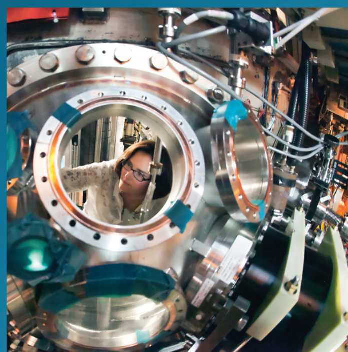

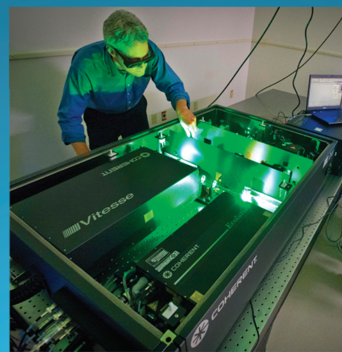

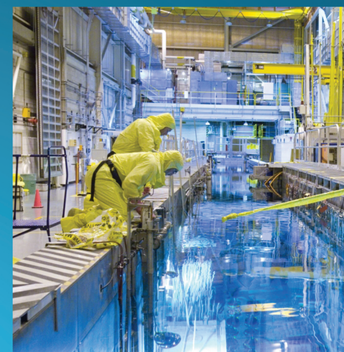

SEP

FISCAL YEAR 2016 SCIENCE AND ENERGY PLAN

September 2015

U.S. DEPARTMENT OF ENERGY

On the Cover

Top Row—The National Spherical Torus Experiment magnetic fusion device at Princeton Plasma Physics Laboratory; The Joint Center for Artificial Photosynthesis-North, operated as a partnership between the California Institute of Technology and Berkeley Laboratory; The Advanced Test Reactor at Idaho National Laboratory.

Bottom Row—The High Flux Isotope Reactor at Oak Ridge National Laboratory; Members of 48 middle school teams from across the country who competed in the 2014 DOE National Science Bowl® in Washington, DC; The Illumina sequencing platform at the DOE Joint Genome Institute.

SCIENCE AND ENERGY PLAN

FISCAL YEAR 2016

U.S. DEPARTMENT OF ENERGY

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Select Acronyms and Abbreviations

AMES	Ames Laboratory
ANL	Argonne National Laboratory
ARPA-E	Advanced Research Projects Agency – Energy
BNL	Brookhaven National Laboratory
DOE	Department of Energy
EERE	Office Energy Efficiency and Renewable Energy
EM	Office of Environmental Management
FE	Office of Fossil Energy
FNAL	Fermi National Accelerator Laboratory
IE	Office of Indian Energy Policy and Programs
INL	Idaho National Laboratory
LANL	Los Alamos National Laboratory
LBNL	Lawrence Berkeley National Laboratory
LLNL	Lawrence Livermore National Laboratory
LPO	Loan Programs Office
NE	Office of Nuclear Energy
NETL	National Energy Technology Laboratory
NNSA	National Nuclear Security Administration
NREL	National Renewable Energy Laboratory
OE	Office of Electricity Delivery and Energy Reliability
ORNL	Oak Ridge National Laboratory
OTT	Office of Technology Transitions
PNNL	Pacific Northwest National Laboratory
PPPL	Princeton Plasma Physic Laboratory
RD&D	Research, development, and demonstration
RDD&D	Research, development, demonstration, and deployment
SC	Office of Science
SEP	Science and Energy Plan
SLAC	SLAC National Accelerator Laboratory, formerly Stanford Linear Accelerator Center
SNL	Sandia National Laboratory
SRNL	Savannah River National Laboratory
TJNAF	Thomas Jefferson National Accelerator Facility
US/SE	Under Secretary for Science and Energy

A full list of acronyms can be found in Appendix A.

Acknowledgments

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—Franklin Orr, Under Secretary for Science and Energy

Science and Energy Plan Executive Steering Committee

Office of the Under Secretary for Science and Energy
Kimberly D. Rasar, Associate Deputy Under Secretary

Office of Electricity Delivery and Energy Reliability
Henry (Hank) Kenchington, Deputy Assistant Secretary, Advanced Grid Integration
David Ortiz, Deputy Assistant Secretary, Energy Infrastructure Modeling and Analysis

Office of Energy Efficiency and Renewable Energy
Steve Chalk, Deputy Assistant Secretary, Operations
Doug Hollett, Deputy Assistant Secretary, Renewable Power

Office of Fossil Energy
Julio Friedmann, Principal Deputy Assistant Secretary
David Mohler, Deputy Assistant Secretary, Office of Clean Coal and Carbon Management

Office of Nuclear Energy
John E. Kelly, Deputy Assistant Secretary, Nuclear Reactor Technologies

Office of Indian Energy
Pilar Thomas, Former Acting Director, Office of Indian Energy Policy and Programs
David Conrad, Deputy Director, Office of Indian Energy Policy and Programs

Office of Technology Transitions
Jetta Wong, Director, Office of Technology Transitions, and Technology Transfer Coordinator

Office of Science
Patricia Dehmer, Acting Director
Steve Binkley, Associate Director, Advanced Scientific Computing Research
Harriet Kung, Associate Director, Basic Energy Sciences

Advanced Research Projects Agency - Energy
Ellen Williams, Director

Office of the Chief Financial Officer
Christopher Johns, Director, Budget Office

Office of International Affairs
Robert Marlay, Director, Office of International Science and Technology Collaboration

Science and Energy Plan Coordination Group

Kimberly D. Rasar, Lead, Office of the Under Secretary for Science and Energy

David M. Catarious, Jr., Co-Lead, Office of the Under Secretary for Science and Energy

Kevin Doran, Co-Lead, Office of the Under Secretary for Science and Energy

Julie Carruthers, Office of Science

David Conrad, Office of Indian Energy Policy and Programs

Matthew Crozat, formerly with the Office of Nuclear Energy

Ian Hamos, Office of Energy Efficiency and Renewable Energy

Henry (Hank) Kenchington, Office of Electricity Delivery and Energy Reliability

John Lushetsky, Office of Energy Efficiency and Renewable Energy

Darren Mollot, Office of Fossil Energy

Charles Russomanno, Office of Technology Transitions

Ann Satsangi, Office of Fossil Energy

Sotirios (Sam) Thomas, Office of the Under Secretary for Science and Energy

Bradley Williams, Office of Nuclear Energy

National Laboratory Representatives

Steven Dierker, Brookhaven National Laboratory

Thomas Lograsso, Ames Laboratory

John DeLooper, Princeton Plasma Physics Laboratory

Ray Stults, National Renewable Energy Laboratory

T. Bond Calloway, Jr., Savannah River National Laboratory

Edward Daniels, Argonne National Laboratory

Carol Adkins, Sandia National Laboratories

Cyrus Wadia, Lawrence Berkeley National Laboratory

Deborah Tate, Idaho National Laboratory

Contributing Authors

Nassima Barrows, NNSA

Robert Boudreau, Office of Nuclear Energy

William Bryan, Office of Electricity Delivery and Energy Reliability

Maureen Clapper, Office of International Affairs

Corey Cohn, Office of Science

William (Dale) Conwell, NNSA

Jared Daniels, Office of Fossil Energy

Rosa Elmetti, Office of Environmental Management

Ron Faibish, ARPA-E

Mark Gilbertson, Office of Environmental Management

Ana Han, Office of Environmental Management

Brian Holuj, Office of International Affairs

Dimitri Kusnezov, NNSA

Lauren Lafaro, NNSA

Terri Lee, Office of Electricity Delivery and Energy Reliability

Sarah Lennon, Office of Nuclear Energy

Geoffrey Lyon, Office of Fossil Energy

Elizabeth O'Malley, Office of Science

Monica Regalbuto, Office of Environmental Management

Robert Sandoli, Office of Energy Efficiency and Renewable Energy

Sydney Schneir, Loan Programs Office

Robert Seifert, Office of Environmental Management

Carissa Vandermey, Office of Electricity Delivery and Energy Reliability

Mark Whitney, Office of Environmental Management

A Message from the Under Secretary and Deputy Under Secretary for Science and Energy

The Department of Energy's (DOE) overarching science and energy mission is to enhance U.S. security and economic growth through transformative science, technology innovation, and market solutions to meet our energy, nuclear security, and environmental challenges. In 2013, with the vision of speeding technology development through basic research, applied research, development, demonstration, and deployment (RDD&D), Energy Secretary Ernest Moniz combined DOE's Under Secretary for Science and Under Secretary for Energy into a single Under Secretary as part of a reorganization of DOE.

The Under Secretary for Science and Energy (US/SE) was charged with building on the legacy of the Department and its National Laboratories as world leaders in science and technology innovation, a role that is now essential to addressing the global challenges of climate change. Toward this end, the US/SE began to develop a framework for the Department's Science and Energy programs to meet this challenge as a single, coordinated enterprise, working together to enhance the Nation's fundamental scientific and engineering strengths, and applying these strengths to the development of the clean energy economy.

While DOE's Science and Energy program offices pursue research, development, demonstration, and deployment activities across different portions of the science and energy landscape, they share a common set of planning drivers and activities. They all find guidance and direction from legislation, execute the priorities of Administration and Departmental leadership, follow the same budget planning cycle, engage their stakeholder communities, plan their activities in multiyear strategic plans, participate in crosscutting RDD&D activities, follow rigorous peer review and performance evaluation practices, and, when appropriate, manage large-scale scientific research facilities. However, despite these common features, the program offices have differing scientific and technological expertise, constituencies, technology development levels, and engagement in the technology marketplace, as well as the time scales upon which success is gauged. These differences necessitate some variance and flexibility in their internal processes and the modalities used to organize and execute their RDD&D activities.

Execution of RDD&D activities depends heavily on DOE's 17 National Laboratories and the Department's critical partners in academia and industry. Separately, the Laboratories are each centers of excellence that cover the range of the Nation's science and energy challenges. Together, they represent a system of RDD&D capabilities that are unmatched by any other country. Likewise, the Department's academic and industry partners occupy all areas of the technology development spectrum and offer specific and differentiated expertise and capabilities. As a whole, they provide the Department, our Laboratories, and our collaborators the capability to deliver scientific and technological advances all the way through the innovation cycle—from conceptual development to commercialized products and services.

Working together, these entities that constitute the DOE Science and Energy enterprise also address significant RDD&D opportunities through a variety of crosscutting initiatives, which leverage knowledge drawn from multiple areas of Departmental expertise. This expertise is applied to various international activities as well that extend the reach of the Department's scientific and technical capabilities globally in areas of strategic interest.

The Science and Energy Plan (SEP) is aimed at improving the overall effectiveness of the Science and Energy enterprise by (1) creating awareness and transparency about how DOE performs its science and energy functions; (2) demonstrating how the Department operates as a coordinated system that takes advantage of both the individual strengths of our programs and our collective strength as we work together to address complex challenges; and (3) providing a baseline to help better align and coordinate programs and integrate the National Laboratories to address new challenges. As an essential foundation of the DOE enterprise, and as partners in the success of the Department's mission, the DOE National Laboratories were involved in both the planning and development of content for the SEP, along with representatives from other non-science-and-energy offices across the Department.

The SEP is intended primarily for those who are substantially engaged in executing our science and energy missions, including the Department and other agencies, Congress, the National Laboratories, and other key collaborators in achieving DOE's missions. This first SEP describes the major programs, performers, and processes involved in the Department's science and energy functions, and the essential role that each plays across the Department and throughout the technology development lifecycle. It describes how these programs align, and how the Department operates the Science and Energy enterprise as a complete system through strategic engagement and proper management, including sustained investment in our National Laboratories to strengthen their world-class science and energy technology capabilities and build on their history of excellence. Finally, this document recognizes both the unique capabilities and expertise of each of the Science and Energy programs and their inherently intertwined and complementary nature—and the many opportunities to leverage these characteristics to address National needs.

In subsequent editions, the SEP will mature into a more forward-leaning document, one that represents the outcomes of a program planning process that incorporates the new US/SE approaches to coordinated planning and management oversight. In this way, the annual updating of the SEP is intended to be a regular process for the Department's Science and Energy programs to come together to identify opportunities—like crosscutting initiatives—and inform programmatic decisions in the way that best serves their individual missions, the Department, and the Nation.

Ultimately, the inaugural SEP offers DOE stakeholders and performers an accessible, clear summary of who we are, what we do, how we do it, and why our science and energy missions are as essential now as when Congress created DOE nearly 40 years ago.

Franklin Orr, Ph.D.
Under Secretary for Science and Energy
U.S. Department of Energy
Washington, DC
USA

Michael Knotek, Ph.D.
Deputy Under Secretary for Science and Energy
U.S. Department of Energy
Washington, DC
USA

Executive Summary

The Department of Energy's (DOE) Science and Energy Plan (SEP) provides a comprehensive overview of DOE's Science and Energy enterprise. The SEP focuses on the research, development, demonstration, and deployment (RDD&D) activities planned and executed by the Office of the Under Secretary for Science and Energy (US/SE) and the US/SE program offices. For these program offices, the SEP identifies and differentiates their missions and core competencies, as well as the activities pursued by the Office of the US/SE to strategically align areas of common interest. The SEP also discusses how the science and energy RDD&D portfolio is coordinated and executed throughout the Department's system of National Laboratories. In short, this plan describes the program planning and management necessary to execute these missions and provides evidence of the value, complementarity, and differentiation of the Science and Energy program activities.

Chapter 1: An Introduction to the DOE Science and Energy Enterprise

DOE is responsible for advancing the energy, environmental, and nuclear security objectives of the United States. The Department's science and technology, environmental management, and nuclear security missions are operationalized through three Under Secretaries who are accountable to the Secretary and Deputy Secretary: the Under Secretary for Science and Energy (US/SE), the Under Secretary for Management and Performance (US/MP), and the Under Secretary for National Security (US/NS). The success of the US/SE program offices, specifically, depends upon those organizations that execute the work—namely, DOE's National Laboratory enterprise and the Department's partners in academia and industry. The Laboratories represent a system of RDD&D capabilities that are unmatched by any country. The academic and industry partners provide the Department and its Laboratories the capability to deliver scientific and technological advances all the way through the innovation cycle—from conceptual development to commercialized products and services.

The Office of the US/SE is tasked with the mission of driving transformative science and technology solutions and achieving the following three organizational goals:

- Goal 1: Develop and implement a comprehensive strategy for the Science and Energy programs.
- Goal 2: Ensure strategic engagement with and investment in the National Laboratories.
- Goal 3: Establish mechanisms for the Science and Energy programs to achieve efficient operational excellence.

The Office of the US/SE achieves these goals through coordinated planning, management, and oversight of the Science and Energy program offices.

Chapter 2: The Science and Energy Portfolio

The US/SE program offices lead the Department's engagement in transformative science, technology innovation, and market solutions:

- Office of Science—serves as the lead Federal entity supporting fundamental scientific research for energy and the Nation's largest supporter of basic research in the physical sciences. Its mission is the delivery and deployment of scientific discoveries and major scientific tools to transform our understanding of nature and transition technologies to advance the energy, economic, and national security objectives of the United States.

- Office of Energy Efficiency and Renewable Energy—leads the Department's efforts to research, develop, demonstrate, and deploy or transfer technologies in sustainable transportation, renewable power, and energy efficiency and to reduce market barriers in these sectors.
- Office of Nuclear Energy—supports the diverse civilian nuclear energy programs by leading Federal R&D efforts in nuclear energy technologies.
- Office of Fossil Energy—plays a key role in helping the United States meet its need for secure, reasonably priced, and environmentally sound fossil energy supplies. FE also oversees the Nation's Strategic Petroleum Reserve and the Northeast Home Heating Oil Reserve, both key emergency response tools to protect the United States from energy supply disruptions.
- Office of Electricity Delivery and Energy Reliability—leads the Department's efforts to strengthen, transform, and improve America's electricity infrastructure and provides national leadership to help ensure that the Nation's energy delivery systems are secure, resilient, and reliable.
- Office of Indian Energy Policy and Programs—assists Native American and Alaska Native tribes with energy development, capacity building, energy infrastructure, energy costs, and electrification of Indian lands and homes through energy planning, education, management, and competitive grant programs.

With significant contributions to the science and energy portfolio, the Department's 17 National Laboratories are the scientific powerhouse that underpins DOE's efforts to tackle the critical scientific challenges of our time. The National Laboratories possess unique instruments and facilities and address large-scale, complex research and development challenges with a multidisciplinary approach that places an emphasis on transitioning basic science to innovation.

Combining the strength of these program offices and National Laboratories, the Office of the US/SE also supervises coordinated initiatives to address science and energy challenges that span traditional and programmatic boundaries. For FY 2016, the Office of the US/SE led the development process for the following four crosscutting activities: the Energy-Water Nexus; Grid Modernization; Subsurface Technology and Engineering; and Supercritical Carbon Dioxide. In addition, other DOE program offices coordinated with Science and Energy programs to develop two crosscuts focused on Exascale Computing and Cyber Security.

In support of all these efforts, the Office of Technology Transitions synchronizes the Department's RDD&D activities toward technology transfer and commercialization. In addition, key international R&D collaborations and partnerships focus on the following three areas allowing DOE to engage in and accelerate science and technology (S&T) initiatives on a global scale:

- engagement with world-class scientific R&D organizations to achieve advancements faster and at lower cost;
- provision of technical assistance to international partners, consistent with U.S. foreign policy, to accelerate their transition to clean energy economies while also creating export opportunities for U.S. companies; and
- participation in international technical exchanges and R&D for nuclear processes and materials with countries consistent with the Treaty on the Non-Proliferation of Nuclear Weapons.

Chapter 3: Science and Energy Planning and Management

Management of DOE's Science and Energy enterprise and its large and complex science and technology (S&T) portfolios requires the ability to accommodate near-term opportunities as well as fundamental S&T challenges. The President's annual budget request to Congress represents the outcome of this coordinated planning and alignment process. Also important is the identification and implementation of best practices in program and project planning and management across program offices.

DOE's efforts have been directed and guided by a combination of legislative mandates and authorities that have defined the DOE mission and responsibilities for the Nation, Administration priorities, and DOE Secretarial and senior leadership direction. Coupled to these drivers are the scientific and technological opportunities identified over time, either through new discoveries and innovation or through extensive planning processes with S&T stakeholders.

Key reports, workshops, advisory committees, and stakeholder input mechanisms, such as the following, further inform the Department's strategic planning efforts:

- **DOE Strategic Plan**—covers Departmental priorities, opportunities, and issues from a multiyear perspective.
- **Quadrennial Energy Review (QER)**—published by the White House, the 2015 edition of the QER assesses the current state of energy infrastructure, considers trends and emerging infrastructure challenges through 2030, and issues recommendations to ensure that U.S. energy infrastructure and the services provided are affordable, clean, and secure.
- **Quadrennial Technology Review (QTR)**—produced by DOE and designed to frame, detail, and analyze RDD&D opportunities for the Nation to consider as it addresses the energy-linked challenges to the economy, environmental quality, and national security.
- **National Laboratory Big Ideas Summit (BIS)**—brings together subject matter experts from DOE's Science and Energy offices, other DOE offices, and all 17 National Laboratories to propose and explore innovative ideas for solutions to key energy issues.
- **Scientific and Technical Workshops**—involve broad participation of scientific and technology communities and are key mechanisms for identifying research opportunities for both the basic and applied research programs.
- **Reviews and Reports by Advisory Committees**—provide advice to DOE leadership and program offices regarding complex scientific and technical issues and provide guidance on opportunities for enabling research, technologies, and facilities.
- **Studies Performed by External Entities**—outside studies, commissioned by DOE and/or other agencies, which can inform DOE planning, programs, and budgets.
- **Interagency Committees and Working Groups**—coordinate R&D program and policy efforts with other Federal agencies to best leverage resources to advance S&T areas of mutual interest and respective missions, to limit potential duplication of efforts, and to ensure mutual agreements on policies where needed.
- **Requests for Information (RFIs) and Funding Opportunity Announcements (FOAs)**—solicit ideas or information to inform a program's future direction in a scientific or technical area and establish selection criteria through which DOE provides funds to outside entities in its financial assistance program.
- **National Meetings**—provide opportunities for S&T professionals to engage in career development, meet and share ideas, foster within-discipline or cross-disciplinary partnerships, and build professional networks, as well as coordinate major community input on particular topics or initiatives.

In the execution of these plans, DOE employs best practices in the management and evaluation of its programs and R&D portfolios. DOE establishes and maintains high-quality R&D portfolios through two well recognized best practices in program management: (1) the open competition of funded work, and (2) merit review by subject matter experts to inform Federal funding decisions. DOE programs use annual meetings with funded principal investigators as well as in-progress peer review procedures that are rigorous, formal, and documented evaluation processes. Using objective criteria and qualified and independent reviewers, these best practices help DOE to make a judgment of the technical, scientific, and/or business merit; evaluate the achieved or anticipated results; and review the productivity and management effectiveness of programs and/or projects.

Chapter 4: DOE National Laboratories, Universities, and Industry Partners

As DOE performers, the National Laboratories, universities, and industry play an important role in executing the Department's science and energy missions and push forward the frontiers of fundamental science, technology research, and commercialization.

The strategic engagement and oversight of the National Laboratories is one of the most important responsibilities of the Department, which employs two general management models for the Labs: the Government-owned, Government-operated (GOGO) model and the Government-owned, contractor-operated (GOCO) model. An evolving set of Laboratory governance committees and working groups— such as the National Laboratory Directors' Council (NLDC), Laboratory Policy Council (LPC), Laboratory Operations Board (LOB), SC Operations Improvement Committee (OIC), and the Field Management Council—are used to develop and sustain positive working relationships and navigate complex policies and issues related to the Labs. The Laboratories undergo a common set of annual planning processes to produce long-term strategic plans for their Laboratories, ten-year site plans, and other multiyear plans to address current RDD&D priorities that are reviewed and approved by their DOE stewards. In addition, Lab management contractors are responsible for internal management assurance programs and for working together in conjunction with DOE oversight processes to form a comprehensive strategic governance and oversight framework for the Labs they manage. DOE line management also conducts oversight of its contractors to maintain awareness of the adequacy of the contractors' performance. The DOE site office manager at each DOE site office serves as the DOE line manager accountable for the management of the M&O contract and oversight of the day-to-day activities at the Laboratory under their cognizance. DOE embraces a performance-based management approach to overall contractor evaluation and establishes requirements in the M&O contract for standards of performance, self-assessment, and comprehensive performance evaluation, which occurs on an annual basis.

The Laboratories are involved in a broad range of partnerships with each other and other Federal agencies, and with a number of academic and private sector entities. On the one hand, they collaborate with universities in fundamental and applied research, as well as support the training of thousands of future scientists and engineers. Universities and consortia of universities are also integrally involved in the management of DOE Laboratories. On the other hand, the Laboratories partner with industry in technology development and deployment to ensure the transfer of their R&D to the marketplace. Partnerships with industry ensure that DOE's science and energy RDD&D portfolio is relevant, market barriers are identified and reduced, investment risk is shared with our private sector participants, solutions are informed by industry practice, and clear responsibility to take advanced technology to market is established. Furthermore, the Department and its Laboratories strive to involve small businesses and have put in place a number of activities that are either targeted at small business or lend themselves particularly well to small business participation.

In addition to these collaborations, the Laboratories share with partners their designated user facilities—which meet broad mission need by enabling a range of S&T research, characterization, and analysis, with operational costs fully supported by DOE—and shared R&D facilities, which include a broad spectrum of DOE Laboratory assets such as technology benchmarking test beds (a.k.a. "test facilities"), large-scale collaborative R&D centers, and specialized materials processing capabilities, among others.

1

Chapter 1: An Introduction to the DOE Science and Energy Enterprise

This chapter provides an overview of the Department of Energy, including its history, present-day missions, and organizational structure. It introduces the Department's Science and Energy enterprise and describes how the constituent elements of this enterprise work together through the Office of the Under Secretary for Science and Energy (US/SE) to address priority national needs. Chapter 1 also introduces the Department's approach to strategic engagement of the National Laboratories.

The introductory material in Chapter 1 provides context for Chapter 2's discussion of the Department's research, development, demonstration, and deployment (RDD&D) activities, including international work; Chapter 3's description of how the Department plans, executes, and manages these activities; and Chapter 4's description of how the Department engages with National Laboratories, academia, and industry to carry out its missions.

1.1 The U.S. Department of Energy

As described in the Department's Strategic Plan, the Department of Energy (DOE) is responsible for advancing the energy, environmental, and nuclear security of the United States; promoting scientific and technological innovation in support of that mission; sponsoring basic research in the physical sciences; and ensuring the environmental cleanup of the Nation's nuclear weapons complex. The Department is led by Secretary Ernest J. Moniz, Ph.D., who was confirmed by the U.S. Senate in May 2013. The Department's Deputy Secretary is Elizabeth Sherwood-Randall, Ph.D., who was confirmed in September 2014.

The science and technology, environmental management, and nuclear security missions of the Department are operationalized through three Under Secretaries who are accountable to the Secretary and Deputy Secretary: the Under Secretary for Science and Energy (US/SE), Under Secretary for Management and Performance (US/MP), and Under Secretary for National Security (US/NS). (See figure 1.1.) The incumbents of these Under Secretarial positions are presented below. The DOE Strategic Plan, 2014–2018, outlines the overarching missions of these Under Secretaries:

- **Science and Energy**—To drive transformative science and technology solutions through coordinated planning and management oversight of the Department's Science and Energy programs.
- **Management and Performance**—To serve as the primary management organization, coordinating project management and the mission support functions of the Department and overseeing the cleanup of the legacy waste of the Cold War.
- **Nuclear Security**—To enhance national security through the military application of nuclear science, enhance the safety, security, reliability and performance of the U.S. nuclear weapons stockpile without nuclear testing, reduce global danger from weapons of mass destruction, provide the U.S. Navy with safe and effective nuclear propulsion, and respond to nuclear and radiological emergencies in the United States and abroad.

U.S. Department of Energy Headquarters at the James V. Forrestal Building located at 1000 Independence Avenue in Washington, DC. The Enid A. Haupt Garden at the Smithsonian Institution Building is visible in the foreground.

As of September 2015, the Under Secretarial positions are held by:

- US/SE: Dr. Franklin Orr
- US/MP: Vacant
- US/NS: Lt. Gen. Frank G. Klotz, USA (Ret.)

The remainder of this document is focused on activities relevant to the mission of the Office of the US/SE.

DOE At-a-Glance

- Established by the Department of Energy Organization Act of 1977
- The Nation's 12th Cabinet-level Department
- Approximately 14,000 Federal employees
- Approximately 90,000 management and operating contractors and other contractor employees
- Washington, DC, and Germantown, MD, headquarters and 85 field locations
- 17 National Laboratories
- Supports more than 31,000 researchers from academia, Government, and industry at Office of Science DOE designated user facilities
- $27.9 billion FY 2015 enacted operating and research budget

1.2 The Department's Science and Energy Programs

DOE leads the Nation in the transformational research, development, demonstration, and deployment of an extensive range of clean energy and efficiency technologies, supporting the President's Climate Action Plan and an "all of the above" energy strategy. The Department identifies and promotes advances in fundamental and applied sciences, translates cutting-edge inventions into technological innovations, and accelerates transformational technological advances in energy areas that industry by itself is not likely to undertake because of technical or financial risk. DOE also leads national efforts to develop technologies to modernize the electricity grid, enhance the security and resilience of energy infrastructure, and expedite recovery from energy supply disruptions.

The domestic energy revolution is one of the great success stories of this new century. DOE programs have contributed to this revolution through continued progress in our understanding of the scientific foundations of energy sciences and technology, clean energy technological innovation and advanced manufacturing research and demonstration, credit support for early commercial deployments, and new technologies and standards to enhance end use energy efficiency. Despite this progress, major opportunities and challenges remain for continued technological innovation that reduces cost and enhances performance, for educating and training the workforce for tomorrow's energy economy, and for modernizing domestic energy infrastructure for the 21st century economy. The DOE FY 2016 budget request for the Science and Energy programs includes $10.1 billion to address these challenges. The strategic framework for the budget proposals is provided by the Administration's all-of-the-above energy strategy and the President's Climate Action Plan.

The $10.1 billion Science and Energy program office budget request, $1.3 billion above the FY 2015 enacted level, sustains DOE's role as the largest Federal sponsor of basic research in the physical sciences and develops and operates cutting-edge scientific user facilities at the National Laboratories to maintain the Nation's primacy in science and innovation. The request also supports transformational research and development (R&D) in critical technology areas, including advanced manufacturing, renewable energy, advanced transportation technology, energy efficiency, electricity grid technology modernization, advanced safe nuclear reactor technology, advanced fossil energy systems with carbon capture and storage, and cross-cutting R&D initiatives that have multiple energy resource areas of application.

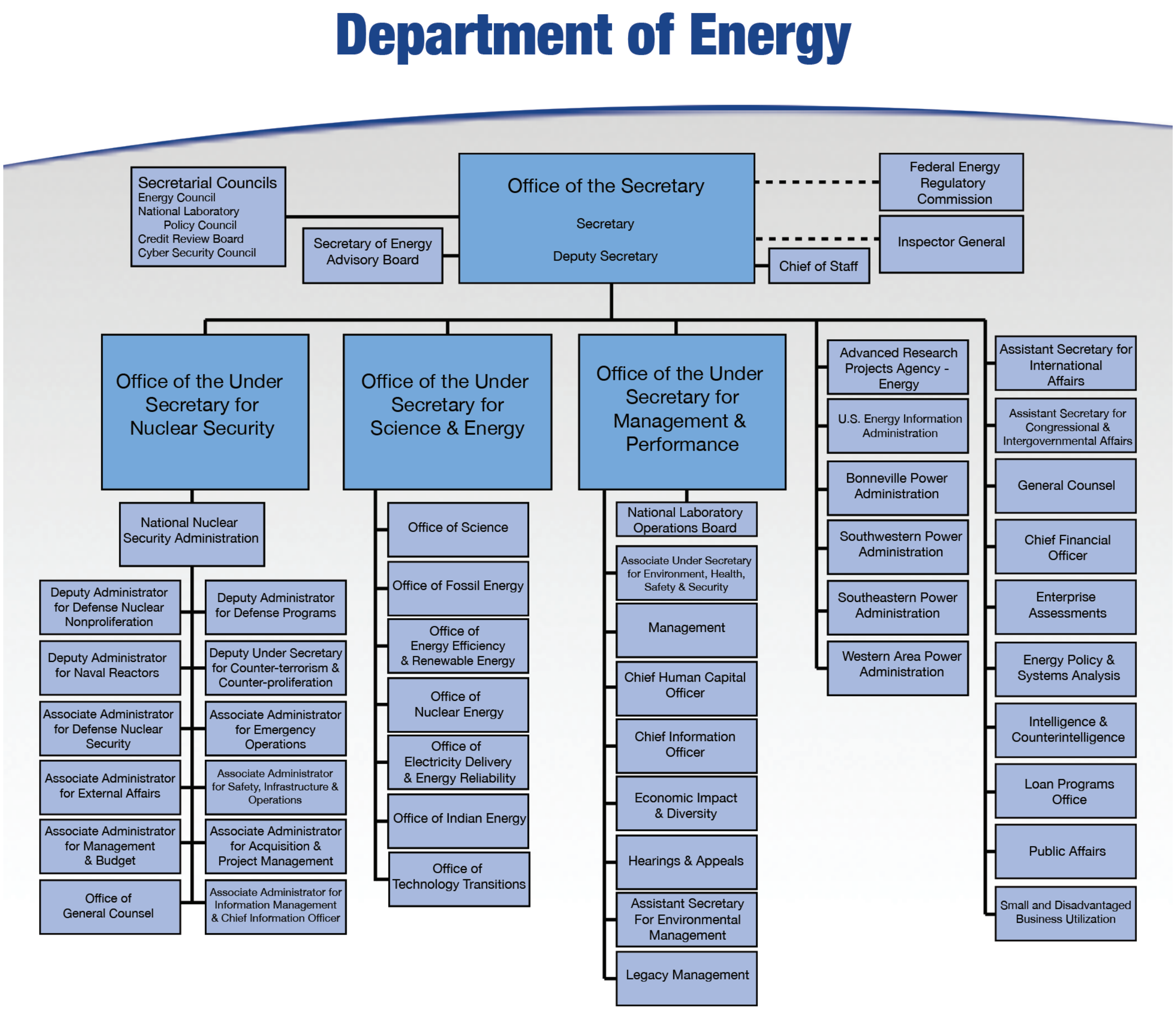


Figure 1.1: U.S. Department of Energy Organizational Chart.
This figure outlines the organizational structure of DOE following the 2013 reorganization. The offices under the US/SE are discussed in section 1.2 and also in Chapter 2. Chapter 2 also includes brief descriptions of key offices outside the purview of the US/SE, including the Advanced Research Projects Agency–Energy, the Loan Programs Office, and the Office of International Affairs. Information on the remaining DOE offices is available at energy.gov.

Building on pilot efforts in FY 2015, the FY 2016 budget request also includes a set of coordinated, multi-program crosscutting initiatives that focus unique program and National Laboratory expertise around shared challenges and opportunities. DOE's Science and Energy programs contribute to the Cybersecurity crosscutting initiative and play a central role in the Energy-Water Nexus, Exascale Computing, Grid Modernization, Subsurface Technology and Engineering, and Supercritical Carbon Dioxide (CO_2) technology crosscutting initiatives. Funding for these initiatives is in the program offices' budget requests.

Informed by the latest science advisory council reports and recommendations, the FY 2016 budget request provides $5.34 billion for the Office of Science (SC), $272 million above the FY 2015 enacted level, to continue to lead basic research in the physical sciences and develop and operate cutting-edge scientific user facilities while strengthening the connection between advances in fundamental science and technology innovation. The Science budget request includes:

- $1.85 billion for basic energy sciences, $116 million above the FY 2015 enacted level, to provide the foundations for new energy technologies and to support DOE missions in energy, environment, and national security through research aimed at understanding, predicting, and ultimately controlling matter and energy, including continued support for Energy Frontier Research Centers (EFRCs), and to provide world-class user facilities.
- $788 million for high energy physics, $22 million above the FY 2015 enacted level, to understand how the universe works at its most fundamental level by discovering the most elementary constituents of matter and energy, probing the interactions among them, and exploring the basic nature of space and time. The Request supports activities and projects based on the High Energy Physics Advisory Panel (HEPAP) May 2014 strategic plan, including design support for a reconfigured international Long Baseline Neutrino Facility hosted at Fermilab.
- $612 million for biological and environmental research, $20 million above the FY 2015 enacted level, to support fundamental research and scientific user facilities to achieve a predictive understanding of complex biological, climatic, and environmental systems for a secure and sustainable energy future, including continued funding for three Bioenergy Research Centers (BRCs).
- $625 million, $29 million above the FY 2015 enacted level, for nuclear physics research aiming to discover, explore, and understand nuclear matter in a variety of different forms, and the continued construction of the Facility for Rare Isotope Beams (FRIB).
- $621 million, $80 million above the FY 2015 enacted level, for advanced scientific computing research in advanced computation, applied mathematics, computer science and networking, as well as development and operation of high performance computing facilities. Funding is included to accelerate development of capable exascale computing systems with a thousand-fold improvement in performance over current high-performance computers.
- $420 million for fusion energy sciences, $48 million below the FY 2015 enacted level, to understand the behavior of matter at high temperatures and densities and to develop fusion as a future energy source, including funding for the U.S. contribution to the ITER project.

The FY 2016 budget requests $4.8 billion for applied energy activities, including:

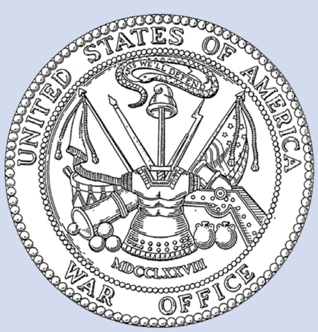
- $2.72 billion for Energy Efficiency and Renewable Energy (EERE), $809 million above the FY 2015 enacted level, to continue a diverse suite of sustained investment in sustainable transportation technologies ($793 million), renewable energy generation technologies ($645 million), and development of manufacturing technologies and enhanced energy efficiency in homes, buildings, and industries ($1.03 billion).
- $908 million for Nuclear Energy (NE), $74 million above the FY 2015 enacted level, for ongoing R&D in advanced reactor and fuel cycle technologies as well as small modular reactor licensing technical support. The Request also continues to lay the groundwork for full implementation of the Administration's Strategy for the Management and Disposal of Used Nuclear Fuel and High-Level Radioactive Waste released in January 2013, and it provides $108 million for research, development, and integrated waste management system activities in the areas of transportation, storage, disposal, and consent-based siting.
- $842 million for Fossil Energy (FE) including: $560 million for fossil energy research and development, essentially unchanged from the FY 2015 enacted level, to advance carbon capture and storage and natural gas technologies; and $257 million for the Strategic Petroleum Reserve, $57 million above the FY 2015 enacted level, to increase the system's durability and reliability and begin addressing the backlog of deferred maintenance.

History Spotlight

Created through the Department of Energy Organization Act of 1977, DOE is the Nation's twelfth Cabinet-level Department. The Department brought together for the first time three programmatic traditions that had long coexisted within the Federal establishment: (1) the design, construction, and testing of nuclear weapons dating from the Manhattan Project effort to build the atomic bomb, (2) energy-related research and development programs that were located throughout the Federal Government, and (3) long-term understanding of, and responsibility for, radioactive materials.

The Manhattan Project

In August 1939, on the eve of World War II, Albert Einstein wrote to President Franklin D. Roosevelt, informing him that recent research showed that a nuclear chain reaction might make possible the construction of extremely powerful bombs. In response, President Roosevelt initiated a Federal research program, and, in 1942, the Army Corps of Engineers established the Manhattan Engineer District to design and produce the first atomic bomb.



Following the war, Congress engaged in a debate over civilian versus military engagement in atomic activities. The Atomic Energy Act of 1946 settled the debate by creating the Atomic Energy Commission (AEC), which took over the Manhattan Project's scientific and industrial complex.

During the early Cold War years, the AEC focused on design and production of nuclear weapons and development of nuclear reactors for naval propulsion. The Atomic Energy Act of 1954 directed the AEC to promote the commercial uses of nuclear power and to protect against the hazards of those commercial applications.

The Energy Reorganization Act of 1974 divided the AEC into the U.S. Energy Research and Development Administration, which focused on research and development efforts to address the Nation's growing need for additional sources of energy, and the U.S. Nuclear Regulatory Commission, which focused on the regulation of civilian uses of nuclear energy.

Security and Prosperity through World-Class Science and Applied Energy Research

The AEC's activities in developing and commercializing nuclear energy represented the Federal Government's largest and most significant energy project into the early 1970s. Thus, as the energy crisis of the mid-1970s prompted a series of Government reorganizations to better coordinate Federal energy policy and programs, the AEC became the focal point of energy research and development.

The establishment of the Department of Energy in 1977 brought most Federal energy activities under one umbrella and provided the framework for a comprehensive and balanced national energy plan. The Department undertook responsibility for long-term, fundamental and high-risk research and development of energy technology, Federal power marketing, energy conservation, the nuclear weapons program, energy regulatory programs, and a central energy data collection and analysis program.

History Spotlight, continued

Throughout its history, the Department of Energy has shifted its emphasis and focus as the needs of the Nation have changed. During the late 1970s, the Department emphasized energy development and regulation. In the 1980s, nuclear weapons research, development, and production took a priority. With the end of the Cold War, the Department focused on environmental clean-up of the nuclear weapons complex and nonproliferation and stewardship of the nuclear stockpile.

Since the 2000s, the Department's priority has been ensuring the Nation's security and prosperity by addressing its energy, environmental, and nuclear challenges through science and technology solutions. The Department has sought to transform the Nation's energy system and secure leadership in clean energy technologies, pursue world-class science and engineering as a cornerstone of economic prosperity, and enhance nuclear security through defense, nonproliferation, and environmental efforts.

Responsibility for Radioactive Legacy of the Cold War

In addition to its energy and science missions, DOE has a mission to complete the safe cleanup of the environment legacy resulting from five decades of nuclear weapons production and Government-sponsored nuclear energy research. Fifty years of nuclear weapons production and energy research generated millions of gallons of liquid radioactive wastes, millions of cubic meters of solid radioactive wastes, thousands of tons of spent nuclear fuel and special nuclear material, along with huge quantities of contaminated soil and water. This has created one of the largest, most diverse, and technically complex environmental cleanup operations in the world.

From 1989 through 1994, the Department's focus was on identification, characterization, and actions to address the most urgent risks of the environmental contamination from the Manhattan Project and Cold War weapons production and research activities. During 1995 through 1999, the focus shifted to active cleanup where significant progress was made across the DOE complex.

Since 2000, DOE has implemented and refined active and long-term cleanup programs to manage accelerated cleanup and closure of sites more efficiently and effectively while continuing to reduce life-cycle costs and shorten site completion schedules. As of 2013, DOE's Environmental Management Program had reduced the number of contaminated sites from 107 sites in 31 states to 16 sites in 11 states. Since 2009, DOE has reduced its active footprint by 688 square miles, from 931 square miles to 243 square miles, demonstrating success in the accelerated cleanup of the Cold War legacy.

- $270 million, $123 million above the FY 2015 enacted level, for Electricity Delivery and Energy Reliability (OE) grid modernization activities to support a smart, resilient electric grid for the 21st century and fund critical emergency response and grid security capabilities, including grant programs to update energy assurance plans and a new effort to support state and multi-state electricity reliability. The request also includes $52 million for R&D to strengthen energy infrastructure against cyber threats.
- $20 million for the Office of Indian Energy Policy and Programs (IE), $4 million above the FY 2015 enacted level, to support DOE's partnership with the Department of the Interior to address the need for clean, sustainable energy systems on Indian lands, and $11 million for a new Tribal Indian Energy Loan Guarantee Program.

1.2.1 Office of the Under Secretary for Science and Energy

The $10.1 billion requested in FY 2016 to fund the Science and Energy program offices is overseen, managed, and coordinated by the Office of the US/SE. Specifically, the Office of the US/SE has purview over SC, EERE, NE, FE, OE, IE, and OTT. Brief descriptions of each of these offices follow; more detailed descriptions of their programmatic activities are discussed in Chapter 2.

To achieve its mission of driving transformative science and technology solutions, the Office of the US/SE has three organizational goals:

- Goal 1: Develop and implement a comprehensive strategy for the Science and Energy programs that recognizes and differentiates the unique values and capabilities of each, and creates new opportunities through their complementarity to develop and transition energy technology solutions and to execute the Department's and Administration's strategy.
- Goal 2: Ensure strategic engagement with and investment in the National Laboratories in order to sustain and strengthen their world-class science and technology capabilities and infrastructure and maintain excellence in mission performance.
- Goal 3: Establish mechanisms for the Science and Energy programs to achieve operational excellence in conducting their research, development, demonstration, and deployment (RDD&D); technology transfer; and other activities with National Laboratories, universities, industry, nonprofits, other stakeholders, and Federal, state, and local governments.

Prior to Secretary Moniz's arrival, SC reported to the then-Under Secretary for Science, while the applied energy technology offices reported to the then-Under Secretary for Energy. Shortly after his confirmation, Secretary Moniz implemented several organizational changes, including realignment of the Science and Energy programs into their current configuration by expanding the position of Under Secretary for Science to encompass SC and the applied energy technology offices. The resulting organizational structure (see figure 1.2) created opportunities for improved coordination among activities that span basic science, applied research, technology demonstration, and deployment as well as strengthened involvement of the associated science and energy laboratories.

Pursuant to its charge to improve alignment and coordination among the Science and Energy program offices—as well as to more strategically engage the National Laboratory enterprise—the Office of the US/SE has initiated a number of key activities and processes. A brief listing of select activities is provided below, with more detail in the following chapters:

- Established a coordinated planning process designed to enable a continuous dialogue, raise awareness, drive effective planning, and enable consistent and comprehensive communication regarding the long-term direction of the Science and Energy program offices.
- Established Technology Teams (or Tech Teams) charged with integrating the activities of the Department around high-priority, high-impact research areas.

- Launched a "National Laboratories Big Ideas Summit" that serves to bring together subject matter experts from DOE's Science and Energy program offices as well as other offices and all 17 National Laboratories to collaboratively explore and propose innovative ideas to advance solutions to key energy issues.
- Formed a joint DOE/National Laboratory Consortium (the Grid Modernization Laboratory Consortium) to help organize the Department's efforts in grid modernization.
- Commenced the development of the QTR to frame, detail, and analyze the energy system and sectors to identify RDD&D opportunities for addressing the national energy-linked challenges to the Nation's economy, environmental quality, and national security.
- Strategically align and leverage programmatic activities.

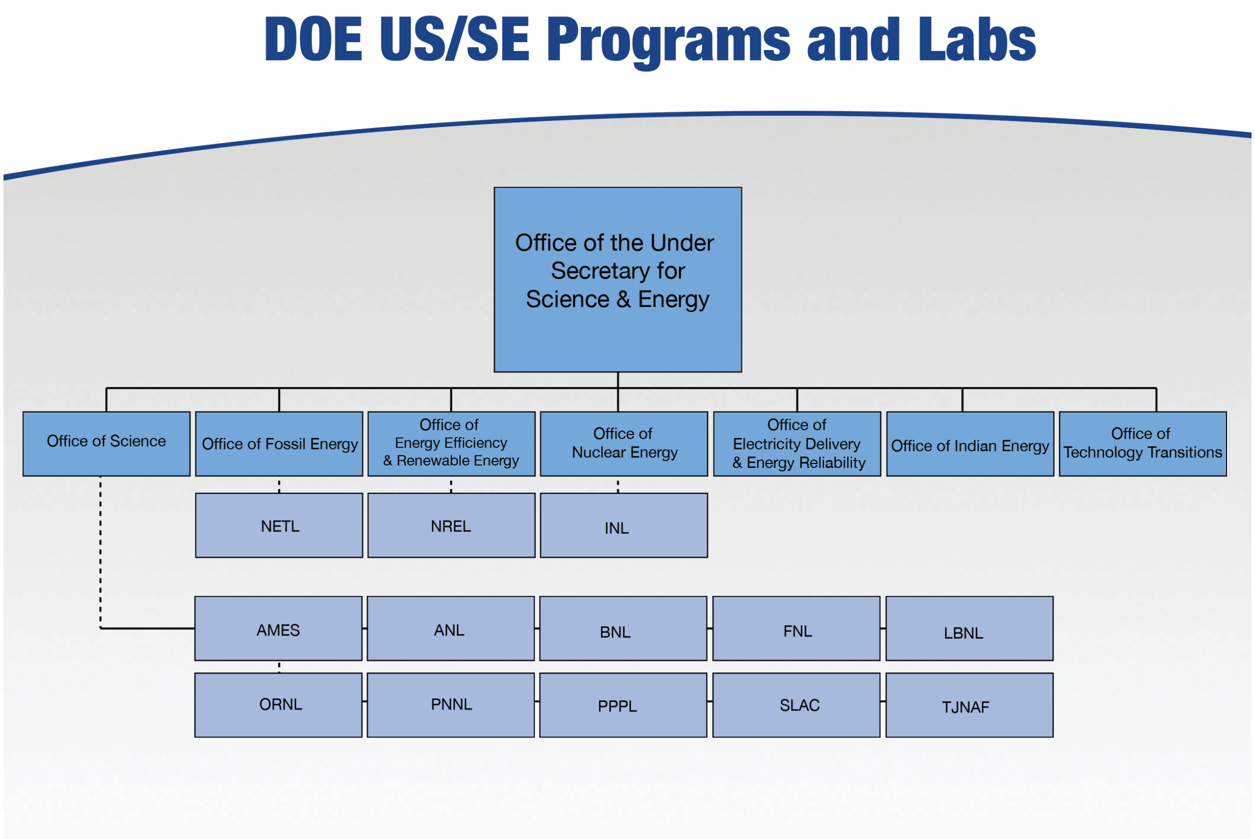


Figure 1.2: Organizational Chart Showing the National Laboratory Stewardship Alignment with SC and the Applied Energy Technology Offices.
The dashed lines indicate the functional responsibility of each program office for stewardship of their respective Laboratories. Not depicted are the Laboratories stewarded outside the purview of the Office of the US/SE. Specifically, as discussed in Chapter 4, Sandia, Lawrence Livermore, and Los Alamos National Laboratories are stewarded by the National Nuclear Security Administration (NNSA), while Savannah River National Laboratory is stewarded by the Office of Environmental Management (EM).

1.2.2 Office of Science

SC is the lead Federal entity supporting fundamental scientific research for energy and is the Nation's largest supporter of basic research in the physical sciences, providing 47 percent of the U.S. Federal support for physical sciences research in FY 2016. Its mission is the delivery and deployment of scientific discoveries and major scientific tools to transform our understanding of nature and to transition technologies to advance the energy, economic, and national security of the United States.

The SC portfolio has two principal thrusts: (1) direct support of scientific research, including discovery-oriented research that pushes the frontiers of science, as well as fundamental research on energy production, conversion, storage, and use; and (2) direct support of the development, construction, and operation of unique, open-access scientific user facilities. These activities have wide-reaching impact. SC supports research in all 50 states and the District of Columbia, at DOE Laboratories and more than 300 universities and institutions of higher learning nationwide. The SC scientific user facilities provide the Nation's researchers with state-of-the-art capabilities that are unmatched anywhere in the world.

SC manages its portfolio of research and scientific facilities through six interdisciplinary scientific program offices: Advanced Scientific Computing Research, Basic Energy Sciences, Biological and Environmental Research, Fusion Energy Sciences, High Energy Physics, and Nuclear Physics. In addition, SC sponsors a range of training and professional development efforts through its Workforce Development for Teachers and Scientists Program, and manages the Department's Small Business Innovation Research and Small Business Technology Transfer programs on behalf of DOE in collaboration with the applied energy technology offices.

SC has primary oversight responsibility for the majority of DOE's National Laboratories, stewarding 10 of the 17 Laboratories, including Ames Laboratory, Argonne National Laboratory (ANL), Brookhaven National Laboratory (BNL), Oak Ridge National Laboratory (ORNL), Pacific Northwest National Laboratory (PNNL), Princeton Plasma Physics Laboratory (PPPL), SLAC National Accelerator Laboratory, Fermi National Accelerator Laboratory, Lawrence Berkeley National Laboratory (LBNL), and the Thomas Jefferson National Accelerator Facility (TJNAF).

1.2.3 The Applied Energy Technology Offices

The applied energy technology offices pursue RDD&D activities across a broad range of energy resources and energy-consuming sectors of the economy. When statutorily directed, the applied energy technology offices exercise or provide their expertise to specific and targeted regulatory authorities. As discussed below and in Chapter 2, the mission and activities of these program offices are guided by legislative authorities from Congress and direction from the Administration.

Synopses of the missions for each of the applied energy technology offices follow. Their missions are designed to be complementary to minimize overlap and ensure proper focus on areas that require Federal engagement, guidance, and direction.

1.2.3.1 Office of Energy Efficiency and Renewable Energy

EERE leads the Department's efforts to research, develop, demonstrate, and deploy or transfer technologies in sustainable transportation, renewable power, and energy efficiency and to reduce market barriers in these sectors.

