The Spallation Neutron Source Instrumentation Next Generation (SING-I) project successfully completed and was transitioned to operations for commissioning. SING-II achieved Critical Decision 3 (CD-3) Approve Start of Construction, and began its construction phase for the fourth and final instrument in the project.	19,400
FY 2012 Enacted	The APS-U project will enter the preliminary design phase post CD-1 and will begin preparations to seek approvals for CD-2, which establishes the project baselines, and CD-3A, which authorizes long lead procurements. After receiving CD-1 approval during the 1st quarter of FY 2012, LCLS-II will work on design, in-house fabrication, long lead procurement, construction of an annex building, exploration and design of the two-tunnel option, and project management. While LCLS-II is supported as an MIE in FY 2012, it will be funded as a construction project starting in FY 2013. The NEXT project achieved CD-1 in early 2012, which provides an alternative selection and cost range for this project. SING-II will receive its last year of funding and is scheduled to complete and start operations of its first instrument, the Vibrational Spectrometer (VISION).	73,500
FY 2013 Request	APS-U and NEXT will continue design work and early procurements during FY 2013 and work toward achieving CD-3 approvals during FY 2013 and begin construction/fabrication of the technical scope. SING-II will be continuing fabrication of the neutron scattering instruments during FY 2013 with the possibility of an early finish for one or more. LCLS-II is included as a construction project in the FY 2013 request.	32,000

(Dollars in Thousands)

	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
Spallation Neutron Source Instrumentation I (SING I)	400	0	0
Spallation Neutron Source Instrumentation II (SING II)	17,000	11,500	0
SNS Power Upgrade (PUP)	2,000	0	0
Advanced Photon Source Upgrade (APS-U)	0	20,000	20,000
Linac Coherent Light Source-II (LCLS-II)	0	30,000	0[a]
NSLS-II Experimental Tools (NEXT)	0	12,000	12,000
Total, Major Items of Equipment	19,400	73,500	32,000

[a] LCLS-II is moved to line item construction in the FY 2013 request.

Research

Overview

This activity supports three electron-beam microcharacterization centers, which operate as user facilities for scientific research and a platform for development of next-generation electron-beam instrumentation. These facilities provide unsurpassed spatial resolution and the ability to simultaneously obtain structural, chemical, and other types of information from sub-nanometer regions. These capabilities allow study of the fundamental mechanisms of catalysis, energy conversion, corrosion, charge transfer, magnetic behavior, and many other processes. All of these are fundamental to understanding and improving materials for energy applications and the associated physical characteristics and changes that govern performance. These centers are the Electron Microscopy Center for Materials Research at Argonne National Laboratory (ANL), the National Center for Electron Microscopy at Lawrence Berkeley National Laboratory (LBNL), and the Shared Research Equipment user facility at Oak Ridge National Laboratory (ORNL).

This activity also supports basic research in accelerator physics and x-ray and neutron detectors. Accelerator research is the cornerstone for the development of new technologies that will improve performance of accelerator-based light sources and neutron spallation facilities. Research areas include ultrashort (attosecond) free electron lasers (FEL), new seeding techniques and other optical manipulation to reduce the cost and complexity and improve performance of next generation FELs, and very high frequency laser photocathodes that can influence the design of linac-based FELs with high repetition rates. Detector research is a crucial, but often overlooked, component in the optimal utilization of user facilities. The emphasis of this activity is on research leading to a new and more efficient generation of photon and neutron detectors. Research includes studies on creating, manipulating, transporting, and performing diagnostics of ultrahigh brightness beams.

Funding and Activity Schedule

Fiscal Year	Activity	Funding ($000)
FY 2011 Current	Funding supports the continued operations of the three electron beam microcharacterization centers, which are routinely available to users during normal operating hours. One key emphasis is on developing in situ techniques to characterize materials and correlate their microstructure with their mechanical and electrochemical behaviors. The accelerator physics and detector research supports development of high-current, high-gradient superconducting accelerating structures that design and test of radio frequency injectors capable of operating at high frequencies and delivering small-area beams, required by future light sources; studies of properties of cathode materials and factors that limit cathode lifetime; and several detector developments, from silicon to germanium and from stripline to 3-D detectors that emphasize high throughput and precision.	30,928
FY 2012 Enacted	In FY 2012, funding is provided to support operations of the three electron beam microcharacterization centers and their corresponding user programs. FY 2012 funding is below the optimal level with likely impact on machine maintenance and user support. Triennial reviews of centers will be conducted in FY 2012 to assess the facility performance, user operations, and the scientific output and impact. Accelerator physics and detector research will continue to be supported at a reduced level. Research in developing superconducting accelerating cavities and cathode development will be reduced. Support will be continued for the development of “smart” detectors, with concurrent signal processing capabilities, and solid state detectors optimized for next generation soft x-rays sources.	24,545

Fiscal Year	Activity	Funding ($000)
FY 2013 Request	Funding will be provided to support optimal operations of the three electron beam microcharacterization centers. The emphasis will be on maintaining a robust user program at the three user facilities. The outcomes of the FY 2012 triennial reviews will be used to inform funding decisions and guide program development at the three centers. The accelerator physics and detector research will maintain a balanced portfolio that continue to push the frontiers in accelerator research in the generation of high-brightness electron beams, ultra-short x-ray pulses, of the order of sub-picoseconds and attoseconds, necessary for the exploration of the atomic structure of matter, and on the development of ultra-fast and high-precision detectors, demanded by the high-flux, high-repetition rate of future light sources and neutron scattering facilities.	27,000

(Dollars in Thousands)

	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
Electron-Beam Microcharacterization	11,587	11,000	12,000
Accelerator and Detector Research	19,341	13,545	15,000
Total, Research	30,928	24,545	27,000

Construction
Funding Profile by Activity

	(Dollars in Thousands)		
	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
Linac Coherent Light Source-II (LCLS-II), SLAC	0	0	63,500
National Synchrotron Light Source-II (NSLS-II), BNL	151,297	151,400	47,203
Total, Construction	151,297	151,400	110,703

Overview

Experiments in support of basic research require construction of state-of-the-art facilities and/or that existing facilities be upgraded to meet unique research requirements. Reactors, x-ray light sources, and pulsed neutron sources are among the expensive, but necessary, facilities required to support critical DOE science missions.