In the area of sustainable transportation, EERE manages a portfolio of research on electric vehicles, engine efficiency, and clean domestic fuels to develop cost-effective opportunities to reduce the Nation's oil dependence, avoid pollution, and create jobs designing and manufacturing better cars, trucks, and petroleum alternatives. In renewable power, EERE leads a network of researchers and other partners to deliver technologies that will make renewable electricity generation cost-competitive with traditional energy resources. To improve overall energy efficiency, EERE supports work to develop cost-effective, energy-saving solutions. These solutions result in more efficient plants, manufacturing processes, products, and new homes, and ways to improve older homes and buildings.

EERE has oversight responsibility for the National Renewable Energy Laboratory (NREL), the Nation's only National Laboratory solely dedicated to researching and developing renewable energy and energy efficiency technologies.

1.2.3.2 Office of Nuclear Energy

NE's primary mission is to advance nuclear power as a resource capable of making major contributions in meeting the Nation's energy supply, environmental, and energy security needs. The Office supports the diverse civilian nuclear energy programs by leading Federal RDD&D efforts in nuclear energy technologies, including power generation, safety, waste management, hybrid energy systems, and security technologies. NE's contributions help the Nation meet energy security, nonproliferation, and clean energy goals.

NE's RDD&D activities specifically include developing technologies and other solutions that can improve the reliability, sustain the safety, and extend the life of current reactors; developing improvements in the affordability of new reactors; developing sustainable nuclear fuel cycles; demonstrating and deploying solutions; and understanding and minimizing risks of nuclear proliferation and terrorism.

NE has primary oversight of the Idaho National Laboratory (INL), which develops advanced nuclear energy technologies and systems to provide affordable, efficient, reliable, safe, and environmentally sound nuclear energy.

1.2.3.3 Office of Fossil Energy

FE plays a key role in helping the United States meet its need for secure, reasonably priced, and environmentally sound fossil energy supplies. FE's primary mission is to ensure the Nation can continue to rely on clean, secure, and affordable energy from fossil fuels with enhanced environmental protection. The Office is responsible for several high-priority initiatives including implementation of the Clean Coal Power Initiative, which provides co-funding for new coal technologies that can help utilities cut carbon dioxide, sulfur, nitrogen, and mercury pollutants from power plants. FE also oversees the Nation's Strategic Petroleum Reserve and the Northeast Home Heating Oil Reserve, both key emergency response tools to protect the United States from energy supply disruptions.

FE R&D focuses on advanced technologies, such as carbon capture and storage (CCS) to facilitate achievement of climate goals, and advanced energy systems such as chemical looping and oxy-combustion. FE R&D is also centered on crosscutting research, such as plant optimization—where advanced technologies are employed to improve performance and reduce emissions—and other efforts associated with the prudent, safe, and sustainable development of unconventional domestic resources like natural gas hydrates.

FE stewards the National Energy Technology Laboratory (NETL), a Government-owned and Government-operated facility, in support of these missions. NETL is the lead field center for FE's R&D program.

1.2.3.4 Office of Electricity Delivery and Energy Reliability

OE leads the Department's efforts to strengthen, transform, and improve U.S. electricity infrastructure and provides national leadership to help ensure that the Nation's energy delivery systems are secure, resilient, and reliable.

To accomplish its mission, OE works with private industry, academia, and Federal, state, local, and tribal governments on a variety of initiatives to modernize the electric grid. OE works to develop new technologies to improve the infrastructure that brings electricity into U.S. homes, offices, and factories and to support the Federal and state electricity policies and programs that shape electricity system planning and market operations. OE also works to bolster the resiliency of the electric grid and assists with restoration when major energy supply interruptions occur such as those resulting from natural disasters and other hazards or threats.

1.2.3.5 Office of Indian Energy Policy and Programs

IE has the responsibility to assist Native American and Alaska Native tribes with energy development, capacity building, energy infrastructure, energy costs, and electrification of Indian lands and homes. Specifically, the mission of IE is to direct, foster, coordinate, and implement energy planning, education, management, and competitive grant programs to assist these tribes.

IE provides the following programmatic activities and support to tribal entities: technical assistance, education, capacity building, research and analysis, and financial assistance. IE works within DOE, across Government agencies, and with Indian tribes and organizations to promote Indian energy policies and initiatives. IE performs these functions within the scope of DOE's mission and consistent with the Federal Government's trust responsibility, tribal self-determination policy, and government-to-government relationship with Indian tribes.

1.2.4 Office of Technology Transitions

In 2015, the Secretary recast the Office of the Technology Transfer Coordinator as OTT in order to coordinate and optimize how the Department transitions early-stage R&D to applied energy technologies through technology transfer, commercialization, and deployment activities. The OTT develops the Department's strategic policy and vision for expanding the commercial impact of DOE's RDD&D portfolio over the short, medium, and long term. OTT synchronizes the Department's multiple paths of RDD&D activities toward technology transfer and commercialization. It is aligned with the President's Climate Action Plan, cross-agency lab-to-market priorities, and goals as set forth in the 2011 Presidential Memorandum—Accelerating Technology Transfer and Commercialization of Federal Research in Support of High Growth Businesses.

Other Complementary Offices and Agencies

Other agencies and DOE offices support the mission work of the Science and Energy program offices by enabling advancement of their research projects and other complementary efforts through short- and long-term investments, technical assistance, and other strategic support for development and, in some cases, potential commercialization.

Advanced Research Projects Agency – Energy

Established by the America COMPETES Act of 2007 following a recommendation by the National Academies in the Rising Above the Gathering Storm report, the Advanced Research Projects Agency – Energy (ARPA-E) is modeled on the successful Defense Advanced Research Projects Agency (DARPA). ARPA-E's overarching mission is to catalyze transformational energy technologies that could create a more secure and affordable American future by advancing high-potential, high-impact energy projects that are too early for private sector investment.

ARPA-E addresses its mission by identifying and funding research to accelerate early and promising fundamental and applied scientific work into breakthrough energy technologies that are too risky for the private sector. Specific key goals include (1) enhancing the economic and energy security of the United States through the development of energy technologies that reduce imports of energy from foreign sources, reduce energy-related emissions (including greenhouse gases), and improve the energy efficiency of all economic sectors; and (2) ensuring that the United States maintains a technological lead in developing and deploying advanced energy technologies.

ARPA-E and the program offices within the Office of the Under Secretary for Science and Energy engage carefully to ensure their respective activities are complementary.

Loan Programs Office

DOE's Loan Programs Office (LPO) invests in the power of American innovation and is dedicated to advancing an all-of-the-above energy strategy that avoids, reduces, or sequesters greenhouse gases. LPO investments accelerate the deployment of innovative clean energy projects and advanced vehicle manufacturing facilities across the United States. LPO supports a large, diverse portfolio of more than $30 billion in loans, loan guarantees, and commitments covering more than 30 projects across the United States. Together, these projects have generated more than $50 billion in total project investment, supported tens of thousands of jobs, cut pollution, and enhanced American competitiveness in the global economy.

In addition to ARPA-E and the Loan Programs Office, the following entities also complement the work of the applied energy technology programs.

Other Complementary Offices and Agencies (continued)

Federal Energy Regulatory Commission

The Federal Energy Regulatory Commission (FERC) is an independent agency that regulates the interstate transmission of natural gas, oil, and electricity and regulates natural gas and hydropower projects. DOE and FERC work closely on transmission projects to improve the efficiency and modernization of the grid.

Energy Information Administration

Established in 1976, the U.S. Energy Information Administration (EIA) collects, analyzes, and disseminates independent and impartial energy information to promote sound policymaking, efficient markets, and public understanding of energy and its interaction with the economy and the environment. The 1977 Department of Energy Organization Act established EIA as the single Federal Government authority for energy information and gave it independence from the rest of DOE with respect to data collection, and from the whole Government with respect to the content of EIA reports. EIA reports cover topics such as energy consumption, alternative fuels, greenhouse gas emissions, fossil fuel transportation rates and distribution patterns, electricity production from renewable energy sources, foreign purchases, and imports of uranium.

Power Marketing Administrations

Established by Congress in 1937, DOE's Power Marketing Administrations (PMAs) distribute and sell electricity from a network of more than 130 federally built hydroelectric dams. The four organizations that make up DOE's PMAs—Bonneville Power Administration, Western Area Power Administration, Southeastern Power Administration, and Southwestern Power Administration—do not own or manage the dams themselves, but rather market the power and in many cases maintain the transmission infrastructure to distribute the low-cost, carbon-free electricity.

1.3 The National Laboratories' Role in the Science and Energy Enterprise

The Department of Energy's National Laboratories (see figure 1.3) are the scientific powerhouse that underpins the Department's efforts to tackle the critical scientific challenges of our time. The National Laboratories possess unique instruments and facilities, many of which are found nowhere else in the world. They address large-scale, complex research and development challenges with a multidisciplinary approach that places an emphasis on transitioning basic science to innovation. Specifically, the National Laboratories:

- conduct research in physical, chemical, biological, and computational and information sciences that advances our understanding of the world;
- advance U.S. energy independence and leadership in clean energy technologies to ensure the ready availability of clean, reliable, and affordable energy;
- enhance global, national, and homeland security by ensuring the safety and reliability of the U.S. nuclear deterrent, helping to prevent the proliferation of weapons of mass destruction, and securing the Nation's borders; and
- design, build, and operate distinctive scientific instrumentation and facilities, and make these resources available to the research community.

DOE National Laboratories

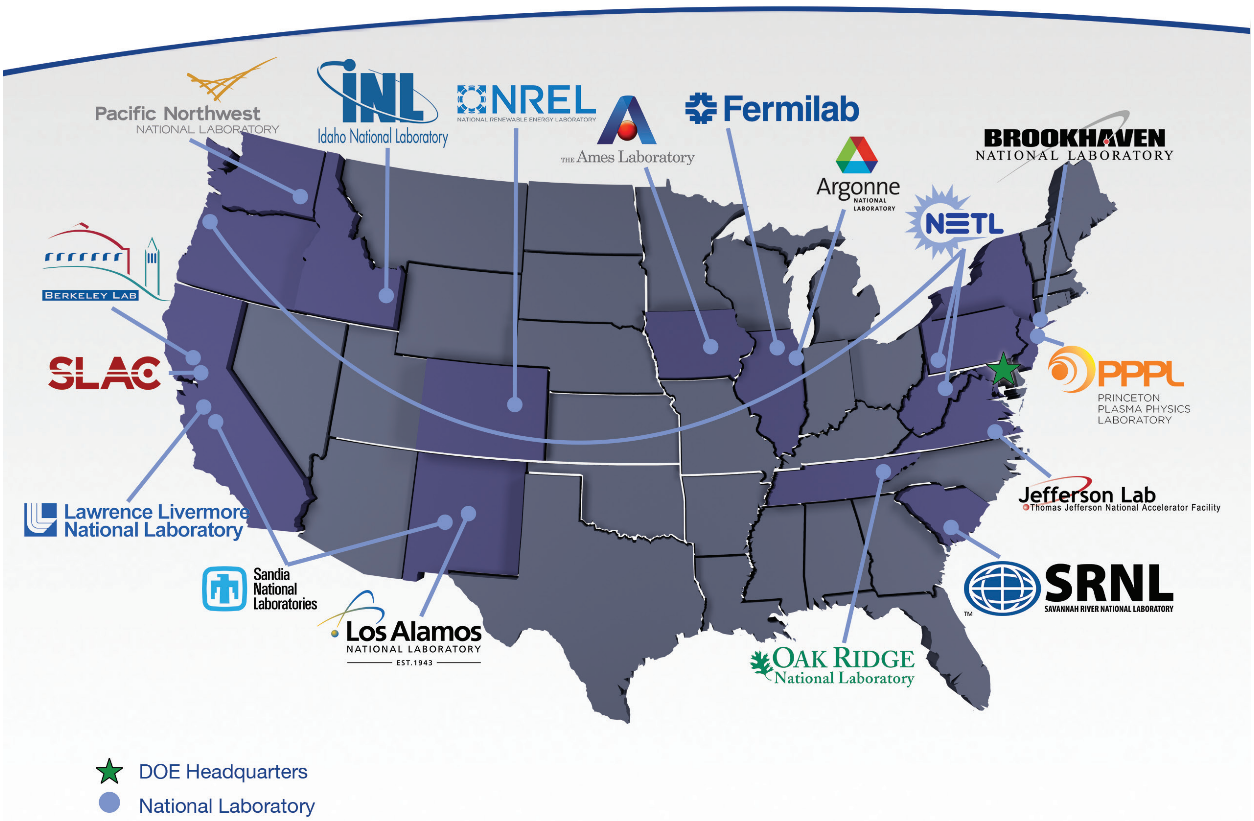


Figure 1.3: Map of DOE National Laboratories.
This figure illustrates the location of the 17 National Laboratories stewarded by DOE. DOE headquarters in Washington, DC, is also denoted.

U.S. National Laboratories are generally managed using one of two models: the Government-owned, contractor-operated (GOCO) model and the Government-owned, Government-operated (GOGO) model. Sixteen of the 17 National Laboratories are Federally Funded Research and Development Centers (FFRDCs) that are managed as GOCOs. The operation of these 16 GOCOs by private sector organizations is conducted under sponsoring agreements known as management and operating (M&O) contracts. M&O contracts are characterized by their special purpose and the close relationship they create between the Department and the contractor. The work performed under M&O contracts is intimately related to DOE's mission, is of a long-term and continuing nature, and, among other things, includes special requirements for work direction, safety, security, cost controls, and site management. The leveraging of the FFRDC operating model helps ensure that the National Laboratories are a long-term partner with DOE and can respond to changing needs while also maximizing the return on taxpayers' investment. The National Energy Technology Laboratory is a GOGO. This model fulfills many of the same services as a GOCO lab, but rather than consisting of third-party contractors, NETL's staff are primarily employees of the Federal Government.

More detailed discussions of the National Laboratories appear in Chapters 2 and 4 of this document.

2

Chapter 2: The Science and Energy Portfolio

This chapter provides a detailed overview of the program offices overseen by the Office of the Under Secretary for Science and Energy (US/SE), with additional information provided on other complementary offices and agencies within DOE that contribute to the Department's science and energy mission. For each US/SE program office, the discussion addresses the mission, organizational structure, facilities and offices, stewarded National Laboratories, and research, development, demonstration, and deployment (RDD&D) activities of the office. The chapter also provides details on crosscutting science and technology initiatives coordinated by the Office of the US/SE. These initiatives address significant RDD&D opportunities using expertise drawn from multiple areas of the Department. The chapter concludes with a discussion of Departmental international activities that globally extend the reach of the Department's scientific and technical expertise.

2.1 Mission and RDD&D Activities by Program Office

The US/SE program offices lead the Department's engagement in transformative science, technology innovation, and market solutions. These offices collectively address fundamental science, technology, and market-based challenges to achieving a clean energy future. The FY 2016 Congressional Budget Request for the US/SE program offices is $10.1 billion, divided among the offices as shown in figure 2.1. The figure details the major programmatic activities undertaken by each of the program offices. Each of the following subsections provides further information on these activities.

Through these offices and the National Laboratories, DOE partners with other governmental agencies, industry, and academia to advance scientific discovery, foster technological innovation and technology transfer, provide technical capabilities to help shape the Nation's science and technology (S&T) agenda, and support our Nation's energy strategy.

Office of Science At-a-Glance

- Supports more than 22,000 Ph.D. scientists, graduate students, engineers, and support staff at more than 300 institutions including all 17 DOE Laboratories
- Provides 47 percent of the U.S. Federal support of basic research in the physical sciences; major U.S. supporter of physics, chemistry, materials sciences, computational sciences, and biology—for discovery science and for energy sciences
- Operates the world's largest collection of scientific user facilities operated by a single organization—used by nearly 31,000 researchers each year
- Supported research that led to more than 100 Nobel Prizes during the past six decades, with more than 20 in the past 10 years
- FY 2015 enacted: $5.068 billion; FY 2016 budget request: $5.340 billion
- Supported approximately 940 Federal full-time employees (FTE) in FY 2015
- Web site: www.science.energy.gov

2.1.1 Office of Science

The mission of U.S. Department of Energy's Office of Science (SC) is to deliver scientific discoveries and major scientific tools to transform our understanding of nature and to advance the energy, economic, and national security of the United States.

SC is the Nation's largest Federal sponsor of basic research in the physical sciences and the lead Federal office supporting fundamental scientific research for energy. SC accomplishes its mission and advances national goals by supporting work in three arenas:

- *The frontiers of science*—discovering nature's mysteries from the study of subatomic particles, atoms, and molecules that are the building blocks of the materials of our everyday world to the deoxyribonucleic acid (DNA), proteins, and cells that are the building blocks of entire biological systems; each of the programs in SC supports research to probe the most fundamental questions of its disciplines.
- *The 21st century tools of science*—providing the Nation's researchers with 28 state-of-the-art national scientific user facilities, research infrastructure that constitutes the most advanced tools of modern science, enabling the United States to remain at the forefront of science, technology, and innovation.
- *Science for energy and the environment*—advancing a clean energy agenda through fundamental research on energy production, conversion, storage, transmission, and use and through advancing our understanding of the earth and its climate; targeted investments include the three DOE Bioenergy Research Centers (BRCs), 32 Energy Frontier Research Centers (EFRCs), two Energy Innovation Hubs, and atmospheric process and climate modeling research.

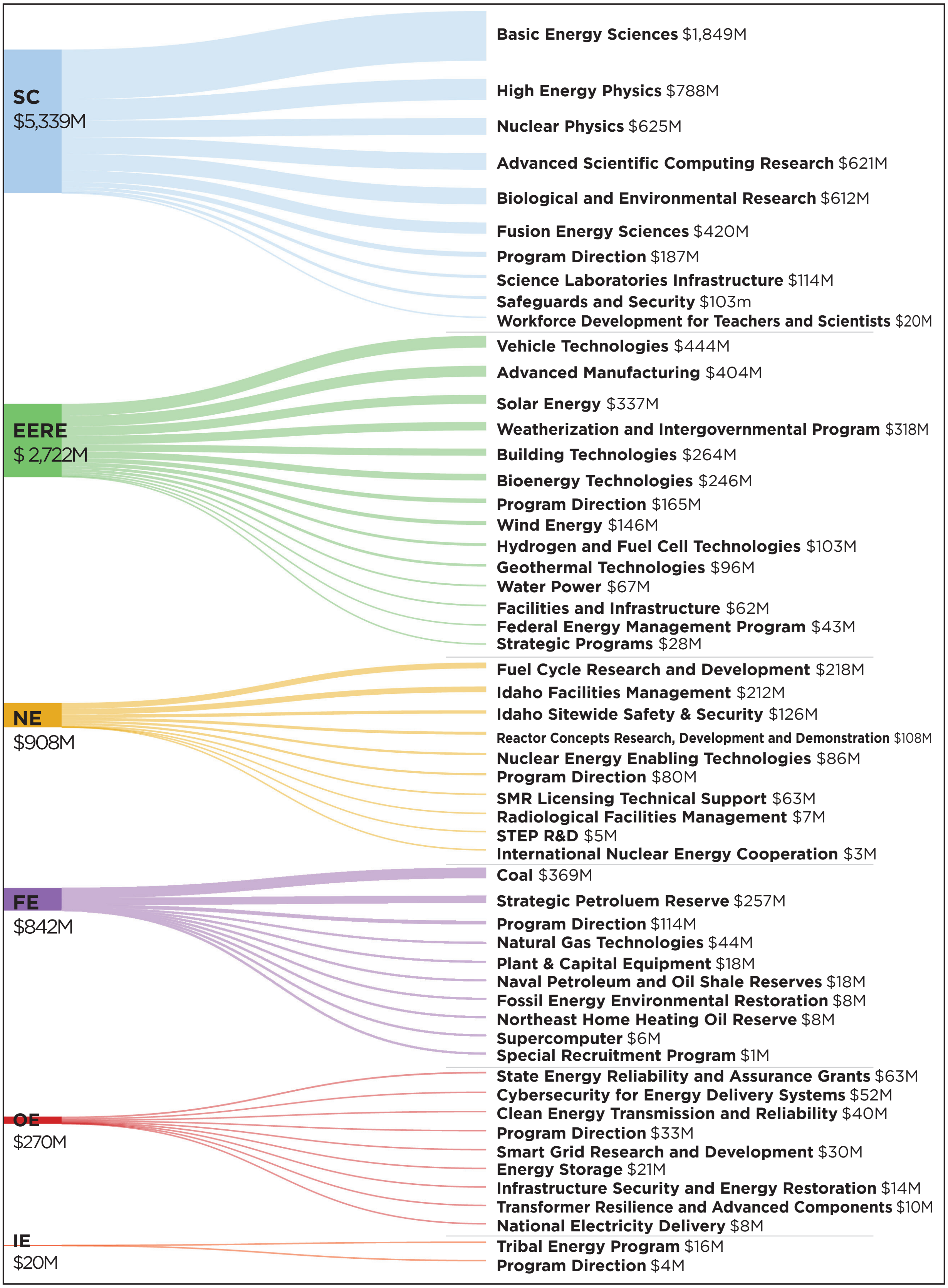


Figure 2.1: The US/SE Program Offices' FY 2016 Congressional Budget Request.
This figure details how the $10.1 billion request is allocated to the Science and Energy program offices for programmatic activities. Note: totaled amounts may vary due to rounding.

SC has long been a leader of U.S. scientific discovery and innovation and plays an integral role in transitioning technologies to enable their deployment and commercialization. Over the decades, SC investments and accomplishments in basic research have provided the foundations for new technologies, businesses, and industries, making significant contributions to our Nation's economy and quality of life. SC supports competitively awarded research at over 300 universities and institutions of higher education nationwide and at all 17 DOE Laboratories. SC also provides the Nation's researchers with state-of-the-art national scientific user facilities—the large machines for modern science. These facilities offer capabilities unmatched anywhere in the world and enable U.S. researchers and industries to remain at the forefront of science, technology, and innovation.

The FY 2016 request for SC is $5.34 billion, an increase of $272 million relative to the FY 2015 enacted level.

2.1.1.1 Background

The origins of SC trace to the Manhattan Project. The all-out effort to create the world's first nuclear weapon created a vast research and development apparatus, including large, multipurpose facilities that became the Nation's first National Laboratories, under the control of the War Department's Army Corps of Engineers. In 1946, the Atomic Energy Act transferred responsibility for nuclear research and development from the War Department to a new independent civilian agency, the Atomic Energy Commission (AEC). The tools needed to carry out this mission were of a scale that required the Federal Government to construct and operate them. Throughout the 1940s and 1950s, the AEC created a network of National Laboratories to host machines, such as particle accelerators, colliders, and calutrons for isotope separation, that became the foundation of this new nuclear science.

Motivated by the 1973 oil embargo, lawmakers placed the research functions of the AEC under the newly created Energy Research and Development Administration (ERDA) in 1974. ERDA consolidated existing energy research activities across the AEC and other agencies; its basic research portfolio included nuclear, solar, fossil, and geothermal energy, as well as conservation, synthetic fuels, and power transmission. In 1977, the establishment of DOE gathered under one authority most of the Federal Government's energy-related research, policy, and regulatory activities (with the exception of regulation of the nuclear power industry). The Department of Energy Organization Act of 1977 specifically created the Office of Energy Research. In 1998, the Energy and Water Development Appropriations Act changed the name of the Office of Energy Research to the Office of Science.

SC is led by the Director for Science, who is appointed by the President of the United States with the advice and consent of the United States Senate. SC executes its activities under the Deputy Director for Science Programs, the Deputy Director for Field Operations, and the Deputy Director for Resource Management.

2.1.1.2 SC Programs

SC supports a diverse portfolio of fundamental research through its six core research programs: Advanced Scientific Computing Research, Basic Energy Sciences, Biological and Environmental Research, Fusion Energy Sciences, High Energy Physics, and Nuclear Physics. Each of these programs supports research to probe the most fundamental questions of its fields and disciplines, as well as world-leading scientific user facilities to advance the forefront of these disciplines. An overview of each program's mission, major research areas, and user facilities is provided below. A more detailed overview of how SC plans, builds, and operates scientific user facilities is provided in section 3.3.3.

The SC research program offices maintain balanced research portfolios to maximize the program's potential to achieve mission goals and objectives. They are also responsible for conducting scientific program planning, execution, and management across a broad spectrum of scientific disciplines; and communicating research interests and priorities to the scientific community.

In addition to the research program offices, SC manages additional programs that work closely with the six research program offices: the DOE Small Business Innovation Research and Small Business Technology Transfer Programs, the Office of Workforce Development for Teachers and Scientists, and the Office of Project Assessment.

All nine of these offices are overseen by the SC Deputy Director for Science Programs.

2.1.1.2.1 Advanced Scientific Computing Research

Advanced Scientific Computing Research's (ASCR) mission is to advance applied mathematics and computer science; deliver the most advanced computational scientific applications in partnership with disciplinary science; advance computing and networking capabilities; and develop future generations of computing hardware and tools for science, in partnership with the research community, including U.S. industry. The strategy to accomplish this has two thrusts: developing and maintaining world-class computing and network facilities for science; and advancing research in applied mathematics, computer science, and advanced networking.

ASCR works with the other SC program offices through the Scientific Discovery through Advanced Computing (SciDAC) program, which is focused on accelerating progress in scientific computing through partnerships among applied mathematicians, computer scientists, and scientists in other disciplines. ASCR also administers the ASCR Leadership Computing Challenge (ALCC) whose mission is to provide up to 30 percent of the computational resources at ASCR's supercomputing facilities for projects of interest to DOE with an emphasis on high-risk, high-payoff simulations in areas directly related to the DOE mission. The ALCC also seeks to broaden the community of researchers capable of using leadership computing resources. ASCR and the National Nuclear Security Administration (NNSA) are partnering to make strategic investments in hardware, methods, and critical technologies to address the exascale technical challenges and deliver a capable system (a system capable of a million trillion or 1018 scientific calculations per second) that will help scientists harness the thousand-fold increase in capability to address fundamental research challenges and will maintain U.S. competitiveness in high-performance computing (HPC). Additional collaborative efforts between ASCR and NNSA are described at the end of Chapter 2.

ASCR's FY 2016 areas of focus are described in their Congressional Budget Request. The FY 2016 request for ASCR is $621 million, divided between $179 million for mathematical, computational, and computer sciences research and $442 million for high-performance computing and network facilities.

The Mathematical, Computational, and Computer Sciences Research subprogram supports research activities to effectively use the current and future generations of DOE's computer and networking capabilities. Computational science is increasingly central to progress at the frontiers of science and to our most challenging engineering problems. Accordingly, the subprogram delivers new mathematics required to more accurately model systems involving processes taking place across a wide range of time and length scales; software, tools, and middleware to efficiently and effectively harness the potential of today's high-performance computing systems and advanced networks for science and engineering applications; operating systems, data management, analyses, representation model development, user interfaces, and other tools required to make effective use of future-generation supercomputers and the data sets from current and future scientific user facilities; computer science and algorithm innovations that increase the productivity, energy efficiency, and resiliency of future-generation supercomputers; networking and collaboration tools to make scientific resources readily available to scientists in university, National Laboratory, and industrial settings; and codesign centers to couple application development, core research results, and technology development in industry. The $179 million for mathematical, computational and computer sciences research in FY 2016 is proposed as $49 million for applied mathematics, $57 million for computer science, $48 million for computational partnerships, and $19 million for next-generation networking for science.

More than two-thirds of ASCR's $442 million request for high-performance computing and network facilities is devoted to Research and Evaluation Prototypes (REP), at $142 million, and Leadership Computing Facilities (LCFs), at $171 million. The REP activity has recently supported R&D partnerships with U.S. vendors to improve the energy efficiency and reliability of critical technologies such as memory, processors, network interfaces, and interconnects for use in next-generation, massively parallel supercomputers. In FY 2016, REP will competitively select R&D partnerships with U.S. computer vendors to initiate the design and development of node and system designs suitable for exascale systems. These efforts will influence the development of prototypes that advance DOE goals and are based on the results of REP investments made in FY 2014–15. The REP activity also supports the Computational Science Graduate Fellowship to provide the trained computational scientists the Department needs at the ASCR facilities and for exascale computing efforts.

ASCR's remaining FY 2016 request supports high-performance production computing ($76 million), Leadership Computing Facilities ($171 million), and high-performance network facilities and testbeds ($38 million). This supports ASCR's four designated scientific user facilities: Leadership Computing Facilities (LCFs) at Argonne and Oak Ridge National Laboratories, the National Energy Research Scientific Computing (NERSC) Center at LBNL, and the Energy Sciences Network at LBNL. The NERSC will be upgraded to approximately 30 petaflops in FY 2016–17. The LCFs have planned upgrades to 75–200 petaflops at each site in the 2018–19 timeframe. The Energy Sciences Network (ESnet) operates the national and international network infrastructure to support critical DOE science applications, SC facilities, and scientific collaborations around the world through a 100 Gbps production network.

Of note, ASCR is a key element of the Department's exascale computing crosscut described in section 2.3.

ASCR's request for SBIR/STTR in FY 2016 is $21 million.

The Argonne Leadership Computing Facility at ANL houses the Mira supercomputer pictured here and is one of four designated scientific user facilities managed by ASCR. Mira will provide billions more processor-hours per year to the scientists, engineers, and researchers who use it to run complex simulations of everything from nuclear reactors to blood vessels, through allocations awarded through the Innovative and Novel Computational Impact on Theory and Experiment (INCITE), ALCC, and Director's Discretionary programs. *Photo credit: ANL*

2.1.1.2.2 Basic Energy Sciences

Basic Energy Sciences (BES) supports 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. The research disciplines that BES 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 important aspect of energy resources, production, conversion, transmission, storage, efficiency, and waste mitigation.

BES's FY 2016 areas of focus are described in their Congressional Budget Request. The FY 2016 budget request for BES is $1.85 billion, of which approximately 90 percent is distributed among three broad topics: $375 million for materials sciences and engineering, $322 million for chemical sciences, geosciences, and biosciences, and $952 million for scientific user facilities. The remaining $200 million supports construction at the Linac Coherent Light Source-II at SLAC.

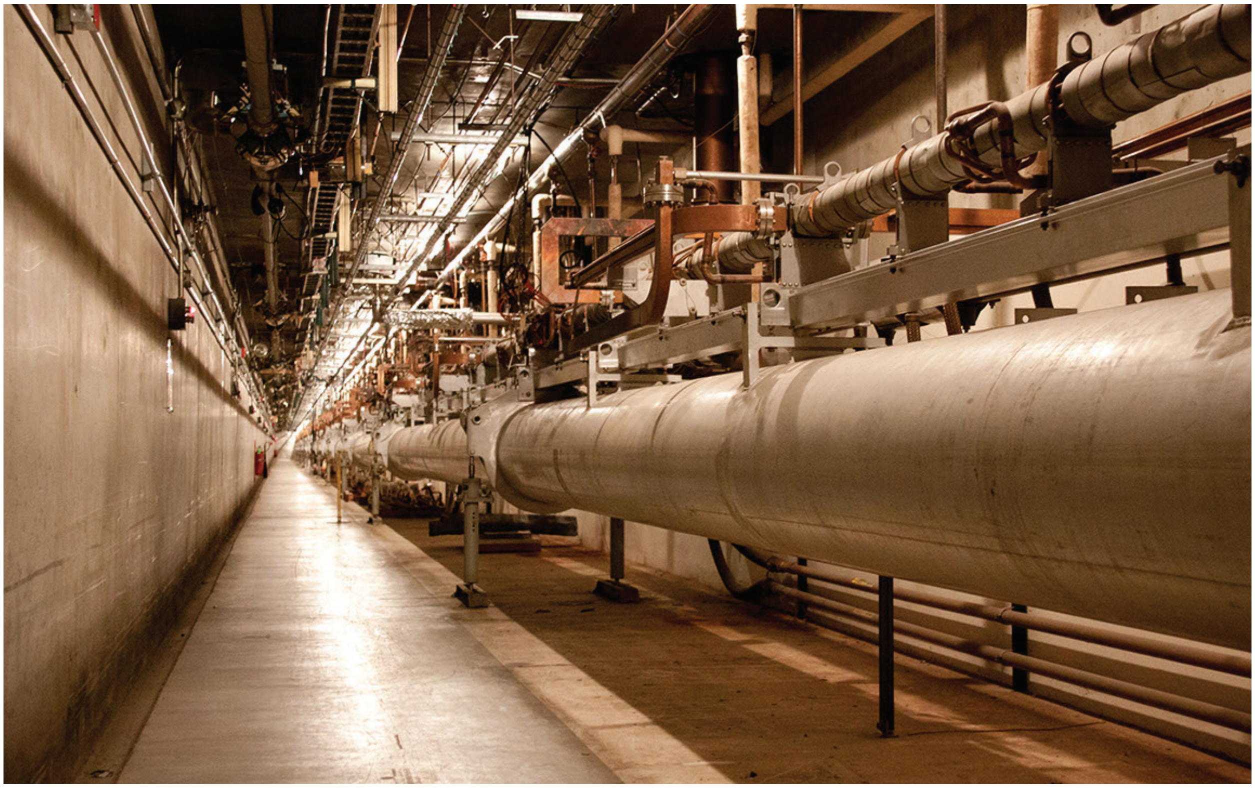
The FY 2016 $375 million request for materials sciences and engineering supports research to provide the understanding of materials synthesis, behavior, and performance that will enable solutions to wide-ranging challenges. This portfolio also supports research that explores the origin of macroscopic material behaviors, their fundamental connections to atomic, molecular, and electronic structures, and their evolution as materials move from nanoscale building blocks to mesoscale systems.

The materials sciences and engineering portfolio includes three integrated research activities: scattering and instrumentation sciences ($67 million), condensed matter and materials physics ($122 million), and materials discovery, design, and synthesis ($72 million). Scattering and instrumentation sciences activities involve advancing science using new tools and techniques to characterize materials structure across multiple length scales and materials dynamics across multiple time scales, and to correlate this data with materials performance under real world conditions. Efforts in condensed matter and materials physics focus on understanding the foundations of material functionality and behavior. In materials discovery, design, and synthesis, the program is developing the knowledge base and synthesis strategies to design and precisely assemble structures in order to control materials properties, enabling discovery of new materials with unprecedented functionalities.

The materials sciences and engineering portfolio also supports the DOE Experimental Program to Stimulate Competitive Research (EPSCoR), at a level of $8.5 million, with the other science and energy program offices, as well as some of the Energy Frontier Research Centers (EFRCs) ($56 million), and the Batteries and Storage Hub, called the Joint Center for Energy Storage Research (JCESR) ($24 million). The final $12 million in materials sciences research is for computational materials sciences, a focus designed to advance U.S. leadership in the development of computational codes in this area.

The $322 million request for the chemical sciences, geosciences, and biosciences portfolio includes coordinated research activities in three areas: fundamental interactions ($79 million), chemical transformations ($93 million), and photochemistry and biochemistry ($69 million). Fundamental interactions support 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 involve the 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 focuses 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 chemical sciences, geosciences, and biosciences portfolio supports the EFRCs ($54 million), the Fuels from Sunlight Energy Innovation Hub, called the Joint Center for Artificial Photosynthesis (JCAP) ($15 million), and general plant projects ($600 thousand).



The FY 2016 budget request for BES includes $200 million to support construction at SLAC's Linac Coherent Light Source-II. It consists of 2 miles of copper cavities, 25 feet underground, that use radio waves to push electrons and their antiparticles, positrons, nearly the speed of light. *Photo credit: SLAC*

BES manages 12 designated scientific user facilities. These include five x ray light sources: the Advanced Light Source at LBNL, the Advance Photon Source at ANL, the Stanford Synchrotron Radiation Light Source and the Linac Coherent Light Source at SLAC, and the National Synchrotron Light Source II at BNL. BES also manages two neutron scattering facilities: the Spallation Neutron Source and High Flux Isotope Reactor at ORNL; and five Nanoscale Science Research Centers: the Center for Functional Nanomaterials at BNL, the Center for Integrated Nanotechnologies at SNL and LANL, the Center for Nanophase Materials Sciences at ORNL, the Center for Nanoscale Materials at ANL, and the Molecular Foundry at LBNL.

Funding for the scientific user facilities, at an FY 2016 request of $952 million, supports the continual development and upgrade of the instrumental capabilities including new x ray and neutron experimental stations, improved core facilities, and new standalone instruments. Also supported is research in accelerator and detector development to explore technology options for the next generations of x ray and neutron sources. The advances enabled by these facilities extend from energy-efficient catalysts for clean energy production to spin-based electronics and new drugs for cancer therapy.

2.1.1.2.3 Biological and Environmental Research

Biological and Environmental Research (BER) supports fundamental research and scientific user facilities to achieve a predictive understanding of complex biological, climatic, and environmental systems for a secure and sustainable energy future. BER research seeks to understand how biological systems work, how they interact with each other, and how they can be manipulated to harness their processes and products. BER research also advances understanding of how the Earth's dynamical, physical, and biogeochemical systems (the atmosphere, land, oceans, sea ice, and subsurface) interact and cause future climate and environmental change.

BER's FY 2016 areas of focus are described in their Congressional Budget Request. The FY 2016 request for BER is $612 million, divided between $294 million for biological systems science and $318 million for climate and environmental sciences.

BER's biological systems science research supports multidisciplinary research focused on plant and microbial systems employing approaches that include genome sequencing, proteomics, metabolomics, structural biology, high-resolution imaging and characterization, and integration of information into computational models that can be iteratively tested and validated to advance a predictive understanding of biological systems from molecules to mesoscale. At the heart of this is research to discover and articulate the principles that guide the translation of the genetic code into functional proteins and the metabolic and regulatory networks underlying the systems biology of plants and microbes as they respond to and modify their environments. BER's effort to provide the fundamental understanding of plants and microbes as the basis for developing cost-effective processes for biofuels production from biomass is significantly advanced through three DOE Bioenergy Research Centers.

In FY 2016, within biological systems science, the heaviest program investments are in genomic science ($193 million), with more than three-quarters of those funds dedicated to foundational genomics research (at $76 million) and the Bioenergy Research Centers (at $75 million). Genomic sciences research activities continue with core research currently underway at DOE Bioenergy Research Centers to provide a scientific basis for sustainable and cost-effective bioenergy production. Genomic science activities are supported by ongoing integrative efforts to combine genomic information in hypothesis-testing computational formats and continued developments to sequence and interpret DNA from a wide variety of plants and microbial communities at the DOE Joint Genome Institute (JGI), which is a designated user facility. JGI, supported by a $70 million request, continues to implement a new strategic plan to incorporate new capabilities to not only sequence DNA but to interpret, manipulate, and synthesize DNA in support of biofuels, biodesign, and environmental research. Funding levels decrease for efforts in structural biology infrastructure and are completed for radiological sciences as biological systems science activities continue to prioritize on DOE's bioenergy and environmental missions.

The remaining funding within biological systems science goes to genomics analysis and validation ($9 million), metabolic synthesis and conversion ($16 million), computational biosciences ($16 million), mesoscale to molecules ($10 million), and radiological sciences ($2 million). Funding of $10 million is also requested for structural biology infrastructure.

BER's climate and environmental sciences research supports fundamental science and research capabilities that enable major scientific developments in climate-relevant atmospheric and ecosystem process and modeling research. The work focuses on the three most important sources of uncertainty in our understanding of the Earth's radiant energy balance: clouds, aerosols, and atmospheric greenhouse gases. BER supports an integrated portfolio of research from molecular-level to field-scales, emphasizes the coupling of multidisciplinary experimentation and advanced computer models, and is aimed at developing predictive, systems-level understanding of the fundamental science associated with climate change and other energy-related environmental challenges.

The $318 million in FY 2016 for climate and environmental research activities will focus on three primary research activities: atmospheric system research ($26 million), environmental system science ($63 million), and climate and earth system modeling ($102 million). The remaining funds support the Program's two scientific user facilities ($108 million) and a data management effort ($7 million). The climate and earth system modeling research includes the interactions of human and natural Earth systems needed to simulate climate variability and change from years to decades to centuries at regional and global scales. The research specifically focuses on quantifying and reducing the uncertainties in Earth system models based on more advanced model development, diagnostics, and climate system analysis.

The climate and environmental sciences program supports BER's remaining two scientific user facilities: the Environmental Molecular Sciences Laboratory at PNNL ($43 million), and the Atmospheric Radiation Measurement Climate Research Facility ($65 million), which is a network of several fixed sites in the United States and mobile sites deployed around the world.

2.1.1.2.4 Fusion Energy Sciences

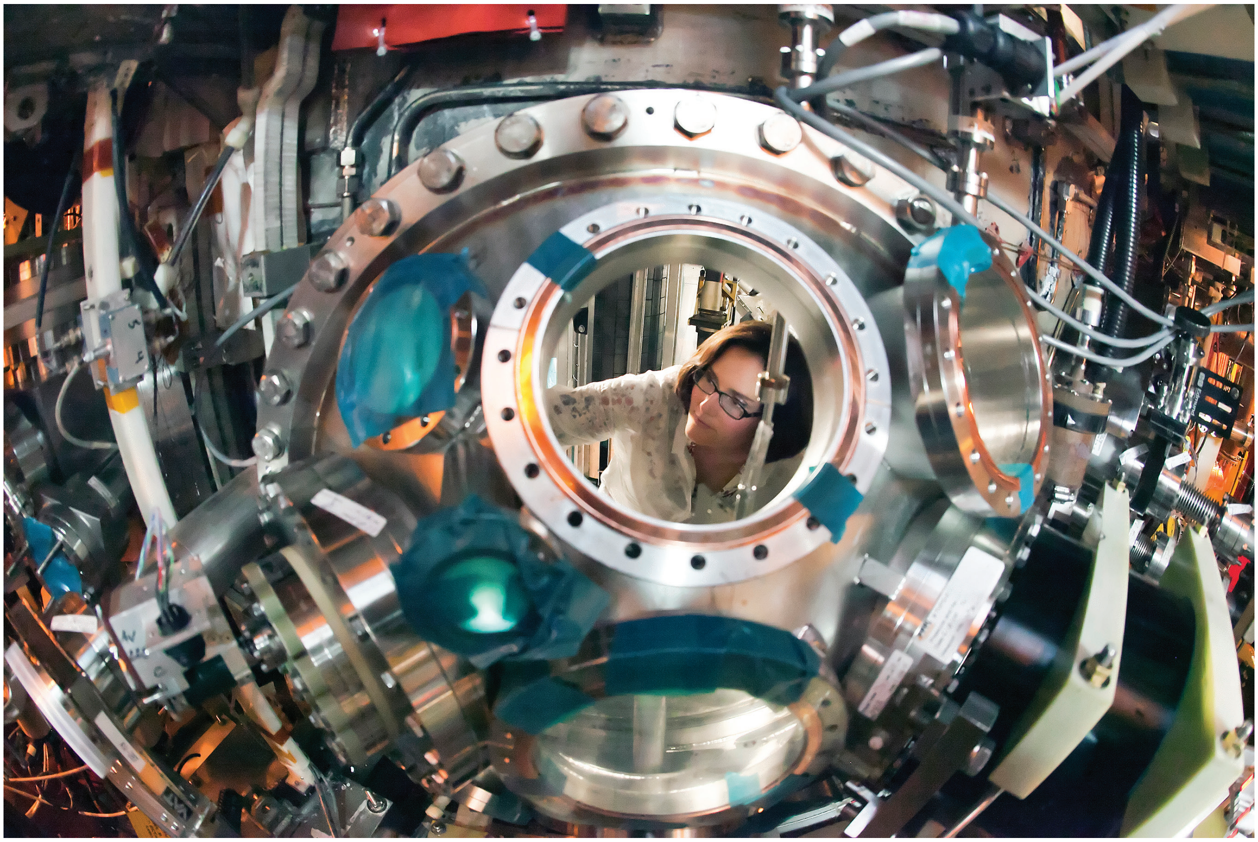
Fusion Energy Sciences (FES) supports research to expand the fundamental understanding of matter at very high temperatures and densities and to build the scientific foundation for fusion energy. This is accomplished through the study of plasma, the fourth state of matter, and how it interacts with its surroundings. The next frontier for all the major fusion programs around the world is the study of the burning plasma state, in which the fusion process itself provides the energy required to sustain the plasma temperature (i.e., self-heating). Production of strongly self-heated fusion plasma will allow the discovery and study of a number of new scientific phenomena.

FES also supports the construction and scientific operation of the ITER project, a major focus of the U.S. fusion research program. ITER will be the world's first magnetic confinement long-pulse, high-power burning plasma experiment aimed at demonstrating the scientific and technical feasibility of fusion energy.

FES's FY 2016 areas of focus are described in their Congressional Budget Request. The FY 2016 request for FES is $420M, divided between $192 million for burning plasma science: foundations, $31 million for burning plasma science: long pulse, $47 million for discovery plasma science, and $150 million for construction of ITER.

Within the largest funding line—burning plasma science; foundations—$92 million is for research, operations, and targeted upgrades to the DIII-D S tokamak facility, and $65 million is for the operations and performance improvements of the National Spherical Torus Experiment (NSTX), which completed a major upgrade in FY 2014. Another $28 million supports fusion science theory and simulation to continue to advance the scientific understanding of the fundamental physical processes governing the behavior of magnetically confined plasmas. A budget of $5 million is requested for general plant projects and infrastructure.

The burning plasma science: long pulse subprogram explores new and unique scientific regimes that can be achieved with long-duration superconducting international machines and addresses the development of the materials required to withstand the extreme conditions in a burning plasma environment. The key objectives of this area are to utilize these new capabilities to accelerate our scientific understanding of how to control and operate a burning plasma, as well as to develop the basis for a future fusion nuclear science facility. This subprogram includes long-pulse international tokamak and stellarator research and fusion nuclear science and materials research. In FY 2016 for burning plasma science: long pulse, $6 million and $5 million are requested for the tokamak and stellarators, respectively. A budget of $20 million is requested for materials and fusion nuclear science.



The FY 2016 budget request for FES includes $65 million for operations and performance improvements to NSTX. The device, pictured here with a research collaborator working inside the NSTX vacuum vessel prior to its most recent upgrade, may open an attractive path towards developing fusion energy as an abundant, safe, affordable, and environmentally sound means of generating electricity. *Photo credit: PPPL*

The discovery plasma science subprogram supports research that explores the fundamental properties and complex behavior of matter in the plasma state to improve the understanding required to control and manipulate plasmas for a broad range of applications. The $47 million request for discovery plasma science includes $33 million for plasma science frontiers, and $4 million for measurement and innovation.

ITER is currently under construction in St. Paul-lez-Durance, France. Funding is provided for ITER project office operations; the U.S. cash contribution; and continued progress on in-kind contributions, including industrial procurements and fabrication of central solenoid magnet modules and structures, toroidal field magnet conductor fabrication and delivery, diagnostics, and tokamak cooling water system component procurement, fabrication, and delivery. The United States contributions to ITER project activity represent 9.09 percent of the ITER project construction costs. The United States contributions are established by the terms of the ITER Joint Implementing Agreement.

FES manages three designated scientific user facilities: the DIII-D National Fusion Facility at General Atomics, the National Spherical Torus Experiment at PPPL, and the Alcator C-Mod at the Massachusetts Institute of Technology.

2.1.1.2.5 High Energy Physics

High Energy Physics (HEP) supports research to understand how the universe works at its most fundamental level by discovering the most elementary constituents of matter and energy, probing the interactions among them, and exploring the basic nature of space and time itself.

HEP's FY 2016 areas of focus are described in their Congressional Budget Request. The FY 2016 request for HEP is $788 million, with $155 million for energy frontier experimental physics, $247 million for intensity frontier experimental physics, and $119 million for cosmic frontier experimental physics. Each of these requests is divided among research activities, facility operations and experimental support, and projects. The three experimental physics areas pursue activities in the following areas:

- *Energy Frontier*, where researchers accelerate particles to nearly the speed of light and collide them to produce and study the fundamental constituents of matter. This requires some of the largest machines ever built, such as the Large Hadron Collider (LHC), which is 17 miles in circumference, located at the European Organization for Nuclear Research (CERN) in Geneva, Switzerland. The LHC accelerates and collides high-energy protons while sophisticated detectors, some the size of apartment buildings, observe newly produced particles that provide insight into fundamental forces of nature and the conditions of the early universe.
- *Intensity Frontier*, where researchers use a combination of intense particle beams and highly sensitive detectors to make extremely precise measurements of particle properties, study some of the rarest particle interactions predicted by the Standard Model of particle physics, and search for new physics. Measurements of the mass and other properties of neutrinos may have profound consequences for understanding the evolution and ultimate fate of the universe.
- *Cosmic Frontier*, where researchers seek to reveal the nature of dark matter and dark energy by using naturally occurring particles to explore new phenomena. The highest-energy particles ever observed have come from cosmic sources, and the ancient light from distant galaxies allows the distribution of dark matter to be mapped and perhaps the nature of dark energy to be unraveled. Ultra-sensitive detectors deep underground may glimpse the dark matter passing through Earth. Observations of the cosmic frontier reveal a universe far stranger than ever thought possible.

These three frontiers are supported by the activities under theoretical and computational physics (which provides the mathematical, phenomenological, and computational framework to understand and extend our knowledge of the dynamics of particles and forces, and the nature of space and time) and the Advanced Technology R&D (which fosters cutting-edge research in the physics of particle beams, accelerator R&D, and particle detection).

SC Science Highlight

Transforming Our Vision of the Universe

SC has been the major supporter of U.S. research in high energy physics over the decades. The contributions of DOE National Laboratories to the design, technology, and construction of the Large Hadron Collider at CERN were critical to the establishment of that facility, and thousands of U.S. scientists from both National Laboratories and universities, supported by SC along with the National Science Foundation (NSF), have participated in LHC research and were instrumental in the discovery of the Higgs boson, a discovery acknowledged in the 2013 Nobel Prize for theorists François Englert and Peter Higgs. DOE also provided early and continuing support for the Supernova Cosmology Project at LBNL, one of two groups responsible for the discovery of dark energy, or the accelerating expansion of the universe. The discovery of dark energy has revolutionized our view of the cosmos. Saul Perlmutter, an investigator with long-time DOE Office of Science sponsorship, shared the 2011 Nobel Prize for this discovery.

The FY 2016 request includes $60 million for theoretical and computational physics, $115 million to support advanced technology R&D, and $14 million to support accelerator stewardship.

HEP manages three designated scientific user facilities: the Fermilab Accelerator Complex at FNAL and the Facility for Advanced Accelerator Experimental Tests at SLAC and the Accelerator Test Facility at BNL. In FY 2016, construction at HEP's two user facilities is supported at a level of $56 million.

2.1.1.2.6 Nuclear Physics

Nuclear Physics (NP) supports research to discover, explore, and understand all forms of nuclear matter, supporting experimental and theoretical research to create, detect, and describe the widely varied forms of nuclear matter that exist in the universe, including those no longer found naturally. Nuclear physicists seek to understand not just the familiar forms of matter we see around us, but also exotic forms such as those that existed in the first moments after the Big Bang and that exist today inside neutron stars, and to understand why matter takes on the specific forms now observed in nature.

NP manages three designated scientific user facilities: the Argonne Tandem Linac Accelerator System (ATLAS) at ANL, the Continuous Electron Beam Accelerator Facility (CEBAF) at the Thomas Jefferson National Accelerator Facility (TJNAF), and the Relativistic Heavy Ion Collider (RHIC) at BNL.

NP's FY 2016 areas of focus are described in their Congressional Budget Request. NP's FY 2016 request is for $625 million, with $517 million for nuclear physics and DOE Isotope Program activities and $108 million for construction at TJNAF and the Facility for Rare Isotope Beams being constructed at Michigan State University.

Seventy percent of the nuclear physics activities funding goes into medium energy nuclear physics ($158 million) and heavy ion nuclear physics ($211 million), which both study different aspects of quantum chromodynamics (QCD). QCD seeks to develop a complete understanding of how the fundamental particles that compose nuclear matter, the quarks and gluons, assemble themselves into composite nuclear particles such as protons and neutrons, how nuclear forces arise between these composite particles that lead to nuclei, and what forms of bulk, strongly interacting matter can exist in nature, such as the quark-gluon plasma. Experimental approaches are used to determine the distribution of up, down, and strange quarks, their antiquarks, and gluons within protons and neutrons, as well as clarifying the role of gluons in confining the quarks and antiquarks within hadrons. Under the medium energy research program, groups at TJNAF, BNL, ANL, LANL, and LBNL, and approximately 160 scientists and 125 graduate students at 33 universities carry out research programs and conduct experiments at CEBAF, RHIC, and elsewhere.

Heavy ion nuclear physics research focuses on studies of matter at extremely high densities and temperatures, and experimental approaches to study these collisions occur at the only collider operating in the United States (RHIC), and the LHC. Heavy ion research groups at BNL, LBNL, LANL, ORNL, and LLNL, and about 120 scientists and 80 graduate students at 28 universities are supported to develop and operate experiments at RHIC, analyze data from RHIC, and participate in a modest program at the LHC. Low energy nuclear physics research focuses on the scientific thrusts of nuclei and nuclear astrophysics, and fundamental symmetries that can be probed by studying neutrons and nuclei. Nuclei and nuclear astrophysics seeks to understand how protons and neutrons combine to form atomic nuclei, including some now being observed for the first time, and how these nuclei have arisen during the 13.8 billion years since the birth of the cosmos. Fundamental symmetries seeks to develop a better understanding of fundamental interactions by studying the properties of neutrons and by targeted, single focus experiments using nuclei to study whether the neutrino is its own antiparticle. Neutrinos are very light, nearly undetectable fundamental particles produced during interactions involving the weak force through which they were first indirectly observed in nuclear beta decay experiments. Experimental nuclear scientists in all NP scientific thrusts participate in the development and fabrication of advanced instrumentation, including state-of-the-art detectors that also have applications in areas such as medical imaging instrumentation and homeland security. NP research in nuclear theory provides the theoretical support needed to interpret the wide range of data obtained from the experimental nuclear science subprograms and to advance new ideas and hypotheses that identify potential areas for future experimental investigations.

NP also manages the Isotope Development and Production for Research and Applications (DOE Isotope Program), funded at $22 million, which supports the production, distribution, and development of production techniques for radioactive and stable isotopes in short supply and critical to the Nation. The DOE Isotope Program focuses on making key isotopes more readily available to meet U.S. needs. It supports R&D efforts associated with developing new, more cost-effective and efficient production and processing techniques, and on the production of isotopes needed for research purposes.

The remaining $126 million in NP is requested to fund activities in low energy NP at $80 million and nuclear theory at $46 million.

2.1.1.2.7 Small Business Innovation Research Program/Small Business Technology Transfer Program

Agencies with annual R&D appropriations greater than $100 million for extramural work are required by the Small Business Innovation Research (SBIR) Program and Small Business Technology Transfer (STTR) Reauthorization Act of 2011 to support innovative research and technology development performed by small businesses. Small businesses that win awards in these programs keep the rights to any technology developed and are encouraged to commercialize the technology. SC manages the DOE SBIR/STTR program on behalf of the Department and works collaboratively with twelve participating offices to administer the program: six R&D programs within SC; OE, EERE, FE, and NE; the Office of Defense Nuclear Nonproliferation; and EM. Table 2.1 summarizes DOE's SBIR/STTR set-aside funding. In FY 2016, the total request from the Science and Energy programs for SBIR/STTR is $217 million.

Historically, each office that collaborates with the SBIR/STTR program is expected to make awards commensurate with its budget allocation, including collaborating with other offices if it is not able to use its full allocation. The 12 participating programs are responsible for topic selection, reviewer assignment, award selection, and project oversight. The SBIR/STTR programs office is responsible for issuing topics and solicitations, managing the review and selection process, working with the SC Integrated Service Center to award SBIR/STTR Phase I and Phase II grants, issuing annual reports to the U.S. Small Business Administration, performing outreach, and setting overall policy for the Department's SBIR and STTR programs.

Each year, DOE issues Funding Opportunity Announcements (FOAs) inviting small businesses to apply for SBIR/STTR grants. These FOAs contain topics in such research areas as clean energy, basic science and engineering, and nuclear security. Grant applications submitted by small businesses must be responsive to a specific topic and subtopic areas as described in the open FOA. Phase I explores the feasibility of innovative concepts with awards up to $225,000 over 9 months. Only DOE Phase I award winners may compete for DOE Phase II funding. Phase II is the principal R&D effort, with awards up to $1,500,000 over two years. Phase III offers opportunities to small businesses to continue their Phase I and II R&D work to pursue commercial applications of their R&D with non-SBIR/STTR funding. Under Phase III, Federal agencies may award noncompetitive, follow-on grants or contracts for products or processes that meet the mission needs of those agencies, or for further R&D.

Each DOE program office considers its high priority research needs and program mission, as well as the Department's goals for the program in developing research topics. The specific research topics selected for the DOE SBIR/STTR programs are developed by the Department's technical program managers from each of the SC and applied technology program offices.

The Federal SBIR and STTR programs were reauthorized in the SBIR/STTR Reauthorization Act of 2011 (Public Law 112—81) through September 30, 2017. The prior authorization for these programs held SBIR at a 2.5 percent set-aside and STTR at a 0.3 percent set-aside for all Federal R&D programs appropriated at $100 million or greater in extramural work. The 2011 Reauthorization set incremental increases for both allocations, for SBIR from 2.5 percent in FY 2011 to 3.2 percent in FY 2017, and STTR from 0.30 percent in FY 2011 to 0.45 percent in FY 2016.

	FY2011	FY2012	FY2013	FY2014	FY2015	FY2016	FY2017
SBIR	2.5%	2.6%	2.7%	2.8%	2.9%	3.0%	3.2%
STTR	0.30%	0.35%	0.35%	0.40%	0.40%	0.45%	0.45%
Combined	2.80%	2.95%	3.05%	3.20%	3.30%	3.45%	3.65%

Table 2.1: SBIR and STTR Set-Aside Percentages by Fiscal Year.
This table, from SC's Web site, includes the percentages of SBIR and STTR set-aside funding for fiscal for fiscal years 2011–17.

2.1.1.2.8 Workforce Development for Teachers and Scientists

The Workforce Development for Teachers and Scientists (WDTS) program mission is to help ensure that DOE has a sustained pipeline of science, technology, engineering, and mathematics (STEM) workers. This is accomplished through support of undergraduate internships, graduate thesis research, and visiting faculty programs at DOE Laboratories. Undergraduate internships are supported through the Science Undergraduate Laboratory Internships (SULI) and Community College Internship (CCI) programs; supplemental support for graduate thesis research conducted at a DOE Lab in collaboration with a DOE Laboratory scientist is provided through the Office of Science Graduate Student Research (SCGSR) program; and the Visiting Faculty Program (VFP) provides opportunities for college faculty to do research projects at a DOE Lab in collaboration with a DOE Laboratory scientist. These activities rely significantly on DOE's 17 National Laboratories, which employ more than 30,000 STEM workers. The DOE Laboratory system provides access to leading scientists, who serve as project mentors and advisors; world-class scientific user facilities and instrumentation; and large-scale, multidisciplinary research programs unavailable in universities or industry. WDTS is also responsible for annual, nationwide, middle- and high-school science competitions culminating in the National Science Bowl® in Washington, DC. These investments help develop the next generation of scientists and engineers to support the DOE mission, administer programs, and conduct research.

The FY 2016 request for activities in the WDTS program is $20.5M, with $9M supporting SULI.

2.1.1.2.9 Office of Project Assessment

SC's Office of Project Assessment (OPA) provides independent advice to the SC Director and to the US/SE on the construction of scientific user facilities. OPA has a 30-year history in providing the SC program offices with technical expertise and advice in the areas of project management, cost engineering, construction management, and project reviews of SC construction projects and large experimental equipment. Regular technical, cost, schedule, and management peer reviews conducted by OPA are an integral part of how SC plans, designs, and constructs major research facilities and keeps projects on schedule, within budget, and aligned with the requirements of DOE Order 413.3B, *Program and Project Management for the Acquisition of Capital Assets*. OPA, as SC's Project Management Support Office, interacts with the Departmental lead offices and working groups for project management, such as the Project Management Risk Committee and the Energy Systems Acquisition Advisory Board discussed in Chapter 3, and thus engages significantly in corporate DOE project management functions and initiatives.

Members of 48 middle school teams from across the country pose for a group photo during the 2014 DOE National Science Bowl® competition, Saturday, April 26, 2014, in Washington, DC. The National Science Bowl® is one of several activities managed through the WDTS program to ensure that DOE has a sustained pipeline of STEM workers. *Photo credit: Jack Dempsey, U.S. Department of Energy, Office of Science*

2.1.1.3 Field Operations and Offices

As noted above, SC is responsible for managing more than $5 billion in annual funding, the majority of which is awarded as grants or cooperative agreements to universities and colleges, or funding for DOE's 17 National Laboratories. Funding opportunity announcements, contract solicitations, and award decisions made by the SC programs above are tightly coordinated with the responsible SC offices. The effective stewardship and management of ten DOE National Laboratories requires ongoing oversight of the maintenance and operational integrity of the Laboratories, as well as R&D work that is added to the M&O contract by DOE (including non-SC offices) and other Federal and non-Federal sponsors. These activities are coordinated and executed through SC's Integrated Support Center (ISC) and SC's ten site offices. Cross-SC laboratory policies and processes for infrastructure planning, laboratory performance oversight and annual laboratory planning, and laboratory safety and security is supported by the following SC offices: the Office of Operations Program Management, the Office of Laboratory Policy, and the Office of Safety and Security Policy. All of these offices are overseen by the SC Deputy Director for Field Operations.

2.1.1.3.1 Integrated Support Center

The Integrated Support Center (ISC) provides the business infrastructure to support the SC enterprise. These functions include legal and technical support; financial management; grant and contract processing; safety, security, and health management; labor relations, intellectual property and patent management; environmental compliance; facility infrastructure operations and maintenance; and information systems development and support. The ISC provides support functions that can be shared across the sites, which allows SC to meet those needs more efficiently by sharing resources across our field organization. The ISC provides support to SC and other DOE programs for contract solicitations and funding opportunity announcements, as well as the negotiation, award, administration, and closeout of contracts and financial assistance awards using warranted contracting officers and professional acquisition staff. Staff of the ISC are located in SC's Chicago office and SC's Oak Ridge office.

2.1.1.3.2 SC Site Offices

To ensure effective management and oversight, SC maintains a site office at each of its ten DOE National Laboratories. SC site offices oversee the operation of their respective Laboratories, including program implementation, acquisition management, and Laboratory stewardship. SC site office personnel are Federal staff charged with maintaining the business and management infrastructure required to support the scientific mission at each SC Laboratory. This includes conducting day to-day business transactions related to contract management activities, approvals to operate hazardous facilities, safety and security oversight, leases, property transfers, subcontracts above defined thresholds, sub-awards, and activity approvals required by laws, regulations, and DOE policy. This also includes coordination with the Office of Technology Transitions regarding technology transfer, data collection and management activities in support of RDD&D portfolio analyses and mandated reporting; and providing Federal project directors to facilitate execution of line item and other construction projects, and evaluating complex integrated laboratory activities including nuclear, radiological, and other complex hazards.

2.1.1.3.3 Office of Operations Program Management

The Office of Operations Program Management provides program management for infrastructure, security and sustainability at the ten SC DOE Laboratories and four additional SC sites. This includes developing the strategic directions and standard procedures for managing infrastructure, including managing the Science Laboratories infrastructure (SLI, funded at $114 million in FY 2016 request) and safeguards and security (S&S, funded at $103 million in the FY 2016 request) programs and budgets. The Office also coordinates with the DOE Office of Environmental Management on matters related to the remediation and clean-up of SC Laboratories and sites.

2.1.1.3.4 Office of Laboratory Policy

The Office of Laboratory Policy coordinates a number of activities that involve the management and oversight of SC's Laboratories, including

- developing, managing, and coordinating implementation of the annual Laboratory strategic planning process on behalf of the Director of the Office of Science and its Deputy Directors;
- coordinating the collection of SC programmatic and field managers' input regarding the performance of SC Laboratory M&O contractors for the annual Laboratory appraisal process;
- overseeing Laboratory Directed Research and Development (LDRD) programs at DOE Laboratories, consistent with DOE Order 413.2B;
- establishing and implementing procedures for oversight and reporting on Strategic Partnership Projects (formerly called Work for Others) at the SC Laboratories; and
- working closely with DOE offices, such as the Office of Technology Transitions and its predecessor entities, regarding technology transfer programs at DOE Laboratories.

2.1.1.3.5 Office of Safety and Security Policy

The Office of Safety and Security Policy establishes and supports implementation of SC-wide policies and procedures for safety and security at SC Laboratories, promoting safe and responsible operations including worker safety and health, emergency management, safeguards and security, and quality assurance systems. These efforts include conducting oversight activities required by regulations, DOE directives, and Executive orders; and providing essential coordination with other DOE offices such as the Office of Health, Safety and Security and the National Nuclear Security Administration.

2.1.1.4 SC National Laboratories

The Office of Science is the steward of 10 of the 17 DOE National Laboratories, listed here along with their respective Federal site offices (see table 2.2). Full descriptions of the SC-owned DOE Laboratories are provided in Chapter 4. SC provides stewardship for six multiprogram Laboratories and four single program Laboratories.

Laboratory Name	Location	Site Office
Ames Laboratory	Ames, Iowa	Ames Site Office
Argonne National Laboratory	Argonne, Illinois	Argonne Site Officev
Brookhaven National Laboratory	Upton, New York	Brookhaven Site Office
Fermi National Accelerator Laboratory	Batavia, Illinois	Fermi Site Office
Lawrence Berkeley National Laboratory	Berkeley, California	Berkeley Site Office
Oak Ridge National Laboratory	Oak Ridge, Tennessee	Oak Ridge National Laboratory Site Office
Pacific Northwest National Laboratory	Richland, Washington	Pacific Northwest Site Office
Princeton Plasma Physics Laboratory	Princeton, New Jersey	Princeton Site Office
SLAC National Accelerator Laboratory	Stanford, California	SLAC Site Office
Thomas Jefferson National Accelerator Facility	Newport News, Virginia	Thomas Jefferson Site Office

Table 2.2: Office of Science's DOE National Laboratories.
This table provides hyperlinks and location information for the 10 DOE National Laboratories that are stewarded by the Office of Science, and their associated site offices.

2.1.1.5 Budget

SC's FY 2016 budget request is $5.340 billion. Table 2.3 details the enacted budget levels for FY 2014 and FY 2015 and the FY 2016 budget request for the programs within SC.

	FY 2014 Enacted	FY 2015 Enacted	FY 2016 Request
Advanced Scientific Computing Research	478,093	541,000	620,994
Basic Energy Sciences	1,711,929	1,733,200	1,849,300
Biological and Environmental Research	609,696	592,000	612,400
Fusion Energy Sciences Program	504,677	467,500	420,000
High Energy Physics	796,521	766,000	788,000
Nuclear Physics	569,138	595,500	624,600
Workforce Development for Teachers and Scientists	26,500	19,500	20,500
Science Laboratories Infrastructure	97,818	79,600	113,600
Safeguards and Securities	87,000	93,000	103,000
Program Direction	185,000	183,700	187,400
Small Business Innovation Research	0	0	0
Subtotal, Science	**5,066,372**	**5,071,000**	**5,339,794**
Use of Prior Year Balances	0	0	0
Rescission of Prior Year Balances	0	-3,262	0
Total, Science	**5,066,372**	**5,067,738**	**5,339,794**

Discretionary dollars in thousands

Table 2.3: Office of Science Budget.
This table provides the FY 2014 enacted, FY 2015 enacted, and FY 2016 budget request for SC.

2.1.2 Office of Energy Efficiency and Renewable Energy

The Office of Energy Efficiency and Renewable Energy (EERE) plays a key role in DOE's efforts to help build a strong clean energy economy, reduce our reliance on foreign oil, save consumers money, and reduce pollution. EERE leads the U.S. Department of Energy's efforts to develop and deliver market-driven solutions for energy-saving homes, buildings, and manufacturing; sustainable transportation; and renewable electricity generation.

EERE conducts applied research, development, and demonstration (RD&D) programs and activities to address key market adoption barriers to ensure technical achievements translate to real world solutions. Technical programs are structured based on detailed roadmaps, informed by extensive inputs from industry and other technical experts, to reduce life cycle costs while also allowing for new disruptive innovations. Market barrier activities include identifying and responding to broad economic, workforce, regulatory, consumer behavior, and business model challenges to transferring technologies to the private sector. This detailed and holistic approach is supported by rigorous program management to maximize the potential for successful impact and efficient use of taxpayer funds. EERE activities are executed through both National Laboratory funding and financial assistance awards.

The FY 2016 request for EERE is $2.723 billion, an increase of $808 million relative to the FY 2015 enacted level.

2.1.2.1 Background

> **Office of Energy Efficiency and Renewable Energy At-a-Glance**
>
> - Serves as the U.S. Government's primary clean energy technology organization
> - Accelerates development and facilitates deployment of energy efficiency and renewable energy technologies and market-based solutions that strengthen U.S. energy security, environmental quality, and economic vitality
> - FY 2015 enacted: $1.914 billion; FY 2016 budget request: $2.723 billion
> - Supported 697 Federal FTEs in FY 2015
> - Web site: http://energy.gov/eere/office-energy-efficiency-renewable-energy

The origins of today's EERE can be traced back to beginning of DOE. In the Department of Energy Organization Act of 1977, Congress emphasized the need to develop and commercialize renewable resources, create strategies to avoid wasting energy, and incorporate environmental protection goals into energy programs.

Today, EERE remains focused on the charge Congress originally entrusted to the agency. As the largest office in the Federal Government focused on developing the next generation of clean energy solutions, EERE is guided by its mission to create and sustain American leadership in the global transition to a clean energy economy and provide a clean, sustainable energy future for all Americans. Across its programs, EERE orients its activities to address seven specific strategic goals:

- Accelerate the development and adoption of sustainable transportation technologies
- Increase the generation of electric power from renewable sources
- Improve the energy efficiency of homes, buildings, and industries
- Stimulate the growth of a thriving domestic clean energy manufacturing industry
- Enable the integration of clean energy into a reliable, resilient, and efficient electricity grid
- Lead efforts to improve Federal sustainability and implementation of clean energy solutions
- Enable a high-performing, results-driven culture through effective management approaches and processes

EERE is led by the Assistant Secretary of Energy for Energy Efficiency and Renewable Energy. EERE's activities are executed under the direction of the Deputy Assistant Secretaries for Sustainable Transportation, Renewable Power, Energy Efficiency, and Business Operations, and the Director of Strategic Programs.

2.1.2.2 EERE Programs

EERE's technology programs are organized into three sectors: Sustainable Transportation, Renewable Power, and Energy Efficiency. The dynamic and diverse nature of the clean energy sector requires a disciplined approach to the management of EERE's program activities. Each program screens and prioritizes its portfolio using five core questions to ensure maximum value from taxpayer investments:

- **Impact:** Is this a high-impact problem?
- **Additionality:** Will EERE funding make a large difference relative to existing funding from other sources, including the private sector?
- **Openness:** Are we focusing on the broad problem we are trying to solve and open to new ideas, approaches, and performers?
- **Enduring Economic Impact:** How will EERE funding result in enduring economic impact for the United States?

A participant with Veterans Green Jobs blows cellulose insulation in the attic of this Lakewood, Colorado, home bringing the R value up to R38. This home is part of EERE's Weatherization Assistance Program that supports energy efficiency upgrades to low-income homes in Denver. Photo credit: *Dennis Schroeder, NREL*

- **Proper Role of Government:** Why is this investment a necessary, proper, and unique role of Government rather than something best left to the private sector?

The technology programs are supported by the Office of Business Operations and the Office of Strategic Programs, which executes critical crosscutting programs enhancing the effectiveness of the EERE portfolio and the Office of Technology Transitions.

The details of EERE's FY 2016 priority activities can be found in the EERE portion of the FY 2016 Congressional Budget Request. Support for the Department's crosscutting activities are noted where appropriate.

EERE's single designated user facility is the Energy Systems Integration Facility at NREL, which is supported by a $36 million request in FY 2016.

2.1.2.2.1 Sustainable Transportation

EERE's sustainable transportation portfolio supports comprehensive and analysis-based strategies to accelerate the development and widespread use of a variety of domestic and cost-effective sustainable transportation technologies. Broadly, EERE pursues two key parallel solution pathways: (1) using less petroleum-derived fuel to move people and freight (vehicle efficiency) and (2) replacing conventional fuels with cost-competitive, domestically produced, sustainable alternatives (alternative fuels) that reduce carbon pollution. The EERE program offices in this sector work closely with the Environmental Protection Agency (EPA) and the Department of Transportation (DOT), exchanging technical information and collaborating on public information resources such as the joint DOE-EPA Web site, fueleconomy.gov.

The overall FY 2016 budget request for sustainable transportation is $793 million. This funding amount is dispersed among the three EERE program offices that constitute the sustainable transportation portfolio—the Bioenergy Technologies Office, the Fuel Cell Technologies Office, and the Vehicle Technologies Office. These offices and their FY 2016 funding requests are described below.

Bioenergy Technologies Office

The Bioenergy Technologies Office (BETO) is focused on developing and transforming our renewable, nonfood biomass resources, such as lignocellulose and algae, into commercially viable, high-performance biofuels, bioproducts, and biopower. The program conducts research, development, demonstration, and market transformation activities on sustainable feedstock supply and logistics systems, cost-competitive conversion processes, and cost-shared scale-up and construction of pilot- and demonstration-scale integrated biorefineries that will reduce the risk of "first-of-a-kind" technologies to enable further private investment necessary to scale-up and achieve market penetration.

Use of advanced biofuels in the transportation sector has significant potential to capitalize on U.S. energy competitive advantage, reduce transportation-related greenhouse gas (GHG) emissions, and support domestic job growth. DOE research estimates the United States potential to sustainably produce at least 1 billion dry tons of nonfood biomass resources by 2030, which if used completely for transportation fuel, could displace approximately 30 percent of the country's present petroleum consumption and reduce GHG emissions significantly without impacting food or feed needs.

BETO's FY 2016 areas of focus are described in their Office At-A-Glance. The FY 2016 budget request allocates $246 million to BETO, with feedstock supply and logistics research (including algae) receiving $39 million, conversion technologies $99 million, demonstration and market transformation $88 million, and strategic analysis and crosscutting sustainability $14 million. NREL will receive $7 million for facilities support.

The feedstock supply and logistics activity continues to work to meet 2017 biomass feedstock cost targets for delivered biomass to the bioenergy conversion plant (from $115/dry matter ton (DMT) in FY 2015 to $95/DMT in FY 2016 and then $80/DMT in FY 2017). Research areas focus on advanced technologies for woody and herbaceous feedstock including advanced harvesting (such as single-pass technologies), preprocessing (i.e., high moisture densification), and blending techniques. The Algae and Advanced Feedstocks activity will focus on research to address yield, productivity, and integration of downstream logistics at the pre-pilot scale. This research will support validating the potential for algae supply and logistics systems to produce 5,200 gallons of oil (or equivalent biofuel intermediate) per acre of cultivation per year by 2022.

The conversion subprogram will select at least two pathways for validation at DOE's National Laboratories integrated bench and/or pilot scale in FY 2016. The final validation is expected to be completed in FY 2017 and will provide data to be used in program models to demonstrate nth-plant cost reductions. The cost reductions will help decrease the risk for private sector investment in first-of-a-kind projects. The program will also fund research consortia to further the integration of bio-oils into petroleum refineries, for the development of biological and chemical catalysts and clean sugar production, for the resolution of gasification and gas-to-liquids issues identified in FY 2014 workshops. The program will also continue to fund incubator (or open-topic funding opportunities to identify "off-roadmap" concepts), carbon fiber, and other renewable chemicals activities.

The Demonstration and Market Transformation subprogram (formerly "Demonstration and Deployment") will focus on scale-up of drop-in hydrocarbon fuel production. Research and development activities will support enhancing markets for advanced biofuels, including collaboration with the Vehicle Technologies

Office to codesign next-generation engines to better utilize biofuels through the Fuel and Vehicle Systems Co-optimization (Optima). The subprogram will also continue support of commercial demonstration of military-specification jet fuel in collaboration with the Departments of Defense and Agriculture through the Defense Production Act (DPA).

Fuel Cell Technologies Office

The Fuel Cell Technologies Office (FCTO) focuses on the development, demonstration, and deployment of innovative hydrogen and fuel cell technologies. The development of early stationary markets by industry (i.e., backup power or small residential cogeneration of heat and power, as well as other early markets such as forklifts and airport/delivery trucks) is also being pursued to help drive down cost, develop a supply base, and provide a strategic pathway to higher volumes while also helping to establish a competitive market for transportation applications.

The Office's portfolio focuses on both fuel cell R&D and hydrogen fuel R&D, with an emphasis on renewable production pathways, advanced materials, and delivery and storage of hydrogen, to meet cost and performance goals. Near-term efforts in real-world demonstration and validation help to accelerate market growth and provide critical feedback for future R&D. The portfolio also addresses a number of nontechnical factors, such as user confidence, ease of hydrogen infrastructure financing, the availability of codes and standards, and refueling infrastructure logistics, particularly for Fuel Cell Electric Vehicles (FCEVs).

FCTO's FY 2016 areas of focus are described in their Office At-A-Glance. The FY 2016 budget request allocates $103 million to FCTO, with $36 million directed to fuel cell R&D, and $41 million directed to hydrogen fuel R&D. The remaining $26 million supports manufacturing R&D; systems analysis; technology validation; safety, codes, and standards; market transformation; and facilities at NREL. Fuel cell R&D will support the goal to reduce the cost and increase the durability of fuel cell systems, with a targeted cost of $40/kW and durability of 5,000 hours, which is equivalent to 150,000 miles, by 2020. In addition, EERE will invest in R&D for technologies that can bring the cost of hydrogen from renewable resources to less than $4.00 per gallon of gasoline equivalent—dispensed and untaxed—by 2020. In FY 2016, fuel cell R&D will emphasize areas such as stack component R&D, systems, and balance of plant components. Hydrogen fuel R&D will focus on technologies and materials that will reduce hydrogen production, compression, transport, and storage costs. Funding will also provide resources to rapidly advance the development of quality control tools for the manufacturing of fuel cell components and systems.

Vehicle Technologies Office

The Vehicle Technologies Office (VTO) supports new technologies to increase energy security and reduce carbon pollution in the transportation sector both by increasing vehicle efficiency and replacing conventional fuels with clean, domestically produced alternatives. The Office's portfolio targets advances in a number of areas, including battery and electric drive technologies, vehicle systems, advanced combustion engines, lightweight and other advanced materials technologies, and fuel and lubricant technologies.

VTO's FY 2016 areas of focus are described in its Office At-A-Glance. The FY 2016 budget request provides VTO with $444 million, of which battery and electric drive R&D receives $144 million, vehicle systems $68 million, advanced combustion engine R&D $65 million, materials technology R&D $71 million, and fuel and lubricant technologies R&D $37 million. An additional $57 million supports outreach, deployment and analysis activities, while $3 million supports facilities at NREL.

One major initiative, the EV Everywhere Grand Challenge, aims to reduce the combined battery and electric drive system costs of plug-in electric vehicles by up to 50 percent by 2022 from a 2012 baseline. Specific technical targets include (1) cutting battery costs from $300 per kilowatt-hour (kWh) in 2014 to $125/kWh by 2022; (2) eliminating almost 30 percent of vehicle weight through light weighting by 2022, compared to a 2002

Deputy Secretary Elizabeth Sherwood-Randall tours the Energy Storage Lab in the Energy Systems Integration Facility (ESIF) at the National Renewable Energy Laboratory in Golden, Colorado. Photo credit: *Dennis Schroeder, NREL*

baseline; and (3) reducing the cost of electric drive systems from $16 per kilowatt (kW) in 2013 to $8/kW by 2022. VTO participates in this DOE-wide initiative ($253 million) through its battery and electric drive, vehicle systems, and materials technology subprograms.

FY 2016 funding also supports a significant new SuperTruck II initiative ($40 million) to achieve improved freight-hauling efficiency goals, as well as work to eliminate technical barriers to increased transportation use of alternative and renewable fuels. Vehicle Technologies will also support a crosscutting initiative to drive significant improvements in the strength, formability, corrosion resistance, and cost of magnesium sheet alloys. A crosscutting fuels and vehicle systems initiative, called Optima, will seek to co-optimize engine efficiency with low-carbon fuel properties. Enhanced support for these activities has resulted in increased investment in vehicle electrification and grid infrastructure, heavy truck technologies including advanced combustion engines, lightweight materials, co-optimization of fuels and engines, and partnerships to build high-impact community-scale demonstrations of alternative fuel vehicles.

Additional VTO activities include working with a nationwide network of local public/private partnerships that brings together key stakeholders to help accelerate the use of alternative fuel and energy-efficient vehicle technologies and the annual DOE/EPA Fuel Economy Guide publication and associated Web site—including the development and dissemination of related data (required by law) to the public.

2.1.2.2.2 Renewable Power

EERE's Renewable Power portfolio focuses on reducing the overall costs of electricity generated from renewable resources through targeted R&D and demonstration projects. The United States has an abundant supply of renewable energy resources, which have the potential to significantly contribute to energy sustainability and stability over the long term in comparison to conventionally fueled power systems. Recent and significant cost reductions of solar and wind technologies are representative of the technical progress EERE has made through its program investments. Additional EERE investments are being made to address unique challenges and barriers to further market advances including power intermittency, distribution and transmission, and regulatory environments. While each renewable power technology has unique opportunities and advantages, and unique geographical distribution of resources potential, EERE seeks to enable the development of multiple renewable power technology options for every region of the country.

The total recommended FY 2016 budget for renewable power is $645 million. This funding amount is dispersed among the three EERE program offices that constitute the renewable power portfolio—the Geothermal Technologies Office, the Solar Energy Technologies Offices, and the Wind and Water Power Technologies Office. A companion but integrated effort, the Grid Modernization Initiative (GMI), involves the renewable power offices as well as other offices within EERE, along with the Office of Electricity. These offices and their FY 2016 funding allocations are described below.

Geothermal Technologies Office

The Geothermal Technologies Office (GTO) supports research and development in innovative technologies that reduce the risk and costs of realizing the estimated 100 GW of U.S. geothermal potential. The Office's technology portfolio prioritizes advancements in both hydrothermal and enhanced geothermal systems (EGS) through two closely related R&D programs that balance near-term growth with long-term sector transformation. New exploration and drilling technologies and tools can reduce the near-term cost and risk of developing undiscovered hydrothermal systems, and new technologies to stimulate hot, yet nonproductive, rock volumes can unlock EGS potential in locations within or near existing hydrothermal fields. These technologies will also advance the development of higher risk/high potential "greenfield" EGS. Additionally, the program invests in coproduced resources (e.g., developing additional revenue streams from geothermal brines) and systems analysis (e.g., addressing regulatory process barriers), which are both focused on improving geothermal economics.

GTO is also a major participant in the Department's Subsurface Technology and Engineering RD&D crosscut (SubTER, see section 2.3). Under this activity, GTO is pursuing the Frontier Observatory for Research in Geothermal Energy (FORGE) as well as separate efforts to develop technologies for protecting the integrity of wellbore environments; provide high-fidelity imagery of the subsurface; develop new tools and methodologies to measure and manipulate subsurface stress, fractures, and fluid flow; and reduce risk associated with creating and managing permeability of the subsurface.

GTO's FY 2016 areas of focus are described in their Office At-A-Glance. The FY 2016 budget request allocates $96 million to GTO, with $45 million directed to enhanced geothermal systems, $36.5 million to hydrothermal, $9 million to low temperature and coproduced resources, and $5 million for analysis. Remaining funds support facilities at NREL. For enhanced geothermal systems, the FY 2016 funding reflects the commencement of Phase 3 of GTO's highest priority, the FORGE EGS initiative, which will focus on R&D and field operations at a single down-selected site. Phase 3 activities will include further subsurface characterization, drilling of wells, and technology R&D and complementary enhanced geothermal systems R&D funded through the National Laboratories Annual Operating Plan (AOP) process. FY 2016 funding will also accelerate geothermal Play Fairway Analysis (PFA), which is an assessment of exploration risk and the probability of finding new geothermal resources at a regional scale, through the analysis and integration of diverse geologic and geophysical datasets using techniques and approaches borrowed from the oil and gas sector. The objective of this first-in-the-world effort is to quantitatively identify the most prospective areas for new U.S. geothermal exploration and development.

Through GTO's hydrothermal subprogram, the FY 2016 request supports implementation of SubTER (see section 2.3) in coordination with the FE and NE offices. The FY 2016 request also reflects a slightly expanded low temperature and coproduced resources subprogram to include new advancements in coproduced strategic materials, as well as additional funding for advanced direct use and cascaded surface plan and system technologies, whose applications will extend the distribution of geothermal well beyond the western United States.

Solar Energy Technologies Office

The Solar Energy Technologies Office (SETO) works to accelerate the market competitiveness of solar energy through two programs: photovoltaics (PV) or the conversion of solar photons to electricity through direct conversion using a semiconductor device, and concentrated solar power (CSP), which entails conversion of solar thermal energy to electricity. The target of the Office's SunShot Initiative—a collaborative national effort to make the United States a leader in the global clean energy race by accelerating solar energy technology development—is to reduce the total installed cost of utility-scale solar energy systems to $0.06/kWh by 2020.

Achieving the SunShot target requires focusing on both reduced hardware costs, which includes increased conversion efficiency, and reduced non-hardware "soft costs," such as permitting, financing, and customer acquisition. Soft costs, in particular, have become an increasingly large fraction of total PV system costs because of decreases in hardware costs, resulting mainly from the increased scale and efficiency of manufacturing. Program efforts to reduce soft costs include supporting streamlined permitting, inspection, and interconnection processes, as well as performing key analyses of policy options and their potential impact on the deployment of solar technologies. The program also invests in invertors and advanced controls to ensure that distributed PV systems can be effectively integrated within the existing utility grid.

SETO's FY 2016 areas of focus are described in their Office At-A-Glance. The FY 2016 budget request allocates $337 million to SETO. Of this amount, $48 million is directed to concentrating solar power, $62 million to photovoltaic, $77 million to systems integration, $67 million to balance of system soft cost reduction, and $73 million to innovations in manufacturing competitiveness. The remaining funds support facilities at NREL. FY 2016 funding will support an effort to reduce soft costs of solar installation, including new efforts focused on commercial-scale solar to reduce barriers for businesses to choose solar energy. SunShot will also support DOE's Clean Energy Manufacturing Initiative by developing and demonstrating innovative manufacturing technologies to increase U.S. competitiveness. Additionally, funding will be used to focus on improved controls, sensors, power electronics, and connection to energy storage as part of the Grid Modernization crosscut (discussed in section 2.3).

Wind and Water Power Technologies Office

The Wind and Water Power Technologies Office (WWPTO) works to accelerate the market competitiveness of a broad range of wind and water technologies. Wind Energy Program activities target lowering U.S. wind power costs (land, offshore, and distributed) to become directly cost-competitive, absent subsidies, with traditional electricity sources. These investments support further gains in the percentage of the Nation's electricity from wind beyond the current 4.5 percent. The program makes significant investments to lower wind turbine capital cost and operating expense, and improve energy capture, taking both an individual component approach as well as the evaluation of integrated systems, such as optimization of total wind farm output. The program also addresses barriers to broader market deployment, including mitigation or prevention of environmental impacts.

The Water Power Program's portfolio includes both traditional hydropower as well as new emerging marine and hydrokinetic (MHK) energy technologies, which capture energy from waves, rivers, and tidal and ocean currents. Hydropower investments are structured across three areas—upgrades and repowering of existing water infrastructure, exploitation of undeveloped streams, and pumped storage—and focus on new and innovative generation technology development, including performance testing and environmental validation. In MHK technologies, the program's portfolio focuses on funding innovation to drive down the cost of electricity through significant performance improvements and reductions in initial investment costs.

WWPTO's FY 2016 areas of focus are described in their Water Power Program At-A-Glance and Wind Program At-A-Glance. The FY 2016 budget request provides $146 million for the Wind Energy Program and $67 million to the Water Power Program. The major components of the requests are described below.

Within the FY 2016 request for the Wind Energy Program, the budget includes $26.8 million to support the "Atmosphere to Electrons" (A2e) initiative. A2e moves beyond a traditional, individual turbine-centric focus, to one that encompasses an entire wind plant, comprising multiple turbines, to address underlying physical and technical barriers to optimized performance. The program invests in wind plant R&D to spur required innovations in high-fidelity modeling capabilities that leverage DOE high-performance computing (HPC) assets and the development of novel measurement techniques to monitor the flow into and through the wind plant.

Also in FY 2016, the Wind Energy Program will provide $40.0 million for year five of a six fiscal-year program previously competed through the Offshore Wind Advanced Technology Demonstration Project FOA, to support the establishment of a competitive U.S. offshore wind industry through offshore system development and demonstration.

The FY 2016 budget request also provides funding for Wind Energy Program activities in support of the Grid Modernization crosscut (see section 2.3).

In the Water Power Program, the FY 2016 request supports efforts in hydropower technologies (at $25.5 million) and MHK (at $41 million). The remaining funding supports facilities at NREL. Areas of focus include the first step in a multiyear HydroNEXT program that supports enabling technology that allows for growth in hydropower from currently nonpowered dams (NPD). The MHK subprogram will complete front end engineering and design for a potential full-scale grid-connected open water wave test facility capable of testing and demonstrating wave energy converter (WEC) components and systems under operating and survival conditions and will also build upon its work initiated in FY 2015 to develop and test new environmental monitoring instrumentation.

Within the FY 2016 budget request, the Water Power Program supports one Departmental crosscut: Energy-Water Nexus (see section 2.3).

2.1.2.2.3 Energy Efficiency

The EERE Energy Efficiency portfolio includes a comprehensive set of programs to improve the energy efficiency of America's homes, buildings, and industries, with an overall goal of cutting energy waste in half. This goal requires investments that give businesses and consumers compelling new energy efficiency options, including products that perform at higher efficiency and with improved performance, new ways of designing new homes and buildings, new approaches for improving the vast stock of existing buildings, and new ways to improve the energy productivity and competitiveness of American manufacturers. These approaches will also better integrate the built environment with our energy system to combat costly peaks in energy demand, enhance energy reliability and resiliency, and increase the capabilities and value of buildings and facilities. They will also take advantage of natural gas as a low-cost, lower-carbon fuel and industrial feedstock, contributing to new U.S. manufacturing capabilities to leverage this advantage.

The overall FY 2016 budget for energy efficiency is $1,030 million. This funding amount is dispersed among the four EERE program offices that constitute the energy efficiency portfolio—the Advanced Manufacturing Office, the Building Technologies Office, the Federal Energy Management Program, and the Weatherization and Intergovernmental Programs Office. These offices and their FY 2016 funding allocations are described below.

Advanced Manufacturing Office

The Advanced Manufacturing Office (AMO) works to identify and invest in emerging technologies with the potential to create high-quality U.S. manufacturing jobs, enhance global competitiveness, and reduce energy use by encouraging a culture of continuous improvement in corporate energy management. Manufacturing is very important to future U.S. innovation, global economic competitiveness, and job growth, particularly the manufacture of clean energy products. With opportunities to improve life cycle energy use by 50 percent or more, the development and deployment of manufacturing technologies has multiple benefits in reducing both the energy footprint and associated GHG emissions from manufacturing as well as supporting the competitiveness in the manufacturing of new clean energy products. U.S. manufacturing can particularly benefit from technologies for energy efficiency across the board, as industry must continually improve productivity and efficiency to remain globally competitive.

This 3D printed Shelby Cobra was printed at DOE's Manufacturing Demonstration Facility at ORNL and will allow research and development of integrated components to be tested and enhanced in real time, improving the use of sustainable, digital manufacturing solutions in the automotive industry. *Photo credit: ORNL*

The Office's RDD&D investments bring together manufacturers, research institutions, suppliers, and universities to advance high-impact technologies for energy efficiency in the manufacturing sector in addition to foundational, crosscutting manufacturing and materials technologies critical to efficient and competitive domestic manufacturing of clean energy products. The Office addresses these clean energy manufacturing challenges using three primary modalities of support: (1) research and development of early stage manufacturing technologies through the support of individual R&D projects, (2) pre-commercial technology development through facilities and manufacturing consortia, and (3) technology assistance through manufacturing partnership participation, assessment, and evaluation tools.

Work in these three modalities of support focuses on manufacturing issues in two categories: (1) energy cost reduction and efficiency for the Nation's most energy-intensive and energy-dependent industries and (2) materials and enabling technologies with crosscutting impact for cost reduction and performance improvement broadly applicable to the manufacturing of clean energy products.

AMO's FY 2016 areas of focus are described in their Office At-A-Glance. The FY 2016 budget request allocates $404 million to AMO, with $133 million directed to advanced manufacturing R&D projects, $241 million to advanced manufacturing R&D facilities, and $30 million to industrial technical assistance.

The FY 2016 budget request supports up to six new competitive funding opportunity announcements (FOAs), plus an additional Advanced Manufacturing Incubator FOA that will be released in the Office's priority thrust areas. Thrust area topics to be considered include grid and resource integration, smart manufacturing, advanced materials manufacturing, next generation electric machines, sustainable manufacturing (including water-energy), and emergent topics for clean energy manufacturing.

The FY 2016 budget request will support the full funding of two new Clean Energy Manufacturing Innovation Institutes and will also support ongoing advanced manufacturing R&D facilities including four Clean Energy Manufacturing Innovation Institutes. As part of its ongoing support of the Wide Bandgap Semiconductor Power

Electronics Institute, AMO will continue to coordinate with SC to implement technical training focused on wide bandgap power electronics that will consist of a mixture of classroom and project-based practical experience.

AMO will continue to partner with industry by providing technical assistance by investing in cost-effective energy efficiency solutions through the Better Plants program, Superior Energy Performance certification program, Industrial Assessment Centers program, Combined Heat and Power Technical Assistance Partnerships, and related efforts.

Two of AMO's subprograms—Advanced Manufacturing R&D Projects and Industrial Technical Assistance—support the Energy-Water Nexus crosscut (see section 2.3) in the FY 2016 budget.

Building Technologies Office

The Building Technologies Office (BTO) conducts work through a balanced portfolio of activities that are determined to contribute to national energy efficiency goals. The Office uses a three-pronged strategy: (1) High Impact Technology Research and Development—R&D targeting opportunities for high-impact, new, cost-effective energy efficiency products and solutions; (2) Technology-to-Market—validating and driving these technology products and solutions into the market by verifying and improving performance and cost, providing improved data and information, and partnering with manufacturers and users; and (3) Lock In Savings—where a Government role is appropriate and justified, locking in the savings through market-based (e.g., Energy Star) and regulatory (i.e., codes and standards) efforts that provide clear public and net economic benefits to both producers and consumers.

BTO's FY 2016 areas of focus are described in their Office At-A-Glance. The FY 2016 budget request allocates $264 million to BTO, with $112.5 million directed to emerging technologies—a subprogram that supports R&D on lighting, space conditioning and refrigeration, transactive controls, the building envelope, analysis tools, and high-impact technology—$32 million to commercial buildings integration, $48 million to residential buildings integration, and $69 million to equipment and building standards. The remaining $2.5 million supports BTO-related facilities at NREL.

The Emerging Technologies (ET) subprogram will continue its research efforts in five high-impact key technology areas: solid state lighting (SSL); heating, ventilation, & air-conditioning (HVAC), including water heating and appliances; windows and building envelope; whole-building energy modeling; and sensors & controls (including transactive controls). Throughout its ET program, BTO supports the Department's Clean Energy Manufacturing Initiative, specifically through its manufacturing R&D for SSL and tech-to-market activities. In addition, the ET subprogram will release a $30 million Advanced Building Energy Materials FOA in collaboration through the Clean Energy Manufacturing Initiative on materials manufacturing R&D, focusing on cost-effective next-generation materials for non-vapor-compression refrigeration systems and high-performance building envelope materials.

In addition to R&D activities, the Office will continue to pursue solutions identification and technology to market initiatives in both the Commercial Buildings Integration (CBI) and Residential Buildings Integration (RBI) subprograms to overcome market barriers to widespread adoption of cost-effective advanced building energy efficiency technologies and solutions. The CBI and RBI subprograms efforts will focus on developing, demonstrating, and releasing a suite of cost-effective technologies, specifications, tools, and solutions, as well as analyzing their ability to deliver the intended energy savings. These subprograms work with industry to promote voluntary activities to prime and support improved energy efficiency in the residential and commercial building sectors, with an emphasis on underutilized high-potential products that meet performance and cost hurdles for commercial building investment.

The Equipment and Buildings Standards subprogram will continue to generate cost-effective energy savings through the development of national appliance and equipment standards. Funding will support rulemakings and standards certification and enforcement in both commercial and industrial products, as well as assisting State and local jurisdictions to improve building energy code compliance rates.

Within the FY 2016 budget request, the Building Technologies Program supports DOE's Grid Modernization crosscut, discussed in section 2.3.

Federal Energy Management Program

The U.S. DOE's Federal Energy Management Program (FEMP) works closely with Federal offices and organizations, bringing expertise from all levels of project and policy implementation to enable Federal agencies to meet energy-related goals and provide energy leadership for the country. As America's largest single energy consumer, the Federal Government has a tremendous opportunity and responsibility to lead by example in cutting energy waste and advancing America's clean energy future. With more than 500,000 buildings and a 600,000 vehicle fleet, the Federal Government can serve as a model for successful approaches, stimulate private markets (such as through the use of performance contracting and Power Purchase Agreements), and make a significant contribution to our national energy and environmental goals.

EERE Science Highlight

Improving Energy Efficiency for Consumers: Appliance and Equipment Standards Program

Since the first standards were enacted—at the State level in California in 1974 and at the Federal level in amendments to the Energy Policy and Conservation Act (EPCA) in 1975 and 1979—appliance and equipment efficiency standards have served as one of the Nation's most effective policies for improving energy efficiency and saving consumers money. For example, a new refrigerator today uses a third of the energy it did in 1973, but offers 20 percent more storage capacity and costs half as much. Today, the Appliance and Equipment Standards Program covers over 50 different products representing about 90 percent of home energy use, 60 percent of commercial building energy use, and approximately 29 percent of industrial energy use. The Program performs detailed technical analysis and works closely with industry and other stakeholders to delineate issues and opportunities in its development of appliance standards. The cumulative energy savings of standards phased in through 2013 will be about 70 quadrillion British thermal units (quads) of energy through 2020, and will amount to 128 quads through 2030. (The United States consumes a total of about 100 quads of energy per year.) The cumulative utility bill savings to consumers of these standards are estimated to be over $950 billion through 2020, growing to over $1.7 trillion through 2030.

Leadership by the Federal Government is an important element of the President's Climate Action Plan, and the Federal Government is pursuing, and making substantial progress toward, a number of challenging energy and sustainability goals established through Executive order and statute. FEMP is positioned to coordinate the deployment of innovative technologies and expertise from the other programs to meet these energy and sustainability goals and provide energy leadership.

FEMP's FY 2016 areas of focus are described in their Office At-A-Glance. The FY 2016 budget request allocates $43 million to FEMP, with $15 million directed to the Federal Energy Efficiency Fund, and $27 million to Federal energy management.

The overall FY 2016 budget request for FEMP increased by $16 million compared to the FY 2015—most of which is directed toward the Federal Energy Efficiency Fund (FEEF), also known as Assisting Federal Facilities with Energy Conservation Technologies (AFFECT) program. In FY 2016, FEMP will expand AFFECT from approximately $3 million in FY 2015 to $15 million in FY 2016 to help agencies fund and invest in priority projects for efficiency and renewables with the greatest impact.

In FY 2016, FEMP will continue to support the President's Performance Contracting Challenge (PPCC) by assisting agencies to successfully meet the $4 billion goal for investing in energy efficiency and renewable energy projects by the end of 2016 and helping agencies to continue their acceleration of using performance contracts to meet future energy investment needs and goals.

Weatherization and Intergovernmental Programs Office

The Weatherization and Intergovernmental Programs Office (WIPO) provides funding and assistance to partners in State and local governments, Indian tribes, and international agencies for their energy programs, including weatherization programs that enable low-income families to reduce their energy bills by making their homes more energy efficient. As part of the President's Climate Action Plan and the Administration's all-of-the-above approach to American energy, the Office addresses the demand and supply sides of energy by facilitating investments in both energy efficiency (demand), and clean energy generation (supply), as well as alternative transportation fuels and vehicles. The Office uses an integrated approach consisting of formula grants to support the core capabilities of State energy offices, and a weatherization provider network that assists low-income families through provision of home energy retrofits. It provides competitive awards to support innovative State and local high-impact and self-sustaining clean energy projects, and technical assistance to facilitate energy efficiency and renewable energy technology delivery through "best practice" tools, "lead by example" methods, peer-to-peer forums, and strategic partnerships.

The Office's subprograms include the Weatherization Assistance Program (WAP) and the State Energy Program.

WIPO's FY 2016 areas of focus are described in their Office At-A-Glance. The FY 2016 budget request allocates $318 million to WIPO, with $228 million directed to WAP, $70 million to SEP, and $20 million to the local energy program.

WAP increases the energy efficiency of dwellings owned or occupied by low-income persons, reduces their total residential energy expenditures, and improves their health and safety. Through retrofitting residential buildings, WAP activities reduce the cost of low-income household energy bills, which are significantly disproportionately higher relative to higher income households. The request supports completion of approximately 33,000 low-income residential energy retrofits, with annual per unit average energy cost savings of $250–$480 per year between 2016 and 2036; continued improvements in workforce training, quality standards, and worker certification to improve the quality of the work performed; and competitively selected and managed high-impact projects on financing models for the retrofit of low-income multifamily buildings.