The new facilities that are currently under construction—the National Synchrotron Light Source-II (NSLS-II) and the Linac Coherent Light Source-II (LCLS-II)—continue the tradition of BES and SC providing the most advanced scientific user facilities for the Nation's research community in the most cost effective way. All BES construction projects are conceived and planned with the broad user community and, during construction, are executed on schedule and within cost. Furthermore, the construction projects all adhere to the highest standards of safety. These facilities provide the research community with the tools to fabricate, characterize, and develop new materials and chemical processes to advance basic and applied research across the full range of scientific and technological endeavor, including chemistry, physics, earth science, materials science, environmental science, biology, and biomedical science.

Performance will be measured by meeting the cost and schedule within 10% of the performance baseline established at Critical Decision 2, Approve Performance Baseline, and reproduced in the construction project data sheet.

Explanation of Funding Changes

	(Dollars in Thousands)		
	FY 2012 Enacted	FY 2013 Request	FY 2013 vs. FY 2012
Linac Coherent Light Source-II (LCLS-II)	0	63,500	+63,500
Funding is provided for PED and civil construction. LCLS-II was funded as a major item of equipment in FY 2012.			
National Synchrotron Light Source-II (NSLS-II)	151,400	47,203	-104,197
Funding for the civil construction will be ramped down, as scheduled.			
Total, Construction	151,400	110,703	-40,697

Supporting Information

Operating Expenses, Capital Equipment and Construction Summary

	(Dollars in Thousands)		
	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
Operating Expenses	1,366,819	1,447,493	1,603,205
Capital Equipment	89,765	73,500	58,000
General Plant Projects	11,375	200	7,315
Accelerator Improvement Projects	19,255	15,500	20,369
Construction	151,297	151,400	110,703
Total, Basic Energy Sciences	1,638,511	1,688,093	1,799,592

Funding Summary

	(Dollars in Thousands)		
	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
Research	691,736	682,026	771,282
Scientific User Facilities Operations	767,963	730,568	809,994
Major Items of Equipment	19,400	73,500	32,000
Construction Projects (includes OPC)	152,797	159,100	135,103
Other	6,615	42,899	51,213
Total, Basic Energy Sciences	1,638,511	1,688,093	1,799,592

Scientific User Facility Operations

	(Dollars in Thousands)		
	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
Synchrotron Radiation Light Source User Facilities			
Advanced Light Source, LBNL	59,600	62,000	70,000
Advanced Photon Source, ANL	137,175	123,000	134,800
National Synchrotron Light Source, BNL	41,500	36,000	39,500
National Synchrotron Light Source-II, BNL	0	0	22,000
Stanford Synchrotron Radiation Lightsource, SLAC	34,950	34,000	42,000
Linac Coherent Light Source (LCLS), SLAC	131,000	124,000	130,500
Total, Light Sources User Facilities	404,225	379,000	438,800

(Dollars in Thousands)

	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
High-Flux Neutron Source User Facilities			
Spallation Neutron Source, ORNL	181,300	180,568	187,194
High Flux Isotope Reactor, ORNL	60,200	58,000	60,000
Intense Pulsed Neutron Source, ANL	3,000	0	0
Lujan Neutron Scattering Center, LANL	11,350	10,500	10,500
Total, Neutron Source User Facilities	255,850	249,068	257,694
Nanoscale Science Research Center User Facilities			
Center for Nanoscale Materials, ANL	22,047	20,500	22,700
Center for Functional Nanomaterials, BNL	20,471	20,000	22,700
Molecular Foundry, LBNL	22,313	20,500	22,700
Center for Nanophase Materials Sciences, ORNL	21,758	20,500	22,700
Center for Integrated Nanotechnologies, SNL/LANL	21,299	21,000	22,700
Total, Nanoscale Science Research Center User Facilities	107,888	102,500	113,500
Total, Scientific User Facility Operations	767,963	730,568	809,994

Facilities Users and Hours

	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
Advanced Light Source			
Achieved Operating Hours	4,916	N/A	N/A
Planned Operating Hours	4,700	4,800	5,200
Optimal Hours	5,600	5,600	5,600
Percent of Optimal Hours	88%	86%	93%
Unscheduled Downtime	<10%	<10%	<10%
Number of Users	1,931	1,900	2,100
Advanced Photon Source			
Achieved Operating Hours	4,906	N/A	N/A
Planned Operating Hours	5,000	5,000	4,800
Optimal Hours	5,000	5,000	5,000
Percent of Optimal Hours	98%	100%	96%
Unscheduled Downtime	<10%	<10%	<10%
Number of Users	3,986	3,800	3,700

	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
National Synchrotron Light Source			
Achieved Operating Hours	5,885	N/A	N/A
Planned Operating Hours	5,400	4,800	5,300
Optimal Hours	5,400	5,400	5,400
Percent of Optimal Hours	109%	89%	98%
Unscheduled Downtime	<10%	<10%	<10%
Number of Users	2,313	2,000	2,200
Stanford Synchrotron Radiation Lightsource			
Achieved Operating Hours	4,775	N/A	N/A
Planned Operating Hours	4,900	5,200	5,200
Optimal Hours	5,400	5,400	5,400
Percent of Optimal Hours	88%	96%	96%
Unscheduled Downtime	<10%	<10%	<10%
Number of Users	1,515	1,500	1,500
Linac Coherent Light Source			
Achieved Operating Hours	3,925	N/A	N/A
Planned Operating Hours	4,100	4,300	4,200
Optimal Hours	4,500	4,500	4,300
Percent of Optimal Hours	87%	96%	98%
Unscheduled Downtime	<10%	<10%	<10%
Number of Users	516	500	450
High Flux Isotope Reactor			
Achieved Operating Hours	4,268	N/A	N/A
Planned Operating Hours	4,000	3,500	4,300
Optimal Hours	4,500	4,500	4,500
Percent of Optimal Hours	95%	78%	96%
Unscheduled Downtime	<10%	<10%	<10%
Number of Users	477	340	450