SEP assists States in establishing and implementing clean energy plans, policies, and programs to reduce energy costs, increase competitiveness, enhance economic competitiveness, improve emergency planning, and improve the environment. SEP will continue support for core capacity and innovation in State energy offices and dissemination of best practices to assist in reducing Government facilities and operations energy use by 2 percent per year through 2020; maintain the viability of the State energy office network and capacity to develop, improve, and implement State energy plans; accelerate investment in public sector use of energy service performance contracts by an additional $2.0 billion by 2016; and support high-impact projects focused on development and implementation of State policies addressing barriers limiting investment in energy efficiency and renewable energy.

The Local Energy Program will enhance local government and community core capabilities in the planning and implementation of energy efficiency and renewable energy programs by providing targeted technical assistance to partnerships on strategic energy and economic planning; expanding best practices tools, models, and strategies across a broad network of local government agencies and regional and national stakeholders; and supporting competitively selected projects that promote the expanded adoption of energy efficient and renewable energy technologies and practices.

2.1.2.2.4 Office of Strategic Programs

The mission of EERE's Office of Strategic Programs (OSP) is to provide high-impact, crosscutting activities that cannot be done solely within EERE's individual technology offices. This includes platform "technology-to-market" activities to catalyze more successful clean energy commercialization, entrepreneurship, technology transfer, and manufacturing competitiveness outcomes from EERE's RDD&D portfolio and sound crosscutting strategic analysis and impact assessments to inform programmatic and management decision-making. Strategic Programs also includes communications efforts to engage with EERE's stakeholders to widely disseminate clean energy information, tools, and resources made available through EERE efforts. Strategic Programs' International subprogram provides support and program management of activities that support Administration initiatives for the transformation of clean energy economies with international partners and development of export opportunities for U.S. clean energy technology companies. More information regarding EERE's international activities is contained in section 2.4. OSP with its progressive pilots actively engages the Office of Technology Transitions for support and guidance in addition to statutorily required reporting of related data.

The FY 2016 request for OSP is $28 million.

2.1.2.3 Field Operations and Offices

The EERE organization consists of two main entities: its headquarters location in Washington, DC, and its field elements at NETL in Pittsburgh, PA, and at the Golden Field Office in Golden, CO, the latter of which oversees the operations of the National Renewable Energy Laboratory (NREL).

Golden Field Office acts as EERE's Business Service Center by awarding grants and contracts for clean energy projects, facilitating R&D partnerships to support those technologies, and overseeing NREL. Golden-based staff help implement WIPO's State Energy Program and Weatherization Assistance Program, and support EERE's technology development activities with expertise ranging from engineering and scientific research, to project management, law, and environmental protection. Staff members ensure that the legal, environmental, and administrative elements of projects and contracts meet applicable requirements.

2.1.2.4 EERE National Laboratories

EERE stewards NREL, the Nation's only National Laboratory with a primary mission dedicated to the RD&D of energy efficiency, renewable energy, and related technologies. EERE also works extensively and has made investments in other National Laboratories operated by other DOE offices including ORNL, Sandia National Laboratories (SNL), ANL, INL, LBNL, and PNNL.

2.1.2.5 Budget

EERE's FY 2016 budget request is $2.723 billion. Table 2.4 details the enacted budget levels for FY 2014 and FY 2015 and the FY 2016 budget request for the programs within EERE.

	FY 2014 Enacted	FY 2015 Enacted	FY 2016 Request
Sustainable Transportation			
Vehicle Technologies	289,737	280,000	444,000
Bioenergy Technologies	232,290	225,000	246,000
Hydrogen and Fuel Cell Technologies	92,928	97,000	103,000
Total, Sustainable Transportation	**614,955**	**602,000**	**793,000**
Renewable Energy			
Solar Energy	257,058	233,000	336,700
Wind Energy	88,126	107,000	145,500
Water Power	58,565	61,000	67,000
Geothermal Technologies	45,775	55,000	96,000
Total, Renewable Energy	**449,514**	**456,000**	**645,200**
Energy Efficiency			
Advanced Manufacturing	180,471	200,000	404,000
Federal Emergency Management Program	28,248	27,000	43,088
Building Technologies	177,868	172,000	264,000
Weatherization and Intergovernmental Program	230,862	243,000	318,499
Total, Energy Efficiency	**617,449**	**642,000**	**1,029,587**
Corporate Support			
Facilities and Infrastructure	45,973	56,000	62,000
Program Direction	162,000	160,000	165,330
Strategic Programs	23,540	21,000	27,870
Total, Corporate Support	**231,513**	**237,000**	**255,200**
Subtotal, Energy Efficiency and Renewable Energy	**1,913,441**	**1,937,000**	**2,722,987**
Use of Prior Year Balances	**-2382**	**0**	**0**
Rescission of Prior Year Balances	-10,418	-22805	0
Total, Energy Efficiency and Renewable Energy	**1,900,641**	**1,914,195**	**2,722,987**

Discretionary dollars in thousands

Table 2.4: Office of Energy Efficiency and Renewable Energy Budget.
This table provides the FY 2014 enacted, FY 2015 enacted, and FY 2016 budget request for EERE.

2.1.3 Office of Nuclear Energy

The primary mission of the Office of Nuclear Energy (NE) is to advance nuclear power as a resource capable of making major contributions in meeting the Nation's energy supply, environmental, and energy security needs. NE supports the diverse civilian nuclear energy programs as well as space and defense programs by leading Federal RDD&D efforts in nuclear energy technologies, including power generation, safety, waste management, hybrid energy systems, and security technologies to help meet the Nation's energy security, nonproliferation, and clean energy goals.

NE partners with industry, academia, State and local governments, and National Laboratories to promote advanced reactor designs, fuel and materials technologies, and a variety of nuclear process technologies that will help develop future generations of nuclear power.

A prerequisite to the continued use of nuclear power is public and commercial confidence in the safety, reliability, and economics of operating reactors. Thus, NE explores life extension and additional improvements to light water reactor systems and fuel forms to further improve performance and enhance safety under severe accident conditions. NE has developed the most advanced and comprehensive modeling and simulation capabilities for reactor and fuel technologies, setting new standards for design and performance and safety analysis. The Office also aids industry in the costly process of design certification and licensing of first-of-a-kind commercial reactors including the AP-1000, the Economic Simplified Boiling Water Reactor (ESBWR), and small modular reactors (SMRs). In the future, NE expects to play a similar role in the licensing of advanced reactors through design, analysis, testing, and licensing support.

Office of Nuclear Energy At-a-Glance:

- Conducts R&D and associated infrastructure support to further nuclear reactor and fuel cycle technology development from the current reactor fleet through advanced reactor and fuel cycle concepts at 10 Laboratories
- Manages bilateral research agreements with 20 international partners
- Since 2009, awarded $401 million to 104 colleges and universities in 39 States and the District of Columbia through its university programs to support nuclear innovation R&D
- FY 2015 enacted: $833 million; FY 2016 budget request: $908 million
- Supported 394 Federal FTEs in FY 2015
- Web site: http://www.energy.gov/ne/office-nuclear-energy

Furthermore, NE directs a fuel cycle program that is heavily focused on solving the decades-old issues associated with the management of used nuclear fuel (UNF). The program aims to develop strategies and technologies to help meet the Federal Government's responsibility to manage and dispose of the Nation's commercial UNF and high-level radioactive waste. The program also includes research to develop technologies in support of sustainable fuel cycle technology options.

Finally, NE and its affiliated Laboratories and universities support a global outreach program that seeks to ensure international cooperation on safe uses of nuclear energy.

The FY 2016 request for NE is $908 million, an increase of $74 million relative to the FY 2015 enacted level.

2.1.3.1 Background

Following the end of World War II, the Federal government created the AEC to promote the development of nuclear energy. A major goal of nuclear research in the mid-1950s was to show that nuclear energy could produce electricity for commercial use. To that end, the AEC authorized the building of the first commercial nuclear reactor in Idaho, which produced the first electricity from nuclear energy in 1951. A series of demonstrations followed to explore a broad range of reactor design concepts.

In 1974, Congress passed the Energy Reorganization Act, which divided the AEC's functions into two new agencies: ERDA, to carry out RDD&D, and the Nuclear Regulatory Commission (NRC), to regulate nuclear power. After a three-year transition period when ERDA was responsible for nuclear energy, NE began carrying out its current assignments in 1977 as an office within the newly established DOE. In 2010, NE absorbed the used fuel activities previously performed by the Office of Civilian Radioactive Waste Management, which was closed after the Yucca Mountain nuclear waste repository project was determined not to be a feasible solution for the storage and disposal of used nuclear fuel.

NE is led by the Assistant Secretary of Energy for Nuclear Energy, who is appointed by the President of the United States with the advice and consent of the United States Senate. Directly reporting to the Assistant Secretary is the Principal Deputy Assistant Secretary, the Chief Operating Officer, the Chief of Staff and Deputy Chief of Staff, five Deputy Assistant Secretaries, and several Senior Advisors.

The Office is headquartered in Washington, DC, and Germantown, MD. It has an operations office in Idaho Falls, ID; and additional Federal staff in Las Vegas, NV, and Oak Ridge, TN. The Chief Operating Officer (COO) is responsible for supporting the overall direction and execution of NE's programs. The COO manages the Office of Human Capital and Business Services and the Office of Budget and Planning.

2.1.3.2 NE Programs

Within the FY 2016 Budget request, NE funds the following major RDD&D programs: SMR Licensing Technical Support; Supercritical Transformational Electric Power Generation (STEP) Research and Development; Reactor Concepts Research, Development and Demonstration; Fuel Cycle Research and Development; Nuclear Energy Enabling Technologies; and International Nuclear Energy Cooperation.

NE also manages additional programs that directly support and complement its research programs: the Radiological Facilities Management program, the Idaho Facilities Management program, and Idaho Site-Wide Safeguards and Security program.

NE makes available a collection of facilities across multiple National Laboratories, universities, and industry sites under the designated user facility umbrella of the Nuclear Science User Facilities (NSUF), which is supported by a $21 million request in FY 2016.

The details of NE's FY 2016 activities can be found in the NE portion of the FY 2016 Congressional Budget Request. Support for the Department's crosscutting activities is noted where appropriate.

2.1.3.2.1 Small Modular Reactor Licensing Technical Support Program

The SMR Licensing Technical Support Program supports costs associated with design certification and licensing activities for first-of-a-kind SMR designs. The Program operates through cost-shared arrangements with industry partners (industry contributions are a minimum of 50 percent of the cost) to promote the commercialization and deployment of SMRs that can provide safe, clean, affordable power. NE has made two awards under the SMR Licensing Technical Support Program that help overcome the financial and regulatory barriers facing the first movers in the SMR industry, with a goal of having the first operational SMR by the mid-2020s.

SMR Licensing Technical Support is planned as a $452 million, six-year program (through 2017). The FY 2016 request for SMR licensing is $62.5 million.

2.1.3.2.2 Supercritical Transformational Electric Power Research and Development

The Supercritical Transformational Electric Power Research and Development (STEP R&D) initiative is a collaborative DOE project to develop and scale up advanced Supercritical Carbon Dioxide (sCO_2) Brayton cycle energy conversion technology to facilitate commercial development. This program supports the STEP R&D initiative through engagement with industry and the broader stakeholder community to develop an effective public-private cost-shared sCO_2 Brayton cycle demonstration program, including research and development of sCO_2 technologies. Further details about this crosscutting activity can be found in section 2.3.

In FY 2016, $5 million in NE funds will support the STEP R&D initiative.

2.1.3.2.3 Reactor Concepts Research, Development, and Demonstration Program

The Reactor Concepts Research, Development, and Demonstration (RD&D) program develops new and advanced reactor designs and technologies to further the state of reactor technology, to improve its competitiveness, and to help advance nuclear power as a resource capable of meeting the Nation's energy, environmental, and national security needs. The Program is implemented by the Light Water Reactor (LWR) Technologies subprogram and the Advanced Reactor Technologies subprogram. Program activities are designed to address technical, safety, and security issues associated with existing and advanced reactor technologies including fast reactors using liquid metal coolants and high temperature reactors using helium or liquid salt coolants. Additionally, Reactor Concepts RD&D conducts research and development (R&D) on advanced technologies that improve the reliability, sustain the safety, and extend the life of the current LWR fleet.

In maximizing the benefits of nuclear power, work must be done to address the following challenges:

- Improving affordability of nuclear energy
- Addressing the management of nuclear waste
- Minimizing proliferation risks of nuclear materials
- Further enhancing safety and incorporating lessons learned from Fukushima

The FY 2016 request for the Reactor Concepts RD&D program is $108 million, divided as $33 million to Light Water Reactor Sustainability and $75 million to Advanced Reactor Technologies.

The Light Water Reactor Technologies subprogram conducts R&D on advanced technologies to improve the reliability, sustain the safety, and extend the life of current LWR reactors as well as address the impacts of the Fukushima accident with a focus on enhancing the accident tolerance characteristics of reactors and their operation through the LWR Sustainability Program. The LWR Sustainability subprogram focuses on material aging issues where research results will help support subsequent license renewal applications expected from industry around 2018. After the Fukushima Daiichi accident the nuclear community has been reassessing safety assumptions and nuclear plant safety performance. Research activities include assessing the validity of modeling and simulation tools using information from Fukushima; working with industry to develop new technologies that could be used to prevent accidents, mitigate consequences, or provide

NE Science Highlight

Developing Regulatory Guidance for Design Certification and Licensing of Advanced Reactors

NE sponsored aging research and industry-led regulatory demonstration projects to develop the technical and licensing basis for the initial license renewal of the existing operating nuclear plants in the United States. As a result of these efforts, 74 of the 99 U.S. operating reactors have been approved by the NRC to operate up to 60 years, with license renewal applications submitted or expected from another 24 reactors. This process has also been modeled by foreign regulators for license extensions of operating nuclear plants overseas. The economic benefit to the nuclear industry for an additional 20 years of operation is in the billions of dollars.

reliable information during accidents; and working with Japan and the international community to conduct forensics on the Fukushima event and provide data to industry so that they can incorporate lessons learned and improve safety. These activities are expected to lead to the enhancement of the accident tolerance of current and future light water reactors and the enhancement of accident response capabilities.

The Advanced Reactor Technologies subprogram sponsors R&D to develop new and advanced reactor designs and technologies to improve reactor technology and its competitiveness as a resource capable of meeting the Nation's energy needs. This subprogram focuses on efforts in advanced reactor coolants, safety and technology for advanced reactors, advanced energy conversion, advanced instrumentation and controls, support to the NRC in the development of an advanced reactor licensing framework, liquid metal reactor component testing, tristructural-isotropic (TRISO) fuel and graphite material qualification, advanced materials development and codification, continued international collaborations, and cost-shared industry R&D collaborations. Research results from this program are expected to help reduce design and construction costs, contribute data to the technical bases for the operation of safety systems, improve proliferation resistance, and provide critical insights to help solve key feasibility and performance challenges.

More than $3 million in activities in the Reactor Concepts RD&D program supports work in the sCO_2 crosscutting initiative, discussed in section 2.3.

2.1.3.2.4 Fuel Cycle Research and Development Program

The Fuel Cycle R&D Program conducts activities to develop used nuclear fuel management technologies and is also charged with laying the groundwork and planning for the implementation of the Administration's strategy on the management of spent nuclear fuel and high-level radioactive waste. The Program is also developing sustainable fuel cycle technologies and options that improve resource utilization and energy generation, reduce waste generation, enhance safety, and limit proliferation risk. The Program is supported by the Material Recovery and Waste Form Development subprogram, the Advanced Fuels subprogram, the Systems Engineering and Integration subprogram, the Materials Protection, Accounting, and Control Technology (MPACT) subprogram, the Used Nuclear Fuel (UNF) Disposition subprogram, and the Fuel Resources subprogram.

The Fuel Cycle R&D Program supports long-term technology development activities to develop next generation light water reactor fuels with enhanced accident tolerance; investigates advanced transmutation fuel forms and fuel/waste management approaches that could dramatically increase the sustainability of nuclear energy including improved utilization of fuel resources; develops techniques that will enable long-lived actinide elements to be repeatedly recycled (i.e., fully closed fuel cycles) to promote a cost-effective and low-proliferation-risk approach that significantly decreases the long-term challenges posed by the waste and its disposal; improves the utilization of fuel resources to reduce the amount of natural material required to produce nuclear energy; and investigates means of ensuring that economically viable resources of nuclear fuel are available.

The FY 2016 request for the Fuel Cycle R&D Program is $218 million, of which almost one quarter ($49 million) supports the Advanced Fuels subprogram. The development of improved and advanced nuclear fuels is a major objective for existing LWRs and future sustainable fuel-cycle options. In FY 2016, the program continues to support accident tolerant fuel (ATF) and clad concepts R&D. This includes fuel fabrication and testing involving irradiations in DOE's Advanced Test Reactor (ATR) and foreign reactors (Halden), steam environments, furnaces, and mechanical property testing. These feasibility and assessment activities also include establishing modeling capabilities for these new concepts, using existing models as the bases for development, as well as studies of impacts on economics, the fuel cycle, operations, safety, and the environment. A major activity in 2016 will be the "downselection/prioritization" of the industrial accident tolerant fuel concepts that will be pursued in the next phase of the program, leading up to the irradiation of a lead fuel rod or fuel assembly in a commercial power reactor in 2022.

The Advanced Test Reactor is the only U.S. research reactor capable of providing large-volume, high-flux neutron irradiation in a prototype environment, making it possible to study the effects of intense neutron and gamma radiation on reactor materials and fuels. The ATR complex lies within INL's 890-square-mile area in a remote part of the Idaho desert. *Photo credit: INL*

Approximately half of the $218 million request—$108 million—is allocated to the UNF Disposition subprogram, which conducts scientific research and technology development to enable storage, transportation, and disposal of UNF and wastes generated by existing and future fuel cycles. Because of the evolution of the domestic UNF inventory, special emphasis is placed on understanding the behavior of high-burnup fuels.

Proposed FY 2016 activities continue to further the understanding of long-term performance of disposal systems in three main geologic rock types: clay/shale, salt, and crystalline rock. These activities include collaborations with international partners to leverage and integrate applicable R&D being conducted by other countries into the U.S. disposal R&D portfolio. In FY 2016, funding increases significantly for R&D on the concept of waste disposal in deep boreholes in crystalline basement rock. The Department will initiate a field test that will include the drilling of a characterization borehole at a volunteer site that will be selected in the future. Also, evaluations will be completed to determine the feasibility of directly disposing existing single (storage only) and dual-purpose (storage and transportation) used-fuel canisters in a mined repository.

The Materials Recovery and Waste Form Development subprogram (funded at $35 million in the FY 2016 request) is developing advanced technologies that could improve current fuel cycle performance and enable a sustainable fuel cycle with minimal processing, waste generation, and potential for material diversion. Additionally, this subprogram provides solutions for environmental remediation, national security missions, and civilian nuclear applications. The ability to engineer, produce, and manage fuel cycle waste forms that are chemically and structurally stable over relevant periods of time from decades to hundreds of thousands of years (depending on the radioisotope) is critical for any advanced fuel cycle.

The MPACT subprogram (funded at $9 million in the FY 2016 request) develops the technologies and analysis tools to support the next generation of nuclear materials management and safeguards for future U.S. nuclear fuel cycles. It also includes assessing vulnerabilities and security of the consolidated storage of used nuclear fuel, and managing and minimizing proliferation and terrorism risk. Addressing the energy security needs of the country will require innovative approaches to materials control and accounting to ensure that nuclear material is not misused, diverted, or stolen.

Decades of research and technology development focused on the nuclear fuel cycle and UNF management have resulted in a significant number of potential options. The Systems Analysis and Integration subprogram (funded at $11 million in the FY 2016 request) was formed to systematically catalogue, evaluate, and screen the full range of options with the goal of identifying technology gaps and priority areas for future research. The results of these efforts inform future activities of the Fuel Cycle R&D program.

The Fuel Resources subprogram, funded at $6 million in FY 2016, supports activities that will ensure economic nuclear fuel resources remain available. The subprogram is developing economic means of extracting uranium from seawater. A key objective is to develop advanced absorbent materials that can simultaneously enhance uranium sorption capacity, selectivity, kinetics, and materials durability; thereby, reducing the development costs and uncertainties.

This Program also provides nearly $40 million in support of the SubTER crosscutting initiative discussed in section 2.3.

2.1.3.2.5 Nuclear Energy Enabling Technologies

The Nuclear Energy Enabling Technologies (NEET) program sponsors R&D and strategic infrastructure investments to develop innovative and crosscutting nuclear energy technologies. This program also makes a strong investment in modeling and simulation efforts to bring 30 years of improved computational and material science to reactor and fuel system simulation. The results will provide researchers, designers, and operators with advanced tools to better understand the behavior of nuclear energy systems; thereby improving safety, economics, and efficiency. Additionally, the program provides access to unique nuclear energy research capabilities through its Nuclear Science User Facilities (NSUF). NEET is supported by the following subprograms: Crosscutting Technology Development (CTD), Nuclear Energy Advanced Modeling and Simulation (NEAMS), Energy Innovation Hub for Modeling and Simulation, NSUF, and Nuclear Energy Traineeships.

These activities create the basis for improvements in safety, performance, reliability, economics, and proliferation risk reduction; and promote creative solutions to the broad array of nuclear energy challenges. They complement those within the Reactor Concepts RD&D and Fuel Cycle R&D programs by developing innovative solutions applicable to multiple reactor and fuel cycle concepts. The knowledge generated through these activities will allow the NE to address key challenges affecting future nuclear energy technology deployment (e.g., capital cost, technology risks, and proliferation concerns). Further, these activities will contribute to sustaining nuclear energy as a key component of our energy portfolio and help to achieve the energy security and greenhouse gas emission reduction objectives of the U.S.

The FY 2016 request for NEET is more than $86 million, divided among its subprograms as described below.

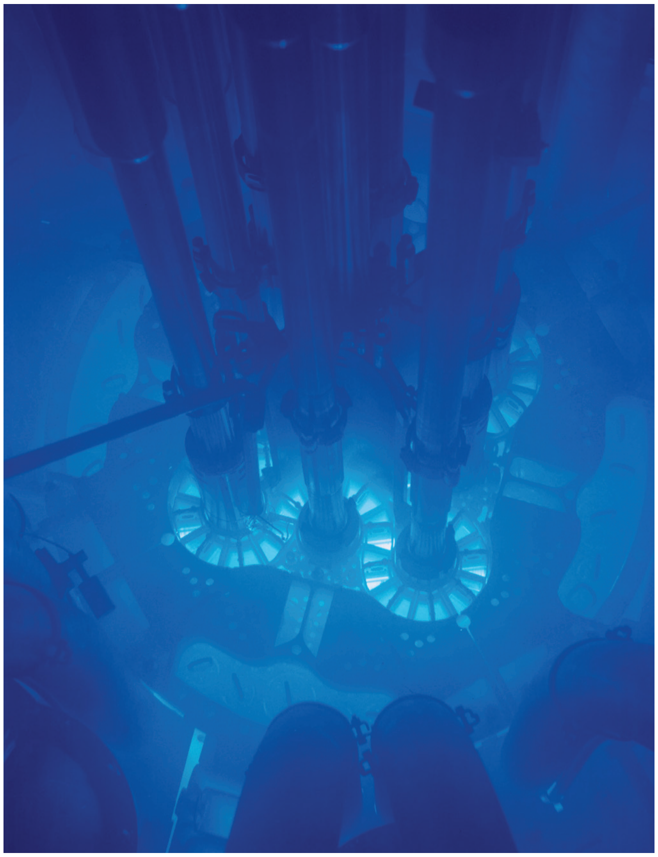
Supported by a request of $15 million in FY 2016, the CTD subprogram competitively awards high-priority R&D to universities, national laboratories, and industry, leading to the development of innovative solutions to unique and crosscutting nuclear energy challenges in areas such as reactor materials, advanced sensors and instrumentation, advanced methods for manufacturing, and nuclear cyber security. Additionally, NEET CTD strategically invests in competitive, nuclear energy-related infrastructure enhancement at national laboratories; ensuring researchers have access to state-of-the-art R&D capabilities. The subprogram leads the coordination with NE's other R&D programs to ensure that developed technologies and capabilities are part of an integrated system offering the potential of revolutionary improvement in safety, performance, reliability, economics, and proliferation risk reduction.

The FY 2016 request provides NEAMS with $23 million in support. NEAMS provides a complex set of computational simulation tools, in support of NE programs, such as the Advanced Reactor Technologies and Fuel Cycle R&D programs. NEAMS engages scientists and engineers in developing state-of-the-art, multiscale models of material properties and advanced computational simulation tools for simulations of nuclear energy systems. NEAMS is developing a computational ToolKit which is comprised of both reactor and fuel systems analysis capabilities that can be exercised either coupled or independently, depending on the needs of the end user. Computational tools developed under the NEAMS program define the state-of-the-art in nuclear simulation and are currently being used by over 60 organizations, both domestically and abroad.

The FY 2016 Budget request provides the Energy Innovation Hub for Modeling and Simulation with $24 million in support. The Hub is creating a virtual reactor model of an actual Westinghouse-designed, pressurized water reactor (PWR), owned and operated by the Tennessee Valley Authority-owned (TVA), to simulate reactor behavior. Once completed, engineers will use this virtual model to improve the safety and economics of reactor operations by simulating proposed solutions to reactor power production increases, and reactor life and license extensions. The combination of data gained from the virtual model and the physical reactor will be used to resolve technology issues that have challenged nuclear energy development. The Energy Innovation Hub for Modeling and Simulation is managed by the Consortium for Advanced Simulation of Light Water Reactors (CASL). CASL is a consortium of National Laboratories, universities, and industry partners, with ORNL serving as the lead institution.

The NSUF, funded at $21 million in FY 2016, represents a "prototype laboratory for the future," promoting the use of unique nuclear research facilities and encouraging active collaboration in relevant nuclear scientific research.

The NSUF is the Nation's only designated user facility dedicated to nuclear energy. The NSUF, through competitive solicitations, provides a mechanism for research organizations to collaborate, conduct experiments and post-experiment analysis at facilities not normally accessible to these organizations. On an annual basis, researchers propose projects to be conducted at these unique facilities, with timelines ranging from a few months to several years. When projects are awarded, the NSUF program pays for experiment support and Laboratory services at the user facilities. In this manner, researchers benefit from the introduction to new techniques, equipment, and personnel.



The Advanced Test Reactor at the Idaho National Laboratory is one of the prime capabilities offered by NSUF.

The final program under NEET in FY 2016 is a $2 million effort to enact a nuclear energy traineeship program. The traineeships will offer 5 year financial assistance awards to provide training for up to 18 graduate students in radiochemistry aligned with DOE workforce needs by employing a competitive selection process that is open, transparent, and peer reviewed. Universities will be required to provide some cost share, which could take the form of providing faculty support and "other student costs."

Advancing university-led nuclear innovation is vital to fulfilling the R&D needs described in the previous sections. This is accomplished primarily through NE's Nuclear Energy University Program (NEUP), which was created in 2009 to consolidate university support under one initiative and integrate university research more closely within NE's technical programs. Utilizing up to 20 percent of NE's R&D funding, NEUP engages U.S. colleges and universities to conduct R&D, enhance infrastructure, and support student education thereby helping to sustain a world-class nuclear energy workforce capability.

2.1.3.2.6 Radiological Facilities Management

In FY 2016, with nearly $7 million, the Department is requesting funding for the Research Reactor Infrastructure (RRI) subprogram. RRI supports the continued operation of U.S. research reactors by providing research reactor fuel services and maintenance of fuel fabrication equipment. In FY 2016, in support of its mission and objectives, the RRI subprogram will provide project management, technical support, quality engineering and inspection, and nuclear material support to 25 reactors located at 24 U.S. universities.

2.1.3.2.7 Nuclear Facility Operations

The Office of Nuclear Facility Operations is responsible for the stewardship of the Idaho Site and the management and operation of INL. The Office is supported by the Office of Facilities Management, the Idaho Operations Office, and the Oak Ridge Site Office.

The Idaho Facilities Management Program (funded in FY 2016 with $212 million) and Idaho Site-Wide S&S Program (funded in FY 2016 with $126 million) manage the planning, acquisition, operation, maintenance, disposition, and protection of NE-owned facilities, capabilities, and nuclear materials at INL in a safe, compliant status. The S&S program funds all physical and cyber security activities for the INL, providing protection of DOE's nuclear materials, classified and unclassified matter, Government property, personnel, and other vital assets from theft, diversion, sabotage, espionage, unauthorized access, compromise, and other hostile acts that may cause adverse impacts on our national security; program continuity; or the health and safety of employees, the public, or the environment.

2.1.3.2.8 International Nuclear Energy Policy and Cooperation

The Office of International Nuclear Energy Policy and Cooperation collaborates with international partners to support the safe, secure, and peaceful use of nuclear energy. The Office provides a coherent strategic direction for NE's international engagement to support the NE mission and broader U.S. Government objectives. The Office is supported by the Office of Bilateral Cooperation, the Office of Multilateral Cooperation, and the Office of International Commercial Activities.

The International Nuclear Energy Cooperation Program serves as the Department's overall lead for all international activities related to civil nuclear energy, including analysis, development, and implementation of international civil nuclear energy policy, and coordination and integration of NE's international nuclear technical activities. These activities support international bilateral and multilateral engagement and civil nuclear energy R&D activities with countries having an established or planned civilian nuclear power sector.

The Office of International Nuclear Energy Policy and Cooperation is supported with a $3 million request in FY 2016.

2.1.3.3 Field Operations and Offices

In addition to executing and overseeing the nuclear energy RDD&D mission of INL, the Idaho Operations Office is focused on cleaning up the legacy facilities and contamination at the 890-square-mile INL site and overseeing INL's new missions focused on performing research and development in energy programs and national defense. The Idaho Operations Office directly supports the Office of Nuclear Facility Operations and provides overall coordination, direction, and management of all Idaho site operations and activities.

The field office oversees three major contracts for operations and research activities, performs procurement services, protects and conserves government property, and performs other inherently federal functions including compliance with the Freedom of Information Act and Privacy Act, and tribal and Congressional relations.

2.1.3.4 NE National Laboratories

NE manages INL, the Nation's premier nuclear energy research and development laboratory, supporting the Department's nuclear energy research, the testing of naval reactor fuels and reactor core components, and a range of national security technology programs. At the INL, and at a dozen other National Laboratories and universities throughout the United States, NE supports a comprehensive suite of nuclear irradiation, testing, and examination facilities that are among the best in the world.

2.1.3.5 Budget

NE's FY 2016 budget request is $908 million. Table 2.5 details the enacted budget levels for FY 2014 and FY 2015 and the FY 2016 budget request for the Programs within NE.

	FY 2014 Enacted	FY 2015 Enacted	FY 2016 Request
Integrated University Program	5,500	5,000	0
STEP R&D	0	5,000	5,000
SMR Licensing Technical Support	110,000	54,500	62,500
Reactor Concepts Research, Development and Demonstration	112,822	133,000	108,140
Fuel Cycle Research and Development	186,205	197,000	217,760
Nuclear Energy Enabling Technologies	71,109	101,000	86,387
Radiological Facilities Management	24,968	25,000	6,800
Idaho Facilities Management	196,276	206,000	211,826
Idaho Sitewide Safeguards and Security	94,000	104,000	126,161
International Nuclear Energy Cooperation	2,496	3,000	3,000
Program Direction	90,000	80,000	80,000
Subtotal, Nuclear Energy	**893,376**	**913,500**	**907,574**
Transfer from Department of State	0	0	0
Use of Prior Year Balances	-5,000	0	0
Rescission of Prior Year Balances	0	-80,121	0
Total, Nuclear Energy	**888,376**	**833,379**	**907,574**

Discretionary dollars in thousands

Table 2.5: Office of Nuclear Energy Budget.
This table provides the FY 2014 enacted, FY 2015 enacted, and FY 2016 budget request for NE.

2.1.4 Office of Fossil Energy

The Office of Fossil Energy (FE) plays a key role in helping the United States meet its need for secure, reasonably priced, and environmentally sound energy generated from fossil resources. FE's primary mission is to promote the prudent development of domestic fossil.

FE consists of three program offices—Coal and Carbon Management, Oil and Natural Gas, and Petroleum Reserves. The Office of Clean Coal and Carbon Management supports research to reduce carbon emissions by improving the performance and efficiency of fossil energy systems and Carbon Capture Utilization and Storage (CCUS) technologies. The Office of Oil and Natural Gas conducts research to support prudent development of domestic oil and natural gas resources onshore and offshore and also oversees DOE's natural gas regulatory activities. The Office of Petroleum Reserves manages energy security programs authorized under the Energy Policy and Conservation Act to provide an emergency inventory of crude oil and some petroleum products to protect the United States against interruption in critical petroleum supplies (international or domestic).

The FY 2016 request for FE is $842 million, an increase of $51 million relative to the FY 2015 enacted level.

Office of Fossil Energy At-a-Glance:

- Supports research and demonstration programs to ensure the availability of clean, affordable energy from coal and other fossil resources
- Regulates natural gas imports and exports and participates in international programs pertaining to natural gas and petroleum
- Manages the Strategic Petroleum Reserve Program to ensure strategic and economic protection against disruptions in petroleum supplies
- The National Energy Technology Laboratory, which is federally owned and operated, is the lead center for FE's R&D program
- FY 2015 enacted : $791 million; FY 2016 budget request: $842 million
- Supported 775 Federal FTEs in FY 2015
- Web site: http://energy.gov/fe/office-fossil-energy

2.1.4.1 Background

The Federal Government's involvement in fossil fuel resources began in early 1900 when the U.S. Navy started powering their ships with unrefined crude oil. To ensure sufficient fuel for the fleet, the Government began withdrawing probable oil-bearing lands from the public domain. Between 1909 and 1924, tracts in California, Utah, and Wyoming were set aside and became the Naval Petroleum and Oil Shale Reserves—the oldest component of today's Fossil Energy organization.

The U.S. Bureau of Mines (established in 1910 in the Department of the Interior) recognized the need to learn more about the extraction of oil and established the Bartlesville Petroleum Experiment Station in 1918. Thus began the Federal Government's petroleum research program. In 1910, the Department of Interior also initiated coal R&D by opening the Pittsburgh Experiments Station to conduct training and research on coal mining safety, equipment, and practices.

With passage of the Synthetic Liquid Fuels Act of 1944, the first concentrated effort to study future ways to use the Nation's abundant coal supplies began. In 1961, Congress established the Office of Coal Research in the U.S. Department of the Interior. Over time, the Office began to study a wide range of coal technologies, including the conversion of coal to gas and liquid fuels and new ways to combust coal more cleanly.

When ERDA was created in 1974, the Office of Coal Research moved from the Interior Department and became the core organization for the Fossil Energy program. Along with coal research, the new Fossil Energy office also became the home for the Government's petroleum research program and a small synthetic fuels research program transferred from the Bureau of Mines.

The oil embargo of 1973 called attention to the need for an emergency stockpile of crude oil. In 1975, the Energy Policy and Conservation Act authorized creation of an emergency oil reserve. The final major piece of today's Fossil Energy organization, leading to the creation of the U.S. Strategic Petroleum Reserve.

In the original Energy Department organization, Fossil Energy programs were managed as a division under the Assistant Secretary for Energy Technology. In 1979, many of the Department's energy research functions were recognized, and the Fossil Energy program was elevated to its current Assistant Secretary-level status.

FE is led by the Assistant Secretary for Fossil Energy, who is appointed by the President of the United States with the advice and consent of the United States Senate. FE executes its activities under the Deputy Assistant Secretaries for Clean Coal and Carbon Management, Oil and Natural Gas, and Petroleum Reserves.

FE conducts a variety of energy analysis studies to identify promising R&D opportunities for fossil-energy-based power systems that provide balanced solutions enabling economic sustainability, energy supply security, and technology solutions that mitigate global climate change and improve environmental performance. Analyses include technical and economic assessments of the specific R&D technologies, strategic analysis to inform how FE-supported R&D can support policy and regulatory proposals, and baseline assessments of the most advanced commercially available power systems.

2.1.4.2 FE Programs

In recent years, FE has transitioned away from production and resource development towards R&D to promote safety and environmental stewardship. In addition to managing and implementing a comprehensive R&D portfolio, FE also conducts detailed engineering and economic analyses. The results of these studies inform the Department's technology plans and provide strategic information and analysis to the Nation's policymakers to enable the most efficient allocation of public funds, and to ensure that the United States has a continuing supply of abundant, clean, affordable, and reliable energy.

FE manages these priorities through the Office of Clean Coal and Carbon Management, the Office of Oil and Natural Gas, and the Office of Petroleum Reserves. FE's specific priority areas for FY 2016 are identified in their Congressional Budget Request.

2.1.4.2.1 Clean Coal and Carbon Management

FE's Office of Clean Coal and Carbon Management supports the RD&D of advanced technologies to improve the efficiency and environmental performance of energy from coal and other fossil fuel resources. In addition to researching new power generation systems that are more amenable to CO_2 capture, such as oxy-combustion and chemical looping, which intrinsically produce a concentrate CO_2 stream, the Office seeks to reduce the cost of pre- and post-combustion CO_2 capture from power and industrial sources, quantify and mitigate the risks of long-term CO_2 storage, and increase efficiency of power generation. As part of this effort, the Office operates the Carbon Capture & Storage (CCS) Demonstration Program, which supports commercial-scale clean coal power and industrial carbon capture and storage demonstration projects. The Office also supports development of advanced second generation materials, sensors, and modeling technologies, distributed communication sensor networks, and energy-economic analysis activities underpinning technology evaluation and policy development.

An integral part of the Office's activities is international engagement through bilateral and multilateral activities, which leverage shared interests and common goals where collaboration can accelerate research and enable large-scale demonstrations. Examples are the U.S.-China Clean Energy Research Center and the Carbon Sequestration Leadership Forum. A more detailed description of FE's international activities can be found in section 2.4.1.3.

Of the total FY 2016 request for FE of $842.1 million, $369 million is allocated to the Coal and Carbon Management program. About one-third ($117 million) of the Coal budget supports the Carbon Capture program, and nearly 30 percent ($109 million) supports the Carbon Storage program. The FY 2016 request increases funding for post-combustion capture from coal and natural gas-fired systems to pursue a new emphasis on optimizing carbon capture on natural gas systems and allows continued scale-up of advanced technologies by providing support for at least two large-scale pilot tests (10 MWe+) that will focus on addressing the key issues of lowering the capital cost of carbon capture systems and reducing the energy penalty for both coal and natural gas-fired power systems. These efforts will support the program's commitment to deliver a demonstration project that captures and stores more than 75 percent of the carbon emissions from a natural gas power system of at least 50 MWe capacity by 2020 using what has been determined to be the best available carbon capture technology available for demonstration at the time.

Carbon Storage includes funding for the Regional Carbon Sequestration Partnerships, small-scale characterization and field projects, and specific testing. The FY 2016 funding request includes support to enhance efforts related to the Energy Data eXchange (EDX) and National Risk Assessment Partnership (NRAP), which will improve data infrastructure and management and expansion of technical risk assessment and quantification methodologies in support of Carbon Storage program goals. Funding for the Carbon Storage subprogram is a crucial part of DOE's subsurface crosscut technical team, which will address identified challenges in the subsurface across DOE R&D programs through coordinated research in wellbore integrity, stress state and induced seismicity, permeability manipulation, and new subsurface signals to ensure enhanced energy security, material impact on climate change via CO_2 storage, and dramatically mitigated environmental impacts from energy-related activities and operations.

FE's remaining Coal and Carbon Management budget is focused on advanced energy systems ($39 million), crosscutting research ($51 million), the Supercritical Carbon Dioxide (CO_2) Technology crosscut ($19 million, described in section 2.3), and coal-related R&D at NETL ($34 million).

In addition to SubTER and Supercritical CO_2 US/SE-led crosscutting activities, the Office of Clean Coal and Carbon Management has contributed to, and collaborated on, the Energy-Water Nexus (described in section 2.3).

FE Science Highlight

Providing Safe, Permanent Underground CO_2 Storage: Regional Carbon Sequestration Partnerships

In 2003, the ability to safely and permanently store CO_2 was untested. Since then, the DOE Regional Carbon Sequestration Partnerships (RCSP) implemented a three-phased technology development strategy to demonstrate feasibility of safe, low-cost, permanent underground storage of carbon dioxide. Leveraged by industry funding, the RCSPs have identified basins across the United States with long-term storage potential, injected over 10 million metric tons of CO_2 as of June 2015, through small- and large-scale field projects, and continue to validate storage technologies, infrastructure needs, and best practices for future commercial projects. One of these projects will soon be injecting in the Nation's first Class VI well. This was achieved at a cost of a $556 million, the majority of which was for the large-scale injections. DOE is now exploring the feasibility for offshore storage by implementing the same strategy.

2.1.4.2.2 Oil and Natural Gas

FE's Office of Oil & Natural Gas seeks to maximize the public benefits of oil and natural gas resources and ensure their responsible development and delivery. Part of this effort is quantification and mitigation of impacts/risks of resource development, with a focus on shale development and offshore oil spill prevention. The R&D focuses on developing technologies to minimize the environmental impact of natural gas production and transport such as reducing the surface footprint and protecting water and air quality, and on conducting research to evaluate new sources of natural gas, such as methane hydrate. This Office also regulates natural gas imports and exports under section 3 of the Natural Gas Act of 1938, maintains statistics on North American natural gas trade, and oversees FE's international programs pertaining to natural gas and petroleum. They actively participate in several global partnerships and initiatives.

The FY 2016 request allocates $44 million to the following three subprograms: Environmentally Prudent Development ($19 million), Emissions Reductions from Midstream Natural Gas Infrastructure ($15 million), and Emissions Quantification from Natural Gas Infrastructure ($10 million). As with the Clean Coal Program, the FY 2016 request also allocates funding through the Environmentally Prudent Development subprogram to support SubTER and the Energy-Water Nexus crosscuts (discussed in section 2.3). For the Emissions Mitigation from Midstream Infrastructure subprogram, the FY 2016 request allocates funding to develop and demonstrate more cost-effective technologies to detect and reduce methane losses from natural gas transmission and distribution systems. The FY 2016 request supports the Emissions Quantification from Natural Gas Infrastructure subprogram by increasing support for research on better methodologies for quantifying methane emissions from the natural gas value chain for updating the national Greenhouse Gas Inventory.

2.1.4.2.3 Petroleum Reserves

The mission of the Office of Petroleum Reserves (OPR) is to protect the United States from severe petroleum supply interruptions and provide economic and domestic security through the acquisition, storage, distribution, and management of emergency petroleum stocks and to carry out U.S. obligations under the International Energy Program.

The OPR manages three stockpiles: the Strategic Petroleum Reserve (SPR), the Northeast Home Heating Oil Reserve, and the Northeast Gasoline Supply Reserve. The SPR is the largest stockpile of Government-owned emergency crude oil in the world, and it provides the President with a powerful response option should a disruption in commercial oil supplies threaten the U.S. economy. The Northeast Home Heating Oil Reserve is a one million barrel supply of ultralow-sulfur diesel for homes and businesses in the northeastern United States, a region heavily dependent upon the use of heating oil. And the Northeast Gasoline Supply Reserve is a one million barrel supply of seasonally adjusted, regionally appropriate gasoline for consumers in the northeastern United States.

OPR is also responsible for completing the environmental cleanup and remediation of the previously sold Naval Petroleum Reserve #1 (Elk Hills, CA).

About 30 percent ($257 million) of the total FE budget supports the SPR. The FY 2016 budget request addresses delayed maintenance on the aging infrastructure and cavern integrity activities as well as management, security, and operational readiness of the Reserve. SPR's underground storage caverns require maintenance to ensure their storage capability and integrity. Likewise, the continued degasification of SPR stocks is required for the crude oil to be available for emergency use and to prevent the off-gassing of volatile organic compounds (VOCs) above safe levels during oil movements through commercial distribution points.

2.1.4.3 Field Operations and Offices

The majority of FE's budget is awarded as grants or cooperative agreements to universities or colleges, industry, or through field work proposals to National Laboratories. FE performs many of the field-operations-related activities through the National Energy Technology Laboratory (NETL).

2.1.4.4 FE National Laboratories

FE supports the operations of the National Energy Technology Laboratory (NETL). As Fossil Energy's National Laboratory, NETL supports the DOE mission by implementing an integrated spectrum of energy and environmental research, discovery, development and demonstration programs that enable the safe, sustainable, and affordable production and utilization of the Nation's domestic coal, natural gas, and oil resources. In addition to conducting research and technology development in its laboratories at three sites, NETL shapes, funds, and manages contracted research in the United States and more than 40 foreign countries. NETL's total research portfolio includes over 1,450 research activities, with a total award value of nearly $19 billion and private sector cost-sharing of $11 billion. The FE portion of this portfolio consists of 1,000 research activities, with a total award value of over $13 billion and private sector cost-sharing of over $8 billion.

2.1.4.5 Budget

FE's FY 2016 budget request is $842 million. Table 2.6 details the enacted budget levels for FY 2014 and FY 2015 and the FY 2016 budget request for the programs within FE.

2.1.5 Office of Electricity Delivery and Energy Reliability

The Office of Electricity Delivery and Energy Reliability (OE) drives electric grid modernization and resiliency in the energy infrastructure. OE leads DOE's efforts to strengthen, transform, and improve the Nation's energy infrastructure so that consumers have access to reliable, secure, and clean sources of energy.

OE accomplishes this mission through RD&D projects, partnerships, facilitation, modeling and analytics, and emergency preparedness. Specifically, OE works with private industry and Federal, State, local, and tribal governments on a variety of research initiatives for grid modernization and to enhance key characteristics of the U.S. electric transmission and distribution systems, which include

- Reliability—consistent and dependable delivery of high-quality power;
- Flexibility—accommodating changing supply and demand patterns and new technologies;
- Efficiency—low losses in electricity delivery and improved use of system assets;
- Resiliency—withstanding and quickly recovering from disruptions and maintaining critical function;
- Affordability—more cost-effective deployment of assets to meet system needs;
- Security—protecting system assets and critical functions; and
- Minimal environmental footprint—implementing grid system designs that reduce total environmental impact of grid components and connected systems.

OE's priorities for FY 2016 are included in the Department's Congressional Budget Request.

The FY 2016 request for OE is $270 million, an increase of $123 relative to the FY 2015 enacted level.

	FY 2014 Enacted	FY 2015 Enacted	FY 2016 Request
Coal			
CCS and Power Systems			
Carbon Capture	92,000	88,000	116,631
Carbon Storage	108,766	100,000	108,768
Advanced Energy Systems	99,500	103,000	39,385
Cross Cutting Research	41,925	49,000	51,242
NETL Coal Research and Development	50,011	50,000	34,031
STEP (Supercritical CO_2)	0	10,000	19,300
Total, Coal	**392,202**	**400,000**	**369,357**
Natural Gas Technologies	20,600	25,121	44,000
Unconventional Fossil Energy Technologies from Petroleum - Oil Technologies	15,000	4,500	0
Program Direction	120,000	119,000	114,202
Plant and Capital Equipment	16,032	15,782	18,044
Fossil Energy Environmental Restoration	5,897	5,897	8,197
Super Computer	0	0	5,500
Special Recruitment Programs	700	700	700
Subtotal, Fossil Energy Research and Development	**570,431**	**571,000**	**560,000**
Use of Prior Year Balances	-8,500	0	0
Rescission of Prior Year Balances	0	-10,413	0
Total, Fossil Energy Research and Development	**561,931**	**560,587**	**560,000**
Fossil Energy Petroleum Accounts			
Naval Petroleum and Oil Shale Reserves			
Production Operations	12,999	13,271	13,330
Management	7,000	6,679	4,170
Total, Naval Petroleum and Oil Shale Reserves	**19,999**	**19,950**	**17,500**
Total, Elk Hills School Lands Fund	**0**	**15,580**	**0**
Strategic Petroleum Reserve (SPR)			
Facilities Development and Operations	164,714	174,999	229,710
Management for SPR Operations	24,646	25,001	27,290
Total, SPR	**189,360**	**200,000**	**257,000**
Northeast Home Heating Oil Reserve			
Northeast Home Heating Oil Reserve	8,000	7,600	7,600
Rescission of Prior Year Balances	0	-6,600	0
Total, **Northeast Home Heating Oil Reserve**	**8,000**	**1,600**	**7,600**
Total, Fossil Energy Petroleum Accounts	**217,359**	**237,130**	**282,100**
Total, Fossil Energy	**779,290**	**791,117**	**842,100**

Discretionary dollars in thousands

Table 2.6: Office of Fossil Energy Budget.
This table provides the FY 2014 enacted, FY 2015 enacted, and FY 2016 budget request for FE.

2.1.5.1 Background

OE was established formally in 2005 by combining DOE's former Office of Electric Transmission and Distribution and former Office of Energy Assurance. Since its inception, OE has been leading efforts to modernize the grid through targeted investments that help further stimulate State and industry ventures in the electric grid and energy infrastructure. Such activities include technological innovations, advancements in addressing State and regional energy issues, and the expansion of capabilities to strengthen security and resilience measures in infrastructure planning through increased partnerships with State and private sector stakeholders.

OE manages its organization under a President-appointed Assistant Secretary confirmed by the Senate, with activities executed by five Deputy Assistant Secretaries and a Chief of Business Operations. The Deputy Assistant Secretaries direct OE's five programmatic divisions:

- Power Systems Engineering Research and Development
- National Electricity Delivery
- Infrastructure Security and Energy Restoration
- Energy Infrastructure Modeling and Analysis
- Advanced Grid Integration

Office of Electricity Delivery and Energy Reliability At-a-Glance

- Leads RD&D efforts to modernize and secure the electricity grid through:
  - Clean energy transmission
  - Smart grid development
  - Cybersecurity
  - Energy storage
  - Advanced grid modeling and analytics
- Provides technical assistance for national grid planning and coordinates approvals for Federal transmission permits
- Enhances the reliability, survivability and resiliency of the energy infrastructure, and expedites recovery from disruptions caused by all hazards, both natural and manmade
- FY 2015 enacted: $147 million; FY 2016 budget request: $270 million
- Supported 83 Federal FTEs in FY 2015
- Web site: http://www.energy.gov/oe

Through these divisions, OE addresses immediate challenges to America's energy security, while sustaining applied research in new technologies and implementing policies to meet future challenges. OE's program activities generally fall into the following categories: research, development and demonstration; planning and assistance; and preparedness, response, and restoration.

Because of its mission regarding the security and resilience of the Nation's energy-related critical infrastructure, the Department is designated as the Sector-Specific Agency for Energy under Presidential Policy Directive 21: Critical Infrastructure Security and Resilience (PPD-21). OE leads the Department's efforts under PPD-21 and works closely with Federal agencies, State and local governments, and industry to protect against and mitigate threats on the energy infrastructure, regardless of whether they are caused by natural disasters, deliberate attacks, or human error. The Department is a key member of the Department of Homeland Security's Critical Infrastructure Partnership Advisory Council (CIPAC), which was established to facilitate interaction between governmental entities and representatives from the community of critical infrastructure owners and operators. Through CIPAC, the Department serves as chair of the Energy Sector Government Coordinating Council, which includes private sector partners.