	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
Lujan Neutron Scattering Center			
Achieved Operating Hours	2,691	N/A	N/A
Planned Operating Hours	3,000	3,000	3,000
Optimal Hours	3,600	3,600	3,600
Percent of Optimal Hours	75%	83%	83%
Unscheduled Downtime	<10%	<10%	<10%
Number of Users	308	300	300
Spallation Neutron Source			
Achieved Operating Hours	5,000	N/A	N/A
Planned Operating Hours	4,900	4,500	4,600
Optimal Hours	4,900	4,900	4,900
Percent of Optimal Hours	102%	92%	94%
Unscheduled Downtime	<10%	<10%	<10%
Number of Users	890	780	830
Center for Nanoscale Materials[a]			
Number of Users	368	350	350
Center for Functional Nanomaterials[a]			
Number of Users	363	340	350
Molecular Foundry[a]			
Number of Users	327	300	350
Center for Nanophase Materials Sciences[a]			
Number of Users	374	350	350
Center for Integrated Nanotechnologies[a]			
Number of Users	348	340	350

[a] Facility operating hours are not measured at user facilities that do not rely on one central machine.

	FY 2011 Current	FY 2012 Enacted	FY 2013 Request
Total, All Facilities			
Achieved Operating Hours	36,366	N/A	N/A
Planned Operating Hours	36,000	35,100	36,600
Optimal Hours	38,900	38,900	38,700
Percent of Optimal Hours	96%	92%	96%
Unscheduled Downtime	<10%	<10%	<10%
Number of Users	13,716	12,800	13,280

Major Items of Equipment

(Dollars in Thousands)

	Prior Years	FY 2011 Current	FY 2012 Enacted	FY 2013 Request	Outyears	Total	Completion
Spallation Neutron Source Instrumentation-I, ORNL (TEC/TPC)	68,100	400	0	0	0	68,500	4Q FY 2011
Spallation Neutron Source Instrumentation-II, ORNL (TEC/TPC)	31,500	17,000	11,500	0	0	60,000	4Q FY 2014
SNS Power Upgrade Project , ORNL (TEC/TPC)	2,000	2,000	0	0	0	N/A [a]	N/A
Advanced Photon Source Upgrade (APS-U), ANL (TEC/TPC)	0	0	20,000	20,000	348,500	388,500	3Q FY 2020
Linac Coherent Light Source-II (LCLS-II), SLAC (TEC/TPC)	0	0	30,000	0 [b]	0 [b]	N/A [b]	N/A
NSLS-II Experimental Tools (NEXT), BNL (TEC/TPC)	0	0	12,000	12,000	66,000	90,000	4Q FY 2017
Total, Major Items of Equipment (TEC/TPC)		19,400	73,500	32,000			

[a] Project is terminated.

[b] LCLS-II is requested as a line item construction project in FY 2013. The TEC/TPC totals under construction include the FY 2012 funding that was requested as an MIE.

Construction Projects

(Dollars in Thousands)

	Prior Years	FY 2011 Current	FY 2012 Enacted	FY 2013 Request	Outyears	Total	Completion
13-SC-10, Linac Coherent Light Source-II (LCLS-II), SLAC							
TEC	0	0	0[a]	63,500	299,500	385,000[a]	4Q FY 2019[b]
OPC	1,126	9,474	0[a]	0	1,400	20,000[a]	
TPC	1,126	9,474	0[a]	63,500	300,900	405,000[a]	
07-SC-06, National Synchrotron Light Source-II, BNL							
TEC	415,000	151,297	151,400	47,203	26,300	791,200	3Q FY 2015
OPC	59,800	1,500	7,700	24,400	27,400	120,800	
TPC	474,800	152,797	159,100	71,603	53,700	912,000	
Total, Construction							
TEC		151,297	151,400	110,703			
OPC		10,974	7,700	24,400			
TPC		162,271	159,100	135,103			

Scientific Employment

	FY 2011 Actual	FY 2012 Estimate	FY 2013 Estimate
# of University Grants	1,100	1,060	1,170
Average Size per year	230,000	230,000	230,000
# Permanent Ph.D's (FTEs)	4,860	4,660	5,260
# Postdoctoral Associates (FTEs)	1,360	1,310	1,480
# Graduate Students (FTEs)	2,140	2,060	2,330

[a] $30,000,000 was requested in FY 2012 as an MIE. This funding is included within the total TPC ($22,000,000 as TEC and $8,000,000 as OPC).
[b] Estimate Only. Project has not been baselined.

13-SC-10, Linac Coherent Light Source-II
SLAC National Accelerator Laboratory, Menlo Park, California
Project Data Sheet is for PED/Construction

1. Significant Changes

This project data sheet is the first submitted for Linac Coherent Light Source-II (LCLS-II) as a line item construction project. LCLS-II was proposed as a Major Item of Equipment (MIE) project in the FY 2012 Budget Request to Congress. However, as part of the conceptual design for CD-1, an alternatives analysis identified another option for the project that better meets SC mission objectives. This alternative requires extensive conventional construction activities, which are not suitable for an MIE project. As a result, the FY 2013 request proposes to convert the LCLS-II project into a line item construction project. FY 2012 funding will be used for design, in-house fabrication, long lead procurement, construction of an annex building, exploration and design of the two-tunnel option, and project management.

The most recent DOE O 413.3B approved Critical Decision, CD-1 (Approve Alternative Selection and Cost Range), was approved on October 14, 2011. The estimated preliminary Total Project Cost (TPC) range for this project is $350,000,000–$500,000,000. CD-0 (Approve Mission Need) was approved on April 22, 2010. SC's Office of Project Assessment (OPA) reviewed the project request for CD-3A (Approve Long-Lead Procurements) on December 6–7, 2011, and the review recommended approval.

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

2. Critical Decision (CD) and D&D Schedule

	CD-0	CD-1	PED Complete	CD-2	CD-3a	CD-3b	CD-4	D&D Start	D&D Complete
FY 2013	4/22/2010	10/14/2011	4QFY2016[a]	1QFY2013[a]	3QFY2012[a]	3QFY2013[a]	4QFY2019[a]	N/A	N/A

CD-0 – Approve Mission Need
CD-1 – Approve Alternative Selection and Cost Range
CD-2 – Approve Performance Baseline
CD-3a – Approve Long-Lead Procurements
CD-3b – Approve Start of Construction
CD-4 – Approve Start of Operations or Project Closeout

3. Baseline and Validation Status

(Dollars in Thousands)

	TEC, PED	TEC, Construction	TEC, Total	OPC, Except D&D	OPC, D&D	OPC, Total	TPC
FY 2013	18,000[b]	367,000[b]	385,000[b]	20,000[b]	0	20,000[b]	405,000[b c]

[a] This project is pre-CD-2; the estimated schedule is preliminary. Construction funds will not be executed without appropriate CD approvals.
[b] This project has not yet received CD-2 approval; funding estimates are preliminary. The preliminary TPC range for this project is $350,000,000–$500,000,000.
[c] The project was included in the FY 2012 Congressional Request as an MIE with a CD-0 cost range of $300,000,000–$400,000,000.

4. Project Description, Scope and Justification

Mission Need

The LCLS-II project's purpose is to expand the x-ray spectral operating range and capacity of the existing Linac Coherent Light Source Facility, which provides coherent laser-like radiation in the 500–9,000 eV photon energy range, 10 billion times greater in peak brightness than any existing x-ray light source. This advance in brightness is similar to that of a synchrotron over a 1960s laboratory x-ray tube. Synchrotrons revolutionized science across disciplines ranging from atomic physics to structural biology. Advances from the LCLS are expected to be equally dramatic. The LCLS facility has convincingly demonstrated that it is a unique tool for transformational science. It has exceeded its initial performance goals in the 1.5–15 Angstrom range and the extraordinary high-brightness x-rays are being utilized on an initial set of scientific problems. It is the world's first such facility.

Scope and Justification for 13-SC-10 Linac Coherent Light Source II

LCLS is based on the existing SLAC linac. The linac was designed to accelerate electrons and positrons to 50 GeV for colliding beam experiments and for nuclear and high energy physics experiments on fixed targets. At present, the last third of the 3 kilometer linac is being used to operate the LCLS facility, and the first 2 kilometers are used for advanced accelerator research. When the LCLS-II is complete, the second kilometer of the linac will be used to produce high-brightness (13.5 GeV) electron bunches at a 120 hertz repetition rate. These electron bunches will be sent to a new undulator tunnel to produce two x-ray beams. The new soft x-ray (SXR) and hard x-ray (HXR) beams will span the tunable photon energy range beyond the existing LCLS facility. The new LCLS-II facilities will largely operate independently of the existing LCLS facility. When traveling through one of the new LCLS-II undulators, the electron bunches will amplify the emitted x-ray radiation to produce an intense, coherent (laser-like) x-ray beam for scientific research. At the completion of the LCLS-II project, the LCLS facility will operate two independent electron linacs and three independent x-ray sources, supporting up to ten experiment stations.

LCLS used technologies developed at SLAC over many years of operation, as well as the world's brightest source of intense electron beams, producing extraordinary x-rays. SLAC's advances in the creation, compression, transport, and monitoring of bright electron beams have spawned a new generation of x-ray synchrotron radiation sources based on linear accelerators rather than on storage rings.

The LCLS produces a high-brightness x-ray beam with properties vastly exceeding those of current x-ray sources in three key areas: peak brightness, coherence, and ultrashort pulses. The peak brightness of the LCLS is 10 billion times greater than current synchrotrons, providing 10^{11} x-ray photons in a pulse with duration in the range 3–500 femtoseconds. These characteristics of the LCLS have opened new realms of research in the chemical, material, and biological sciences.

The LCLS-II project will construct a new 135 MeV injector to be installed at Sector 10 of the SLAC linac to create the electron beam required for an x-ray free-electron laser. This electron beam will be extracted from the linac near Sector 20, just upstream of the existing LCLS injector. The new electron beam will be transported in sectors 21–30 of the linac in a "bypass line," originally built for the PEP-II B-Factory. Sectors 11–20 of the linac will be modified by adding two magnetic bunch compressors and the magnets guiding the electrons from the linac to the bypass line. Most of the existing linac and its infrastructure will remain unchanged.

The existing LCLS Beam Transport Hall will be expanded and extended to connect to the new undulator hall. This new hall will house the new SXR and HXR sources, electron beam dumps, and x-ray optics. The new Experimental Hall will be constructed for the exploitation of the new x-ray sources.

The combined characteristics (spectral content, peak power, pulse duration, and coherence) of the new SXR and HXR sources will surpass the present capabilities of the LCLS beam in spectral tuning range and brightness. Experience with LCLS has, for the first time, provided data on performance of the x-ray instrumentation and optics required for scientific experiments with the LCLS. The LCLS-II Project will take advantage of this knowledge base to design LCLS-II x-ray transport, optics, and diagnostics matched to the characteristics of these sources. The LCLS-II project scope includes a comprehensive suite of instrumentation for characterization of the x-ray sources. Also included in the scope of the LCLS-II project are basic instrumentation and infrastructure necessary to support research at the LCLS.

Funding for conceptual design in FY 2011 supported the creation of a facility concept which has been reviewed and approved by DOE. The project will initiate engineering design and long lead procurements in FY 2012. FY 2013 funding will continue long lead procurements, design, and start of construction.

Key Performance Parameters

The key performance parameters the LCLS-II project must fulfill to achieve CD-4 Project Completion are listed below. These parameters are the minimum acceptable level of performance to mark the end of the project phase and do not represent the final or ultimate performance to be achieved by the upgrade. It is anticipated that during operations following the project completion that most of the technical parameters below will be exceeded. These parameters are preliminary, pre-baseline values. The final key parameters will be established as part of CD-2 Performance Baseline.

Preliminary Key Parameters	Performance
Electron Beam Energy	12.0 GeV
Photon Beam Tuning Range	800-8,000 eV
Additional Space for Instruments	4 Experiment Stations
Facilities Gross Square Feet	>30,000 GSF

5. Financial Schedule

	(Dollars in Thousands)		
	Appropriations	Obligations	Costs
Total Estimated Cost (TEC)			
PED			
FY 2012	2,000[a]	2,000	1,800
FY 2013	5,000	5,000	5,100
FY 2014	4,000	4,000	4,000
FY 2015	4,000	4,000	4,000
FY 2016	3,000	3,000	3,100
Total, PED	18,000[b]	18,000[b]	18,000[b]

[a] FY 2012 funding was requested as an MIE. FY 2012 funding will be used for design and long lead procurement.