2.1.5.2 OE Programs

OE's programmatic divisions collaborate to execute the following primary activities:

- Clean energy transmission and reliability (CETR)
- Smart grid research and development
- Cybersecurity for energy delivery systems
- Energy storage
- Transformer resilience and advanced components
- National electricity delivery
- Infrastructure security and energy restoration
- State energy reliability and assurance grants

Descriptions of these activities follow. Activities across the entire span of OE support the Department's Grid Modernization crosscut, described in section 2.3. Support for other crosscutting efforts is noted where applicable.

2.1.5.2.1 Clean Energy Transmission and Reliability

Clean Energy Transmission and Reliability (CETR) Program provides tools and analytical products to inform energy system decision-making, manage uncertainty, and support system reliability and resilience. Diverse energy system stakeholders, ranging from system operators and planners to State energy officials, look to CETR to convene the best minds in Government and industry and provide expert insight on energy issues through leading-edge analysis, modeling, and innovation.

CETR supports RD&D in three areas:

- Transmission reliability: Demonstrating value-added applications of new technologies, including the ability to do forensic analysis after an event (e.g., the 2011 Southwest Blackout), identify when a power system component is to facilitate equipment maintenance, and improve the estimate of the state of the system to improve market behavior and reliability and overall system efficiency.
- Advanced modeling grid research: Developing decision support tools that use advanced modeling of real-time performance to enable predictive capabilities and improve operational decision-making.
- Energy systems risk and predictive capability (ESRPC): Combining "big data" and energy systems analysis to assess energy infrastructure system risks and inform emergency response.

CETR activities also focus on advancing university-based power systems research to ensure an enduring strategic national capability for innovation in this essential area.

In FY 2016, CETR is supported with a $40 million request. The largest single component of this request is $18 million for the transmission reliability area, in which OE will complete development of multiple synchrophasor-based, production-grade software applications that will be purchased by utilities committed to installing these applications at their own expense. These applications will monitor and control the grid with advanced analysis, visualization, and decision-support tools, and will maximize the value of synchrophasor data now available to grid operators to improve reliability. OE will also focus on inter-entity data exchange to ensure seamless and secure operations and operational planning.

The request includes $15 million for advanced modeling grid research. The program supports research and development in three major areas:

- Data Management and Analytics. These activities focus on the way data are collected, used, stored, and archived to facilitate the use of large, multi-source datasets to support operations and off-line planning.

- Mathematical Methods and Computation. These activities develop new algorithms and software libraries for use on high-performance computing platforms, which leverage the investments of the Advanced Scientific Computing Research program in the Office of Science and work at ARPA-E in stochastic optimization. These new methods will form the foundation of the next generation of tools that operators and operational planners will use to manage the system.
- Models and Simulations. These activities perform research and development on new classes of models and fast simulations that are able to incorporate operational data, analyze potential futures, and guide decision-making to ensure reliable operation in a large-scale, dynamic, and uncertain environment.

In FY 2016, the program plans to conduct a competitive solicitation to accelerate the transition of the foundational research in mathematics and models into industry-relevant applications to improve reliability and security.

Finally, the CETR request includes $7 million for ESRPC. In FY 2016, ESRPC will focus on furthering the development of analytical tools that estimate seasonal and regional extreme weather risks to energy systems for stakeholders including the general public, the energy industry, and State and Federal partners. Funding in FY 2016 will also be used to connect and further integrate the research outputs of the Transmission Reliability and Advanced Modeling Grid Research subprograms into the products developed by ESRPC.

2.1.5.2.2 Smart Grid Research and Development

The Smart Grid Research and Development program focuses primarily on the development of technologies, tools, and techniques to modernize the distribution portion of the electric delivery system (the infrastructure that takes power from the power plants or sources and delivers it to individual businesses and homes). Strategic investments in this program are pursued to improve reliability, operational efficiency, resiliency, and outage recovery, building upon previous and ongoing grid modernization efforts. For example, in one OE-supported project, more than 400,000 residential customers are being empowered to better manage their electricity use through improved access to their electricity consumption data.

Another important research area for next-generation electric distribution systems is microgrids, i.e., localized grids that can disconnect from the broader electric grid to operate autonomously and help mitigate grid disturbances to strengthen grid resilience. Microgrids use advanced smart grid technologies and the integration of distributed energy resources such as backup generators, solar panels, and storage.

OE's Smart Grid R&D program is supported by a $30 million request in FY 2016. The FY 2016 request includes a new investment in developing the Advanced Distribution Management System. An initial version of an open source integrated software platform for varying vendor systems will be developed that supports the full suite of distribution management applications (such as voltage and reactive power optimization; fault location, isolation, and service restoration; economic dispatches; and optimization routines). This integrated platform, based on specifications and requirements to be developed jointly with utilities, will allow information to flow between individual applications across the entire utility enterprise, enabling enhanced visibility and controllability of system assets. Smart Grid investments will also explore market-based controls in FY 2016, including developing simulation tools and test cases, as well as validating tools using the initial test cases that were developed under Recovery Act Grid Modernization projects.

FY 2016 Microgrid R&D activities support ongoing work to develop reliable and resilient microgrid concepts and will also include new projects to be awarded through a funding opportunity announcement (FOA) on networked microgrids, following the defined R&D pathway from single microgrids toward an integrated network of multiple microgrids as a building block for the smarter grid of the future. Resilient Electric Distribution Grid R&D activities in FY 2016 will continue to support the Administration's initiatives to establish partnerships with U.S. cities and tribal communities on deployment of smart grids and microgrids for climate preparedness and resilience.

2.1.5.2.3 Cybersecurity for Energy Delivery Systems

The Cybersecurity for Energy Delivery Systems (CEDS) Program strengthens the energy infrastructure against cyber threats, working closely with private and public partners in industry and Government. Support provided by this program includes RD&D of cutting-edge cybersecurity solutions; information-sharing of cyber threats in partnership with industry; implementation of tools to guide best practices and cybersecurity investment decisions in the electric sector; and efforts to build an effective, timely, and coordinated cyber incident management capability in the energy sector. For example, in FY 2014, OE released new Cybersecurity Capability Maturity Models that help organizations in the electricity and oil and gas sectors evaluate, prioritize, and improve their cybersecurity capabilities using a common set of industry practices that help strengthen their defenses.

OE's cybersecurity activities align with the vision of the *Roadmap to Achieve Energy Delivery Systems Cybersecurity* of having resilient energy delivery systems designed, installed, operated, and maintained to survive a cyber incident while sustaining critical functions by 2020. The Roadmap was developed by industry and facilitated by OE.

OE's FY 2016 Request for CEDS is $52 million.

> **OE Highlight**
>
> **Modernizing the Electric Grid and Improving Reliability with Synchrophasor Technologies**
>
> The 2003 Northeast Blackout affected 50 million people and exposed the need to improve visibility into the power grid, detect grid stress, and prevent widespread outages. Beginning in the 1990s, DOE funded R&D to develop phasor measurement units (PMUs), which accurately measure grid conditions with high resolution. Measurements from PMUs located across the grid and networked together (called synchrophasor technology) provide an accurate, real-time view of system conditions, stress points, and hazards. Under the American Recovery and Reinvestment Act of 2009 (ARRA), DOE funded the development and deployment of more than 1,300 PMUs, which along with industry investments, contribute to a network of more than 2,000 PMUs today to provide wide-area visibility across the United States. Data and analytics derived from synchrophasor technology provide grid operators with real-time situational awareness so they can take actions to avoid blackouts such as that which occurred in 2003. Moreover, the data provided by these sensors is the foundation of a modern grid, enabling applications such as system dynamics monitoring, post-event forensics, system model validation, and, in the near future, automated system control.

The FY 2016 areas of focus for CEDS include the following:

- Accelerating information-sharing to enhance situational awareness in the electricity and oil and natural gas sectors. This activity specifically supports the Cybersecurity Risk Information Sharing Program (CRISP), a Government–energy-sector collaboration to facilitate the timely bidirectional sharing of classified and unclassified threat information and develop and deploy situational awareness tools to enhance the sector's ability to identify and mitigate threats and coordinate the protection of critical infrastructure. DOE will issue a competitive solicitation to identify and fund commercially available technologies and services that can be incorporated into CRISP via operational pilots designed to enhance all aspects of the program.
- Expanding implementation of the Cybersecurity Capability Maturity Model and Risk Management Process for both the electricity and oil and natural gas sectors.
- Researching, developing, and demonstrating cutting edge cybersecurity solutions in the electricity and oil and natural gas sector. In FY 2016, CEDS will issue a competitive solicitation for energy sector-led

R&D to advance cybersecurity for energy delivery systems to transition mid-term R&D projects into real world cybersecurity capabilities that address the changing threat landscape. In addition, CEDS will continue to support applied research and strengthen the core capabilities at the National Laboratories.

- Exercising and refining the energy sector's cyber incident response capabilities.
- Establishing a Virtual Energy Sector Advanced Digital Forensics Analysis Platform through issuing a competitive solicitation.

The entirety of these activities support the Cybersecurity crosscut, described in section 2.3.

2.1.5.2.4 Energy Storage

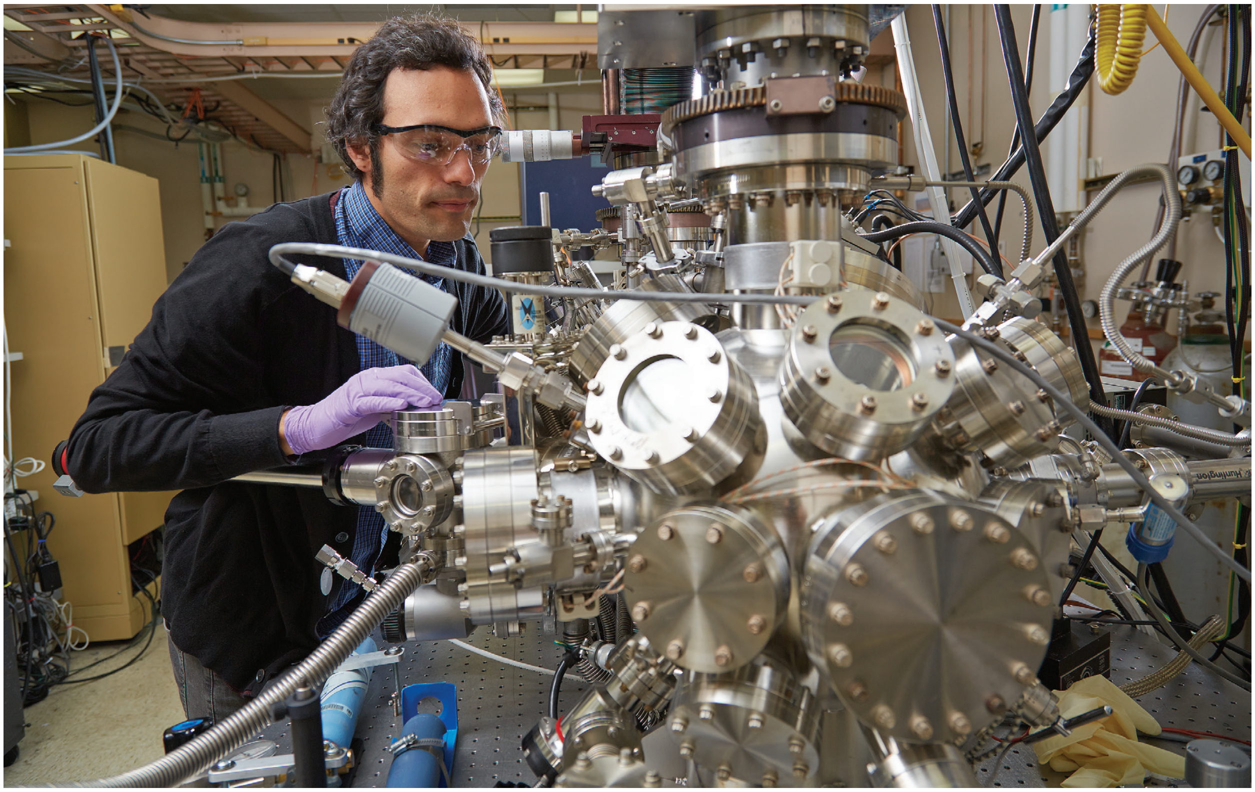
The Energy Storage Program is designed to develop and demonstrate new and advanced grid-scale energy storage technologies that will enhance the stability, resiliency, and reliability of the future electric grid. The Program also enables increased integration of variable renewable energy resources such as wind and solar power generation onto the grid. This Program directly addresses the four principal challenges identified in the 2013 DOE Grid Energy Storage report: cost competitive energy storage technology, validated reliability and safety, equitable regulatory environment, and industry acceptance.

One example of an OE-supported storage project is the Tehachapi Wind Energy Storage Project. In May 2014, OE provided cost-share funding to Southern California Edison to construct and install equipment for a prototype 8 megawatt/32 megawatt-hour battery storage plant for wind integration at Tehachapi, CA. Positioned to demonstrate the effectiveness of lithium-ion battery and smart inverter technologies to improve grid performance and assist in the integration of variable energy resources, the Tehachapi Wind Energy Storage Project is one of the world's largest battery storage systems.

OE's work in redox battery and cell optimization has also led to a bench-top battery with four times the power and a 50 percent greater current density, compared to the 2013 state-of-the-art battery technology.

The FY 2016 request for energy storage within OE is $21 million. In FY 2016, storage system R&D will turn its focus toward new electrochemical systems and improved power conversion technologies. In particular, the electrochemical systems efforts will include new redox-flow battery chemistries where substantial improvements are expected. Work will include organic carbonyl/phenol systems; multi-variant redox couples; lithium, magnesium, and sodium metal–organic hybrids; and zinc-iodine hybrid flow systems that promise some ten times the density of current flow batteries. Research will also include the development of new low-cost sodium metal technologies capable of operating at room temperature (compared to current 250 °C) for greater safety. Finally, the second use of batteries from electric vehicles and plug-in hybrid vehicles (EV/PHV) will be evaluated for stationary applications through experiments and analysis.

Energy storage work will also support the development of advanced wide bandgap electronic devices. To support widespread deployment, OE will continue efforts to establish grid energy storage standards for performance, control interface, and grid interconnection, and to promulgate these standards internationally. Collaborative test-bed and field trial evaluation of new storage technologies will be undertaken in collaboration with States, utilities, and storage providers to elucidate storage benefits, integration challenges, and opportunities, and to build confidence regarding the safety and performance of deployed technologies. The Energy Storage program, in close collaboration with utilities, vendors, regulatory agencies, and underwriters, will also maintain a coordinated series of Stationary Energy Storage Safety and Reliability projects to assess potential failure modes, prepare mitigation measures, and develop guidelines for operation and incident preparedness.



A Sandia physicist aligns a lithium-iron-phosphate battery electrode sample for chemical characterization with x ray photoelectron spectroscopy. The samples will then be thinly sliced for state-of-the-art synchrotron x ray microscopy. In FY 2016, storage system R&D will turn its focus toward new electrochemical systems and improved power conversion technologies. *Photo credit: Jeff McMillan*

2.1.5.2.5 Transformer Resilience and Advanced Components

The Transformer Resilience and Advanced Components (TRAC) program supports modernization and resilience of the grid by addressing the unique challenges facing transformers and other critical components that are responsible for transporting electricity from where it is generated to where it is needed. The TRAC program will support R&D and testing to validate transformers and other vital grid components as the grid modernizes. The TRAC program will also address the impact of geomagnetic disturbances (GMD), electromagnetic pulses (EMP), and other physical stressors on transformers and grid components in a systematic and comprehensive manner, in close cooperation with equipment manufacturers and electricity asset owners and operators. Additionally, increased deployment of distributed generation will introduce new challenges with reversed power flows, increased harmonics, and larger fault currents that can impact transformers and other grid components.

The $10 million requested for TRAC in FY 2016 will support the Administration's strategy on resilience and physical security. Working with the National Aeronautics and Space Administration, National Oceanic and Atmospheric Administration, U.S. Geological Survey, National Institute of Standards and Technology, and National Science Foundation, OE will examine transformer failure mechanisms through multi-physics modeling and engaging in reduced- and full-scale physical testing. Assessing mitigation options such as testing of blocking devices, solid state solutions, conducting system-wide analyses, and monitoring GICs will be included.

2.1.5.2.6 National Electricity Delivery

This program provides technical assistance to States, tribes and regions on their electricity policies, programs, and market mechanisms. The assistance can identify approaches that encourage the development and deployment of reliable and affordable electricity infrastructure, whether generation, transmission, storage, distribution, or demand side electricity resources. OE supports strengthening these individual systems, which in turn, strengthens the entire electricity infrastructure. The National Electricity Delivery (NED) program also carries out authorization of the export of electricity, permitting for the construction of transmission infrastructure across international borders, and coordination of the permitting of transmission on Federal lands, in accordance with the Federal Power Act, Executive orders, and other authorities.

The FY 2016 request for $7.5 million for NED supports the implementation OE's legal responsibilities surrounding transmission infrastructure. OE executes a range of activities that include conducting and publishing the triennial *National Transmission Congestion Study*; preparing and publishing DOE's annual *Transmission Data Review*; conducting environmental and technical analyses needed for Federal authorization of transmission projects that cross the Canadian and Mexican borders; coordinating Federal permitting by other agencies of new transmission that involves Federal lands, as required by section 216(h) of the Federal Power Act; and evaluating applications under section 1222 of the Energy Policy Act of 2005. NED will also engage with stakeholders and provide targeted technical assistance to State public utility commissions, State legislatures, regional State associations, Governors' offices, localities, and tribes.

2.1.5.2.7 Infrastructure Security and Energy Restoration

Infrastructure Security and Energy Restoration (ISER) leads national efforts, in cooperation with public and private sector stakeholders, to enhance the reliability, survivability, and resiliency of the U.S. energy infrastructure (electricity, petroleum, and natural gas). While OE's other programs focus on development of advanced tools, technologies and innovative methods for modernizing the grid, ISER serves as the operational function of OE. ISER fulfills DOE's role as the lead agency for Emergency Support Function #12—Energy (ESF-12), an emergency support function under the National Response Framework administered by the Federal Emergency Management Agency (FEMA).

ISER's focus is to mitigate energy disruptions to consumers by facilitating an efficient restoration process when energy emergencies occur, such as those caused by natural disasters, cyber attacks, or other threats. This program aligns its activities under three focus areas:

- Executing effective emergency preparedness, response, and restoration operations
- Providing reliable energy infrastructure tactical analysis (event analysis) and situational awareness to all stakeholders
- Encouraging a risk-based approach to energy system assurance

When activated by FEMA in the event of an emergency, OE has a team of responders that specialize in energy infrastructure who can be quickly activated and deployed to the location of an event. When activated, OE personnel coordinate with deployed personnel, other DOE offices, and Federal, State, and local agencies in responding to the emergency. For example, in FY 2014, OE supported responses to 24 energy emergency events, as well as physical security events, wildfires, winter storms, fuel shortages, national security events, storms, and typhoons.

OE also conducts national- and regional-level exercises, workshops, and forums to enhance information sharing with Federal, State and industry partners in support of strengthening disaster preparedness and response operations. OE regularly participates with the Department of Homeland Security (DHS) and other partners in exercises focused on the security and resilience of the electric grid, such as the GridEx II exercise led by the North American Electric Reliability Corporation that includes a tabletop discussion involving electricity industry executives and senior Government officials.

ISER's activities are supported in FY 2016 with a request for $14 million.

2.1.5.2.8 State Energy Reliability and Assurance Grants

State Energy Reliability and Assurance Grants is a new program in FY 2016 providing grants to States, localities, regions, and tribal entities (or groups of States and tribes). Under the programmatic heading are two new distinct grant programs: Grants for Electricity Transmission, Storage, and Distribution Reliability and Grants for Energy Assurance. States have significant jurisdiction over the electricity system and are excellent test beds for the evolution of the electric power system and, with Federal support, can provide innovative ways to address new trends through more coordinated and efficient processes that allow the electric sector to reliably provide services that meet environmental, resiliency, efficiency, and energy assurance goals.

In FY 2016, with a request for $27.5 million, an Electricity Transmission, Storage, and Distribution Reliability planning grants program is proposed to finance State, local, regional and tribal entities and including multi-State cooperation, to advance electric reliability planning and integrate it with environmental protection (including climate mitigation), climate resilience, and efficiency infrastructure planning and action. Building on a history of success working with States and leveraging previous technical support to States for planning tools development, DOE will provide planning grants to promote and integrate electricity reliability, efficiency, renewable energy, environmental protection (including climate adaptation), and climate resiliency planning and action.

An additional $35.5 million in FY 2016 is requested for a Grants for Energy Assurance program to finance State, local, and tribal governments to enhance resiliency through energy assurance planning and the test of, training to, and exercising of those plans.

2.1.5.3 Budget

OE's FY 2016 budget request is $270 million. Table 2.7 details the enacted budget levels for FY 2014 and FY 2015 and the FY 2016 budget request for the programs within OE.

	FY 2014 Enacted	FY 2015 Enacted	FY 2016 Request
Clean Energy Transmission and Reliability	32,383	34,262	40,000
Smart Grid Research and Development	14,592	15,439	30,000
Cybersecurity for Energy Delivery Systems	43,476	45,999	52,000
Energy Storage	15,192	12,000	21,000
Transformer Resilience and Advanced Components	0	0	10,000
National Electricity Delivery	5,997	6,000	7,500
Infrastructure Security and Energy Restoration	7,996	6,000	14,000
State Energy Reliability and Assurance Grants	0	0	63,000
Program Direction	27,606	27,606	32,600
Subtotal, Electricity Delivery and Energy Reliability	**147,242**	**147,306**	**270,100**
Rescission of Prior Year Balances	0	-331	0
Total, Electricity Delivery and Energy Reliability	**147,242**	**146,975**	**270,100**

Discretionary dollars in thousands

Table 2.7: Office of Electricity Delivery and Energy Reliability Budget.
This table provides the FY 2014 enacted, FY 2015 enacted, and FY 2016 budget request for OE.

2.1.6 Office of Indian Energy Policy and Programs

DOE's Office of Indian Energy Policy and Programs (IE) provides American Indian/Alaska Native tribes and other eligible tribal entities with technical and financial resources to assist with energy and energy infrastructure development in Indian Country.

Specifically, the mission of IE is to build energy planning, education, management, and competitive grant programs to assist these tribes. This includes the following focus areas:

- Promoting American Indian/Alaska Native tribal energy development, efficiency and use
- Reducing or stabilizing energy costs
- Enhancing and strengthening Indian tribal energy and economic infrastructure relating to natural resource development
- Bringing electrical power and service to Indian lands and the homes of tribal members

The FY 2016 request for IE is $20 million, an increase of $4 million relative to the FY 2015 enacted level.

2.1.6.1 Background

IE was established by Congress in accordance with the Energy Policy Act of 2005, Title V, Sec. 502. Initially, the program was housed in the Office of Congressional and Intergovernmental Affairs. In 2011, DOE structured it as one of six program offices in the Office of the US/SE. As a DOE-led program office, IE coordinates and manages the Government-to-Government and intertribal collaboration involved in carrying out programmatic initiatives and all other DOE tribal energy-related activities and initiatives prescribed through the Energy Policy Act.

IE manages multiple technical assistance projects through contracts with four National Laboratories (NREL, SNL, LBNL, and NETL), other contracts, and partnerships with other DOE offices and entities, including EERE, FE, OE, Office of Congressional and Intergovernmental Affairs (CI), Office of Energy Policy and Systems Analysis (EPSA), and the Western Area Power Authority (WAPA). IE coordinated closely with EERE's Tribal Energy Program (TEP) until FY 2015, when Congress moved EERE-TEP financial assistance program funding under IE.

IE also coordinates with other Federal agencies through the White House Council on Native American Affairs Energy Subgroup and the Executive Committee of the Arctic Council. In addition, the office hosts the Indian County Energy and Infrastructure Working Group, which consists of 11 geographically representative tribes with energy project expertise.

Office of Indian Energy At-a-Glance

- Established by Congress in accordance with the Energy Policy Act of 2005, Title V, Sec. 502
- Assists 566 federally recognized Native American tribes, 226 federally recognized Alaska Native tribes, and 12 regional and more than 160 Alaska Native corporations
- Key initiatives
  - Strategic Technical Assistance and Response Team (START) Program
  - On-Demand Technical Assistance
  - Energy Resource Library
  - Tribal Renewable Energy Webinar Series
  - Renewable Energy Course Curriculum
  - Indian Country Energy and Infrastructure Working Group (ICEIWG)
  - Tribal Energy Education Series
  - Tribal Leader Forums
- FY 2015 enacted: $16 million; FY 2016 budget request: $20 million
- Supported 7 Federal FTEs in FY 2015
- Web site: www.energy.gov/indianenergy

2.1.6.2 IE Programs

IE coordinates programmatic activities—such as technical assistance, education and capacity building, research and analysis, and financial assistance—across DOE related to the development of resources and facilities on Indian lands. The office also works with other government agencies, American Indian/ Alaska Native tribes and corporations, and tribal energy resource development organizations to promote Indian energy policies and initiatives.

2.1.6.2.1 Technical Assistance

Technical assistance involves using subject matter experts to assist tribes with deploying clean energy projects, as well as high-level technical support for energy planning, project development, transmission interconnection, and utility formation. IE provides this support to tribes through On-Demand Technical Assistance and the Strategic Technical Assistance and Response Team (START) Program (see figure 2.2), which helps better position tribal energy projects for financing and construction on Indian lands.

START Projects and Technical Assistance for Tribes

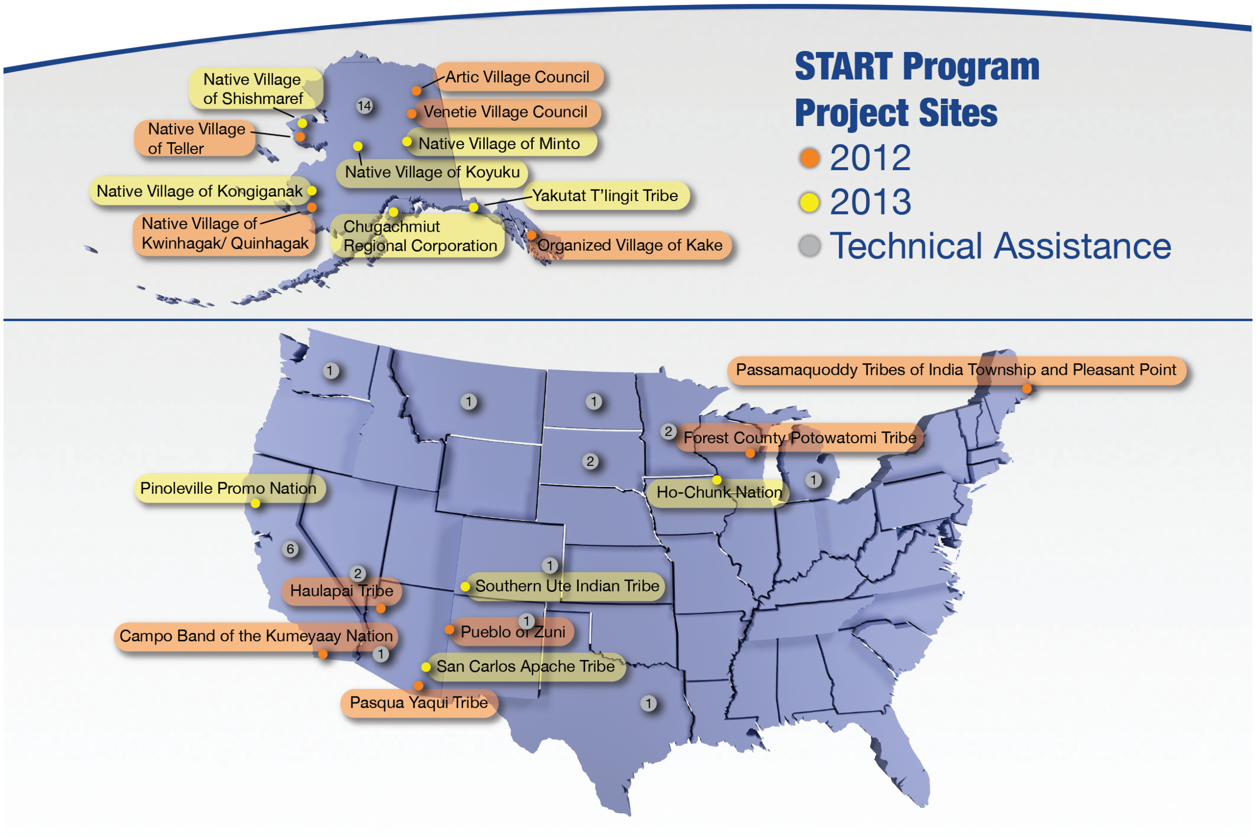


Figure 2.2: Map of START Projects and IE Technical Assistance to Tribes.
Since 2012, IE has supported 56 American Indian tribes and Alaska Native villages through START projects and On-Demand Technical Assistance.

2.1.6.2.2 Education and Capacity Building

These efforts for tribal communities involve access to key resources and opportunities such as webinars, forums, and workshops. The following outreach activities support tribes with information-sharing and training: Energy Resource Library, Renewable Energy Webinar Series, Renewable Energy Course Curriculum, Indian Country Energy and Infrastructure Working Group, Tribal Energy Education Series, and Tribal Leader Forums.

2.1.6.2.3 Research and Analysis

IE surveys energy needs of tribal lands, including available infrastructure support and natural resources, and develops subsequent strategies for electrification and energy deployment. Some examples of this include mapping reservation proximity to transmission lines, providing small community microgrid design, performing infrastructure vulnerability and utility assessments, and supporting development of the National Strategy for the Arctic Region's rural community renewable energy ten-year plan.

2.1.6.2.4 Financial Assistance

Of IE's $20 million FY 2016 request, $16.5 million funds the Tribal Energy Program that supports clean energy development, energy efficiency improvements, electrification projects, remote community renewable energy hybrid systems, microgrid deployment, water-energy project support, and other greenhouse gas emission mitigation technologies for Indian tribes.

Of the total request for the Tribal Energy Program, $700 thousand and $500 thousand support the Energy-Water Nexus and Grid Modernization crosscuts, respectively.

IE Highlight

Providing Tribes with Energy Planning and Education Initiatives

In FY 2014, IE and its predecessors invested over $4 million in technical assistance, education and capacity building, and outreach activities. Education and capacity building efforts included a partnership with Western Area Power Administration to conduct a monthly webinar series focused on the major renewable energy technologies, and project development and funding for smaller community- and facility-scale renewable energy projects. In addition, regional workshops in Alaska, Oregon, Colorado, and Minnesota helped bring best practices models, technology and development information, and regional development considerations to hundreds of tribal attendees. Lastly, several tribal leader forums were held throughout 2014 addressing energy development topics such as financing and investment, biomass, and waste-to-energy technology development. These and other efforts served to increase education, understanding, and awareness for tribal leaders and tribal staff to support sustainable development efforts of clean energy and energy efficiency projects in Indian Country and Alaska Native villages.

2.1.6.3 Budget

IE's FY 2016 budget request is $20 million. Table 2.8 details the enacted budget levels for FY 2014 and FY 2015 and the FY 2016 budget request for the programs within IE.

	FY 2014 Enacted	FY 2015 Enacted	FY 2016 Request
Indian Energy Programs (IE)			
Office of Indian Energy Policy and Programs	0	0	3,510
Tribal Energy Program	0	0	16,490
Total, Indian Energy Programs (IE)	**0**	**0**	**20,000**
Office of Indian Energy Policy and Programs (DA)			
Office of Indian Energy Policy and Programs	2,506	16,000	0
Total, Indian Energy Policy and Programs	**2,506**	**16,000**	**20,000**

Discretionary dollars in thousands

Table 2.8: Office of Indian Energy Policy and Programs Budget.
This table provides the FY 2014 enacted, FY 2015 enacted, and FY 2016 budget request for IE.

2.1.7 DOE Designated User Facilities and Shared R&D Facilities

The Department builds and operates research and development facilities that not only advance the science and energy missions of the Department, but also collectively serve as a significant pillar of the U.S. research enterprise. The Department supports two broad types of research facilities that can be accessed by researchers from the S&T community: designated user facilities and shared R&D facilities. A primary distinction between these two types of facilities is their access model. To access a designated user facility, researchers must submit a proposal, which is subject to peer review. Users whose proposals are accepted gain access to the facility under a standard, preapproved user agreement that does not need further DOE review and approval. No user fees are charged for nonproprietary work that the researcher intends to publish. Shared R&D facilities are also available to the broader research community. Operational costs for use must be provided by the user, and the work is supported through other formal agreements that require DOE approval on a case-by-case basis.

Throughout the descriptions in this chapter of DOE Science and Energy program offices, each program's designated user facilities are mentioned. This section describes designated user facilities and shared R&D facilities from a broad perspective in order to capture their collective purpose and structure in a single location in the SEP.

A list of DOE's user facilities and shared R&D facilities can be found on OTT's Web site.

2.1.7.1 Designated User Facilities

Designated user facilities are typically purpose-built and feature an open-access operating mode in order to accelerate advancement of science and technology to meet DOE mission needs. To use these facilities, researchers must participate in a competitive, peer-reviewed proposal process. To encourage innovation and the exploration of new scientific knowledge, the Department removes financial barriers to researchers by both fully supporting the operational costs of these facilities and not charging fees for designated user facilities as long as researchers plan to openly publish the results in the scientific and technical literature. However, users who wish to carry out proprietary work must reimburse the Government on a full cost recovery basis. Because proprietary user projects are a small percentage of the overall number of projects, the recovery of proprietary user fees defrays a negligible-to-minimal amount of

> **Office of Science User Facilities Principles**
>
> A user facility is a federally sponsored research facility available for external use to advance scientific or technical knowledge under the following conditions:
>
> - The facility is open to all interested potential users without regard to nationality or institutional affiliation.
> - Allocation of facility resources is determined by merit review of the proposed work.
> - User fees are not charged for nonproprietary work if the user intends to publish the research results in the open literature. Full cost recovery is required for proprietary work.
> - The facility provides resources sufficient for users to conduct work safely and efficiently.
> - The facility supports a formal user organization to represent the users and facilitate sharing of information, forming collaborations, and organizing research efforts among users.
> - The facility capability does not compete with an available private sector capability

operations costs. The policy of not charging user fees for nonproprietary work is longstanding, as it has been successful in attracting scientists from around the world to perform outstanding research at DOE facilities. Most of DOE's designated user facilities are highly oversubscribed, with many facilities receiving two to three times the number of proposals that can be accommodated. Nongovernmental users are also able to access these facilities through CRADAs or Strategic Partnership Projects (SPP) agreements. These mechanisms are discussed in more detail in Chapter 4.

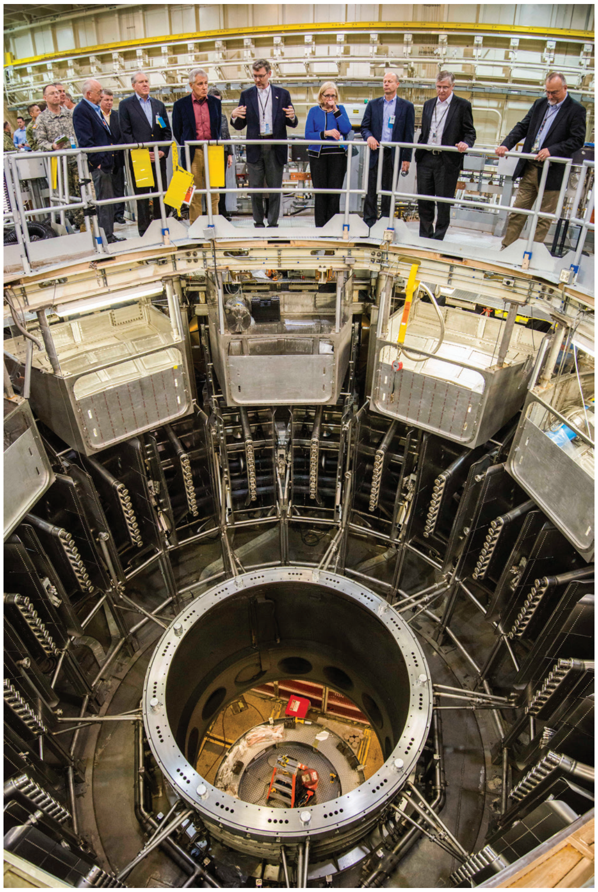
The Office of Science has a defined process for designation of a user facility. Each SC user facility exists through investment by a program "owner"—that is, the Office of Science program that provides funds through Congressional appropriations for construction and operations. Each user facility represents a substantial commitment on the part of its sponsoring program, which provides oversight and works closely with the facility management to maximize scientific impact and productivity. Typically, the scientific impact of each facility is assessed triennially through a major external peer review. Most user facilities are sited at DOE National Laboratories and also fall under the broader oversight models embodied in the Laboratory's M&O contract.

The Office of Science has the largest portfolio of designated user facilities (also referred to as scientific user facilities) and has invested in a variety of user facilities over the last four decades. As of 2015, SC oversees 28 designated user facilities. As noted earlier, DOE's applied technology program offices also design, build, and operate designated user facilities (such as NE's NSUF and EERE's ESIF) that operate much the same as those housed at SC Laboratories.

2.1.7.2 Shared R&D Facilities

DOE's shared R&D facilities have most often been constructed to meet specific program mission needs, but time may be available for users as the program office mission needs evolve. Access to these facilities is gained through other formal agreements, such as CRADAs and SPP agreements, with the host DOE Laboratory. In these facilities, operational costs are supported by DOE for mission activities, but operational costs for all external use must be supported through cost recovery mechanisms.

Shared R&D facilities are located throughout DOE's National Laboratory complex and among university partners. For example, NREL hosts 18 shared R&D facilities, in addition to its designated user facility. NETL also hosts 18 shared on-site R&D facilities and supports the Pittsburgh Supercomputing Center—a facility dedicated to advancing the state-of-the-art in high-performance computing, communications, and data analytics—and the National Carbon Capture Center, a facility dedicated to proof-of-concept scale testing of pre- and post-combustion capture technologies. INL hosts nine shared R&D facilities, in addition to its three designated user facilities.



Former Secretary of Defense Chuck Hagel (sixth from right) looks into the center of the Z Pulsed Power Facility during a tour at SNL, January 8, 2014. The Z Pulsed Power Facility is one of several shared R&D facilities stewarded by NNSA program offices. *Photo credit: Randy Montoya*

NNSA programs also steward these facilities, such as the National Ignition Facility at Lawrence Livermore National Laboratory (LLNL), the Z Pulsed Power Facility at SNL, and the Laboratory for Laser Energetics at the University of Rochester. A list of shared R&D facilities, including designated user facilities, is available on OTT's Web site. Note that not all of the US/SE programs (such as OE, for example) host these facilities.

Work at shared R&D facilities is most often supported by technology partnership agreements, such as CRADAs, or SPP contracts. For example, access to EERE's shared R&D facilities by external stakeholders is typically managed through a CRADA (when Laboratory personnel are working collaboratively with a partner) or SPP agreement (when the Laboratory is performing a specific activity for an external stakeholder). The contractual mechanism for accessing the shared R&D facilities at NETL is slightly different than for the other DOE Laboratories.

2.2 Office of Technology Transitions

Technology transfer is a component of DOE's overall mission to promote scientific and technological innovation that advances the economic, energy, and national security interests of the country. To accomplish this, OTT oversees and coordinates technology transitions involving Departmental programs, works with corporate staff offices to ensure that best practices in technology transitions are identified and implemented, coordinates technology transitions across other Departmental programs, including NNSA, and EM, facilitates exchange of information regarding innovative technology and commercialization with entities such as ARPA-E and LPO, and is responsible for statutorily mandated programs and reports regarding technology transfer.

OTT adds operational value to the Department by establishing and maintaining a core group of experts who enable laboratory-to-market collaborations and technology transition opportunities. At the corporate level, OTT develops and implements a strategic plan and vision that ensures the Department's and the Administration's ability to transition technologies to the market. At the program level, OTT coordinates and optimizes crosscutting activities and the hand-off of early-stage R&D to later stage applied energy programs.

2.2.1 Overview

In 2015, the Secretary recast the Office of the Technology Transfer Coordinator (TTC) as the Office of Technology Transitions (OTT) in order to coordinate and optimize how the Department transitions early-stage R&D to applied energy technologies through technology transfer, commercialization, and deployment activities. The OTT develops the Department's strategic policy and vision for expanding the commercial impact of DOE's RDD&D portfolio over the short, medium, and long term. OTT provides an operational focus on the Department's multiple paths of RDD&D activities toward technology transfer and commercialization outcomes. It is aligned with the President's Climate Action Plan, cross-agency lab-to-market priorities, and goals as set forth in the 2011 Presidential Memorandum – Accelerating Technology Transfer and Commercialization of Federal Research in Support of High Growth Businesses.

Additionally, the OTT implements public laws passed by Congress. While a number of public laws shape how DOE transitions technologies to the market, two laws lay the foundation for how the Department spurs innovation and guides technology transfer. First is the Bayh-Dole Act of 1980 (Public Law 96–517), which directs how DOE treats ownership of new inventions through patents from R&D funding agreements with small business, nonprofit, and university contractors. The second is the Stevenson-Wydler Technology Innovation Act of 1980 (Public Law 96–480), which was the first major U.S. technology transfer law. This public law states that Federal agencies and federally funded scientists, including M&O contractors that manage National Laboratories, are responsible for the "full use of the results of the Nation's Federal investment in research and development. To this end the Federal Government shall strive where appropriate to transfer federally owned or originated technology to State and local governments and to the private sector."

These laws have been amended numerous times to provide tools, like CRADAs, for conducting the technology transfer mission of the Department. More recent technology transfer provisions, found in the Energy Policy Act of 2005 (P.L. 109–58), pertain to the Technology Transfer Coordinator, Technology Commercialization Fund, and the Technology Transfer Working Group described below.

The Director of OTT is dual-hatted as the Technology Transfer Coordinator of the Department serving as the senior advisor to the Secretary for technology transfer and commercialization, as well as the Director of the OTT with reporting responsibilities to US/SE.

Office of Technology Transitions At-A-Glance

- Established February 11, 2015, by the Secretary of Energy
- Pursues opportunities to expand the commercial impact of DOE's portfolio of RDD&D activities over the short, medium, and long term
- Key Initiatives:
  - Engage with DOE Laboratories and others to promote rapid technology transfer to U.S. commercial sectors
  - Collect and analyze data to develop and assess technology transfer methods and outcomes
  - Communicate with DOE Laboratories, private sector, and stakeholders on DOE technology transfer opportunities and outcomes/successes
  - Provide evidence-based evaluations of technology transition pilot programs and activities of the Department to help prioritize and elevate essential practices
  - Administer the Energy Technology Commercialization Fund (TCF) for applied RD&D for high-impact commercial applications
- Supported 7 Federal FTEs in FY 2015
- Web site: http://techtransfer.energy.gov/

2.2.2 Program Activities

The OTT has Department-wide responsibilities to develop and coordinate activities to further the technology transfer and commercialization mission of the Department. The OTT conducts the following activities to ensure this mission.

2.2.2.1 Stakeholder Engagement

The OTT conducts several stakeholder roundtables, workshops, and other meetings in Washington, DC, as well as across the country. The Office engages with DOE Laboratories and stakeholders to promote rapid technology transfer to U.S. commercial sectors through, for example, streamlined contract mechanisms and increased information sharing on DOE-funded technologies. OTT works to engage the private sector more by developing programs and activities like a 'partnering service' that can help break down barriers of engagement with Federal scientists by facilitating effective communication with potential partners about the capabilities of DOE Laboratories. Additionally, the OTT encourages regional economic development by holding workshops in regions and engaging and connecting Laboratory leaders to State and regional organizations.

2.2.2.2 Evidence-Based Impact Evaluations

The OTT emphasizes how DOE long-term investments in science and technology have grown into critical technologies that support the economic, energy, environment, and national security missions of the Department. The OTT analyzes and evaluates programs and collects metrics for technology transitions across the Department. Evaluation metrics, outputs and outcomes, and other information from National Laboratories and DOE grantees are analyzed to understand the Department's impact on the commercial sector. Studies are conducted on the programs and activities, such as the Agreements for Commercializing Technology pilot, to inform DOE decision-making and policy-setting. Additionally, in-depth case studies are conducted on specific technology areas to be used to evaluate the impact of DOE's RDD&D portfolio. The OTT Web site contains a complete set of cases studies recently conducted in FY15 on DOE-managed public-private consortia summarizing their charters, operations, precompetitive joint research activities on platform technologies, memberships, successes, and lessons learned.

2.2.2.3 Data Collection and Analysis

The OTT is required to develop statutorily mandated technology transfer-related reports annually. These reports consist of data collected from across the DOE enterprise including all of the DOE Laboratories, sites, and facilities. DOE collects over 70 different technology transfer-related data points for these reports. OTT is focused on streamlining these activities to enable more accurate communication of this information. The data collection and analysis helps establish clear goals and objectives for the National Laboratories, other partners, and the Department by facilitating the evaluation of best practices and effective metrics. The information is used to continually improve the delivery of the DOE missions over the short, medium, and long term, and it also is used to help understand and encourage laboratory planning, evaluation, and professional development of Laboratory staff.

2.2.3 Technology Commercialization Fund

A core responsibility of the Technology Transfer Coordinator is to oversee the expenditure of DOE technology transfer funds. The OTT is responsible for implementing the Technology Commercialization Fund (TCF) authorized in section 1001 of the Energy Policy Act of 2005 (42 U.S. Code § 16391(e)). The TCF states, as amended:

"The Secretary shall establish an Energy Technology Commercialization Fund, using 0.9% of the amount made available to the Department for applied energy research, development, demonstration, and commercial application for each fiscal year based on future planned activities and the amount of the appropriations for the fiscal year, to be used to provide matching funds with private partners to promote promising energy technologies for commercial purposes."

DOE has complied with section 1001 by retroactively accounting for relevant activity supported by DOE's applied energy program offices from 2006 through 2015. In FY 2016 the OTT will take a more forward-looking approach to implementing the Technology Commercialization Fund that enhances the effectiveness of the Department's expenditures in commercialization. To inform the TCF design, OTT performed a gaps analysis of the energy technology commercialization pipeline—including early-stage laboratory technology maturation, first valley of death seed-stage commercialization, and pilot-scale demonstration projects—to identify key areas where a targeted TCF could have a substantial impact.

2.2.4 Streamlined Agreement Activities

The OTT is responsible for managing the Agreements for Commercializing Technology (ACT) pilot, which was established in 2012 and provides an alternative contract mechanism for the National Laboratories to offer less restrictive contract terms to industry by privately assuming some of the risks and liabilities typically presented by industrial partners. The ACT enables DOE M&O contractors to engage with the private sector using terms that are more consistent with commercial practices, helping further accelerate the movement of technology from DOE facilities to the marketplace.

2.2.5 National Laboratory Technology Transfer

The OTT helps coordinate technology transfer activities carried out at all 17 DOE National Laboratories, as well as at other DOE research and production facilities, by implementing the TTC's responsibility to oversee the activities of the statutorily created Technology Transfer Working Group (TTWG). The TTWG facilitates technology partnerships, coordinates technology transfer activities, and shares lessons learned among practitioners. The TTWG has operated formally and informally, as small subsections and larger working groups, and with variations in membership, to improve technology transfer activities within the Department and its Laboratories.

2.3 Crosscutting Initiatives

The Office of the US/SE coordinates a process for identifying and building science and energy research initiatives that draw from the diverse and unique expertise of the program offices. Formally known as "crosscuts," these initiatives leverage knowledge and resources from multiple areas of Departmental expertise. Of the six crosscuts discussed below, the Office of the US/SE serves as the primary coordinating entity for the first four: Energy-Water Nexus; Grid Modernization; Subsurface Technology and Engineering; and Supercritical Carbon Dioxide.

Energy-Water Nexus Crosscut

The FY 2016 budget request directs $38.35 million to the Energy-Water Nexus crosscut, of which $9 million comes from EERE, $12 million from FE, $11.8 million from SC, $4.5 million from EPSA, and less than $1 million each from IA and IE. This crosscut is composed of an integrated set of cross-program collaborations that (1) builds and deploys a DOE mission critical data, modeling, and analysis platform to improve understanding and inform decision-making for a broad range of users; (2) strategically targets crosscutting technology research, development, demonstration, and deployment opportunities within the system of water and energy flows; and (3) is informed and supported by focused policy analysis and outreach and stakeholder engagement. Taken as an integrated whole, these investments position DOE to contribute strongly to the Nation's transition to more resilient coupled energy-water systems.

Assisting the Nation in moving towards resilient and sustainable coupled energy-water systems is the overarching goal of the Energy-Water Nexus crosscut. Success will be measured through DOE's ability to

- optimize the freshwater efficiency of energy production, electricity generation, and end use systems;
- optimize the energy efficiency of water management, treatment, distribution, and end use systems;
- enhance the reliability and resilience of energy and water systems;
- increase safe and productive use of nontraditional water sources;

- promote responsible energy operations with respect to water quality, ecosystem, and seismic impacts; and
- exploit productive synergies among water and energy systems.

In FY 2015, DOE continues to manage its Energy-Water Nexus activities as separate, modest programmatic efforts with an incremental increase in coordination. For FY 2016, major expansions are planned and included within the budget requests for six major programs: EERE, EPSA, FE, IA, IE, and SC. Additionally, FY 2016 efforts will strategically align and actively coordinate around four pillars:

- *Data, Modeling, and Analysis (DMA)* helps in understanding current energy system vulnerabilities while exploring complex systems dynamics for subsequent applications in planning the resilient, efficient, and competitive energy-water systems of the future. Efforts will advance foundational models, produce and analyze modeled output, and integrate data sets at spatial and temporal scales that matter to decision-makers at Federal, regional, State, and municipal levels. Improving capabilities will provide insights into technology RDD&D opportunities.
- *Technology Research Development, Demonstration, and Deployment* produces technology solutions and infrastructure options to address vulnerabilities and increase resilience, and it offers the possibility of efficiency improvements and cost reductions to facilitate accelerated technology deployment.
- *Policy analysis* informs understanding of the motivation and barriers to addressing vulnerability and resilience that can impact diverse regional, national, and global stakeholders. This analysis can also help identify priority questions to be examined through DMA and identify technology deployment barriers and opportunities. It can catalyze the timely and efficient transformation of the national energy-water systems to ensure that U.S. industry remains at the forefront of clean and sustainable energy production and use.
- *Outreach and stakeholder engagement* strengthens this overall collection of proposed activities by sharpening understanding of end-user needs, regional considerations, and other data sets, while helping to identify pathways and potential partners for deployment and implementation.

Grid Modernization Crosscut

The FY 2016 budget requests $356 million for the Grid Modernization crosscut, of which $202 million comes from OE, $152.5 million from EERE, and less than $1 million each from EPSA and IE. This crosscut is a coordinated program of activities to help set the Nation on a cost-effective path to an integrated, secure, and reliable grid system that is flexible enough to provide an array of emerging services while remaining affordable to consumers. Though small relative to industry size, strategic investments by DOE in foundational technology development, enhanced security capabilities, and greater institutional support and stakeholder engagement will provide tools necessary for the evolution to the grid of the future.