[b] This project has not yet received CD-2 approval; funding estimates are preliminary. The preliminary TPC range for this project is $350,000,000–$500,000,000.

(Dollars in Thousands)

	Appropriations	Obligations	Costs
Construction			
FY 2012	20,000[a]	20,000	14,200
FY 2013	58,500	58,500	58,050
FY 2014	76,300	76,300	75,200
FY 2015	90,000	90,000	91,400
FY 2016	102,300	102,300	90,800
FY 2017	19,900	19,900	32,150
FY 2018	0	0	5,200
Total, Construction	367,000[b]	367,000[b]	367,000[b]
TEC			
FY 2012	22,000[a]	22,000	16,000
FY 2013	63,500	63,500	63,150
FY 2014	80,300	80,300	79,200
FY 2015	94,000	94,000	95,400
FY 2016	105,300	105,300	93,900
FY 2017	19,900	19,900	32,150
FY 2018	0	0	5,200
Total, TEC[b]	385,000[b]	385,000[b]	385,000[b]

[a] FY 2012 funding was requested as an MIE. FY 2012 funding will be used for design and long lead procurement.
[b] This project has not yet received CD-2 approval; funding estimates are preliminary. The preliminary TPC range for this project is $350,000,000–$500,000,000.

	(Dollars in Thousands)		
	Appropriations	Obligations	Costs
Other Project Cost (OPC)			
OPC except D&D			
FY 2010	1,126	1,126	1,126
FY 2011	9,474	9,474	6,799
FY 2012	8,000[a]	8,000	9,875
FY 2013	0	0	800
FY 2014	700	700	500
FY 2015	0	0	200
FY 2016	700	700	500
FY 2017	0	0	200
Total, OPC	20,000[b]	20,000[b]	20,000[b]

Total Project Cost (TPC)			
FY 2010	1,126	1,126	1,126
FY 2011	9,474	9,474	6,799
FY 2012	30,000	30,000	25,875
FY 2013	63,500	63,500	63,950
FY 2014	81,000	81,000	79,700
FY 2015	94,000	94,000	95,600
FY 2016	106,000	106,000	94,400
FY 2017	19,900	19,900	32,350
FY 2018	0	0	5,200
Total, TPC[b]	405,000	405,000	405,000

[a] FY 2012 funding was requested as an MIE. FY 2012 funding will be used for design and long lead procurement.

[b] This project has not yet received CD-2 approval; funding estimates are preliminary. The preliminary TPC range for this project is $350,000,000–$500,000,000.

6. Details of Project Cost Estimate

(Dollars in Thousands)

	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
Total Estimated Cost (TEC)			
Design (PED)	18,000	N/A	N/A
Design	14,500	N/A	N/A
Contingency	3,500	N/A	N/A
Total, PED	18,000[a]	N/A	N/A
Construction			
Site Preparation	2,000	N/A	N/A
Equipment	188,752	N/A	N/A
Other Construction	86,048	N/A	N/A
Contingency	90,200	N/A	N/A
Total, Construction	367,000[a]	N/A	N/A
Total, TEC	385,000[a]	N/A	N/A
Contingency, TEC	93,700	N/A	N/A
Other Project Cost (OPC)	20,000	N/A	N/A
OPC except D&D			
Conceptual Planning	1,126	N/A	N/A
Conceptual Design	11,974	N/A	N/A
Research and Development	1,100	N/A	N/A
Start-Up	1,200	N/A	N/A
Contingency	4,600	N/A	N/A
Total, OPC	20,000[a]	N/A	N/A
Contingency, OPC	4,600	N/A	N/A
Total, TPC	405,000[a]	N/A	N/A
Total, Contingency	98,300	N/A	N/A

[a] This project has not yet received CD-2 approval; funding estimates are preliminary. The preliminary TPC range for this project is $350,000,000–$500,000,000.

7. Funding Profile History

Request Year		(Dollars in Thousands) Prior Years	FY 2012	FY 2013	FY 2014	FY 2015	FY2016	FY2017	Total
FY2012 (MIE)	TEC	0	22,000	TBD	TBD	TBD	TBD	TBD	TBD
	OPC	10,600	8,000	TBD	TBD	TBD	TBD	TBD	TBD
	TPC	10,600	30,000	TBD	TBD	TBD	TBD	TBD	TBD
FY2013	TEC	0	22,000	63,500	80,300	94,000	105,300	19,900	385,000
	OPC	10,600	8,000	0	700	0	700	0	20,000
	TPC	10,600	30,000	63,500	81,000[a]	94,000[a]	106,000[a]	19,900[a]	405,000[a]

8. Related Operations and Maintenance Funding Requirements

Not applicable. Project does not have CD-2 approval.

9. Required D&D Information

New construction will be offset by banked space.

10. Acquisition Approach

DOE has determined that the LCLS-II project will be acquired by the SLAC National Accelerator Laboratory under the existing DOE M&O contract (DE-AC02-76-SF00515).

A Conceptual Design Report (CDR) for the project was completed and reviewed. Key design activities were specified for the undulator to reduce schedule risk to the project and expedite the startup. Also, the LCLS-II Project management systems put in place and tested during the first LCLS Project have been updated and are now maintained as a SLAC-wide resource. Lawrence Berkeley National Laboratory (LBNL) is an institutional partner to SLAC in the LCLS-II Project, with responsibility for design and construction of the necessary high-performance variable gap undulators.

Technical systems design (injector, linac, bunch compressors, transport lines through the undulators) are heavily based on designs from LCLS. Cost estimates for these systems are based on actual costs from LCLS. The availability of reliable, recent cost data has been exploited fully in planning and budgeting for the LCLS-II Project. Design of the technical systems will be completed by SLAC or LBNL staff. Technical equipment will either be fabricated in-house or contracted to vendors with the necessary capabilities.

The conventional construction design, including the tunnels for the undulator and experimental facilities, are heavily based on the designs used successfully in the original LCLS Project. It is anticipated that the conventional construction design will be contracted to an experienced Architect/Engineering (A/E) firm to perform Title I and II design. An experienced General Contractor will be hired to carry out conventional facilities construction.

All contracts will be competitively bid and awarded based on best value to the government.

Lessons learned in the LCLS Project are documented in its project completion report and will be exploited fully in planning and executing LCLS-II.

[a] This project has not yet received CD-2 approval; funding estimates are preliminary. The preliminary TPC range for this project is $350,000,000–$500,000,000.

07-SC-06, National Synchrotron Light Source II (NSLS-II)
Brookhaven National Laboratory, Upton, New York
Project Data Sheet is for PED/Construction

1. Significant Changes

The most recent DOE O 413.3B approved Critical Decision (CD) is CD-3, Start of Construction, which was approved on January 9, 2009, with a Total Project Cost (TPC) of $912,000,000. The overall project is approximately 67% complete with cumulative project Cost Performance Index (CPI) and Schedule Performance Index (SPI) at the end of November 2011 at 1.01 and 0.96 respectively.

The Federal Project Director is certified at level 4.

This PDS is an update of the FY 2012 PDS.

2. Critical Decision (CD) and D&D Schedule

	CD-0	CD-1	(Design/PED Complete)	CD-2	CD-3	CD-4
FY 2007	08/25/2005	1Q FY 2007	4Q FY 2008	TBD	TBD	TBD
FY 2008	08/25/2005	2Q FY 2007	2Q FY 2009	TBD	TBD	TBD
FY 2009	08/25/2005	07/12/2007	2Q FY 2009	2Q FY 2008	2Q FY 2009	3Q FY 2015
FY 2010	08/25/2005	07/12/2007	2Q FY 2009	01/18/2008	01/09/2009	3Q FY 2015
FY 2011	08/25/2005	07/12/2007	4Q FY 2010	01/18/2008	01/09/2009	3Q FY 2015
FY 2012	08/25/2005	07/12/2007	4Q FY 2011	01/18/2008	01/09/2009	3Q FY 2015
FY 2013	08/25/2005	07/12/2007	09/30/2011	01/18/2008	01/09/2009	3Q FY 2015

CD-0 – Approve Mission Need
CD-1 – Approve Alternative Selection and Cost Range
CD-2 – Approve Performance Baseline
CD-3 – Approved Start of Construction
CD-4 – Approve Project Completion

	D&D Start	D&D Complete	Performance Baseline Validation
FY 2007	N/A	N/A	N/A
FY 2008	N/A	N/A	N/A
FY 2009	N/A	N/A	12/11/2007
FY 2010	N/A	N/A	12/11/2007
FY 2011	N/A	N/A	12/11/2007
FY 2012	N/A	N/A	12/11/2007
FY 2013	N/A	N/A	12/11/2007

D&D Start – Start of Demolition & Decontamination (D&D) work. Not Applicable to this project
D&D Complete – Completion of D&D work. Not Applicable to this project

3. Baseline and Validation Status

(Dollars in Thousands)

	TEC, PED	TEC, Construction	TEC, Total	OPC Except D&D	OPC D&D	OPC, Total	TPC
FY 2007	75,000	TBD	TBD	TBD	TBD	TBD	TBD
FY 2008	75,000	TBD	TBD	TBD	TBD	TBD	TBD
FY 2009	60,000	731,200	791,200	120,800	0	120,800	912,000
FY 2010	60,000	731,200	791,200	120,800	0	120,800	912,000
FY 2011	60,000	731,200	791,200	120,800	0	120,800	912,000
FY 2012	60,000	731,200	791,200	120,800	0	120,800	912,000
FY 2013	60,000	731,200	791,200	120,800	0	120,800	912,000

4. Project Description, Scope, and Justification

Mission Need

Major advances in energy technologies will require scientific breakthroughs in developing new materials with advanced properties. A broad discussion is given in several recent reports, including the Basic Energy Sciences (BES) Advisory Committee reports entitled *Opportunities for Catalysis in the 21st Century*, *Basic Research Needs to Assure a Secure Energy Future*, *Basic Research Needs for the Hydrogen Economy*, and *Basic Research Needs for Solar Energy Utilization*, in addition to the Nanoscale Science, Engineering, and Technology Subcommittee of the National Science and Technology Committee report entitled *Nanoscience Research for Energy Needs*.

Collectively, these reports underscore the need to develop new tools that will allow the characterization of the atomic and electronic structure, the chemical composition, and the magnetic properties of materials with nanoscale resolution. Non-destructive tools are needed to image and characterize structures and interfaces below the surface, and these tools must operate in a wide range of temperature and harsh environments. The 1999 BES report *Nanoscale Science, Engineering, and Technology Research Directions* identified the absence of any tool possessing these combined capabilities as a key barrier to progress.

In order to fill this capability gap, the Office of Science determined that its mission requires a synchrotron light source that will enable the study of material properties and functions, particularly materials at the nanoscale, at a level of detail and precision never before possible. Only x-ray methods have the potential of satisfying all of these requirements, but advances both in x-ray optics and in x-ray brightness and flux are required to achieve a spatial resolution of 1 nm and an energy resolution of 0.1 meV. Ultimately, the ring is expected to operate a stored electron beam current of 500 mA at 3.0 GeV.

Scope and Justification for 07-SC-06 National Synchrotron Light Source II

An alternatives analysis found no existing light sources in the U.S. could fulfill the requirements identified above. There are no alternative tools with a spatial resolution of 1 nm and energy resolution of 0.1 meV that also have the required capabilities of being non-destructive and able to image and characterize buried structures and interfaces in a wide range of temperatures and harsh environments. In the case of NSLS-I, it was found that it would be impossible to upgrade this light source due to numerous technical difficulties, including accelerator physics and infrastructure constraints, such as its small circumference, which limit the feasible in-place upgrade options. The decision was made to design and build a new synchrotron facility.

The National Synchrotron Light Source II (NSLS-II) will be a new synchrotron light source, highly optimized to deliver ultra-high brightness and flux and exceptional beam stability. It will also provide advanced insertion devices, optics, detectors, robotics, and an initial suite of scientific instruments. Together, these will enable the study of material properties and functions with a spatial resolution of about 1 nm, an energy resolution of about 0.1 meV, and the ultra-high sensitivity required to perform spectroscopy on a single molecule.