It is clear that the future of the Nation's economic competiveness, energy security, and environmental stewardship depends on the modernization of the Nation's grid infrastructure. Technologies, markets, governing policies, and regulatory structures must change to adapt to current and future innovations. The Federal challenge is to enable adaptation that is efficient, coherent, and strategically aligned.

DOE proposes to achieve grid modernization through a multiyear collaborative initiative involving public and private sector energy stakeholders including utilities, regulators, developers, the North American Electric Reliability Corporation, Electric Power Research Institute, and many others. This will be led by three DOE offices, as described below, with additional participation from IE:

- OE, whose role is to enable the grid to use all available energy sources to serve all loads while meeting climate, security, reliability, resiliency, safety, and affordability objectives, and provide overall management of DOE's Grid Modernization efforts;
- EERE, whose role is to enable energy efficiency, renewable power, and sustainable transportation technologies to be integrated into the grid in a safe, reliable, and cost-effective manner; and

- EPSA, whose role is to provide rigorous analysis, robust stakeholder engagement, and recommendations for policy options that support the public interest in efficient markets, clean reliable energy, and modernization of the Nation's energy systems.

The Department's Grid Modernization program has three parts:

- *Institutional Support and Alignment:* Create an overarching stream of grid-related "institutional" analyses, workshops, and dialogues to highlight challenges and explore the option space for grid transformation, focusing on key policy questions related to new technologies, regulatory practices, market designs, and business models.
- *Technology Innovation:* Increase the emphasis on the coordination of relevant existing base-level, grid-related R&D among DOE offices on core technological challenges and propose additional funding for R&D that will create tools and technologies that measure, analyze, predict, and control the grid of the future.
- *Grid Security and Resilience:* Help the U.S. electricity sector protect, prevent, and respond to natural and directed threats.

Subsurface Technology and Engineering RD&D Crosscut

The FY 2016 budget request directs $244 million to Subsurface Technology and Engineering RD&D (SubTER), of which $120.5 million comes from FE, $71 million from EERE, $39.5 million from NE, $8 million from EM, and $5 million from SC. While subsurface resources constitute the Nation's primary source of energy (providing more than 80 percent of total U.S. energy needs today), they are also critical to the Nation's low-carbon and secure energy future. Next generation advances in subsurface technologies will enable access to more than 100 gigawatt-electric (GWe) of clean, renewable geothermal energy, as well as safer and more sustainable development of domestic natural gas supplies. The subsurface provides hundreds of years of safe storage capacity for carbon dioxide (CO_2) and opportunities for environmentally responsible management and disposal of hazardous materials and other energy waste streams. The subsurface can also serve as a reservoir for energy storage for power produced from intermittent generation sources, such as wind and solar. These opportunities are directly linked to Administration priorities and to broader societal needs.

The SubTER Crosscutting Team, in collaboration with the National Laboratories, has identified Adaptive Control of Subsurface Fractures and Fluid Flow as a key crosscutting theme. The ability to have real-time control or "mastery" of the subsurface can have a transformative effect on numerous industries and sectors, impacting the strategies deployed for subsurface energy production and storage. Mastery of the subsurface requires efforts to address the following key challenges to optimize energy production, energy/CO_2 storage, and waste storage/disposal:

- *Discovering, characterizing, and predicting:* Efficiently and accurately locating target subsurface geologic environments; quantitatively inferring their evolution under future engineered conditions; and characterizing the subsurface at a relevant scale.
- *Accessing:* Safe and cost-effective drilling or mining with properly managed reservoir integrity
- *Engineering:* Creating the desired conditions in challenging high-pressure/high-temperature environments.
- *Sustaining:* Maintaining these conditions over long time frames throughout complex system evolution.
- *Monitoring:* Improving observational methods and advancing understanding of the microscopic basis of macroscopic complexity throughout system lifetimes.

In response to these challenges, SubTER proposes initiatives for planning and implementing jointly funded targeted research, development, and field demonstrations emphasizing the following four topic areas: (1)

wellbore integrity, (2) subsurface stress and induced seismicity, (3) permeability manipulation, and (4) new subsurface signals. These four topics will complement and be coordinated with a set of program-specific ongoing subsurface-related R&D investments.

Supercritical Carbon Dioxide Crosscut

The FY 2016 budget request directs $43.6 million to the Supercritical Carbon Dioxide (sCO_2) crosscut, of which $34.8 million comes from FE, $8.3 million from NE, and less than $1 million from EERE. Power cycles based on sCO_2 as the working fluid, instead of steam, have the potential for higher thermal efficiencies with lower capital cost when compared to state-of-the-art steam-based power cycles. Taken together, the unique features of sCO_2—the potential for lower capital cost and the compounding performance benefits from a more efficient cycle on balance of plant requirements, fuel use, emissions, water use and cost of electricity—are creating broad interest in the sCO_2 power cycle. EERE, FE, and NE have formed a sCO_2 crosscut initiative with the specific mission of reducing the technical barriers and risk to commercialization of the sCO_2 power cycle.

The sCO_2 crosscut is structured around a common objective to establish a 10 MWe supercritical transformational electric power (STEP) pilot-scale facility for evaluating power cycle and component performance over a range of operating conditions. Demonstrating favorable performance at this scale is the next step required to address technical issues, reduce risk, and mature this promising technology. The 10 MWe facility will be developed through competitive funding opportunity announcements that are cost-shared with industry. Where appropriate, the facility will be used to address and resolve technology-specific issues relevant to the different heat source applications.

The 10 MWe STEP facility to be built under the sCO_2 crosscut will have the flexibility to test in a variety of configurations that will be required by the sCO_2 power cycle. Since this will be the first integrated test of a system operating at this size and under these conditions, the indirect-fired configuration will be used initially. This configuration eliminates the additional challenges related to a natural gas/sCO_2 turbine. However, once the indirect-fire cycle has successfully operated and been tested through the necessary suite of transient and steady-state conditions, DOE will begin the transition to testing key elements of the direct-fired sCO_2 power cycle.

The FY 2016 budget request continues the Department's coordinated efforts in research, development, and demonstration of the transformative sCO_2 Brayton cycle energy conversion technology. Recognizing that the near-term deployment and potential market applications for commercial sCO_2 power cycles are primarily in the fossil energy area, the Department requested FY 2016 funding for the STEP demonstration facility in FE (the STEP request was previously included in NE's FY 2015 request).

In FY 2016, NE will fund stakeholder engagement that will continue through industry and utility outreach efforts to better understand the commercial deployment business case and the technical issues associated with maturing this technology for a variety of heat sources. This outreach will engage industry technology vendors, utilities, National Labs, other research organizations, and academia. Targeted research and technology development activities will be conducted to address critical risk areas and industry needs specifically related to the STEP pilot-scale facility.

Exascale Computing Crosscut

The FY 2016 budget request directs $272.6 million to the Exascale Computing crosscut, of which $208.6 million comes from SC and $64 million from NNSA. Over the past several years, the Department has become aware that future-generation systems will require significant changes in how high-performance computers are designed and developed. The new designs proposed by industry to address the growing need for energy efficiency will result in massive parallelism all the way down to the processor level, which the high performance computing (HPC) user community has never experienced before. Technology development has reached a point where the continued improvement in processing performance requires breakthroughs in resolving the

Von Neumann memory bottleneck, reducing power consumption, and solving problems of computing at unprecedented scales. As a consequence, the Department's approach to overcoming HPC technology challenges is aimed not simply at realizing a single, albeit exceptional, computing performance objective, but rather at setting the United States on a new design trajectory of a broad spectrum of capabilities over the succeeding years. A significant investment by the Federal Government involving strong leadership from Department headquarters and close coordination by Government, National Laboratories, industry, and academia is required to address this national challenge.

A critical component of a federally funded effort in exascale computing is concurrent research and development in applications that will optimally exploit these emerging new exascale computing architectures. These "extreme scale" applications, i.e., applications enabled by exascale computing, must address the full spectrum of computing, including terascale and petascale as well as the targeted exascale applications. They should include those that support nuclear weapons stockpile stewardship, scientific discovery, energy technology innovation, renewable electrical generation and distribution, nuclear reactor design and longevity, data assimilation and analysis, and climate modeling. The Office of Science (SC) and National Nuclear Security Administration (NNSA) have already initiated R&D efforts in extreme scaling for applications. In FY 2016, these two offices will pursue greater engagement with the applied energy offices, to provide leadership and assist with the enabling of the next generation of important applications for strategic applied energy problems.

The key exascale challenges that must be addressed are parallelism, resilience, energy efficiency, and memory and storage. In addition to the exascale challenges, our Nation's HPC efforts face serious security threats that must be addressed by the Exascale Computing Initiative (ECI). ECI's goal is to significantly accelerate the development of capable exascale computing systems to meet national security needs. This is defined as a

Titan supercomputer at ORNL's Oak Ridge Leadership Computing Facility represents a crosscutting initiative for exascale computing involving DOE's Office of Science and NNSA. Key exascale challenges that must be addressed by DOE and NNSA are parallelism, resilience, energy efficiency, and memory and storage. *Photo credit: ORNL* hundred-fold increase in sustained performance over today's computing capabilities, enabling applications to address next-generation science, engineering, and data problems to advance DOE missions.

The plan is organized around four different focus areas: (1) applications development, which targets specific R&D activities and outcomes that address critical DOE mission applications; (2) software technology with efforts that span low-level operational software to high-level applications software development environments, including the software infrastructure to support large data management and workflows; (3) hardware technology, which supports vendor-based R&D efforts; and (4) exascale systems, which includes any additional activities needed to prepare sites for exascale resources and the acquisition and deployment of prototype systems and testbeds for application and software development across ECI.

Cyber Security Crosscut

The FY 2016 budget request directs $306 million to the Cyber Security crosscut. DOE is engaged in three categories of cyber-related activities:

- Protecting the DOE enterprise, including Government-owned, contractor-operated sites, from a range of cyber threats that can adversely impact mission capabilities.
- Bolstering the U.S. Government's capabilities to address cyber threats.
- Improving cybersecurity in the electric power subsector and the oil and natural gas subsector.

In 2013, the Department established a cybersecurity crosscut process to strengthen the coordination of budget activities related to cybersecurity across the Department so cybersecurity is managed on the basis of strategic priorities. DOE also established an internal Cyber Council in 2013 to serve as the principal forum for coordinating cyber-related activities across the Department and for consideration of cyber-related issues requiring decisions by DOE senior leadership.

Other Complementary Offices and Agencies

Other agencies and DOE offices support the mission work of these program offices by enabling advancement of their research projects and other efforts through short- and long-term investments, technical assistance, and other strategic support for development and, in some cases, potential commercialization.

Advanced Research Projects Agency-Energy (ARPA-E)

In the relatively short time since its official launch in 2009, the Advanced Research Projects Agency-Energy (ARPA-E) has implemented a unique model for the support and management of high-risk energy research that complements the work in the programs of the Office of the US/SE and applied it to ARPA-E's goal to enhance U.S. economic and energy security by innovations that reduce emissions, improve energy efficiency, and reduce our dependence on energy imports. This model employs:

- continuous assessment of opportunities in potentially disruptive technologies;
- rapid evolution of ARPA-E's portfolio of potentially disruptive technology programs along with highly engaged management of projects toward technological success; and
- a unique emphasis on moving prototype technology from the laboratory to the marketplace.

Other Complementary Offices and Agencies (continued)

As a result of this model, ARPA-E supports a constantly evolving portfolio of energy technology projects that are new pathways to overcome high-risk technological barriers.

ARPA-E's strategic planning process runs on a three-year cycle with annual updates. The ARPA-E team evaluates the technological areas within the agency's mission space to identify high-impact technical opportunities, in the context of economics, market drivers, and programmatic work in the Office of the US/SE. As strategic areas of focus are identified, ARPA-E hires program directors and tech-to-market advisors on three-year assignments to execute programs in the chosen areas. The program directors are given broad responsibility in developing specific programs. The process for doing so involves internal analysis, consultation with DOE program offices, elicitation of external expert advice, and workshops to draw input from industry and the R&D community. Using all of this input, the program directors develop proposals for new programs, which are internally reviewed against metrics of technical and commercial impact. For each of the selected programs, a detailed call for proposals is developed, which specifies the technical and commercial goals that must be met for any projects under the program.

The program calls are released as focused FOAs. ARPA-E also issues periodic OPEN FOAs to identify high-potential projects that address the full range of energy-related technologies, as well as funding solicitations aimed at supporting America's small business innovators. These solicitations fall within the SBIR/STTR Government-wide programs. Typically one SBIR/STTR FOA will be announced in any given year alongside one of the periodic FOAs to provide additional funding opportunities for the chosen program. ARPA-E's management team decides which program would be supported by both the normal and SBIR/STTR funding mechanisms.

Proposals received under FOAs are rigorously reviewed in a two-stage process, with initial concept papers followed by full proposals. For projects that are recommended for funding, the ARPA-E program directors and tech-to-market advisors work with the project teams to develop a timeline of technical and commercial milestones, which then become a formal component of the funding award. During execution of the projects, ARPA-E program directors provide awardees with technical guidance that combines scientific expertise and real-world experience, while ARPA-E tech-to-market advisors supply awardees with critical business insight and strategies to move technologies toward market realization. A key component of the ARPA-E model is hands-on engagement with awardees. ARPA-E works with an awardee to rectify issues that may arise during the life of the project, and in cases where issues cannot be resolved, ARPA-E discontinues the project. The technology-to-market program also provides awardees with practical training and critical business information to equip projects with a clearer understanding of market needs to guide technical development and help projects succeed.

One example of early impact is ARPA-E's program in Carbon Capture that selected a set of high-risk/high-potential technologies and drove them with aggressive technical and economic milestones. As a result of de-risking these technologies, five projects were rapidly picked up for further development by DOE's Office of Fossil Energy. In fact, one has already undergone scale-up tests (250 kW coal power), surpassed DOE's original technical and economic milestones, and has attracted industrial support for further commercial development. This example also highlights the collaborative spirit between ARPA-E and program offices at DOE, which is enhanced by frequent information exchange and consultation meetings between ARPA-E program directors and peers at DOE.

The enduring impact of ARPA-E's programs and projects requires market uptake, often in competition with incumbent technologies. One key indicator of impact is follow-on-development of projects through new company formation and follow-on funding. Compiled data as of February 2015 shows

- more than 30 ARPA-E project teams have formed new companies;
- at least 37 projects have partnered with other Government agencies for further development; and
- 34 ARPA-E projects have attracted more than $850 million in private sector follow-on funding.

Loan Programs Office

Overview

DOE's Loan Programs Office (LPO) invests in the power of American innovation to accelerate the deployment of innovative clean energy projects and advanced vehicle manufacturing facilities across the United States.

The mission of LPO is to provide loans and loan guarantees to finance the domestic commercial deployment of advanced technologies at a scale sufficient to contribute meaningfully to the achievement of our national clean energy objectives, including job creation, reducing dependency on foreign oil, improving our environmental legacy, and enhancing American competitiveness in the global economy of the 21st century.

With this focus, LPO endeavors to

- encourage commercial- and utility-scale development and adoption of new or significantly improved energy technologies;
- finance innovative technologies that avoid, reduce, or sequester greenhouse gas emissions;
- create jobs by financing the growth of commercial clean energy technologies;
- provide direct loans to eligible automobile manufacturers and component suppliers for projects that re-equip, expand, and establish manufacturing facilities in the United States to manufacture advanced technology vehicles and components for such vehicles; and
- protect U.S. taxpayers by ensuring the loans and loan guarantees provided have a reasonable prospect of repayment.

Investing in the Power of American Innovation

Commercial banks and bondholders are often unwilling to finance the first few commercial-scale projects that use a new technology since there is not yet a history of credit performance or operation. As a result, the initial commercial deployment of new energy technology is often limited by a project developer's inability to secure sufficient, long-term debt financing to build the project.

LPO was established to finance the first deployments of a new technology to bridge the gap with commercial lenders. Once the technology is proven at commercial scale through the first few projects, DOE ceases to provide financing and lets the private market take over. Equity invested from private sources must represent at least 20% of the total cost of every project, and usually represents more.

Other Complementary Offices and Agencies (continued)

DOE will not issue a loan or loan guarantee under this program until substantial private equity support is committed.

LPO currently manages a portfolio comprising more than $30 billion of loans, loan guarantees, and conditional commitments covering more than 30 projects. These projects include some of the world's most innovative and largest solar, wind, geothermal, biofuel, and nuclear facilities, as well as advanced technology vehicle manufacturing facilities in six States producing some of America's best-selling vehicles. Overall, these loans and loan guarantees have resulted in more than $50 billion in total project investment, supported tens of thousands of jobs, cut pollution, and enhanced American competitiveness in the global economy.

Applications to finance innovative clean energy projects and advanced technology vehicles manufacturing are currently accepted through two programs: (1) the Title XVII Innovative Clean Energy Project Loan Guarantee program, and (2) the Advanced Technology Vehicle Manufacturing program.

In FY 2016, the Department's budget request also includes a proposal for a new Tribal Indian Energy Loan Guarantee Program. This program will be coordinated between LPO and IE and will provide, or expand the provision of, electricity on Indian land. The loan guarantees will support the development or expansion of generation projects on Indian lands that employ commercially proven and available clean energy technologies.

Office of Energy Policy and Systems Analysis

Recognizing that unbiased policy analysis will provide the best foundation for least cost, highest impact ways to transform our energy systems, Secretary Moniz launched the Office of Energy Policy and Systems Analysis (EPSA) within the Department of Energy in October 2013.

EPSA advises the Secretary and senior leadership in DOE on critical energy issues and policies through analysis of and recommendations on the range of energy subsectors—from fossil fuels and renewable resources to transmission and distribution to efficiency and end uses. EPSA synthesizes and analyzes information from and collaborates with the Department's program offices and the National Labs. It also works with stakeholders from industry and NGOs and our Congressional, state, local and tribal partners to develop a more comprehensive, integrated and analytically based understanding of energy systems, various jurisdictions, and impacts to its participants.

To develop policy responses to these issues and prepare for others, EPSA has teams focused on several policy areas, including climate, environment, and efficiency; energy security; finance, incentives, and program analysis; and state, and local, and tribal cooperation. Another team within EPSA serves to integrate analysis across these areas, and the entire office will support the work undertaken in the Quadrennial Energy Review (QER).

The Office of Energy Policy and Systems Analysis includes the Secretariat of the QER with primary responsibility for supporting the White House interagency process and providing to it data collection, analysis, stakeholder engagement, and data synthesis.

2.4 International Programmatic Activities

The Science and Energy enterprise engages internationally to execute and enhance key components of its organizational mission.

The Department of Energy's international activities carried out by the Science and Energy programs are focused in three primary areas: (1) engagement with world-class scientific R&D organizations to achieve advancements faster and at lower cost than could be accomplished alone, (2) provision of technical assistance to international partners, consistent with U.S. foreign policy, to accelerate their transition to clean energy economies while also creating export opportunities for U.S. companies, and (3) participation in international technical exchanges and R&D for nuclear processes and materials with countries consistent with the Non-Proliferation Treaty.

In addition to international engagement by the Science and Energy programs, EM and NNSA participate in international activities.

The Department's Office of International Affairs (IA) serves as the central node for the international engagements of DOE. IA performs a combination of strategy-setting, central coordination, and staff support functions for the international engagements of DOE. At the heart of this role, IA integrates the institutional capacity found across DOE's program elements and its National Laboratories—capacity in energy technologies, markets, and policies— to pursue U.S. Government (USG) objectives on energy and national security issues.

When DOE or another foreign entity is the signatory to an international agreement, the National Laboratories often act as technical and project-level partners by providing key technical assistance and implementing technical projects. In this case, DOE will fund National Laboratory activities directly through the Annual Operating Plan. In addition to the National Laboratories, the Department's production facilities and sites also provide the vital and necessary tools, knowledge, and infrastructure to implement the Department's international engagement strategy and programs.

The Department also maintains an overseas presence with a cadre of energy attachés and specialized personnel in DOE offices located in U.S. embassies, missions, consulates, military commands, and international organizations as part of the DOE Overseas Corps. DOE maintains offices in twelve countries and is opening

Department of Energy International Programmatic Activities at a Glance

- Engagement with world-class scientific R&D organizations
- Technical assistance to international partners
- International technical exchanges and R&D for nuclear processes and materials
- Other Departmental programs with international activities
- Key Organizations:
    - Office of International Affairs
    - Department of Energy National Laboratories
    - Office of Science
    - Office of Energy Efficiency & Renewable Energy
    - Office of Fossil Energy
    - Office of Electricity Delivery and Energy Reliability
    - Office of Nuclear Energy
    - Office of Environmental Management
    - Office of Environment, Health, Safety and Security
    - National Nuclear Security Administration

a new office this year at the U.S. Embassy in London. The DOE Overseas Corps functions as a liaison between Headquarters and our international counterparts, to advance Departmental goals and objectives in areas of energy security, nuclear security, nuclear energy, nonproliferation, counterterrorism, environmental clean-up, energy efficiency, renewable energy, and scientific discovery and innovation.

DOE's international engagements are facilitated by coordination across DOE and the USG and by establishing agreements and various funding vehicles. For example, The Office of Science works closely with the White House Office of Science and Technology Policy and with the State Department to establish agreements with foreign partners. Such written instruments can include legally binding international agreements, nonbinding statements of intent, or contracts created between DOE Laboratories and their foreign collaborators.

DOE program offices work with Laboratories, often through site offices, to ensure that Laboratory international activities:

- provide an affirmative benefit to DOE and/or the USG,
- are consistent with the foreign policy and national security interests and priorities of the USG,
- do not create a resource burden to the relevant DOE program offices or DOE Laboratory,
- aim to leverage domestic capabilities to advance DOE and DOE Laboratory goals,
- advance global efforts related to DOE missions, and
- may ultimately benefit the U.S. economy.

International S&T Agreements

Legally binding (this can include intergovernmental treaties approved by Congress and executive-type Government-to-Government or agency-level agreements) and/or non-legally binding agreements can be used for engagements with any foreign partner, whether governmental or private.

The following sections describe examples of international activities carried out by the Science and Energy programs within each of the three primary areas and briefly highlight international activities of the other Departmental programs (EM and NNSA).

2.4.1 Engagement with World-Class Scientific Research and Development Organizations

R&D collaborations through international partnerships allow for DOE to engage and accelerate S&T initiatives on a global scale. Brief examples of achieving faster advancements at lower costs through engagement with international scientific R&D organizations from the Office of Science, Office of Energy Efficiency and Renewable Energy, Office of Fossil Energy, and the Office of Electricity Delivery and Energy Reliability follow.

Examples of DOE National Laboratories and World-Class Scientific R&D Collaborations

- U.S.-China Collaboration

  DOE and ORNL collaborated with Shanghai Institute of Nuclear and Applied Physics to further understand salt-cooled reactors.
- U.S.-Argentina Collaboration

  Through the Light Water Reactor Sustainability program, SNL participated in a joint research effort contributing to an understanding of cable aging and its potential impact on the continued safe long-term operation of nuclear power plants.
- U.S.-Korea Collaboration

  DOE and ANL collaborated with the Korea Atomic Energy Research Institute to further the development of Korea's Prototype Generation IV Sodium-Cooled Fast Reactor.
- U.S.-Japan Collaboration

  This is a joint project on Technological Assessment of Plasma Facing Components for DEMO Reactors. Funded by the National Institute for Fusion Science and the U.S. DOE Office of Fusion Energy Sciences, the collaboration involves site work performed at ORNL and INL.
- Atmospheric Radiation Measurement (ARM) Climate Research

  Los Alamos National Laboratory provides project management, logistical, and operational support services for international and off-site remote instrument deployments and field campaigns that primarily support the ARM program's fixed and mobile ARM Climate Research Facilities.

2.4.1.1 Office of Science

SC, through its programs and National Laboratories, utilizes S&T agreements with international partners to leverage respective programs, resources, and knowledge to advance and facilitate mutually beneficial goals. These legal framework agreements facilitate researcher, equipment, and sample exchanges, and they protect intellectual property. Typical collaborations may include information sharing, staff visits, facility resource sharing, research partnerships, or mutual contributions to each respective Laboratory. In most cases, SC funds the U.S. effort through its core programs and solicitations, and the foreign partner funds their own participation.

International engagement has led to many discoveries and advancements under nearly all areas of SC research. The discovery of the Higgs boson at the European Organization for Nuclear Research (CERN) is one such example in the area of high energy physics. The discovery of the Higgs boson by two detector experiments, the A Toroidal LHC Apparatus (ATLAS) and the Compact Muon Solenoid (CMS), at the Large Hadron Collider in July 2012 was the culmination of a global effort that began in 1964 when theorists proposed such a particle as the final piece to the Standard Model. Over a thousand SC-funded scientists participate at the Large Hadron Collider, approximately 20 percent of the participants in the ATLAS collaboration and 30 percent of those in the CMS collaboration. In May 2015, a new agreement was signed between DOE, the NSF, and CERN to continue and expand collaborations including CERN participation in SC-funded projects in the United States.

Beyond participation at a specific facility, international collaborations also facilitate access to different environments. ARM began operations in 1989 and supports a global network of permanent and mobile long-term atmospheric observational facilities. ARM is a multi-Laboratory effort, and is a major contributor to

The ARM West Antarctic Radiation Experiment, or AWARE, team performs full operations testing in Pagosa Springs, CO. ARM operates in situ and remote sensing observatories in the U.S. Southern Great Plains, North Slope of Alaska, and the Azores, with an additional three mobile temporary facilities stationed around the world. *Photo credit: ARM Climate Research Facility*

national and international research efforts related to climate research. ARM operates in situ and remote sensing observatories in the U.S. Southern Great Plains, North Slope of Alaska, and the Azores, with an additional three mobile temporary facilities stationed around the world. With knowledge produced by ARM, for example, we can improve our understanding of precipitation processes and thus better predict important climate-induced effects on matters such as food production.

The largest, and perhaps most complex, international science project currently under way may one day revolutionize the energy landscape. The ITER Project is a seven-member international collaboration to design, build, and operate a first-of-a-kind international research facility in France aimed at demonstrating the scientific and technical feasibility of fusion energy. The collaboration includes China, the European Union, India, Japan, the Republic of Korea, the Russian Federation, and the United States. The Office of Science leads the U.S. contributions to the ITER project with over 80 percent of the U.S. ITER funding for hardware contributions spent within the United States for the research, development, design, and fabrication of components by U.S. industry, universities, and laboratories that will ultimately be shipped to the ITER site for assembly and research operation. The construction, itself, is a scientific and technological endeavor since many of the components are state-of-the-art. Once operations commence, the U.S. fusion energy scientific community will be part of one of the most ambitious science projects of our time.

Partners from abroad contribute to DOE-funded projects and to the advancement of scientific frontiers pursued in the United States in several ways. Foreign scientists often visit and enhance capabilities at DOE National Laboratories by sharing knowledge and contributing to the fabrication of detectors, instrumentation, and other components. Foreign researchers also join the large user base at the many user facilities located at these Laboratories, which are made available to scientists worldwide, free-of-charge through peer-reviewed proposals. The Office of Science national scientific user facilities provide researchers with the most advanced tools of modern science including accelerators, colliders, supercomputers, light sources, and neutron sources, as well as facilities for studying the nanoworld, the environment, and the atmosphere. In FY 2014, for example, researchers from academia, industry, and Government Laboratories, spanning all fifty States, the District of Columbia, and from across the globe utilized these unique facilities to perform new scientific research. Visitors in FY 2014 included over a thousand scientists from Europe and over 500 researchers from Asia, and in many cases, advance the science at the user facility and the facilities' capabilities.

2.4.1.2 Office of Energy Efficiency and Renewable Energy

EERE engages in a number of international technical collaborations. As an example, the Solar Energy Technologies Program has a significant collaboration with research facilities in Australia and Germany that can contribute to the SunShot Initiative's goal of reducing the cost of utility-scale solar power to $0.06 per kilowatt-hour by 2020. The Fuel Cell Technology Office is collaborating with Korea and Hyundai to collect data on performance of fuel cell vehicles in real-world driving conditions. EERE funds the U.S.-Israel Binational Industrial R&D (BIRD) Foundation to execute the U.S.-Israel Energy Cooperative Agreement. The program funds U.S. and Israeli companies performing joint research and technology development. Launched in 2009, the program has already resulted in tens of millions of dollars in follow-on investment, as well as new commercialized clean energy technologies.

EERE technology offices as a whole collaborate on R&D primarily with the Organization for Economic Cooperation and Development (OECD) countries as they possess the most significant resources (human, financial, facilities) to advance R&D topic areas. EERE and FE also participate in the U.S.-China Clean Energy Research Center (CERC) (see text box).

The U.S.-China Clean Energy Research Center

The U.S.-China Clean Energy Research Center (CERC) was announced in November 2009 by President Obama and Chinese President Hu Jintao with a pledge of $150 million in funding. The CERC is a virtual partnership of U.S. and Chinese research teams conducting research in advanced coal technologies, efficient buildings, and clean vehicles, with funding provided by relevant DOE programs. Funding is matched by China, and combined Government funding is matched again by industry, leveraging each DOE dollar 3:1. The CERC continues to receive high-level support in both countries, and in November 2014, President Obama and Chinese President Xi Jinping announced the extension and expansion of CERC, to add a new technical track on energy and water research. This international collaboration builds on over 30 years of bilateral cooperation between the United States and China on energy and the environment.

The CERC is managed by DOE's IA Office in coordination and with contributions from FE and EERE.

EERE conducts activities that contribute directly to exports and reduced emissions. EERE helped India improve its solar resource maps by refining satellite and ground station data. The maps were used by developers for large-scale solar projects, which resulted in over $300 million in U.S. exports of solar photovoltaics (PV) and related equipment, with the help of U.S. Export-Import bank financing. EERE's technical collaboration on modeling the integration of variable renewable energy into the grid contributed to China doubling its solar PV deployment target for 2015, from 20 GW to 40 GW, allowing world PV oversupply to be absorbed while China reduced emission growth. According to Chinese officials, these same modeling efforts informed their decision to reach a peak of greenhouse gas emissions by 2030, the basis of the landmark joint Presidential announcement on climate commitments in November 2014. EERE has also funded policy analysis and feasibility studies at select sites in Indonesia to demonstrate how renewable energy technologies can reduce or eliminate that country's use of diesel generators for electricity generation on remote island grids. All of this work is conducted with the direct support of U.S. companies and relevant U.S. trade promotion agencies.

2.4.1.3 Office of Fossil Energy

FE R&D programs focus on identifying, creating, and advancing new technologies to commercial readiness to allow the continued use of fossil fuels while achieving economic, security, and environmental goals. Activities supported and implemented by FE with international partners focus on joint R&D and large-scale demonstration projects, exchanging information on technologies, best practices, regulations, financing, and cost and performance analyses of new technologies. These exchanges include bilateral collaboration on ongoing carbon capture, utilization, and storage (CCUS) demonstrations with the United Arab Emirates, Saudi Arabia, Norway, Japan, the United Kingdom, Canada, and China.

Bilateral collaboration with China includes supporting the U.S.-China Climate Change Working Group, the U.S.-China Clean Energy Research Center, as well as a long-standing cooperation on fossil energy science and technology under the Fossil Energy Protocol. FE also cohosts with China annual Oil and Gas Industry Forum and an annual Clean Coal Industry Forum. In November 2014, President Obama and Chinese President Xi announced collaboration on two CCUS efforts—a large-scale CCUS science project in China and collaboration on a novel approach to combining carbon storage with producing freshwater (Brine Extraction Storage Test-BEST). Also worth noting is collaboration with Japan on the DOE domestic CCUS demonstration project at WA Parrish in Texas (the PetraNova Project), which included 50 percent funding from Japanese banks and investors. FE will also provide technical assistance to Japan to support Japan's Tomokomai carbon capture and offshore storage pilot project in Hokkaido.

In addition to the bilateral efforts, FE manages a ministerial-level, multilateral collaborative effort on CCUS called the Carbon Sequestration Leadership Forum (CSLF), and serves as CSLF executive secretariat. FE also chairs the International Energy Agency (IEA) Working Party on Fossil Fuels, and actively participates on the executive committees for both the IEA Clean Coal Centre and the IEA Greenhouse Gas Programme. Furthermore, FE chairs the Expert Group of Clean Fossil Energy under the Asia Pacific Economic Cooperation (APEC) forum. For those countries with which FE does not have an existing bilateral relationship, we engage directly through these platforms. FE also works with the Global Carbon Capture and Storage Institute and with the United Nations Economic Commission for Europe (UNECE), for which FE currently serves as vice-chair of the Sustainable Energy Bureau, to support the development and promotion of policies and regulations for cleaner fossil energy technologies while pursuing climate goals.

The FE Office of Clean Coal and Carbon Management developed an engagement strategy for international collaborations on CCUS that guides engagement with other countries in accelerating global deployment of advanced energy systems, carbon capture technology, carbon storage, and major demonstrations of CCUS. Working with foreign R&D organizations can provide access to unique expertise and facilities that can result in cleaner, more efficient, lower cost, and more reliable technologies, as well as help accelerate RD&D, and technology commercialization. Leveraging FE's funding through cost-shared engagements can reduce technology development and demonstration costs to U.S. taxpayers while developing technology that is more affordable.

2.4.1.4 Office of Electricity Delivery and Energy Reliability

OE coordinates closely with the governments of Canada and Mexico on electric grid issues such as the 2003 Northeast Blackout investigation. Regulatory authorities include authorizations of electricity exports and Presidential permits of cross-border transmission lines. Technical assistance has covered topics such as regulatory alignment (Canada and Mexico) and the International Smart Grid Action Network (ISGAN) that will create a mechanism to accelerate the development and deployment of smarter electric grids. OE's energy security efforts are "work for others" in which DOE provides security training, assessments of energy infrastructure risks, and mitigation solutions to critical energy infrastructure in coordination with government sponsors. For example, OE has provided technical assistance to Iraq facilitating the assessment of their infrastructure risks.

Contribute to International Efforts to Address Global Climate Change

"DOE will continue to play a major role in supporting the Administration's international efforts to achieve significant global greenhouse gas emission reductions, enhance climate preparedness, and promote global deployment of clean energy technologies... DOE will simultaneously advance the President's Climate Action Plan and National Exports Initiative by catalyzing international markets for U.S. clean energy solutions. DOE efforts will include advice, tools, and reviews of technical data, promotion of standards, test procedures and certification prevalent in the United States, and actions to promote sustainable renewable energy development, fuel switching to cleaner supplies, support for the safe and secure use of nuclear power, cooperation on clean coal technologies, and collaboration to promote market access for American clean energy technologies and services."

DOE Strategic Plan 2014–2018

2.4.2 International Technical Exchanges and R&D for Nuclear Processes and Materials

Today, nuclear energy represents the single largest source of carbon-free base load electricity in the United States, with its 99 reactor fleet accounting for nearly 20 percent of the electricity generated and over 60 percent of low-carbon electricity production. With 437 commercial reactors operating in 30 countries, and 300 more planned in the next 15 years, nuclear power will continue to be a major clean energy source and economic engine with a globally integrated supply chain. In this context, NE orchestrates a robust international engagement effort to leverage R&D dollars, increase energy security, support nonproliferation goals, and support U.S. civil nuclear energy exports.

NE participation in international technical exchanges and R&D for nuclear processes and materials application with countries consistent with the Non-proliferation Treaty is evidenced by RD&D collaboration with mature civil nuclear programs in France, China, Japan, the UK, Republic of Korea, and India, as well as multinational efforts in programs such as the Generation IV International Forum (GIF). The United States benefits greatly from this collaborative work that shares knowledge in the development of advanced nuclear reactors and advanced nuclear fuel, in particular accident-tolerant fuels after Fukushima. Additionally, joint research on materials could have a direct impact on extending the life of aging existing reactors.

NE's international engagement takes two general paths—bilateral and multilateral. Bilateral engagement with key countries is the most significant and largest arena for collaboration. NE currently maintains 20 bilateral arrangements with foreign governments to develop and implement civil nuclear energy cooperation. These mechanisms vary from significant joint technical work under formal R&D agreements with a number of legal protections built into the agreement, to less formal information exchanges under action plans, memorandums of understanding (MOUs), the International Nuclear Energy Research Initiative (INERI), and the International Nuclear Cooperation Program (INC). Multilateral engagement support and policy activities encompass a broad scope of cooperation with multiple entities. DOE maintains sound engagement with the international community through the International Framework for Nuclear Energy Cooperation (IFNEC), the International Atomic Energy Agency (IAEA), the OECD/Nuclear Energy Agency (NEA), and GIF. NE's work within these organizations complements the bilateral R&D activities and helps influence the future development of nuclear energy globally.

Another key NE activity focuses on international commercial activities in order to promote U.S. exports of civilian nuclear goods and services through collaboration with other USG agencies, including the Department of State, Department of Commerce, and the U.S. Export-Import Bank, utilizing a whole-of-government approach to facilitate these exports. NE addresses back-end fuel cycle challenges by advancing the Comprehensive Fuel Services (CFS) concept including the development of a multinational repository by means of engagement with governments through IFNEC and its Reliable Nuclear Fuel Services Working Group and the nuclear industry.

NE's international engagement transcends specific R&D objectives and reflects overall U.S. bilateral and regional policy objectives. For example, in concert with direction from the National Security Council, and in coordination with the Departments of State and Commerce, the NRC, and the National Nuclear Security Administration, NE plays an active role in implementation of Peaceful Uses Agreements (123 Agreements), clearance of export control requests, and Committee on Foreign Investment in the U.S. (CFIUS) applications. In recent years, engagement with specific countries to support U.S. civil nuclear commerce (and therefore jobs in the United States) has become a priority.

2.4.3 Other Departmental Programs with International Activities

Other departmental programs leverage international activities to enhance environmental cleanup and national security through the application of nuclear science. These include coordination of international efforts in the use of emerging technologies for safe and effective environmental cleanup of radioactive wastes resulting from decades of global weapons production; working with international partners to build and sustain the programs and capabilities required to prevent, counter, and respond to nuclear proliferation and nuclear/radiological terrorism; and managing international engagements and leading a variety of scientific technical exchanges with international partners regarding weapons science.

2.4.3.1 Office of Environmental Management

DOE's Office of Environmental Management (EM) has a mission to utilize emerging technologies to complete the safe cleanup of the environmental legacy resulting from six decades of weapons production and energy research. This effort is recognized as one of the largest, most diverse, and technically complex environmental cleanup operations in the world. EM collaborates with several other USG program offices and agencies in carrying out its mission.

A vital component to the success of the EM mission is leveraging the expertise within the international community to provide exposure to global technological advances in areas related to the EM mission. EM pursues international interactions in areas of technical expertise, as well as management best practices, in order to identify the best solutions and strategies for our cleanup challenges.

EM works with countries on a multilateral basis through the IAEA and the NEA to enhance the level of safety in radioactive waste and spent fuel management worldwide. EM also participates in Joint Convention (JC) on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management. Through EM's participation in the JC, the United States benefits from a candid exchange of information and sharing of knowledge with the other international partners of the Convention.

U.S. Support to the Government of Japan – DOE's Contribution

On March 11, 2001, an earthquake and earthquake-triggered tsunami crippled the Fukushima Dai-ichi Nuclear Power Station (NPS), resulting in the release of radioactive particles across a large inhabited region of Japan. Following on from the initial DOE-led U.S. crisis response effort, the Department and its National Laboratories continue to provide vital technical support to address the many technical challenges associated with remediation of the damaged Dai-ichi NPS. This work, conducted under the auspices of the U.S.-Japan Bilateral Commission on Civil Nuclear Cooperation, directly supports the Japanese government's recovery efforts in the surrounding countryside, helping to reclaim the environment for human habitation to the extent possible.

EM works with a selective number of countries on a bilateral basis. A key example is the ongoing relationship between DOE and the UK through an established statement of intent (SOI) with the UK's Nuclear Decommissioning Authority and the National Nuclear Laboratory on the management of radioactive waste and nuclear materials. This SOI provides the mechanism for exchange of scientists and engineers between the two organizations and facilitates technology development. In 2014, leaders from EM headquarters and field offices and the UK's Sellafield nuclear site gathered in Washington, DC, to discuss the development of technologies needed to address decommissioning challenges across the Cold War clean-up program.

U.S.-Japan Bilateral Commission on Civil Nuclear Cooperation

Japanese counterparts working with EM include the Ministry of Economy, Trade, and Industry (METI) and the Ministry of Environment (MOE). In July 2012, President Obama and Prime Minister Noda agreed to create a U.S.-Japan Bilateral Commission (BLC) on Civil Nuclear Cooperation. The first meeting of the BLC was held on July 24, 2012, in Tokyo, at which time five working groups were launched to coordinate bilateral cooperation. They cover the following subjects: nuclear security, civil nuclear energy research and development, safety and regulatory issues, emergency management, and decommissioning and environmental management, which are co-led by EM, the Environmental Protection Agency (EPA), METI, and MOE. Through this working group, EM is supporting direct partnerships between U.S. National Laboratories, U.S. companies, and Japan. Since the initial BLC meeting, two others have been held, the most recent on June 12, 2014, in Tokyo.

2.4.3.2 Office of Environment Health, Safety and Security

The DOE Office of Environment, Health, Safety and Security is the U.S. Government Agency responsible for the co-funding and management of the Radiation Effects Research Foundation (RERF) in Hiroshima and Nagasaki, Japan with the Japanese Ministry of Health, Labour and Welfare. The Office of Environment, Health, Safety and Security reports to the US/MP. The objectives of RERF are to: "conduct research and studies for peaceful purposes on medical effects of radiation and associated diseases in humans, with a view to contributing to maintenance of the health and welfare of the atomic bomb survivors and to enhancement of the health of all humankind." The RERF Life Span Study is the core epidemiological study of 120,000 A-bomb survivors that relates radiation exposure to risk of mortality, cancer, and other diseases. The RERF research program also includes in-utero, genetic, mechanistic, and clinical (Adult Health Studies) studies, as well as, follow-up studies on the children of the survivors (F1 studies). DOE, as a science Agency, supports studies that assist U.S. regulatory Agencies and the international bodies in developing risk assessments for radiation exposures. RERF results are the primary basis for world-wide radiation protection standards. They are important to the well-being of DOE and nuclear industry workers, and for compensation issues.

2.4.3.3 National Nuclear Security Administration

The NNSA is a semi-autonomous agency within DOE responsible for enhancing national security through the military application of nuclear science. NNSA maintains and enhances the safety, security, reliability, and performance of the U.S. nuclear weapons stockpile without nuclear testing, works to reduce global danger from weapons of mass destruction, provides the U.S. Navy with safe and effective nuclear propulsion, and responds to nuclear and radiological emergencies in the United States and abroad.

NNSA fulfills its mission to reduce global nuclear threats through three strategic approaches: preventing the spread of weapons-usable materials and technology, countering efforts by state and non-state actors to acquire the ingredients for a weapon or improvised nuclear or radiological threat device, and responding to nuclear or radiological terrorist acts, or accidental/unintentional incidents, by searching for and rendering safe threat devices, components, and/or radiological and nuclear materials, and by conducting consequence management actions following an event.

International activities within the NNSA's Offices of Defense Nuclear Security and Defense Programs are briefly highlighted in the sections that follow.

2.4.3.3.1 Defense Nuclear Nonproliferation

The Office of Defense Nuclear Nonproliferation (DNN) works with key international partners, particularly the IAEA and the Preparatory Commission (PrepCom) for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO), to build and sustain the programs and capabilities required to prevent, counter, and respond to nuclear proliferation and nuclear/radiological terrorism. These relationships have extended the reach of the NNSA programs and have played a key role in broadening and sustaining international actions against global nuclear proliferation and terrorism threats. DNN's international activities and partnerships include the following:

- Nonproliferation research and development focusing on unilateral and multilateral technical capabilities to detect, identify, and characterize foreign nuclear weapons programs, illicit diversion of special nuclear materials (SNM), and global nuclear explosive detonations. This work includes development of capabilities to meet U.S. nuclear treaty verification and detonation detection requirements, as well as broader U.S. government nuclear security requirements. Essential elements of this research straddle the cooperative and non-cooperative realms of international policy, and enhance capabilities to detect SNM production, movement, and weaponization, as well as improve current technologies and approaches for transparent nuclear reductions and monitoring.
- Evaluation and deployment of science-based solutions and technologies around the world to prevent the spread of nuclear materials and technologies. These activities are wide-ranging and include strengthening global material security, minimizing the use of highly enriched uranium (HEU),

disposing of excess weapons plutonium, working with foreign partners to enhance export control and safeguards infrastructure, working with the IAEA and other international organizations to enhance monitoring capabilities, and strengthening the international nonproliferation regime. DNN supports international technology deployment and development efforts in the following areas:

- Minimize the use of HEU by working with domestic and foreign partners to convert HEU-fueled research reactors to low enriched uranium (LEU) fuel. To enable these conversions, it is necessary to find an LEU fuel that still retains as much of the original reactor performance as possible. To this end, DNN sponsors development of very high-density LEU fuels for research and test reactors. Fuels developed under this project are deployed both domestically and internationally.
- Work with partner countries to plan and implement, on a cost-shared basis, security upgrades for sensitive sites containing nuclear and radiological materials and assist with transport security.

2.4.3.3.2 Defense Programs

Within the NNSA Office of Defense Programs, the Office of Research, Development, Test and Evaluation has responsibility for managing international engagements and leading a variety of scientific technical exchanges with international partners. Active collaborations across the fields of science and stockpile stewardship are ongoing with partners from the UK and France.

The *1958 Agreement between the Government of the United States of America (U.S.) and the Government of the United Kingdom of Great Britain and Northern Ireland (UK) for Cooperation on the Uses of Atomic Energy for Mutual Defense Purposes* (MDA) is an enduring agreement enabling the exchange of atomic information, hardware, and material between the United States and UK governments. The MDA permits the transfer between the United States and UK of information concerning atomic weapons, nuclear technology and controlled nuclear information, material and equipment for the development of defense plans, training of personnel, evaluation of potential enemy capability, development of delivery systems, and the research, development, and design of military reactors.

Numerous engagements with the UK at the technical level take place throughout the fields of weapon science. During more than 50 years of close and extensive cooperation, there has been significant joint advancement by the United States and UK in the fields of weapon science, hydrodynamic testing, primary and secondary physics, and nuclear weapon code development, all of which have enabled a greater understanding of nuclear weapon performance. Active technical exchanges are ongoing between NNSA, the U.S. Laboratories and production plants, and the UK's Ministry of Defence (MOD) and Atomic Weapons Establishment (AWE) under the auspices of the MDA. Joint U.S.-UK working groups collaborate frequently across the fields of warhead sciences and high-performance computing, including nuclear warhead physics; plasma physics; computational technology; code development; radiation effects; nuclear, nonnuclear, and energetic materials; and certification portfolios. In addition to frequent peer reviews and staff exchanges, the United States and UK are jointly partnering on several hydrodynamic experiments, the results of which will contribute to a greater understanding of material behaviors.

The NNSA and its counterpart in France, the Direction des applications militaires of the Commissariat à l'énergie atomique, have developed 27 active collaborative projects under the auspices of the *Agreement on Cooperation on Fundamental Science Supporting Stockpile Stewardship*. Topics include nuclear reaction cross section measurement, multiphase equation of state and kinetics of phase changes, explosives chemistry, radiography, opacity measurements, and materials modeling.

Special Feature—Science and Energy Research: Direct Contributions to National Security

While numerous studies and reports document the value of national security work to basic and applied science, the reciprocal result is well evidenced in the work conducted by DOE's SC and the applied energy technology programs. Stewarded by the Office of the US/SE, this foundational, applied, and use-inspired work contributes directly and indirectly to U.S. national security.

In some cases, this link is fairly straightforward. The high-energy physics and nuclear physics research in SC, for example, undergirds mission-critical work on nuclear and conventional weapons. However, the range of work and its security impacts extend beyond these kinds of straightforward relationships. The examples below illustrate the broad reach of the Science and Energy programs, and the importance of this work to national security. These examples represent only a small fraction of recent and ongoing efforts. Such efforts save the Nation money in national security efforts, save the lives of soldiers in the field, help rehabilitate the wounded, and provide solutions to difficult security problems that enhance U.S. force projection abroad and safety at home.

Basic and Use-Inspired Science Examples:

- **Adaptive Optics for Telescopes:** Laser Guide Star is a science program for land-based telescopes that has led to a breakthrough in using laser ranging in the upper atmosphere to correct for optical distortions in real time. This is now used for all large land-based telescopic systems. It also is used for precision in finding, managing, and destroying aerial platforms for friendly and unfriendly units.
- **Advanced Combustion Research:** The Sandia Combustion Research Facility has sustained basic combustion R&D for decades. This unique facility, funded by SC as well as other offices and from industry, exists to answer basic questions about how fuels burn and the nature of combustion. It has empowered radical rethinking of the auto industry (and its associated military support), including high efficiency and low emissions engines. It has also directly led to dramatic improvements in the design and function of rocket propulsion systems and military jet applications, as well as modern land-based mobile military platforms.
- **Compound Semiconductor III-V Devices:** DOE support of novel semiconductors includes both basic science work on the physics and chemistry of these materials, as well as efforts to improve the performance of solar photovoltaic materials. Years of work at universities and National Laboratories (notably Sandia and NREL) played a key role in developing Compound Semiconductor III-V devices, which rests on a foundation of state-of-the-art III-V semiconductor crystal growth and regrowth using metal-organic chemical vapor deposition and post-growth quantum-well band-gap modification. These devices have important technological uses in military hardware, as well many domestic security and civilian applications. These include vertical-cavity surface-emitting lasers, which can achieve the lowest power consumption of any electrically driven lasers, highly attractive for low-power optical microsystems that include lasers, lenses and other optical elements, photodiodes, and standard integrated circuits for laser driving and photodiode sensing. They also include photonic integrated circuit design and fabrication capabilities.