The NSLS-II project will design, build, and install the accelerator hardware, experimental apparatus, civil construction, and central facilities including offices and laboratories required to produce a new synchrotron light source. It includes a third generation storage ring, full energy injector, experimental areas, an initial suite of scientific instruments, and appropriate support equipment, all housed in a new building.

Key Performance Parameters

Key Parameters	Performance
Accelerator Facilities:	
Electron Energy	3.0 GeV
Stored Current	25 mA
Conventional Facilities: Building Area	>340,000 GSF
Experimental Facilities: Beamlines installed and ready for commissioning with X-ray beam	6

The key performance parameters are defined in the project execution plan. The NSLS-II project is expected to deliver an electron energy of 3.0 GeV with a stored current of 25 milliamps; build a third generation storage ring of approximately one half mile in circumference and experimental and operations facilities with a total conventional construction of approximately 400 thousand gross square feet, and include an initial suite of six beamlines ready for commissioning with x-ray beam. These are the minimum performance requirements to achieve CD-4.

Current Status

As of December 2011, the project is 69.0% complete. The cumulative cost and schedule performance indices are 1.01 and 0.96 respectively, both well within the BES performance goal of 0.90 to 1.10. The project is expected to take beneficial occupancy of pentant 5, the final pentant in the Ring Building, in January 2012. Installation of the accelerator systems equipment has started. Construction of the Lab Office Buildings (LOBs) is making excellent progress with the erection of the structural steel for LOB 5 having begun in November 2011. Conventional construction is on track to finish the ring building by April 2012 and the Lab Office Building scope by 1st quarter FY 2013. Installation for the Linac components started in September 2011 and is expected to be complete in December 2012. The start of Linac testing and commissioning with beam is anticipated in February 2012. The first container of booster ring components was shipped in November 2011. Installation, test and commission of technical systems will continue through FY 2012 and into FY 2013. The target date for the start of commissioning for the Storage Ring is the third quarter of FY 2013. The target early finish date remains June 2014 with CD-4 in June 2015.

During FY 2013, NSLS-II will continue the fabrication/procurement of accelerator systems components, beamline components and other support system components. The project will continue with the installation of accelerator components, most notably the ring girders/magnets, continue testing of components as they are installed, and will begin commissioning various parts of the accelerator systems. Construction of conventional facilities should be complete by early FY 2013. The FY 2013 funds are requested for contingency.

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, and all appropriate project management requirements have been met.

5. Financial Schedule

(Dollars in Thousands)

	Appropriations	Obligations	Recovery Act Costs	Costs
Total Estimated Cost (TEC)				
PED				
FY 2007	3,000	3,000	0	2,292
FY 2008	29,727	29,727	0	28,205
FY 2009	27,273	27,273	0	23,044
FY 2010	0	0	0	6,173
FY 2011	0	0	0	286
Total, PED	60,000	60,000	0	60,000
Construction				
FY 2009	66,000	66,000	0	24,092
FY 2009 Recovery Act	150,000	150,000	14,751	0
FY 2010	139,000	139,000	67,424	84,826
FY 2011	151,297	151,297	42,322	162,288
FY 2012	151,400	151,400	22,822	134,675
FY 2013	47,203	47,203	2,681	125,825
FY 2014	26,300	26,300	0	41,230
FY 2015	0	0	0	8,264
Total, Construction	731,200	731,200	150,000	581,200

	(Dollars in Thousands)			
	Appropriations	Obligations	Recovery Act Costs	Costs
TEC				
FY 2007	3,000	3,000	0	2,292
FY 2008	29,727	29,727	0	28,205
FY 2009	93,273	93,273	0	47,136
FY 2009 Recovery Act	150,000	150,000	14,751	0
FY 2010	139,000	139,000	67,424	90,999
FY 2011	151,297	151,297	42,322	162,574
FY 2012	151,400	151,400	22,822	134,675
FY 2013	47,203	47,203	2,681	125,825
FY 2014	26,300	26,300	0	41,230
FY 2015	0	0	0	8,264
Total, TEC	791,200	791,200	150,000	641,200
Other Project Cost (OPC)				
OPC except D&D				
FY 2005	1,000	1,000	0	0
FY 2006	4,800	4,800	0	4,958
FY 2007	22,000	22,000	0	20,461
FY 2008	20,000	20,000	0	15,508
FY 2009	10,000	10,000	0	7,101
FY 2010	2,000	2,000	0	5,852
FY 2011	1,500	1,500	0	4,575
FY 2012	7,700	7,700	0	9,521
FY 2013	24,400	24,400	0	24,000
FY 2014	22,400	22,400	0	22,400
FY 2015	5,000	5,000	0	6,424
Total, OPC	120,800	120,800	0	120,800

(Dollars in Thousands)

	Appropriations	Obligations	Recovery Act Costs	Costs
Total Project Cost (TPC)				
FY 2005	1,000	1,000	0	0
FY 2006	4,800	4,800	0	4,958
FY 2007	25,000	25,000	0	22,753
FY 2008	49,727	49,727	0	43,713
FY 2009	103,273	103,273	0	54,237
FY 2009 Recovery Act	150,000	150,000	14,751	0
FY 2010	141,000	141,000	67,424	96,851
FY 2011	152,797	152,797	42,322	167,149
FY 2012	159,100	159,100	22,822	144,196
FY 2013	71,603	71,603	2,681	149,825
FY 2014	48,700	48,700	0	63,630
FY 2015	5,000	5,000	0	14,688
Total, TPC	912,000	912,000	150,000	762,000

6. Details of Project Cost Estimate

(Dollars in Thousands)

	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
Total Estimated Cost (TEC)			
Design (PED)			
Design	60,000	60,000	49,000
Contingency	0	0	11,000
Total, PED	60,000	60,000	60,000

(Dollars in Thousands)

	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
Construction			
Site Preparation	9,243	9,243	9,243
Equipment	31,579	31,579	31,579
Other Construction	608,961	567,885	518,381
Contingency	81,417	122,493	171,997
Total, Construction	731,200	731,200	731,200
Total, TEC	791,200	791,200	791,200
Contingency, TEC	81,417	122,493	182,997
Other Project Cost (OPC)			
Conceptual Planning	24,800	24,800	24,800
Research and Development	35,800	35,800	35,800
Start-Up	50,200	50,200	50,200
Contingency	10,000	10,000	10,000
Total, OPC	120,800	120,800	120,800
Contingency, OPC	10,000	10,000	10,000
Total, TPC	912,000	912,000	912,000
Total, Contingency	91,417	132,493	192,997

7. Funding Profile History

(Dollars in Thousands)

Request Year		Prior Years	FY 2009	FY 2009 Recovery Act	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	Total
FY 2007[a]	TEC	75,000	0	0	0	0	0	0	0	0	75,000
	OPC	46,000	0	0	0	0	0	0	0	0	46,000
	TPC	121,000	0	0	0	0	0	0	0	0	121,000
FY 2008[a]	TEC	65,000	10,000	0	0	0	0	0	0	0	75,000
	OPC	50,800	0	0	0	0	0	0	0	0	50,800
	TPC	115,800	10,000	0	0	0	0	0	0	0	125,800

[a] The FY 2007 and FY 2008 requests were for PED funding only.