Special Feature—Science and Energy Research: Direct Contributions to National Security, continued

- **Subsurface Geophysical Imaging:** Two- and three-dimensional reflection seismology is the primary tool used in subsurface energy resource exploration and production. While much was developed by industry, DOE-funded basic and use-inspired research was essential in many applications. One important example, the widespread use of 3-D seismic surveying, required novel data storage and processing systems that were initially available only at DOE Laboratories. Investment from DOE in the 1990s created (a) the core algorithms used by the oil and gas industry today for processing seismic data, and (b) the basic data sharing platforms for file sharing and data storage. These basic mathematical and computational tools are still used today in defense and weapons work, and have led to the United States current role as the world's largest oil and gas producer, which itself has important national security implications.
- **Advanced Supercomputing:** Much has been written on how the need to simulate nuclear weapons without testing has produced dramatic gains in computer power. It is also true that major investments in algorithm development, novel architectures, high-throughput computing, etc., have produced major gains and capabilities in national security. Funding from NNSA helped finance, operate, and maintain the machines and facilities, which in turn have transformed and provided the foundation for U.S. leadership in hardware and software development. However, basic science research on these machines has produced radical scientific and technical breakthroughs, which themselves have impacted national security. These breakthroughs include the ability to simulate structural mechanics (used in automobile crash testing, soldier helmet design, and aerospace design), hydrodynamic and aerodynamic flow (used in wind turbine design and weapons testing), and materials design and discovery (including drugs, catalysts, and explosives). These codes and capabilities, initially used in weapons designs, are the computational core to global climate models, which themselves have led to important national security actions and planning. The impact on U.S. economics and security is immense.
- **Quantum Computing:** The ability to compute beyond binary (1 or 0) remains a basic research enterprise, but with the potential to dramatically improve computing density and performance with tremendous energy use and cost reductions. One of the leading candidates for a solid-state quantum bit is the spin of a single donor electron in silicon (Sandia)—its long spin lifetime is promising for quantum computing applications. Efforts in this technology as well as others leverage and help to enhance materials and fabrication capabilities directly relevant to national security. In addition to pursuing specific success in quantum computing, the exploration of "Beyond CMOS" (complementary metal–oxide–semiconductor) computing technologies serves to enhance computer science capability focused on the coupling between advanced algorithms and unconventional architectures, which is a key element of codesign. Work

Special Feature—Science and Energy Research: Direct Contributions to National Security, continued

continues at Oak Ridge, Los Alamos, and other Laboratories and universities through SC support.

- **Treaty Monitoring and Verification Geophysics:** The stringent requirements of treaty monitoring have resulted in a very sophisticated capability in geophysics. Detecting the source strength and location of a clandestine subsurface detonation, amidst the noise of natural and other anthropogenic processes, requires detailed signature analysis, often considering multiple lines of evidence, simultaneously. Such capabilities are synergistic with those required in assessing production, sustainability, and hazard components in subsurface fossil and geothermal energy development. Recent advances sponsored by FE and EERE have led to novel methods for locating very small seismic events caused by energy extraction in the crust. These methods have directly improved the capabilities and precision of treaty monitoring, which in turn has improved the capabilities and precision of test-ban monitoring, currently used to monitor Iran and North Korea, as well as the core algorithms in the ShotSpotter sniper detection system. Using joint inversion of multiple geophysical observations also permits evaluation of subsurface stress beyond boreholes in exploration, helping manage risks such as induced seismicity from water disposal from shale gas production.

The Illumina sequencing platform, which has been incorporated in the DOE Joint Genome Institute's production line since 2008, allows for real-time detection during the sequencing-by-synthesis process. Genomic analysis and finishing efforts provide insight into the nature of infectious disease, the development of advanced therapeutics, and treatment approaches based on our increased understanding of disease mechanisms. *Photo credit: LBNL, Roy Kaltschmidt, photographer*

Special Feature—Science and Energy Research: Direct Contributions to National Security, continued

- **Biosecurity:** DOE successfully built and led the Nation's effort to sequence the human genome. In addition to the immense scientific and human health benefits, this extraordinary scientific understanding and advanced technology and bioinformatics knowledge is applied to significant national security problems in energy, health, and warfighter protection. Genomic analysis and finishing efforts provide insight into the nature of infectious disease, the development of advanced therapeutics, and treatment approaches based on our increased understanding of disease mechanisms. The ability to sequence and finish genomes at higher and higher rates have driven both technology development, such as rapid, field-deployable diagnostic platforms for pandemic detection, and the computational tools for predictive systems biology. The resulting epidemiological and modeling capabilities are the basis for advancing areas as diverse as vaccine design (e.g., the mosaic vaccine for HIV) and adaptation of algae populations for biofuels production. The resulting science base in areas such as biosurveillance and therapeutics provides the opportunity to address issues in both threat response as well as public health. Fundamental research on genome sequencing and analysis continues at DOE's Joint Genome Institute and work within DOE programs with broad benefits for other programs in national security.

- **Grid resilience:** A secure, resilient, and efficient power grid lies at the heart of a secure domestic economy and our Nation's ability to respond to external threats. Sustained investments by EERE and OE created tools and platforms to make modern grids more flexible, robust, and resilient. These include abilities to model faults and failures in power distribution networks, identify and respond to weather-induced grid stresses, gather and integrate real-time voltage, variance, and phase data from the grid, and develop solutions to cyber threats. The fruits of this work serve rural and remote communities today, increase our ability to load intermittent renewable power onto the grid, and reduce the economic costs of grid failure. It also serves military bases and the communities around them by providing solutions like islanding and microgrid autonomy.

In many of the examples above, a virtuous cycle begins between basic R&D, applied R&D, and security-sponsored R&D. In some of these cases, it is hard to distinguish which kind of investment was the first or the most important. Part of the strength of the DOE research enterprise as a whole—and the operations overseen by the Office of the US/SE—is that prudent management and investment begets opportunities and outcomes much larger than the individual investments because of the ability to work across disciplines, silos, and funding lines to focus on the transformational solutions.

3

Chapter 3: Science and Energy Planning and Management

A core responsibility of the Office of the Under Secretary for Science and Energy (US/SE) is to drive the program offices to accomplish their missions while also seizing opportunities to leverage complementary activities. Achieving the appropriate integration and alignment requires defined planning and management structures.

As Chapter 2 demonstrates, DOE's science and energy enterprise spans a wide spectrum of DOE program offices, 17 National Laboratories, and many partners in industry and academia. Planning and managing a strategically designed RDD&D portfolio requires processes that accommodate near-term opportunities as well as fundamental science and technology science and technology (S&T) challenges. Successful management of such large and complex S&T portfolios also requires the identification and implementation of best practices in program and project planning and management across the science and energy program offices.

This chapter delineates the strategic drivers and planning and management mechanisms of DOE's science and energy leadership and program offices.

3.1 Planning Drivers

Since its inception in 1977, DOE's efforts have been directed and guided by a combination of authorities and legislative mandates that have defined the DOE mission and responsibilities for the Nation, Administration priorities, and DOE Secretarial and senior leadership direction. Coupled to these drivers are the scientific and technological opportunities identified over time, either through new discoveries and innovation or through extensive planning processes with S&T stakeholders—opportunities that can, over time, become planning drivers themselves.

3.1.1 Legislative Mandates and Authorities

The present-day incarnation of DOE was established by the Department of Energy Organization Act of 1977. That legislation set forth the mission of the Department, including the charge to:

- develop plans and programs dealing with domestic energy production and import shortages;
- create and implement an energy conservation program;
- carry out a balanced and comprehensive energy research and development program (with a major emphasis on solar, geothermal, recycling, and other technologies utilizing renewable energy sources);
- facilitate establishment of an effective strategy for distributing and allocating fuels in periods of short supply; and
- promote interests of consumers through the provision of an adequate and reliable supply of energy at the lowest reasonable cost.

That initial mission set still continues in the Department's current organization with much of it carried out in the US/SE organization.

Throughout the ensuing years, Congress modified its initial charge to the Department through a variety of legislative vehicles. Some of the legislation has been broad in its impact, while other legislation affects the Department principally through the US/SE programs.

Since 2005, two pieces of broadly drafted and influential energy legislation have impacted the operations of DOE and specifically the Office of the US/SE: the Energy Policy Act of 2005 (EPAct 2005) and the Energy Independence and Security Act of 2007 (EISA 2007). EPAct 2005 issued guidance and direction across a broad spectrum of US/SE programs and activities, ranging from energy-efficient product standards and programs to renewable energy requirements to tax and production incentives for nuclear, fossil, efficiency, alternative fuels, and renewable electricity. EPAct 2005 also included management-focused provisions, such as establishing the roles and responsibilities of the then-Under Secretary for Science and the appointment of the Department's Technology Transfer Coordinator, as well as requirements for the management of DOE technology transfer and the establishment of the Energy Technology Commercialization Fund and the Laboratory-led Technology Transfer Working Group.

Two years after EPAct 2005, Congress again prompted broad changes across DOE through the passage of EISA 2007. Among other items, this legislation included a focus on RDD&D of renewable energy technologies, smart grid technologies for grid modernization, carbon capture and sequestration programs, energy efficiency improvements in Federal agencies, appliance efficiency standards, and renewable fuels RDD&D.

Another significant piece of legislation that signaled Congress' ongoing support for DOE science and innovation is the "America Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science Act of 2007," or America COMPETES Act (which was reauthorized in 2010). This law signaled the need for the United States to renew its commitment to the Nation's efforts to remain globally competitive by increasing the Federal investment in basic research in the physical sciences, including the budget of the DOE Office of Science, creating new programs dedicated to the development of a skilled workforce that positions the United States as a leader in the advancement of science and technology.

3.1.2 Administration Priorities

In addition to legislative authorities and responsibilities, the Department is a key implementer of policy and directives of each Administration. DOE facilitates many of the President's highest priorities, which have included supporting clean energy technology development, cutting carbon pollution, increasing climate preparedness, ensuring the United States remains an international leader in science and innovation, and protecting Americans from the threat of nuclear harm and pollution, all of which are critical to job creation, long-term economic growth, and national security.

The Department addresses current Administration priorities through a variety of forms. For example, two flagship Presidential energy-related strategies are being implemented currently in the Department:

- The May 2014 "All-of-the-Above Energy Strategy as a Path to Sustainable Economic Growth," which emphasizes economic growth and job creation, energy security enhancement, and the deployment of low-carbon energy technologies.
- In support of the June 2013 "Climate Action Plan (CAP)," DOE has moved forward to lead initiatives and support interagency efforts that cut carbon pollution, augment resilience and preparedness in the face of climate impacts, and strengthen international partnerships addressing the issue. This effort involves activities all across the Department.

The President also provides specific direction to the Department through an Executive order applicable to all Federal agencies. Since the beginning of the current Administration in 2009, numerous Executive orders have impacted the activities of DOE. For example, in October 2011, the White House issued a Presidential memorandum entitled "Accelerating Technology Transfer and Commercialization of Federal Research in Support of High-Growth Businesses," which directed agencies to establish goals, measure performance, streamline administrative processes, and facilitate local and regional partnerships to facilitate R&D commercialization.

Another example is a new Executive order issued by the White House in March 2015 that will cut the Federal Government's greenhouse gas emissions 40 percent over the next decade (from 2008 levels) and increase the share of electricity the Federal Government consumes from renewable sources to 30 percent. In coordination with the White House's Council on Environmental Quality, DOE's Federal Energy Management Program (FEMP) plays a leading role in implementing this emissions reduction across the range of Federal agencies.

In addition to the aforementioned Administration priorities, the White House published its inaugural Quadrennial Energy Review (QER) in April 2015. On November 29, 2010, the President's Council of Advisors on Science and Technology (PCAST) issued a report to the President on accelerating the transformation of energy technology within the United States. One of PCAST's primary recommendations was for the Administration to initiate the QER to provide a long-term comprehensive energy strategy for the Nation. President Obama stated in his January 9, 2014, memorandum initiating the QER that "Affordable, clean, and secure energy and energy services are essential for improving U.S. economic productivity, enhancing our quality of life, protecting our environment, and ensuring our Nation's security." The QER assesses the current state of energy infrastructure, considers trends and emerging infrastructure challenges through 2030, and issues recommendations to ensure that U.S. energy infrastructures and the services they provide are affordable, clean, and secure. It identifies the threats, risks, and opportunities for U.S. energy and climate security, enabling the Federal Government to translate policy goals into a set of integrated actions. The QER's findings and recommendations will guide energy policy and programmatic decisions across the Executive Branch. DOE in particular will carry out recommendations to improve energy data gathering, analysis and coordination, will study the need for and impact of energy policy adjustments and Federal energy infrastructure investments, and will accelerate RDD&D on advanced energy technologies. The QER was led by a task force cochaired by the Director of the Office of Science and Technology Policy (OSTP) and the Director of the Domestic Policy Council (DPC). DOE, under the leadership of the Office of Energy Policy and Systems Analysis, served as the Secretariat for the QER, and in this role coordinated stakeholder and interagency engagement and conducted policy analysis and modeling.

3.1.3 Departmental Priorities

Building on the guidance from Congress and the Administration, the Department also receives internal direction. This section discusses the Secretary's guidance as transmitted in the DOE Strategic Plan and the Office of the US/SE's technology-focused assessment in the Quadrennial Technology Review (QTR).

3.1.3.1 DOE Strategic Plan

In March 2014, the Department of Energy published its Strategic Plan of the Department of Energy for 2014–2018. The Plan provides a roadmap for the Department's work, highlights its major priorities for the next few years, and guides the development of plans for individual programs.

Within "Science and Energy," the Plan addresses three primary goals. First, the Plan advances the objectives in the President's Climate Action Plan by supporting the prudent development, deployment, and efficient use of "all of the above" energy resources that also create new jobs and industries. This is to be accomplished by improving energy productivity, advancing options for diverse energy resources and conversion devices for power, leveraging increased private sector financing for deployment of "all of the above" energy technologies, accelerating development and deployment of new transportation technologies, and supporting environmentally responsible development, delivery, and use of domestic petroleum and natural gas.

Second, the Plan supports the need for a more economically competitive, environmentally responsible, secure, and resilient U.S. energy infrastructure. These objectives will be achieved by supporting the recommendations from the Quadrennial Energy Review, developing, demonstrating, and deploying technologies to modernize the electric grid, strengthening the effectiveness of DOE incident management capabilities, managing the Strategic Petroleum Reserve, improving cybersecurity in the energy sector, and working with States, localities, and other stakeholders to develop climate change prevention and adaptation resilience strategies.

Finally, the Plan emphasizes the importance of delivering the scientific discoveries and major scientific tools that transform our understanding of nature and strengthen the connection between advances in fundamental science and technology innovation and deployment. This objective is to be accomplished by conducting discovery-focused research to increase our understanding of matter, materials, and their properties through partnerships with universities, National Laboratories, and industry, and by providing the Nation's research scientists and engineers with world-class scientific user facilities that enable advanced scientific discovery and mission-focused RD&D of energy technology.

The remaining two sets of goals—on "Management and Performance" and "Nuclear Security"—focus largely on DOE program offices outside the purview of the Office of the US/SE. Briefly, the "Management and Performance" goals focus on improving performance in the areas of legacy environmental cleanup from Cold War-era activities, implementing cybersecurity, overseeing large construction projects, and attracting and maintaining a strong workforce. The "Nuclear Security" goals focus on maintaining the Nation's nuclear deterrent without underground testing; maintaining and modernization the nuclear weapons stockpile; strengthening key science, technology, and engineering capabilities and modernizing the national security infrastructure; and reducing global nuclear security threats.

When executing their planning activities, the programs under the Office of the US/SE ensure they are aligned with the goals of the DOE Strategic Plan, particularly the strategic objectives under the "Science and Energy" goal.

3.1.3.2 Quadrennial Technology Review

The QTR is designed to frame, detail, and analyze RDD&D opportunities for the Nation to consider as it addresses the energy-linked challenges to the economy, environmental quality, and national security. The Office of the US/SE oversees the development and publication of the QTR.

The first QTR was issued in 2011 and the second was published in September 2015. The QTR identifies and focuses on the most important technologies to address the Nation's energy challenges and to provide key data and analysis to help inform budget decisions over the next four years.

The 2015 edition of the QTR describes the Nation's energy technology landscape and the changes that have taken place since the first report in 2011. The 2015 QTR approaches the analysis from a systems perspective to explore the integration of science and technology. It includes specific focus on:

- advancing systems and technologies to produce cleaner fuels,
- enabling modernization of electric power systems (grid),
- advancing clean electric power technologies (generation),
- increasing efficiency of building systems and technologies,
- innovating clean energy technologies in advanced manufacturing,
- advancing clean transportation and vehicle systems and technologies, and
- enabling capabilities for science and energy.

The outputs of the 2015 QTR include a summary volume of findings and links to Web-based appendices that will provide more detailed technology assessments. It also informs annual budget planning and helps the Office of the US/SE and its program offices align their activities with the technology analyses and areas of greatest potential to achieve the Administration's energy, environmental, and economic goals.

Development of the 2015 QTR overlapped with formulation of the Department's FY 2016 budget request. While the QTR was published in September 2015, staff from throughout the Department, in close collaboration with non-DOE subject matter experts, were engaged in the technical analysis required to develop the QTR over the preceding two years. Through a series of workshops and other external stakeholder engagements, DOE and National Laboratory staff developed technical assessments and roadmaps covering dozens of energy technology research areas. As a result, early QTR analysis helped influence the FY 2016 budget request.

The primary theme that emerged during the analysis phase was the interdependent, highly coupled nature of the energy system, which supports the Secretary's goal of increasing collaboration between DOE's science and applied energy enterprises. In the FY 2017 budget request, the 2015 QTR will serve as a foundational input in setting priorities for the Department's RDD&D portfolio.

3.1.4 Federal Budget Cycle

The Department uses the results of the above planning drivers to develop priorities for the annual Federal budget process, which guides the timing of various planning inputs. As with other Federal agencies, the Federal budget for DOE's Science and Energy program offices is appropriated on an annual basis. At any given time, however, the program offices are engaged in three different fiscal year budgets, as illustrated in figure 3.1. They are executing the appropriated funds of the current fiscal year (budget execution); they are engaged in budget

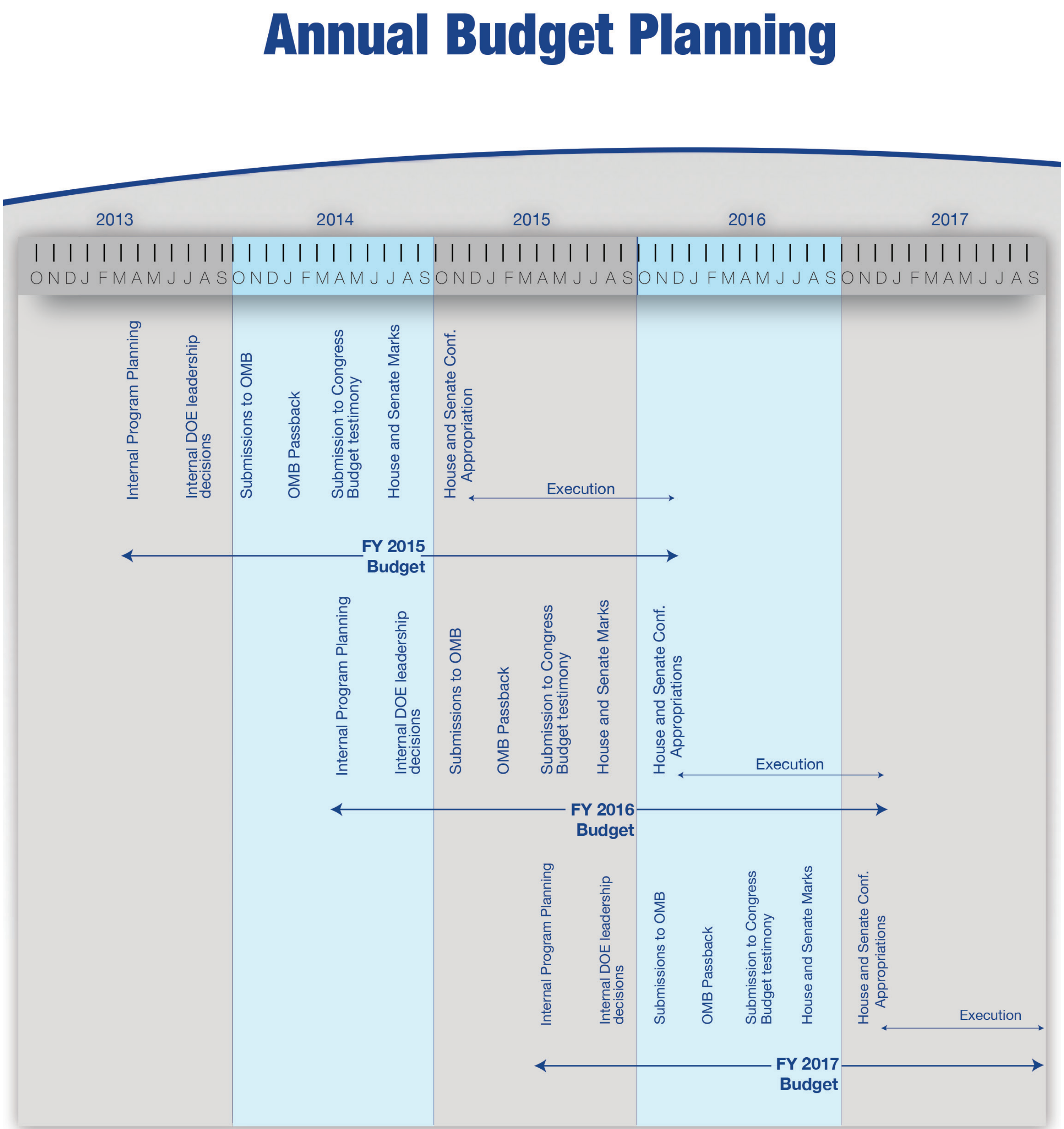


Figure 3.1: DOE Annual Budget Planning.
This figure illustrates the budget planning cycles for FY 2015, FY 2016, and FY 2017, showing timing and progression of planning activities and how they overlap year to year.

justification discussions and hearings with Congress and Congressional staff on the President's Budget Request (PBR) for the following fiscal year (budget defense); and they are engaged in budget formulation processes for the fiscal year that is two years out (budget formulation).

While planning processes by the program offices are ongoing, there are two major points at which new and significant decisions from those planning processes are put into motion: (1) each February, the President submits a budget request to Congress for the upcoming fiscal year, and (2) each October 1st begins a new Government fiscal year for which Department funding must be appropriated by Congress.

Although February and October are the most notable dates in the budget calendar, DOE engages in planning activities throughout the year. As such, it continually deliberates on major actions (such as Administration policies) and assesses scientific and technical opportunities, gathering input from a wide array of sources and stakeholders. The PBR to Congress is the primary formal document by which the Department distills the input from its planning and evaluation processes into proposals that may make major changes to existing programs and activities or proposes new activities requiring funding and Congressional approval. The Department's annual budget formulation proceedings drive that distillation process and begin in earnest in February, almost two years before the budget execution year and immediately after the release of the PBR for the upcoming fiscal year.

Pursuant to Secretarial guidance, DOE's internal budget formulation activities are typically initiated independently at the program office level, in advance of, and in anticipation of, the Department's formal budget formulation process. The formal guidance to the program offices is provided by the DOE Office of the Chief Financial Officer (CFO). In addition to Secretarial direction, the CFO guidance takes into consideration general guidance issued by the White House, the Office of Management and Budget (OMB), and more tailored mission guidance through the Office of Science and Technology Policy (OSTP). The guidance issued by the CFO is transmitted to the Science and Energy program offices through the Office of the US/SE with additional budget and policy guidance, as well as the process and timeline for internal briefings and review prior to submission of the budget to the CFO. Once DOE senior management reviews the draft budgets submitted to the CFO, further internal discussions and decisions are made leading to the Secretary's review. Upon the Secretary's approval, DOE's budget proposal is prepared with associated narrative materials for submission to OMB in early September.

During September and October, OMB analyzes the DOE budget request and invites DOE and program office leadership to present briefings to and have discussions with its staff. The OMB-vetted version of the proposed budget is passed back to the Agency typically in late November or early December for modifications and revisions. Following regular negotiations, which includes aligning DOE and Administration priorities, DOE prepares the OMB-approved budget request for the final PBR that is released in early February. During this OMB review and negotiation phase, new information resulting from programmatic planning processes may identify timely opportunities or needed course-corrections that become the subject of negotiation for the final PBR.

Following the PBR submission to Congress, the U.S. House of Representatives and U.S. Senate Appropriations Subcommittees and Committees conduct hearings with and receive briefings from senior DOE officials on the proposed budget. Between February and the end of the current fiscal year, September 30th, Congress must pass a final appropriations bill for the Department to be sent to the President to sign into law. During the time that Congress is considering the appropriations bills of their respective chambers, they may also respond to new information resulting from DOE programmatic planning processes or other events or actions that impact DOE programmatic decisions between the time the PBR is submitted in February and the final Appropriations bill is considered in conference, the result of which may be adjusted funding levels from those in the PBR and additional Congressional direction.

If a final full-year appropriation for the Department is not approved by October 1st, typically temporary extensions of the previous year's budget, referred to as Continuing Resolutions (CRs), are passed by Congress. CRs complicate the management of Federal agencies in many ways. For example, CRs generally prohibit the start of new programs or facilities and the termination of old ones; inadequate funding for a construction project for which a funding increase was planned would impact the ability of the project to meet its cost and schedule milestones. When a final budget is adopted, the Department crosses the second major point with the execution program plans and priorities for the fiscal year, as appropriated.

3.2 Role of US/SE in Planning, Management, and Evaluation

As noted above, US/SE provides budget and policy guidance to the Science and Energy program offices to assist in the formulation of their respective budgets. In implementing its responsibility for these budgets, US/SE works in a collaborative and iterative process with senior program and Departmental leadership to identify areas of science and energy growth, maintenance, and reduction relative to a spectrum of different future funding scenarios. While specific components of a program office's budget are built and proposed by the Assistant Secretaries, US/SE's authority for budget submissions helps to ensure mission priority is given to key strategic areas.

This section discusses the process used by the Office of the US/SE to coordinate and align planning activities, how the Office of the US/SE and its program offices collaborate on complementary, crosscutting initiatives, and how the Office of the US/SE strategically engages the National Laboratory system through efforts such as the Big Ideas Summit to help ensure new strategic investments focus on areas of national importance and impact.

3.2.1 US/SE Coordinated Planning Process

As the planning and alignment activities designated and delegated to the Office of the US/SE require coordination across many DOE programs and through many levels of the line management, the Office of the US/SE implements a standardized but flexible coordinating planning process. This process is a key tool in the management of the Science and Energy program offices. The planning process is designed to enable a continuous dialog, raise awareness, drive effective planning, and enable consistent comprehensive communication regarding the long-term direction of the Science and Energy program offices.

This generalized process is used to execute many functions of the Office of the US/SE, including aligning program activities and budgets, maintaining management and administrative oversight, and developing and executing Departmental strategies. In addition, this process is used to produce the Office of the US/SE flagship documents—the QTR and the SEP.

The governance structure for the coordinated planning process consists of three levels: (1) decision- makers; (2) an executive steering committee (ESC) and Office of the US/SE coordinators; and (3) coordination groups and origination teams. The decision-makers consist of:

- Office of the US/SE principals: the US/SE and the Deputy US/SE, and
- Science and Energy program principals: the applied energy technology office Assistant Secretaries, Director of SC, and Technology Transitions Director.

Office of the US/SE principals coordinate with the Secretary and Secretarial boards and councils (see section 4.2.3), as appropriate, and work in close coordination with the program principals to guide various planning processes. The principals maintain decision-making authority, provide direction, and approve products prior to their submission to the Deputy Secretary and Secretary. The Science and Energy program principals advise on the structure, development, content, and other matters related to the products, and select the members of the executive steering committee (ESC).

The ESC and Office of the US/SE coordination team consist of:

- ESC: senior executives or other leaders, appointed by the US/SE program principals, and
- Office of the US/SE coordinators: Office of the US/SE staff.

The ESC represents the Science and Energy program principals, provides guidance on the design of the deliverables, and ensures selection of Federal staff with requisite expertise to participate in this planning process. The Office of the US/SE coordination team works closely with the ESC to oversee the planning process, lead the coordination groups, and ensure product alignment.

The coordination groups and origination teams consist of:

- coordination groups: senior program and National Laboratory staff, with broad and deep knowledge of science, technologies, and programs, and authority to act on behalf of their Principals. These groups help plan and coordinate the development of the products; and
- origination teams: program and National Laboratory subject matter experts that participate on work teams to create the document content.

The National Laboratory principals and scientific and technical staff engage in this process through participating in workshops, such as the National Laboratory Big Ideas Summit (discussed in section 3.2.3), and serving on coordination groups and origination teams. The National Laboratory principals are also informed through their membership on the Department's boards and councils.

3.2.2 Crosscutting Technology Opportunities

One of the goals of the Office of the US/SE is to better link the activities of the program offices under its purview. As described above, the Office of the US/SE engages with its program offices throughout their budget and strategic planning processes to ensure the respective missions of the programs are appropriately differentiated, diversified across science and energy research arenas, and linked where productive connections are appropriate.

While the Science and Energy program offices are working to achieve their own missions and goals, science and technology research opportunities should overlap the boundaries of the program offices. Fundamental science advances will create potential technology applications, and technology advances will illuminate opportunities for better understanding of fundamental physics, chemistry, and transport phenomena to advance applications. To address these areas of complementarity, the Office of the US/SE oversees the science and energy "Technology Teams" (or Tech Teams) to integrate program staff and planning activities.

In January 2014, the Office of the US/SE convened a planning summit in which six Tech Teams were charged with establishing coordinated plans for integrating targeted activities of the Department around the following high-priority, high-impact research areas: grid modernization, subsurface technology and engineering, advanced computing, the water-energy nexus, advanced manufacturing, and Brayton cycle turbines using supercritical carbon dioxide (sCO2) as a working fluid. These are research topics of interest to multiple program offices across DOE, and thus represent areas in which efficiencies could be achieved through close collaboration and planning.

The Tech Teams were charged with activities ranging from engaging in information sharing across programs to developing joint proposals for funding in the FY 2016 budget. Each of the Tech Teams engaged in months-long planning processes to pursue these activities. The result of this activity was the crosscutting budget proposals discussed in section 2.3. Four of the Tech Teams were featured in the FY 2016 budget proposal; the manufacturing team developed specific proposals that appeared in the budget requests of specific program offices.

To provide guidance and direction from the Office of the US/SE, following the January 2014 Tech Team planning summit, the two cochairs of each Tech Team have met biweekly through the Tech Team Coordination Group, which is organized per the Office of the US/SE coordinated planning process. The meetings are chaired by a representative from the Office of the US/SE.

A brief description of each of the Tech Teams is included on the Web page of the US/SE.

The Office of the US/SE annually evaluates the need to continue, sunset, or stand up new Tech Teams. For example, based on outcomes of the QTR and QER, the Office of the US/SE stood up an Energy Storage Tech Team in 2015 to join the others that have continued.

3.2.3 National Laboratory Big Ideas Summit

A key mechanism used by the Office of the US/SE to engage the National Laboratory enterprise in strategic, technical planning is the National Laboratory Big Ideas Summit (BIS). The Summit brings together subject matter experts from DOE's science and energy offices as well as EPSA, the NNSA, and all 17 National Laboratories to propose and explore innovative ideas for solutions to key energy issues. The BIS is timed to occur in the spring so as to help inform the planning processes leading into formulating budgets for the next fiscal year, thus helping to shape the Department's planning for future investments and priorities.

The first BIS, held in March 2014, featured presentations by the National Laboratories. The requirement for these presentations was that they were to be organized by multiple Laboratories in a collaborative fashion. After a planning process in January and February, the Laboratories presented ideas at the Summit on eight topics:

- Creating an adaptive and resilient U.S. electric grid
- Systems integration: accelerating the clean energy future
- Adaptive control of subsurface fractures and fluid flow
- Sustainable and secure water management
- Accelerating materials to manufacture
- Climate change science and adaptation
- Nuclear energy: enabling rapid commercialization
- Accelerating sustainable transportation

The first three ideas listed above (or major elements of them) resulted in major Departmental initiatives in FY 2015 and in the FY 2016 Presidential Budget Request. These ideas were captured in the crosscutting proposals discussed in section 2.3.

The remaining ideas from the 2014 Summit also informed the Department's planning in meaningful ways. The water management and climate change science and adaptation ideas proved influential to the Department's request for $38 million to support modeling, analysis, demonstrations, and outreach on the water-energy nexus. The nuclear energy idea heavily informed nuclear energy activities going forward and has facilitated renewed focus on more rapid commercialization for advanced reactor technology, which includes work with the NRC. And the manufacturing and transportation ideas inspired follow-on work that was refined into ideas presented at the 2015 BIS.

In April 2015, the Office of the US/SE convened the second annual National Laboratory BIS. Topics at the second Summit focused on the following ideas:

- Energy-water nexus
- Accelerating the path to economic and sustainable fuels and vehicles
- DOD/DOE coordinated energy research program
- Urban systems science and engineering
- Bridging nano to macro: enabling advanced materials scale-up for industrial manufacture
- Chemical conversions for sustainable energy

At each of the Summits, both plenary and working group sessions were used to communicate the ideas and gather feedback on the specific proposals. During these sessions, the key topics discussed included the following:

- What would be the critical short- and mid-term next steps for DOE to have a mission impact in the next fiscal year?
- Is there a clear and appropriate role for DOE and the Federal Government?
- Will a major investment create a step change in the United States energy future?
- Do the Laboratories have unique capabilities and facilities for the big idea?
- If successful, will this effort lead to tangible, enduring benefits to the economy, environment, and/or national security?
- What does success look like? What metrics would indicate success?
- Does the big idea lend itself to cross-Laboratory collaboration or alignment?
- What existing programs could be re-vectored to achieve the goals of the big idea?

A notable difference between the first and second BIS was the incorporation of partners in the DOD in formulating the big ideas. DOE Laboratories and DOD personnel engaged in several planning sessions throughout the winter to facilitate the development of a specific idea focused on the DOD and DOE nexus.

The BIS grew out of similar conferences convened in the applied energy technology offices. In May 2013, the Office of Electricity Delivery and Energy Reliability (OE) and the Office of Energy Efficiency and Renewable Energy (EERE) hosted a Grid Integration Lab Summit. This meeting identified key areas for future impact on grid modernization and captured DOE's National Laboratories' core capabilities related to grid integration and enabled improved collaboration and planning in this high priority area. In June 2013, EERE held a two-day National Lab Planning Summit to obtain input on its strategic planning and to listen to "big idea" proposals from the Laboratories. Thirteen Laboratories collaborated and presented six big ideas (e.g., energy systems integration, next generation transportation, and advanced manufacturing) and demonstrated how each Laboratory could contribute its unique core capabilities to address a national energy issue. It was from these models that the BIS developed. These engagements encourage inter-Laboratory leveraging of core capabilities, better communicate DOE leadership priorities, and empower Laboratories to think "out of the box."

The participants in the Summits represent the senior leadership of the Department and the Laboratories. At both BISs, attendees included the Laboratory Directors; their chief scientific personnel; the Applied Energy Technology Assistant Secretaries and their Deputy Assistant Secretaries; the Director of the Office of Technology Transitions, the Director of the Advanced Research Projects Agency-Energy (ARPA-E), the Director of the Office of Science and other SC senior leaders; the leaders of the six DOE Tech Teams; and other key staff from DOE headquarters (HQ). The Summits represent a prime opportunity for senior leadership at DOE headquarters and the Laboratories to work in partnership to address the Nation's most important energy challenges.

3.3 Program Planning

This section describes the major program planning activities carried out by Science and Energy program offices and overseen by the Office of the US/SE. The portfolio planning and portfolio management practices at the program office level described in this section, coupled with the activities coordinated by the Office of the US/SE, form the basis for how the Department plans and manages for performance in order to deliver on the Department's strategic goals and priorities in science and energy.

This section begins with an overview of how the program offices pursue their strategic and multiyear planning. It discusses the many mechanisms by which the program offices engage S&T stakeholders from DOE Laboratories, universities, and the private sector, as well as the general public. This section also includes a description of the processes used by the program offices to solicit, review, and select proposals for new RDD&D activities, as well as how the offices periodically review ongoing research and facilities to ensure funded performers and DOE-funded facilities—whether at DOE Laboratories or universities or industry—are delivering on the work being funded and meeting or exceeding expectations.

In addition, the Science and Energy program offices have stewardship responsibilities for DOE National Laboratories. The program offices' detailed annual planning activities that help ensure a healthy and productive future for the Laboratories, as well as annual appraisal processes that assess how well the Laboratories are performing on the S&T, management, and operational goals, conclude this section.

3.3.1 Multiyear Planning

Program offices must assess and balance competing drivers as they establish priorities for investments in RDD&D. Some DOE program offices steward entire disciplines for the Nation, as the primary Federal sponsors for R&D in those particular areas, and as such, must think about the long-term health of those disciplines and avoid stagnation. Program offices must also think about global competition and the threat of losing intellectual and innovation leadership in certain fields, technologies, or capabilities. Those program offices that have stewardship responsibility for DOE National Laboratories have a commitment to ensure that these Laboratories have a compelling long-term S&T vision and enabling infrastructure. In addition, program offices consider the direction provided to them by the legislative and Administration priorities discussed above, as well as the Departmental priorities, opportunities, and issues expressed in the DOE Strategic Plan, QTR, and QER. Program offices must also assess opportunities and requirements for near-term commercialization, the proper role of Government, and optimal ways of delivering needed value to ongoing private sector activities.

As part of portfolio planning, programs offices routinely balance and assess near-term with long-term opportunities, ranging from several years to decades in the future. They need to remain flexible to take advantage of current scientific and technical breakthroughs, while maintaining a long-term vision to achieve their program office goals over decadal timeframes. Program offices also consider these responsibilities and opportunities in the context of their current research, development, and facility portfolios, and in the context of the annual appropriations process and finite budgets.

These planning drivers necessarily require multiyear program planning. All of the Science and Energy program offices engage in multiyear program planning, informed by extensive formal stakeholder input. While each Office engages in this process, they produce different types of documents based on their specific or unique S&T development challenges.

For example,the Office of Fossil Energy (FE) develops its strategic vision, mission, and objectives and works with the National Energy Technology Laboratory (NETL) to develop the program office goals and pathways to achieve these objectives. Specifically, FE HQ and NETL staff develop a roadmap in which each technology area defines its contributions and individual pathway required to achieve the goals of the program office. The product is a roadmap for achieving the objectives set in the FE Strategic Plan that mitigates risk by providing multiple pathways to success. These two documents, i.e., the FE Strategic Plan and the roadmap, lay out a multiyear effort that defines the necessary RD&D for each technology area to meet the program office's objectives. In addition, the program office develops multi-year program plans (MYPP), which define how the program will be implemented over the next 5 years based on projected budget requests, a strategy for National Laboratory engagement, near-term priorities, strategic initiatives, and funding opportunity announcements.

Similarly, EERE employs two types of planning documents—roadmaps and MYPPs—to define the program office's future for key stakeholders. EERE's technology roadmaps have an eight- to ten-year planning horizon. At the most strategic level, these roadmaps set out a vision and develop broad and long-range goals to provide overall program direction. In general, they answer the question, "Where are we going, and why?" and thus link trends in technology and markets with strategic objectives. The MYPPs, which are developed on a three- to five-year planning horizon, serve as operational guides for program offices to manage their activities, and as a source of information to help EERE management identify clear linkages between key program activities and progress toward goals. They also inform a broad group of stakeholders on the future direction of the program office. MYPPs are more operational in nature than roadmaps and are closely integrated with the program and EERE strategic plans. EERE uses the MYPPs to directly inform its annual operating plan (AOP). An example of an EERE MYPP (specifically for its Bioenergy Technologies Office) is available online.

The Office of Nuclear Energy (NE) also uses its Nuclear Energy R&D Roadmap as a key document to guide its multiyear planning process. The Nuclear Energy R&D Roadmap defines the major challenges to expanding the use of nuclear power; NE's overarching RD&D objectives to address these challenges; and NE's science-based, engineering-driven approach to nuclear energy RD&D.

3.3.2 Engaging Experts and Stakeholders

In addition to relying on the expertise of leadership and personnel in the Office of the US/SE and its program offices, program planning relies significantly on input from academia, National Laboratories, industry, international institutions, and other members of the S&T community. Program offices continuously assess new scientific knowledge and technological developments, the state of the science and engineering in core disciplines, and changing market drivers to identify new opportunities as well as refine priorities. Effective stakeholder engagement practices are thus key to the Science and Energy planning process, particularly as the private sector owns and operates the vast majority of the Nation's energy systems. The expert judgment and insight provided by individuals and organizations helps inform the Office of the US/SE and its program offices in their prioritization of activities and the development of high-quality, leading-edge R&D portfolios. For the applied energy technology offices, engagement of industrial representatives is particularly important, as their portfolios of technologies are expected to quickly transition to commercial application. Potentially affected communities and other stakeholders must also be engaged for program success.

To connect with their communities of stakeholders, the Office of the US/SE and each of the Science and Energy program offices use a common set of outreach processes and mechanisms, including:

- DOE-led scientific and technical workshops;
- reviews and reports by advisory committees;
- contracted and independent studies performed by external entities;
- interagency committees and working groups;

- Requests for Information (RFIs) and Funding Opportunity Announcements (FOAs); and,
- national meetings and S&T conferences.

A detailed discussion of each of these mechanisms, including examples of how they are utilized as planning tools in DOE's program offices, follows.

3.3.2.1 DOE-Led Scientific and Technical Workshops

Department-sponsored scientific and technical workshops involve broad participation of the scientific and technology communities and have long been mechanisms for identifying research opportunities for both the basic and applied research programs. These workshops typically form the technical basis for determining new research areas that could benefit from better coordinated efforts and enhanced funding. Participants include science and technology experts from academia, Government, the National Laboratories, and industry.

The resulting workshop reports describe the scientific or technical challenges and identify high priority research areas that, if pursued, have significant potential to provide needed knowledge to overcome barriers to particular energy technologies. In general, the workshop reports are a product of the S&T community and help inform DOE's R&D portfolio investment decisions; they also serve to provide the S&T community with knowledge of what the research needs are and where the opportunities for basic-applied R&D integration exist.

An example of a particularly influential set of scientific and technical workshops was the "Basic Research Needs" (BRN) workshop series, led by the SC's Basic Energy Sciences (BES). The workshop series began with the inaugural "Basic Research Needs to Assure a Secure Energy Future" workshop in October 2002, led by the Basic Energy Sciences Advisory Committee (BESAC). This workshop led to ten follow-on workshops organized by BES, each focused on a particular energy technology area or technology-enabling area. The workshop participants included subject matter experts from academia, Government, the National Laboratories, and industry, and involved participation, or cosponsoring and coplanning, of DOE's technology programs. Each BRN workshop identified priority research directions for the respective scientific community. These BES workshops initiated over 13 years ago established a successful model for productive scientific technical workshops now routinely carried out by other Office of Science programs. The BRN workshop series, along with the 2007 BESAC report, "Directing Matter and Energy: Five Challenges for Science and the Imagination," formed the scientific foundation for the 2009 BES solicitation for Energy Frontier Research Centers (EFRCs). The EFRCs are major collaborative research efforts intended to accelerate high-risk, high-reward fundamental research that will provide a strong scientific basis for transformative energy technologies of the future. The research at each EFRC must address one or more of five interrelated grand challenges that define the roadblocks to progress and the opportunities for transformational discovery, as well as one or more of the priority research directions identified in the BRN workshop series.

Technical and scientific workshops are also commonly used by the applied energy technology offices, as shown in the following examples:

- Since 2013, OE has organized over 50 workshops with representatives from industry, other Federal and State agencies, and academia to identify industry-relevant R&D needs for grid modernization. OE has also used these workshops as a key input to develop the Energy Storage Safety Strategic Plan, a roadmap for grid energy storage safety that addresses the range of grid-scale, utility, community, and residential energy storage technologies being deployed across the Nation.
- In March 2015, NE sponsored the Nuclear Energy Innovation Workshops—a series of simultaneous workshops focused on nuclear innovation—in order to seek innovative and forward-looking ideas for advancing and utilizing nuclear energy technologies. The event was organized by Idaho National Laboratory (INL) and hosted with six university partners. The four focus areas of the workshops

included innovative concepts, innovative use of existing technologies, an innovative RD&D paradigm, and an innovative licensing paradigm. The results of these workshops are currently helping to inform NE's future planning and prioritization.

- FE organizes workshops with interested stakeholders that provide information on state-of-the-art technologies and discuss innovative research opportunities across its numerous programs. In August 2014, FE conducted a workshop focused on key areas for new water-energy research initiatives. The workshop featured breakout sessions on topics that included cooling water systems design, water treatment technologies, solid waste disposal issues, and other water-related topics. Utilities, Government agencies, research entities, National Laboratories, universities, and other industry stakeholders including Southern Company, Tampa Electric, U.S. Environmental Protection Agency (EPA), Electric Power Research Institute (EPRI), Southern Research Institute, Los Alamos National Laboratory, University of Chicago, and West Virginia University, among others, were represented.

DOE also uses workshops to address challenges in commercializing technologies at a later stage of development. Similar to S&T workshops, commercialization-focused workshops seek to identify and address barriers to moving cutting-edge energy technologies into commercial application and furthering industry growth. Participants can include vendors and suppliers, potential customers of the technology, regulatory or standard-setting agencies, legal and finance experts or others within industry that can identify stumbling blocks and navigate the best path forward. Outcomes from these commercialization workshops can feed into program planning or catalyze direct action in the private sector to address critical barriers.

NE has held a series of these commercially focused workshops over the last few years to develop regulatory guidance for non-light water reactor designs (a market barrier noted in 2012 by both DOE and NRC). It had been recognized that the existing licensing guidance is written for light water reactors and that a regulatory framework is needed to support reasonable timelines for design certification and licensing of advanced reactors. In 2013, NE and NRC initiated a joint project for development of general design criteria for non-light water reactor concepts. During phase one of that initiative, DOE prepared draft design criteria and led workshops in March and July 2014 to explain the licensing initiative to the advanced reactor stakeholder community and to receive inputs on the draft general design criteria. The well-attended workshops were beneficial in the development of general design criteria that could be of use to designers of several advanced reactor types. DOE issued a report to the NRC in December 2014 that proposed the draft general design criteria and requested development of regulatory guidance.

FE and the Bioenergy Technologies Office (BETO) in EERE hosted the Bioenergy with Carbon Capture and Sequestration (BECCS) workshop on May 18, 2015, in Washington, DC. The BECCS Workshop was held to focus on low-carbon and carbon-negative power systems and the use of biomass in power generation to achieve lower greenhouse gas emissions in a sustainable manner. The workshop incorporated discussion sessions to facilitate future research and development ideas and collect input from all participants. The results from these discussion sessions along with follow-up comments and inputs collected after the workshop will be compiled into a workshop report that will be used to assist DOE leadership in identifying opportunities for technology development and deployment in the power industry, as well as to assist FE and BETO in strategic planning for future program activities.

The Advanced Manufacturing Office (AMO) at EERE and FE hosted a workshop November 12–13, 2014, in Coraopolis, Pennsylvania, as a follow-up to the President's Climate Action Plan and the DOE meeting series on reducing methane emissions from natural gas pipeline systems. The workshop was part of the larger Administration strategy to reduce methane emissions associated with natural gas transmission and distribution infrastructure. Information gained from the workshop will assist DOE leadership in identifying opportunities for increasing the operational efficiency of natural gas infrastructure and in detecting and eliminating leaks. Feedback from the workshop will assist AMO and FE in strategic planning for future activities.

3.3.2.2 Reviews and Reports by Federal Advisory Committees

DOE seeks formal advice from stakeholders through a range of advisory committees. The most structured and formal of these are formed under and governed by the Federal Advisory Committee Act (FACA) of 1972 (Public Law 92–463; 92nd Congress, H.R. 4383) and all applicable FACA amendments, Federal regulations, and Executive orders. Each committee has a charter, renewed every two years, outlining its mission and duties.

Under the FACA, advisory committees can be created only when they are essential to the performance of a duty or responsibility conveyed upon the executive branch by law or Presidential directive. Before committees can be set up, high-level officials within the sponsoring agency must review and approve the request. Once a committee is approved, a charter is prepared outlining the committee's mission and specific duties and forwarded to the General Services Administration's (GSA) Committee Management Secretariat for final review. Following a required public notification period, and the filing of the charter with Congress, the committee may begin operation.

DOE's Federal advisory committees provide independent advice to DOE program offices regarding the complex scientific and technical issues that arise in the planning, management, and implementation of the R&D programs. The Federal advisory committees generally provide guidance on new opportunities for enabling research, technologies, and facilities. Programs also periodically charge their advisory committees to address specific questions on new opportunities and provide guidance for carrying out these activities.

A designated Federal official is assigned to manage each committee, which comprises representatives of universities, National Laboratories, and industries involved in program-relevant scientific and technical R&D. Committee members are non-Federal experts who are appointed as special Government employees. Attention is paid to obtaining diverse membership, and balancing disciplines, interests, experiences, points of view, and geography. FACA requires that the committees be "fairly balanced in terms of the points of view represented and the functions represented and the functions to be performed." Open-access committee meetings are announced to the public at least two weeks in advance in the Federal Register; meeting agendas, presentations, and minutes are supposed to be publically posted. A full list of DOE's chartered Federal advisory committees can be found on the Federal Government's FACA database.

Although Federal advisory committees are used throughout much of DOE's programs, they are used and organized in a variety of ways. SC, for example, has formed Federal advisory committees to align with each of its six research program offices. Two of these Federal advisory committees (under High Energy Physics and Nuclear Science) offer advice not only to SC, but also to the National Science Foundation (NSF). The cocommissioned nature of these Federal advisory committees is unique to SC among DOE's program offices.

NE's advisory committee—the Nuclear Energy Advisory Committee (NEAC)—provides independent advice to the Assistant Secretary for NE on complex scientific and technical issues that arise in the planning, managing, and implementation of DOE's nuclear energy program. The committee is self-organized into several subcommittees to focus on specific aspects of NE's programs. NEAC periodically reviews the elements of the NE programs, and on the basis of these reviews, provides advice and recommendations on the programs' long-range plans, priorities, and strategies to effectively address the scientific and engineering aspects of NE's R&D efforts. For example, the Reactor Subcommittee is currently tasked with assessing NE's process for selecting the next test and demonstration reactor that will support continued R&D, and the Infrastructure Subcommittee is supporting NE's efforts to catalogue nuclear-related infrastructure in the Nuclear Energy Infrastructure Database.

OE works closely with their FACA Committee—the Electricity Advisory Committee (EAC)—which provides advice in implementing relevant portions of the Energy Policy Act of 2005 and the Energy Independence and

Security Act of 2007 as well as modernizing the Nation's electricity delivery infrastructure. The specific role of the EAC is to:

- advise on electricity policy issues pertaining to DOE;
- review and make strategic recommendations concerning DOE electricity programs and initiatives;
- advise DOE on issues related to current and future capacity of the electricity system (generation, transmission, and distribution, regionally and nationally);
- advise on the coordination between DOE and State and regional officials and the private sector on matters affecting electricity supply, demand, and reliability; and
- advise on the coordination between Federal, State and utility industry authorities required to cope with supply disruption or other emergencies related to electricity generation and distribution.

FE manages their FACA committees in a different manner from the other US/SE offices. Several distinct Federal advisory committees support the mission of FE, but while the other programs' Federal advisory committees advise program leadership, FE's Federal advisory committees directly report to the Secretary of Energy. A brief description of FE's five active Federal advisory committees captures the various diverse roles and purview of their activities:

- National Petroleum Council advises the Secretary of Energy on matters related to oil and natural gas, or the oil and natural gas industries.
- National Coal Council provides advice and guidance on a continuing basis as requested by the Secretary of Energy on general policy matters pertaining to coal.
- Methane Hydrate Advisory Committee advises the Secretary of Energy on potential applications of methane hydrate; assists in developing recommendations and priorities for the methane hydrate R&D program; and submits to Congress one or more reports on an assessment of the research program and an assessment of the DOE 5-year research plan.
- Ultra-Deepwater Advisory Committee advises on the development and implementation of programs related to ultra-deepwater natural gas and other petroleum resources and reviews and comments on the program's annual plan.
- Unconventional Resources Technology Advisory Committee advises on the development and implementation of programs related to onshore unconventional natural gas and other petroleum resources and reviews and comments on the program's annual plan.