(Dollars in Thousands)

Request Year		Prior Years	FY 2009	FY 2009 Recovery Act	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	Total
FY 2009[a]	TEC	32,727	93,273	0	162,500	252,900	166,100	57,400	26,300	0	791,200
	OPC	47,800	10,000	0	2,000	1,500	7,700	24,400	22,400	5,000	120,800
	TPC	80,527	103,273	0	164,500	254,400	173,800	81,800	48,700	5,000	912,000
FY 2010	TEC	32,727	93,273	150,000	139,000	151,600	151,400	46,900	26,300	0	791,200
	OPC	47,800	10,000	0	2,000	1,500	7,700	24,400	22,400	5,000	120,800
	TPC	80,527	103,273	150,000	141,000	153,100	159,100	71,300	48,700	5,000	912,000
FY 2011	TEC	32,727	93,273	150,000	139,000	151,600	151,400	46,900	26,300	0	791,200
	OPC	47,800	10,000	0	2,000	1,500	7,700	24,400	22,400	5,000	120,800
	TPC	80,527	103,273	150,000	141,000	153,100	159,100	71,300	48,700	5,000	912,000
FY 2012	TEC	32,727	93,273	150,000	139,000	151,600	151,400	46,900	26,300	0	791,200
	OPC	47,800	10,000	0	2,000	1,500	7,700	24,400	22,400	5,000	120,800
	TPC	80,527	103,273	150,000	141,000	153,100	159,100	71,300	48,700	5,000	912,000
FY 2013	TEC	32,727	93,273	150,000	139,000	151,297	151,400	47,203	26,300	0	791,200
	OPC	47,800	10,000	0	2,000	1,500	7,700	24,400	22,400	5,000	120,800
	TPC	80,527	103,273	150,000	141,000	152,797	159,100	71,603	48,700	5,000	912,000

8. Related Operations and Maintenance Funding Requirements

Beneficial occupancy of the experimental floor:	4Q FY 2012
Expected useful life (number of years):	25
Expected future start of D&D of this capital asset (fiscal quarter):	N/A

(Related Funding Requirements)

(Dollars in Thousands)

	Annual Costs		Life cycle costs	
	Current Estimate	Prior Estimate	Current Estimate	Prior Estimate
Operations	119,400	119,400	4,470,000	4,470,000
Maintenance	21,100	21,100	789,000	789,000
Total Operations and Maintenance	140,500	140,500	5,259,000	5,259,000

[a] FY 2009 reflects the original validated funding baseline.

9. Required D&D Information

	Square Feet
Area of new construction:	Approximately 400,000
Area of existing facilities being replaced:	N/A
Area of any additional space that will require D&D to meet the "one-for-one" requirement:	NA (see below)

The existing facility (NSLS) will be converted to another use. The one-for-one replacement has been met through completed and planned elimination of space at Brookhaven National Laboratory (BNL) along with "banked" space at the Massachusetts Institute of Technology (MIT) in Middleton, MA, and at the East Tennessee Technology Park (ETTP) in Oak Ridge, TN. A waiver from the one-for-one requirement to eliminate excess space at Brookhaven to offset the NSLS-II project was approved by Secretary Bodman on April 20, 2007. The waiver identified approximately 460,000 square feet of banked excess facilities space that were eliminated in FY 2006 at MIT and ETTP.

10. Acquisition Approach

The acquisition strategy selected relies on the BNL management and operating (M&O) contractor to directly manage the NSLS-II acquisition. The acquisition of large research facilities is within the scope of the DOE contract for the management and operation of BNL and consistent with the general expectation of the responsibilities of DOE M&O contractors.

The design, fabrication, assembly, installation, testing, and commissioning of the NSLS-II project will largely be performed by the BNL NSLS-II scientific and technical staff. Much of the subcontracted work to be performed for NSLS-II consists of hardware fabrication and conventional facilities construction. Each system or component will be procured using fixed price contracts, unless there is a compelling reason to employ another contract type. Best-value competitive procurements will be employed to the maximum extent possible.

Many major procurements are either build-to-print, following BNL/NSLS-II drawings and specifications, or readily available off-the-shelf. Source selection will be carried out in accordance with DOE-approved policies and procedures. Acquisition strategies have been chosen and will continue to obtain the best value based on the assessment of technical and cost risks on a case-by-case basis. For standard, build-to-print fabrications and the purchase of off-the-shelf equipment for routine applications, available purchasing techniques include price competition among technically qualified suppliers and use of competitively awarded blanket purchase agreements are used.

The architect-engineer (A-E) contract was placed on a firm-fixed-price basis for the Final (Title II) Design and (Title III) construction support services. The general construction contract was also placed on a firm-fixed-price basis. The design specifications are detailed and allow prospective constructors to formulate firm-fixed-price offers without excessive contingency and allowances.

NSLS-II project management has identified major procurements that represent significant complexity or cost and schedule risk. Advance procurement plans (APPs) have been prepared for each major procurement. The APPs include discussion of contract type, special contracting methods, special clauses or deviations required, and lease or purchase decisions. These final APPs will identify critical procurement activities and help to mitigate or avoid schedule conflicts and other procurement-related problems. At appropriate dollar levels, the APPs are approved by the responsible Division Director, the NSLS-II Procurement Manager, the NSLS-II Deputy Director, the NSLS-II Project Director and the DOE Site Office.