Finally, while many DOE programs employ the services of FACA committees, such advisory bodies are not required. Because of the emerging and rapidly changing nature of the clean energy industry, EERE has leveraged workshops, seminars, and RFIs to gather external input toward its development process and relied less on FACA committees. EERE's FACA committees—the State Energy Advisory Board (STEAB), the Hydrogen and Fuel Cell Technical Advisory Committee, the Biomass Research and Development Technical Advisory Committee, and the Appliance Standards and Rulemaking Federal Advisory Committee—are focused on specific EERE programs.

Unless specified by law, advisory committees formed under FACA are the only type of committees that may comprise non-DOE Federal or contractor employees and be allowed to provide consensus advice to DOE.

3.3.2.3 Studies Performed by External Entities

DOE program offices sponsor outside studies that can influence its planning, programs, and budgets. Structured studies performed, for example, by the National Academies (composed of the National Academy of Sciences, the National Academy of Engineering, and the National Research Council) may be commissioned by DOE and/or other agencies; requested by Congress, OMB, or OSTP; or proposed by the Academies. Other external studies may be organized through professional-society-sponsored activities, or studies may be commissioned through other professional organizations (e.g., the National Academy of Public Administration, American Association of Arts and Sciences, and Council on Competitiveness). Most activities involve large numbers of inputs, sometimes collected over a period of a year or more using town hall meetings and Web-based mechanisms. Activities are usually organized by a cognizant DOE program office, and reports are generally public.

The following are examples of recent and influential reports issued by external entities:

- In 2013, the National Academy of Sciences issued a report titled "Improving the Assessment of the Proliferation Risk of Nuclear Fuel Cycles," which built upon coordinated efforts within NE and the NNSA and helped inform future planning of DOE's fuel cycle and nonproliferation activities.
- The Blue Ribbon Commission on America's Nuclear Future was formed in 2010 by the Secretary of Energy at the request of the President to conduct a comprehensive review of policies for managing the back end of the nuclear fuel cycle and recommend a new strategy. The strategy recommended eight key elements including consent-based siting of future nuclear waste management facilities, and prompt efforts to develop one or more consolidated storage facilities and geologic disposal facilities. In 2013, the Administration released its "Strategy for the Management and Disposal of Used Nuclear Fuel and High-Level Radioactive Waste." In support of this Strategy, DOE is pursuing preliminary generic process development and associated activities related to storage, transportation, and consent-based siting.

3.3.2.4 Interagency Committees and Working Groups

The Department coordinates several R&D program and policy efforts with other Federal agencies to best leverage resources to advance S&T areas of mutual interest and respective missions, to limit potential duplication of efforts, and to ensure mutual agreements on policies where needed. The Office of the US/SE, NNSA, ARPA-E, and other DOE entities coordinate a broad range of activities with other Federal agencies. These DOE entities may choose to employ one or more coordination mechanisms, including coordination of respective R&D areas through the National Science and Technology Council (NSTC); targeted coordination of R&D with other Federal agencies, including joint solicitations; statutory and Executive order-established committees (other than NSTC); and White House-convened ad hoc working groups. The Department also participates in jointly chartered Federal advisory committees, which were discussed in section 3.3.2.2. The remaining mechanisms are discussed below.

3.3.2.4.1 National Science and Technology Council

The NSTC is a key interagency coordinating entity of relevance to DOE. The NSTC was established by Executive order on November 23, 1993. This Cabinet-level council is the principal means within the Executive branch to coordinate S&T policy across the diverse entities that make up the Federal R&D enterprise. A primary objective of the NSTC is the establishment of clear national goals for Federal S&T investments in a broad array of areas spanning virtually all the mission areas of the Executive branch. The Council prepares R&D strategies that are coordinated across Federal agencies to form investment packages aimed at accomplishing multiple national goals.

The work of the NSTC is organized under five primary committees: Science; Technology; Environment, Natural Resources and Sustainability; Homeland and National Security; and STEM Education. Each of these committees oversees standing subcommittees and working groups focused on different aspects of science and technology and working to coordinate across the Federal government.

Examples of NSTC subcommittees or interagency working groups that DOE is actively engaged in because of our significant R&D investments and mission include the Networking and Information Technology Research and Development (NITRD) Program, which coordinates research for high-performance computers and networks; the Nanoscale Science, Engineering, and Technology (NSET) subcommittee, which coordinates the implementation of the National Nanotechnology Initiative; the subcommittee on Global Change Research, which coordinates and implements activities of the interagency U.S. Global Change Research Program; the subcommittee on Smart Grid; and the subcommittee on the Materials Genome Initiative.

3.3.2.4.2 Targeted Coordination of R&D with Other Federal Agencies

The Office of the US/SE and its program offices also engage in bilateral and multilateral activities with other members of the interagency. For example, SC engages in bilateral and multilateral coordination of RD&D with other Federal agencies for targeted research areas through such endeavors as the joint Office of Science/Biological and Environmental Research (SC/BER) and USDA annual solicitation on plant feedstocks genomics research, and the Office of Science/High Energy Physics (SC/HEP) and NSF collaborations on the Large Synoptic Survey Telescope (LSST) and Mid-Scale Dark Energy Spectroscopic Instrument (DESI) Projects.

Another important interagency activity that guides Science and Energy programmatic activities is the Mission Executive Council (MEC), an executive-level forum at which strategic planning for the utilization of DOE National Laboratory capabilities and other laboratories is coordinated and discussed. Participating agencies are DOE, DHS, DOD, and the Office of the Director of National Intelligence (ODNI). The US/NS chairs the MEC, and the US/SE is a participant.

The Department also engages in a number of interagency activities through memorandums of understanding (MOUs). For example, in July 2010, DOE and DOD signed an MOU entitled "Concerning Cooperation in a Strategic Partnership to Enhance Energy Security." In the 2010 Quadrennial Defense Review, the DOD expressed intent to partner with other U.S. agencies to research, develop, test, and evaluate new sustainable energy technologies. The DOD aims to speed innovative energy and conservation technologies from laboratories to military end users. DOE has been a long-time supporter of projects aimed at improving energy efficiency and renewable energy efforts across the country, particularly with the Military Services. The DOE-DOD MOU was signed to establish a formal relationship between the Departments on energy matters to accelerate the development of clean energy technologies and bolster national security. The MOU established an executive-level forum to ensure integrated planning for the utilization, through DOE, of the unique National Laboratory capabilities, encouraging optimal alignment with the highest priority national security needs in a coordinated, effective, and efficient manner. The activities under the MOU are coordinated by the Office of the US/SE.

Individual Science and Energy program offices also collaborate directly with other agencies. For example, OE works with DHS and other Government agencies on the Electricity Sub-Sector Coordinating Council (ESCC) to provide effective coordination of energy sector efforts to ensure a secure, reliable, and resilient energy infrastructure. The ESCC addresses initiatives that include policy considerations, program goals, and communication across Government as well as between the Government and the private sector to support the Nation's energy security and resilience mission in accordance with the Presidential Policy Directive 21: Critical Infrastructure Security and Resilience, the National Infrastructure Protection Plan (NIPP)2013 as well as the National Security Strategy.

3.3.2.4.3 Statutory and Executive Order-Established Committees

The Science and Energy program offices also participate in other statutory and EO-established committees beyond the NSTC. For example, IE's primary interagency activities are guided by the White House Council on Native American Affairs, created by Executive Order 13647 on June 26, 2013, to coordinate Federal Government engagement with tribes, with the goal of promoting and sustaining more prosperous and resilient tribal communities. The White House Council on Native American Affairs encompasses the Federal Government's effort to promote "sustainable economic development, particularly energy, transportation, housing, other infrastructure, entrepreneurial, and workforce development to drive future economic growth and security."

Energy Secretary Moniz and Interior Secretary Sally Jewell committed to establishing a subgroup on energy under the White House Council on Native American Affairs, whose overarching goal is to "assist in the development of prosperous and resilient tribal communities as well as the restoration and protection of tribal lands." To support this commitment, DOE and DOI initiated interagency discussions with the USDA and EPA to begin collecting information about the major energy, energy infrastructure, and environmental Federal programs and regulations that are, or can be, leveraged to support energy development and deployment in Indian Country. In addition, the Departments have begun to collect information from other Federal agencies that administer energy and energy infrastructure development or related economic development programs for tribes, tribal businesses, and other tribal entities.

EERE participates in several interagency activities that guide its planning activities and promote alignment of mutual interests. For example, EERE's Office of Bioenergy Technologies participates in the interagency Biomass Research and Development Board, which was created by the Biomass Research and Development Act of 2000. The Biomass R&D Board is cochaired by DOE and USDA and includes participation of the DOE Office of Science and more than nine other Federal agencies.

3.3.2.4.4 White House-Convened Ad Hoc Working Groups

The Science and Energy program offices also participate in ad hoc working groups convened by the White House to address high-priority items to meet Administration or National-level goals. For example, NE participates in the Civil Nuclear Energy Working Group, which is an interagency coordination mechanism led by the National Security Staff Director of Nuclear Energy. This working group was established to develop an all-of-government common messaging and strategies approach to support U.S. industry in key nuclear power markets, including countries with both established and emerging nuclear power programs.

3.3.2.5 Requests for Information and Funding Opportunity Announcements

To facilitate a program's future direction in a particular scientific or technical area, new ideas and information are often sought from industry through RFI or FOA. An RFI is an inquiry to help with agency planning and does not further commitment the Government to take any action or expend any Federal funds.

FE, for example, issued an RFI in FY 2014 to help identify ideas for recovery of rare earth elements (REE) from dilute and highly distributed sources. The RFI requested information on promising options that are either available for large-scale testing today, or are currently in R&D stages and scheduled to become available for large-scale testing in 2020 and deployment in the 2025 time frame. This information was valuable not only for program planning purposes, but also as an aid in preparation of a Report to Congress; to identify and assess technology and knowledge gaps; to forecast potential U.S. benefit; to contribute to the development of a balanced multiyear R&D program; and to assist in establishing content for the preparation of one or more competitive FOAs to solicit R&D projects in the area of REE recovery from coal and coal byproducts.

Program offices can also use FOAs for planning purposes. A FOA is the first step in the DOE financial assistance process, which includes grants, cooperative agreements, and loans. Program offices sometimes use FOAs to solicit new ideas for RDD&D portfolios. For instance, SC solicits new ideas from the scientific community through a continuously open FOA each year that invites proposals for new, renewal, or supplemental support of research in areas of interest to SC.

DOE program offices may also use FOA responses to gauge the interest of external stakeholders in a particular topic. For example, FE's Crosscutting Research Technology Program may ask for responses to FOAs for advanced sensor information that FE could then use to broaden or narrow the scope of an FOA to ensure that it results in a successful research project.

3.3.2.6 National Meetings and S&T Conferences

S&T meetings and conferences, hosted largely by scientific and engineering professional societies or industry or trade organizations, provide regular forums for S&T professionals to gather and present major research findings, or new research methodologies or capabilities, in the form of oral presentations or posters. These meetings offer opportunities for S&T professionals to engage in career development, to meet and share ideas, foster within-discipline or cross-disciplinary partnerships, and build professional networks, as well as coordinate major community input on a particular topic area or initiative. DOE program office S&T staff participation in these types of meetings is essential for program planning.

To conduct effective planning and research portfolio management, a program manager's expertise must remain current to enable them to recognize new opportunities for high-risk, high-return research areas important for advancing the S&T fields within their programs. Program manager participation in major meetings sponsored by the scientific and technical professional societies and associations, such as the American Chemical Society, American Institute of Chemical Engineers, American Wind Energy Association, American Physical Society, American Geophysical Union, American Nuclear Society, American Rock Mechanics Association, and the Materials Research Society, is one of the most productive mechanisms by which program managers can stay informed of the cutting-edge discoveries and discussions, communicate with investigators and leaders of the field, communicate research needs and research priorities to the S&T communities, and stay abreast of the latest scientific and technical literature.

Program managers' participation in major S&T meetings and conferences also provides the kind of direct interactions with research performers needed to cultivate professional relationships required to later successfully solicit peer reviewers among the community.

3.3.3 Planning for DOE Designated User Facilities and Shared R&D Facilities

Because of the level of investment required to construct, maintain, and operate the typically multi-decadal infrastructure associated with DOE designated user facilities and shared R&D facilities, DOE engages in extensive planning when building or transitioning designated user facilities.

3.3.3.1 Planning for New Designated User Facilities

The creation of a new designated user facility requires an extensive planning process, which typically involves broad input by the S&T community and evolves over a period of years. The time between the original conception and call for a facility and its ultimate commissioning has sometimes been as long as two decades. Throughout the process, there is continual dialogue with the wider community of scientists and experts who will either contribute to the conception and design of the facility and/or plan to take advantage of it as users when it becomes operational. Therefore, bringing a major new user facility to fruition requires the effort of many minds as well as continuity in planning and disciplined focus by the sponsoring DOE office over a sustained period.

SC has evolved an effective process to take major facilities successfully from original concept to construction, commissioning, and operations. The process includes significant ongoing dialogue with the scientific community on long-range planning. That dialogue often includes one or more of the Office's six formal Federal advisory committees, the National Academy of Sciences, and specialized scientific workshops organized by SC that bring leading researchers together with SC Federal program managers. The purpose of this ongoing dialogue is to help chart new directions in science and to help identify the new facilities that will be needed to accomplish scientific goals and forefront research.

The initial dialogue is centered on two primary elements: scientific need—including pushing the boundaries of science and innovation—and alignment with DOE's mission. This is true regardless of the type of field. A strong sense of strategic direction and pushing the frontiers of scientific disciplines is a hallmark of the SC approach to sponsoring both research and scientific user facilities.

Several factors are considered in the conception of a new facility. One factor is technological readiness: it makes sense to embark on the construction of a new user facility only if the technology is at the point where it can be successfully designed and implemented. Typically these projects require significant R&D on the core technology and the design of the facility before one can proceed to actual construction. Another major factor—and a major constraint—is project cost. Stable and realistic funding profiles are essential for project success. As promising as a proposed facility may be, it must also fit into realistic multiyear budget planning constraints, and its promise must be weighed against other program investments, including support for research and ongoing facilities operations, that compete for funding.

A new facility may be needed to address a new scientific thrust, but a lack of technological readiness and/or funding constraints may delay its implementation for some time. For example, the $1.4 billion Spallation Neutron Source (SNS) at ORNL was originally proposed in the so-called Seitz-Eastman Report from the National Academies in 1984; construction did not begin until 1999, and SNS was not commissioned for operations until 2006, with the project completed on time and within budget.

The applied energy technology offices have generally adopted SC's planning model. For example, EERE has built two designated user facilities in recent years, with the National Renewable Energy Laboratory's (NREL) Energy Systems Integration Facility (ESIF) being the most recent. EERE generally follows SC's process, but as it focuses more heavily on later stage and commercially relevant technologies, it also accounts for the need to move more quickly in order to be responsive to dynamic industry needs.

3.3.3.2 Planning for Decommissioning and Transitioning Designated User Facilities

DOE's designated user facilities do not operate forever. The decision to decommission facilities is just as important as the decision to create them. It is important to understand when a scientific user facility has completed its useful life; often this is when new technologies make possible either an upgrade or a replacement facility that will further advance science. In this way DOE can sustain U.S. leadership in our areas of highest priority while maintaining an appropriate balance of our investments among research, facility construction, and facility operations. As noted above for designated user facilities, in particular SC's scientific user facilities, the time between the original conception and call for a facility and its ultimate commissioning has sometimes been as long as two decades. During this time, the S&T community is also assessing what the natural lifetime of existing facilities may be, considering a facility's productivity, its state-of-the-art nature (or waning thereof), and the compelling opportunities afforded by the timely investment in the next generation facilities. DOE's program offices seek considerable input on this topic using several of the planning processes noted earlier in this chapter. For example, in 2013, as one of the Department's agency priority goals (APGs), SC charged each of its six Federal advisory committees to weigh in on SC's existing and proposed user facilities and provide their expert input on the ability of each facility to contribute to world-leading science in the next decade (2014–2024).

When planning for a next-generation facility, timing of the closure of the older facility and commissioning of the new, next-generation facility is essential to ensure continuity in the availability of the facilities for the user community. For example, once ONRL's Spallation Neutron Source (SNS), one of the world's most advanced neutron scattering facilities, became operational in 2006 and experimental stations came online as users began to transition to the more advanced facility, SC closed the Intense Pulsed Neutron Source (IPNS) at ANL in 2008. The National Synchrotron Light Source at BNL ceased operations in September 2014, as the operations of NSLS-II, the next-generation photon source, began to ramp up rapidly in 2014 and 2015. Often the scientific user community that intends to use the new facility self-assembles an official user group that is focused on further developing the science case for a given facility and advocates for the needs of the user community during project construction. A user group may also help ensure user readiness once the facility is commissioned. The host institution of a new facility may play a strong role in stewarding a new, associated user group, or will engage significantly with a user group that has already self-assembled.

The sponsoring program office may consider the appropriateness and value of transitioning a designated user facility to a shared R&D facility model, particularly when the facility provides unique capabilities for researchers and industry, but the level of demand no longer supports an open-access model. For example, SC's Combustion Research Facility (CRF) at SNL opened to researchers in 1980 and became a designated user facility in 1999 after a significant expansion. In 2009, SC transitioned the CRF to a shared R&D facility where it remains a productive center for research and collaboration with visiting researchers and industrial partners. The 88-Inch Cyclotron at LBNL started operations in 1963 and has provided beams of protons, heavy ions, and medium energy particles for research in nuclear science and astrophysics, and fundamental interactions and symmetries for several decades. The facility also provides a unique radiation-testing environment for technology and national security applications. In 2004, SC transitioned the 88-Inch Cyclotron to a shared R&D facility for conducting basic research and technology development by LBNL and University of California (Berkeley) scientists and students, and DOE entered into an interagency agreement with the U.S. Air Force (USAF) and the National Reconnaissance Office (NRO) to continue to allow USAF and NRO the ability to directly support their use of the facility for experimentation and radiation testing related to their national security space mission.

The disposition of facilities requires considerable planning as well. For a large facility, the decommissioning to a safe storage mode, or the decommissioning and demolition of a facility, can cost tens of millions of dollars. The disposition of facilities is guided by DOE Order 430.1B, "Real Property Asset Management," and associated guides, and requires that a disposition and long-term stewardship (LTS) plan be developed for the facility. Disposition includes stabilizing, preparing for reuse, deactivating, decommissioning, decontaminating, dismantling, demolishing, and/or disposing of the facility and associated assets. Disposition and LTS requirements are directly influenced by decisions made during the acquisition, maintenance, and operation of the facility. When making the decision regarding the disposition of a facility, a balance must be established between accomplishment of the DOE mission and the disposition and LTS required to reduce risks to workers and the public and minimize real property asset life-cycle costs.

In many instances, deactivating and decommissioning a facility to a "safe storage" state is a cost-effective way to preserve the site and major facility components for possible future use in the construction of new facilities. For example, the Linac of the Stanford Linear Collider at SLAC, which produced high-energy electrons for cutting-edge high energy physics research for almost 50 years on the SLAC site, ceased operations in 2008, and its two-mile-long linear accelerator was repurposed for the construction of the Linac Coherent Light Source, which started operations in 2010 and is the world's first hard x ray free-electron laser. The 50-foot wide electromagnet that was central to the Alternate Gradient Synchrotron facility at BNL, which ceased operations in 2002, was recently moved more than 3,200 miles to Fermilab to be used as the centerpiece for the planned Muon g-2 experiment. The Muon g-2 experiment will investigate the properties of an elusive subatomic particle called the muon.

Over the past two decades, SC has designed, built, and commissioned more than 20 new formal user facilities; and during this period, SC also closed over 15 user facilities. Figure 3.2 provides a historical illustration of the SC facilities investments over the past 25 years. The figure indicates user facilities, color-coded by the sponsoring SC research program, that have been commissioned and also terminated, as indicated by the "(T: [year])," in order to pursue the most promising new investments in research, tools, and major facilities.

3.3.3.3 Planning for Shared R&D Facilities

Much like designated user facilities, shared R&D facilities are planned and operated specifically to address DOE mission needs while being relevant to the R&D community. For example, EERE's shared R&D facilities must be responsive to the needs of a rapidly changing clean energy industry and therefore require strong input from industry stakeholders to be effective.

Feedback on the capabilities or operations of shared R&D facilities is gathered through program workshops or annual program peer reviews. In some cases, National Laboratories also makes extensive use of their own external advisory committees to help ensure that its facilities and operations are responsive to industry needs. This is the case, for example, with NREL's facilities.

In the case of construction of new facilities, significant stakeholder input is gathered. In addition, program leadership must determine that the capabilities of these facilities are among recognized core S&T capabilities necessary to achieve the program's mission. EERE, for example, demonstrates their stewardship responsibilities throughout their life cycles by engaging the National Laboratories to clearly identify necessary facilities, funding them directly through AOPs (i.e., not competing them), and encouraging industry utilization. Both core S&T capabilities and major research facilities are decommissioned or transitioned to other uses when appropriate and, when possible, with advance notice.

3.3.4 Program Planning for DOE National Laboratories

The Department's Science and Energy program offices and the National Laboratories engage each other in their respective planning processes to ensure that the missions of all organizations are designed for success. Because of the detailed nature of their long-term planning (both for R&D activities as well as infrastructure needs), there are formal processes governing this information exchange.

The Office of the US/SE and its Science and Energy program offices receive routine formal input from DOE National Laboratories through standard processes. The level and specificity of the input varies by program office and by Laboratory, but generally serves the purpose of providing the sponsoring program office information on the DOE Laboratory's funding needs for ongoing or proposed activities at the Laboratory for the next fiscal year and projected out-years.

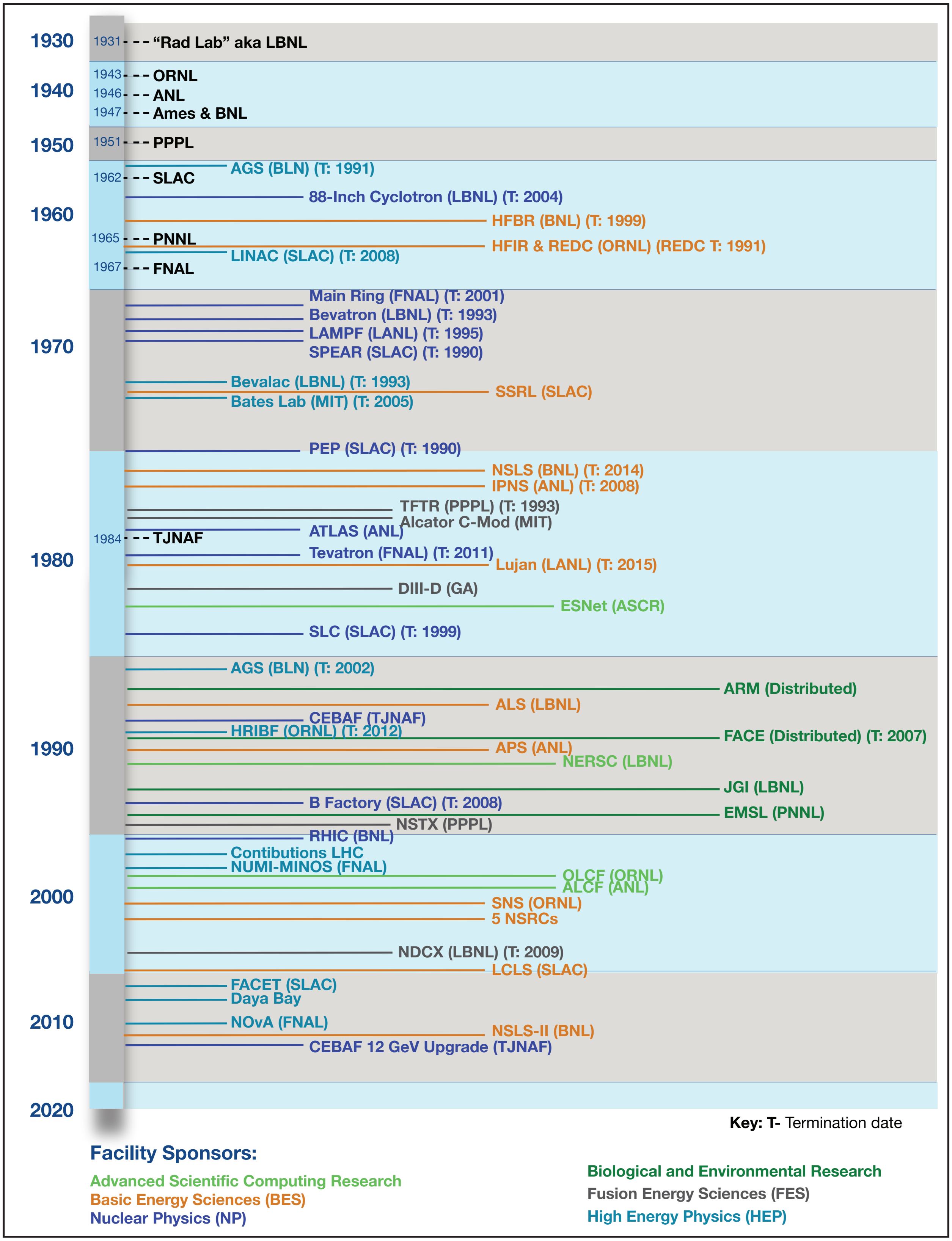


Figure 3.2: Office of Science Scientific User Facilities by Date the Facility Became Operational.
Of the more than 55 scientific user facilities established since 1960, nearly half have been terminated to date (A listing of all figure acronyms can be found in Appendix C.).

As part of the Department's annual budget formulation process, and in accordance with DOE Order 130.1, the DOE Office of the Chief Financial Officer transmits the field budget call to each DOE program office in the December time frame, two years in advance of the budget execution year. The field budget call includes guidance on matters such as assumptions for escalation rates for DOE projects. In coordination with the program office's site office(s), guidance is transmitted to the DOE Laboratories, who in response prepare field work proposals (FWPs) for ongoing work anticipated in the fiscal year being formulated, as well as FWPs for new work requested by the Laboratory. For some program offices, the FWPs for new work must be submitted through a formal solicitation process established by the sponsoring program office. The FWPs inform the program offices' internal budget formulation efforts.

At the time of the field budget call, or shortly following, and in advance of the kick-off to a program office's internal budget formulation process, the program office's S&T programs may host briefings from the DOE Laboratories that are leading substantial research or facility development efforts sponsored by the program. These briefings may also take place during site visits by program staff to DOE Laboratories. The briefings provide additional context for the FWPs that have been submitted to the program office. The formal briefings are typically focused on the near-term (1–3 years) to inform budget formulation, but must take into consideration long-term commitments and out-year budget needs. These briefings help the program office formulate reasonable and justifiable budget requests, but no funding commitments are made to the Laboratories at that time, as funding requests are subject to appropriations.

DOE Science and Energy program offices also engage in annual strategic planning for the Laboratories they steward. Each program office is required under DOE Order 430.1B, Real Property Asset Management, to establish a performance-based approach to real property asset management that links asset planning, programming, budgeting, and evaluation to program mission projections and performance outcomes. As part of meeting this requirement, program offices are responsible for having a ten-year site plan for each DOE Laboratory that is updated annually. These planning activities are discussed in detail in Chapter 4.

3.4 Program Management and Evaluation

Section 3.4 provides an overview of recognized best practices for science and energy program and project management and evaluation practices.

3.4.1 Program and Project Managers as Subject Matter Experts

Good program and project management begins with placing a high priority on hiring and ongoing training of the best experts. Program and project managers in the Science and Energy program offices must be experts in fields of S&T relevant to the portfolios they are managing. Program managers are expected to maintain a balanced R&D portfolio that includes high-risk, high-reward activities to maximize the program's potential to achieve mission goals and objectives. They conduct scientific program planning, execution, and management across what may include a broad spectrum of S&T disciplines, and they communicate R&D interests and priorities to the S&T communities. And they must ensure rigorous external merit review of research proposals, selection of appropriate peer review experts, development of award recommendations informed by expert evaluations received during merit review processes and internal program policy factors, and regularly evaluate research programs.

Knowledgeable and skilled Federal program and project managers are essential for managing complex S&T research and facility portfolios, and as such, program offices place a high priority on recruiting and retaining highly qualified talent from academia, DOE Laboratories and the private sector who wish to pursue a career in public service. Relatively new Federal human resources authorities serve to address the universal challenge of an aging Federal workforce by allowing for a phased retirement in order to facilitate the mentoring of new employees or new work scope assignments of established employees when a Federal employee retires. Authorized under Section 313 of Division D of the Consolidated Appropriations Act, 2014, (Public Law 113–76), the Excepted Service hiring authority can be used to enhance DOE's recruitment of exceptionally well-qualified candidates into scientific, engineering, or other critical technical positions for up to four-year appointments as Federal employees to advance DOE's strategic mission.

DOE's Science and Energy programs also benefit from the ability to recruit temporary technical assistance from subject matter experts for specific projects or programmatic activities. Several mechanisms exist to bring in these experts for short-term assignments, including detail appointments of contractor employees of DOE National Laboratories, Intergovernmental Personnel Act (IPA) Assignments, American Association for the Advancement of Science (AAAS) S&T Policy Fellowship Program, and the Presidential Management Fellowship Program.

3.4.2 Open Competition and Merit Review of Proposed R&D Activities

DOE establishes and maintains high-quality R&D portfolios through well-recognized best practices in program management, including (1) the open competition of funded work, and (2) using merit review by external subject matter experts to inform Federal funding decisions. The Federal Acquisition Regulation, 48 CFR Parts 1–51, its supplement, the Department of Energy Acquisition Regulation, and other policy documents, identify the requirements and guidelines for Federal contracts, including the DOE's Management & Operating (M&O) contracts for managing DOE's National Laboratories. DOE's requirements for financial assistance—issued as grants or cooperative agreements—are governed by 2 CFR 200, 2 CFR 910, the DOE Merit Review Guide for Financial Assistance, the DOE Financial Management Handbook, and related documents.

3.4.2.1 Competitive and Merit-Based Funding Decisions

Open competition encourages all capable and qualified entities to apply for Federal funding to perform DOE's mission critical work. The M&O contracts are periodically openly competed and include substantial scopes for basic and applied research, technology development and deployment, facility construction and operations, and complex mission-essential functions such as environmental clean-up and nuclear weapons stockpile stewardship. Once awarded, DOE Laboratories are held to high standards of performance. Specifically, ongoing work is regularly reviewed, while new tasks assigned to DOE Laboratories after the base M&O contract has been awarded are generally done following peer review of field work proposals submitted by the Laboratory to DOE. Overall DOE Laboratory performance (mission accomplishment and management) is appraised on an annual basis.

The CFR for DOE for financial assistance (2 CFR 910.126(a)) specifies that "DOE shall solicit applications for Federal financial assistance in a manner which provides for the maximum amount of competition feasible."

Each Science and Energy program office makes a determination of what portion of its portfolio it will openly compete among DOE Laboratories, academia, and the private sector. The exact portion varies by program office depending on its mission needs, technology characteristics, and identification of the most qualified and capable performers. Guided by the requirements under the CFR, the Science and Energy programs issue FOAs, conduct review and selection processes, negotiate awards, and implement award oversight. Rigorous merit review of proposals received through open FOAs or FWPs submitted by DOE Laboratories contributes to sound funding decisions by program offices.

3.4.2.2 Merit Review

The Department's RDD&D activities, whether at universities, National Laboratories, or private sector organizations, are evaluated at multiple stages. The primary mechanism of evaluation for financial assistance awards is through a process called merit review. Merit review is defined as a thorough, consistent, and objective examination of applications based on preestablished criteria by persons who are independent of those submitting the applications and who are knowledgeable in the field of endeavor for which support is requested. Formal merit review processes are conducted using several formats and may vary depending on the stage at which a merit review is applied, the type of R&D activity being reviewed (e.g., research vs. facility focus), and by the regulations and the program policies under which a program office operates.

Program offices generally review applications under a common process using one or more of the merit review mechanisms outlined in Appendix B, even though the funding award mechanism (e.g., grant, cooperative agreement, contract, or M&O work authorization) may be different depending on the institution type of the applications selected for award. Depending on the work scope, program need, and understanding of capabilities of various institutions, DOE program offices may solicit R&D applications on a limited basis. For example, DOE may restrict eligibility to certain types of institutions, or solicit applications or proposals on a noncompetitive basis, consistent with DOE financial assistance regulations and Federal Acquisition Regulation.

DOE program offices may also use merit review processes in their evaluation of ongoing RDD&D activities as a means of assessing progress of activities; identifying the quality of S&T output; identifying S&T challenges; and identifying performance and operational challenges and potential actions to take.

Merit Review Mechanisms

Depending on the needs of the program, the Federal program manager may decide to use one of five mechanisms (mail review, panel review, internal review, site visit, and reverse site visit) or a combination of any of these mechanisms (such as a mail/panel combination review). More information on the use of these mechanisms is provided in Appendix B.

3.4.3 Evaluation and Review of Ongoing RDD&D

As noted above, the Department's RDD&D activities, whether at universities, National Laboratories, or private sector organizations, are evaluated at multiple stages during their execution phase. The general merit review processes described above also serve as examples of some of the types of processes used for the evaluation, including peer review (a type of merit review) of ongoing, in progress, RDD&D activities at defined periods after the work is awarded and initiated. The following two subsections describe how the Science and Energy programs oversee basic and applied RDD&D activities, respectively.

3.4.3.1 Evaluation of Ongoing Basic Research Activities and Facilities

The evaluation of ongoing basic research activity awards may vary depending on the size of the award. For small or single investigator research financial assistance awards, the primary evaluation may be done by the program manager's review of required annual progress reports throughout the award term and the end-of-award term final report. For multiyear awards, program managers use annual progress reports to ensure sufficient progress on the proposed research is being made each year to justify continuation funds for subsequent award terms. For complex, small-scale research activities, program managers may have regular conference calls with project principal investigators (PIs) to assess progress. Additionally, the PIs will often notify the program managers when research papers have been published in the scientific literature, or other milestones are accomplished.

For large and multi-institution research activities, external peer reviews are often conducted during the award period to assess management and/or scientific progress. These are typically performed as panel reviews and can involve a site visit or reverse site visit.

For SC activities, panels of subject matter experts are assembled to review a research project. As part of the evaluation, awardees will prepare documents for evaluation that demonstrate progress towards research goals and milestones defined in the funded award, research results (both published and unpublished), discussion of scientific, technical, and/or management challenges that have been identified, and plans for overcoming or addressing those challenges. These scientific and management peer reviews are confidential. Information provided by reviewers informs program management decisions for the ongoing management of research awards. The review information, a program summary of the overall findings, and program office instructions or guidance based on the review findings, is provided back to the PI.

Some examples of such reviews include reviews of the three DOE BRCs, where each has received a 5-year award at $25M per year. As part of the initial 5-year award, BER held management reviews of the three BRCs within the first 3 months of the award term to assess how well their management teams and management plans were being formed. Each of the BRCs then underwent an annual scientific review by peer review panels, including site visits or reverse site visits, to determine how well the BRCs were performing relative to their proposed research plan and stated milestones. The BRCs are still reviewed annually under their current awards.

The EFRCs awarded in 2010 are another example. Each EFRC was given a 5-year award at $2M–$5M per year. BES conducted management reviews of all 46 EFRCs awarded in 2010 within the first 3–5 months to assess how well their management teams and management plans were being formed. Each of the EFRCs underwent a midterm scientific review by peer review panels during the 3rd year of the EFRC award terms to determine how well the EFRCs were performing relative to their proposed research plan and stated milestones.

SC's large core research activities at DOE National Laboratories are also evaluated through external peer review on a regular basis, typically every 2–3 years in the form of a site visit or reverse site visit, as part of the process for program decisions for ongoing funding. This typically includes the entire research portfolio in a particular subject area funding by an SC program office at a particular Laboratory; for example, BES will conduct a peer review of the full materials sciences and engineering portfolio that it funds at a particular Laboratory such as Ames or ANL. SC program offices may review the entire portfolio of core research in a particular programmatic area at all funded DOE Laboratories in a given year; for example, BER might use site visit reviews to review the core genomic sciences research it supports at DOE Laboratories that maintain substantial genomic sciences research efforts, and may use reverse site visits for smaller DOE Laboratory efforts in genomic sciences.

SC projects for major items of equipment, such as the development of major instrumentation or detectors for scientific user facilities, or for the construction of scientific user facilities, are implemented either formally under the processes defined in DOE Order 413.3B, Program and Project Management for the Acquisition of Capital Assets, Program and Project Management for the Acquisition of Capital Assets, discussed later in this chapter, or under the principals of the DOE order. Such projects would be subject to regular reviews by SC's Office of Project Assessment.

3.4.3.2 Evaluation of Ongoing Applied Development, Demonstration, and Deployment Activities

The evaluation by the applied energy technology programs is similar in nature to those used by SC, although they vary in the details of their execution. As with DOE's basic energy research, the applied development and demonstration activities are constantly being reviewed and evaluated.

EERE, for example, performs in-progress, formal peer review procedures, using objective criteria and qualified and independent reviewers, to judge the technical, scientific, and/or business merit, and evaluate the achieved or anticipated results These reviews typically occur every other year and cover 80 to 90 percent of the program's RDD&D funding. Managers and staff in EERE provide the resources and other support necessary to conduct these reviews properly. The review process is tailored to the level of review (activities in an entire program, portfolio of projects, or individual project), to characteristics of the program/project being reviewed, and to the purpose and goals of the review. The findings of these in-progress reviews are considered by EERE managers, staff, and researchers in setting priorities, conducting operations, and improving projects.

NE activities subject to evaluation on a regular basis are reviewed using a variety of mechanisms including annual technical working group meetings held throughout the year and annual PI meetings. Working groups comprising Federal program managers and National Laboratory, university, and industry researchers meet regularly to review the progress of existing work and discuss future opportunities. To supplement its review process, NE uses a dedicated software package called the Program Information and Collection System (PICS:NE), which tracks work package/project performance and financial performance. Researchers provide updates to their performance against milestones and associated financial data. This information is collected in PICS:NE and rolled up for program manager and upper management review. NE also uses the PICS:NE to perform annual go/no-go reviews for multiyear competitive projects to confirm appropriate performance for continuation and transition reviews to inform future actions at the completion of current activities. NE discusses the operations of its designated user facilities as part of regular working group meetings and conducts specific, dedicated reviews and site visits, as needed. The DOE Idaho Operations Offices is charged with overseeing the day-to-day operations of NE's facilities at the INL.

OE evaluates ongoing projects and programs using formal, documented peer reviews, with objective criteria and qualified and independent reviewers. These reviews are used to evaluate the technical, scientific, and/or business merit; evaluate the achieved or anticipated results; and review the productivity and management effectiveness of programs and/or projects. Using a standard set of selection criteria, each technology program selects projects to be peer reviewed that represent the program's project portfolio. Selected projects undergo a rigorous review during which the PIs summarize the status of their research, accomplishments, and future planned activities to an independent panel of experts. Projects are evaluated using a standard set of metrics to assess the progress of the project team towards achieving the program goals as well as specific project milestones of the research. Following the peer review, OE uses the results to guide and redirect the projects, as appropriate, underscoring OE's commitment to funding and managing a portfolio of high-quality research.

FE follows similar peer review processes for the majority of its projects. Peer reviews are conducted on a biannual basis where external subject matter experts identify strengths and weaknesses, recommendations, and action items for each project reviewed. As part of routine project management, FE project managers coordinate with project PIs to have regular project briefings to interested DOE stakeholders. These meetings focus on the project status from both a technical and administrative perspective. These are usually conducted on at least a semiannual basis either by remote Web-conference or an in-person meeting at a DOE site or the project location. This is supplemented by review of quarterly progress reports, telephone calls, and site visits, as needed. The end-of-award final technical report is also reviewed and approved.

FE's demonstration activities—carried out under the Clean Coal Power Initiative (CCPI), Industrial Carbon Capture & Storage (ICCS), and Carbon Capture & Storage (CCS) programs—are funded primarily through financial assistance awards to non-Government organizations. Individual awards are evaluated in a periodic manner that is aligned with, and staged by, the normal progression of large-scale project implementation: definition, design, construction, and operation. Using this "stage-gate" approach, FE project awards are structured with these distinct phases, and evaluated within these phases, each concluding with a decision point on progression to the next project phase. Awardees must demonstrate project performance in meeting the objectives of the phase, with objectives being completed before DOE authorizes them to proceed into the next phase. DOE funding is also aligned to these phases, and awardees are authorized to expend only DOE funds that have been allocated to the current, authorized phase. The portfolio of demonstration projects is also assessed from a program implementation perspective annually by FE during budget development. Project progress is evaluated against the program goals to discern which aspects are at risk given any technical, schedule, financing, or environmental permitting problems that may have arisen with the projects. In this way, needs are identified for any gaps that have become likely, and program actions are then developed to address or mitigate the goal risks identified.

3.4.4 Regular Principal Investigator and Contractor Meetings

Another program management best practice of the US/SE program offices is the establishment of regular (e.g., annual) PI program meetings. These PI meetings bring together the scientists and engineers currently funded within an R&D portfolio along with facility users and DOE program managers to share R&D results and discuss possible future directions. Periodic meetings such as these are opportunities for university, DOE Laboratory, and private sector awardees and contractors to share results with the relevant S&T community supported within the same portfolio or across related portfolios; engage with DOE program managers who manage the research portfolios as well as relevant program managers from partnering Federal agencies; and learn firsthand about planned research priorities and opportunities. These types of meetings are essential for an S&T agency that has a long-term commitment to R&D in order to accomplish mission goals. Program offices from SC and from the applied energy technology offices may also plan joint PI meetings or colocated PI meetings to foster productive discussions across the basic research and applied research and technology development communities.

SC program offices typically hold PI meetings annually for each subprogram area. The primary focus of these meetings is for SC-funded researchers to present their research findings. PI meetings are attended by SC program managers associated with the research portfolio. SC program offices may hold joint PI meetings encompassing more than one subprogram area to help foster interdisciplinary discussions and new ideas in areas where the program offices want to see better collaboration and integration of research. Such meetings usually take the format of a scientific professional society meeting, with a combination of plenary talks and parallel sessions. Program offices may also include a mini-scientific workshop to brainstorm new ideas within the scientific community and relevant to the SC program office's future planned directions.

Within the applied energy technology offices, EERE encourages semi-annual face-to-face meetings with PIs and contractors to discuss project progress, inclusive of video teleconference (VTC) meetings. In addition, EERE's programs hold annual or biannual peer reviews whereby the PIs currently funded within an R&D portfolio come together with DOE program managers to share results, evaluate project progress, and discuss possible future directions. For example, EERE's Building Technologies Office convened their latest peer review in April 2015; the agenda and reports from the agenda are posted online for public consumption.

NE hosts similar processes with its funded researchers. Working group meetings are held throughout the year in each technical area and are typically held quarterly. The purpose is to review the progress on existing work and discuss future opportunities. Annual meetings are held at the programmatic level to discuss research results, collaborations, and future opportunities—a process analogous to the Building Technologies Office example above.

FE hosts regular annual meetings for most of its applied technology development programs. These are two- to three-day meetings where presentations and poster sessions are used to disseminate technical information. Topics include programmatic updates, technical presentations for funded projects, and open discussions where new ideas, approaches, and peer feedback are encouraged. These regular meetings are supplemented by ad hoc, smaller topic meetings, on an as-needed basis as well as participation by DOE personnel in technical conferences, frequently in leadership roles, pertinent to program technologies.

3.4.5 Assessments of Overall DOE Federal Program Office Management

The previous sections have focused on the processes by which the US/SE program offices use processes to review the RDD&D activities that they sponsor; this section, by contrast, describes the processes by which the program offices seek external evaluation of their own internal business practices in order to maintain high standards for program and project management and to garner external advice for continuous improvement. The mechanisms described for SC and NE, who charge their Federal advisory committees to conduct such reviews of internal processes, are well-recognized practices used by other large Federal R&D organizations such as the NSF and the NIH.

3.4.5.1 Office of Science Committee of Visitors Reviews

SC routinely uses its FACA committees to assess the efficacy and quality of the processes used to solicit, review, recommend, monitor, and document funding actions and to assess the quality of the resulting portfolio. The national and international standing of the funded program elements are part of the evaluation of the breadth and depth of the portfolio. The portfolio under review by a committee of visitors (COV) generally includes all actions—both awards and declinations—for universities, National Laboratories, and industry administered by the SC program office for a set period of time, usually three years.

Every SC program element (typically either at the program office level or division level) must be reviewed by a COV at least once every three years. Each COV panel is composed of a group of recognized scientists and research program managers with broad expertise in the designated program areas. Panel members are familiar with DOE research programs; however, a significant fraction of the COV membership does not receive DOE funding. Each panel member signs a Conflict of Interest statement. The COV process includes a two- to three-day site visit to review documents and meet with SC program managers. The COV prepares a report, which is presented to the full Federal advisory committee at a public meeting. The Federal advisory committee reviews and may make modifications to the report prior to acceptance. Following acceptance, the report is transmitted to the SC Director and released publicly. The Associate Director of SC in charge of the program element under review provides a response to the review within 30 days of the acceptance of the report by the Federal advisory committee. All of the SC COV reports and official SC response to the recommendations of the reports, as well as the SC guidance for COVs, are available on SC's Web site.

3.4.5.2 Office of Nuclear Energy Internal Reviews

NE charges its FACA committee, NEAC, on occasion to conduct reviews of the NE program office with a scope similar to the reviews of a COV. NE also periodically organizes internal reviews not associated with NEAC focused on certain aspects of the Office and its programs. These reviews are conducted by outside experts in the particular area being reviewed and include interviews, review of documents, and site visits as necessary and result in a report prepared for consideration.

3.4.5.3 Other Reviews of Internal Federal Program Business Practices

Although the FACA committees for the other applied energy technology offices do not have a formal COV process, other external entities have provided periodic reviews and recommendations to these offices with regard to internal program business practices, including the State Energy Advisory Board (STEAB), the National Academy of Public Administrators (NAPA), and the Partnership for Public Service. The DOE Office of the Inspector General (DOE IG) also conducts several dozen routine audits and reviews of the activities of program offices across the Department each year, which can identify opportunities for improvement to current business practices.

3.4.6 Project Management for R&D Facilities and Capital Assets

One of the hallmarks of DOE is its ability to design, build, and operate large and complex scientific and technical facilities to address its diverse missions in basic and applied research. These missions and the focus of facilities that DOE builds and operates span a spectrum from discovery-oriented fundamental research, to energy research and energy systems, to environmental restoration, nuclear waste management, and contaminated facility deactivation and decommissioning, to nuclear weapons stewardship. The Department is currently managing 34 projects that have reached their Critical Decision (CD)-2 milestone, meaning that the project has established a performance baseline with a detailed schedule and cost profile, and a set of key performance parameters to which the project will be held. These 34 projects collectively total more than $26 billion in total project costs (TPCs). Fourteen of these projects are under the US/SE programs, with a combined total of almost $2 billion in TPCs. The scale of these projects, the importance of the delivery of these projects to the DOE program mission, and the need for responsible stewardship of taxpayer dollars demands that the Department take project management and oversight very seriously.

3.4.6.1 DOE Project Management Principles and Requirements

The Department's strategy for managing capital assets has steadily evolved since the late 1970s, driven by changes in the project management body of knowledge and overarching institutional management organization and practice. The current strategy described in the DOE Acquisition Management System, as defined in DOE Order 413.3B, Program and Project Management for the Acquisition of Capital Assets, establishes principles and processes by which DOE manages the development and construction of reliable and sustainable facilities, systems, and assets that provide a required mission capability. The system is organized by project phases based on a gated and formal decision-making process (defined as critical decisions, or CDs) modeled after the approach used within the DOD for acquisition of major weapons systems. Currently, DOE Order 413.3B applies to all capital asset projects sponsored by DOE that have a total project cost (TPC) greater than or equal to $50 million. The Order does not apply to activities supported under financial assistance agreements (grants and cooperative agreements) even if they involve capital assets; however, DOE program offices may elect to apply the principles of the Order to construction projects funded as financial assistance agreements. DOE Order 413.3B implements several requirements from OMB (e.g., Circulars A-11, Part 7; A-123; and A-131), such as using value engineering as a management tool.

As of the publication of this document, the Department is currently in the process of finalizing new policy and updating the DOE Order 413.3B to lower the applicable threshold from $50M TPC to $10M TPC, as recommended by the Program Management Risk Committee (PMRC) and informed by the 2014 evaluation of the DOE Contract and Project Management Working Group; and other changes informed by the Secretarial policy memo of December 2014, Improving the Department's Management of Projects.

The Department's ultimate objective is to deliver every project at the original performance baseline, on schedule, within budget, and fully capable of meeting mission performance, safeguards and security, quality assurance, sustainability, and environmental, safety, and health requirements. The authority and accountability for any project, including its costs, is vested firmly in the hands of accountable project line managers extending from the project management executive (PME), through the project owner (person responsible for providing project funding) to the Federal project director (FPD), who is the first tier of accountability for DOE.

Within DOE, projects typically progress through five CDs, which serve as major milestones approved by designated managers based on a hierarchical structure defined by threshold values of TPC. Each CD (except CD-4, or project completion) marks an authorization to increase the commitment of resources by DOE and requires successful completion of the preceding phase or CD. While the amount of time between CDs will vary, they progress from broadly stated mission needs into well-defined requirements resulting in operationally effective, suitable, and affordable facilities, systems, and other products. The CDs are:

- CD-0, Approve Mission Need;
- CD-1, Approve Mission Alternative Selection and Cost Range. The selected alternative and approach is the best available solution;
- CD-2, Approve Performance Baseline. Definitive scope, schedule and cost baselines have been developed;
- CD-3, Approve Start of Construction/Execution. The project is ready for implementation; and
- CD-4, Approve Start of Operations or Project Completion. The project is ready for turnover or transition to operations, if applicable.

The details of requirements for each critical decision are described in DOE Order 413.3B. Figure 3.3 illustrates the requirements for the typical implementation of the DOE Acquisition Management System for line item capital asset projects. Implementation for other capital asset projects such as major items of equipment (MIE) and operating expense projects follows a similar procedure.

3.4.6.2 Department-Wide Project Organization and Oversight Processes

DOE's Office of Project Management Oversight and Assessments (PMOA) serves as the corporate project management support office and is responsible for providing oversight of DOE's project portfolio; developing and implementing DOE-wide project management policies, procedures, and systems; supporting professional development for DOE's cadre of Federal project directors; and serving as the primary interface with key stakeholders such as Congress, OMB, and GPO.

PMOA establishes and maintains the corporate project assessment and reporting system (PARS II) used by all DOE programs and projects and uses this system to generate routine and ad hoc reports. As required,

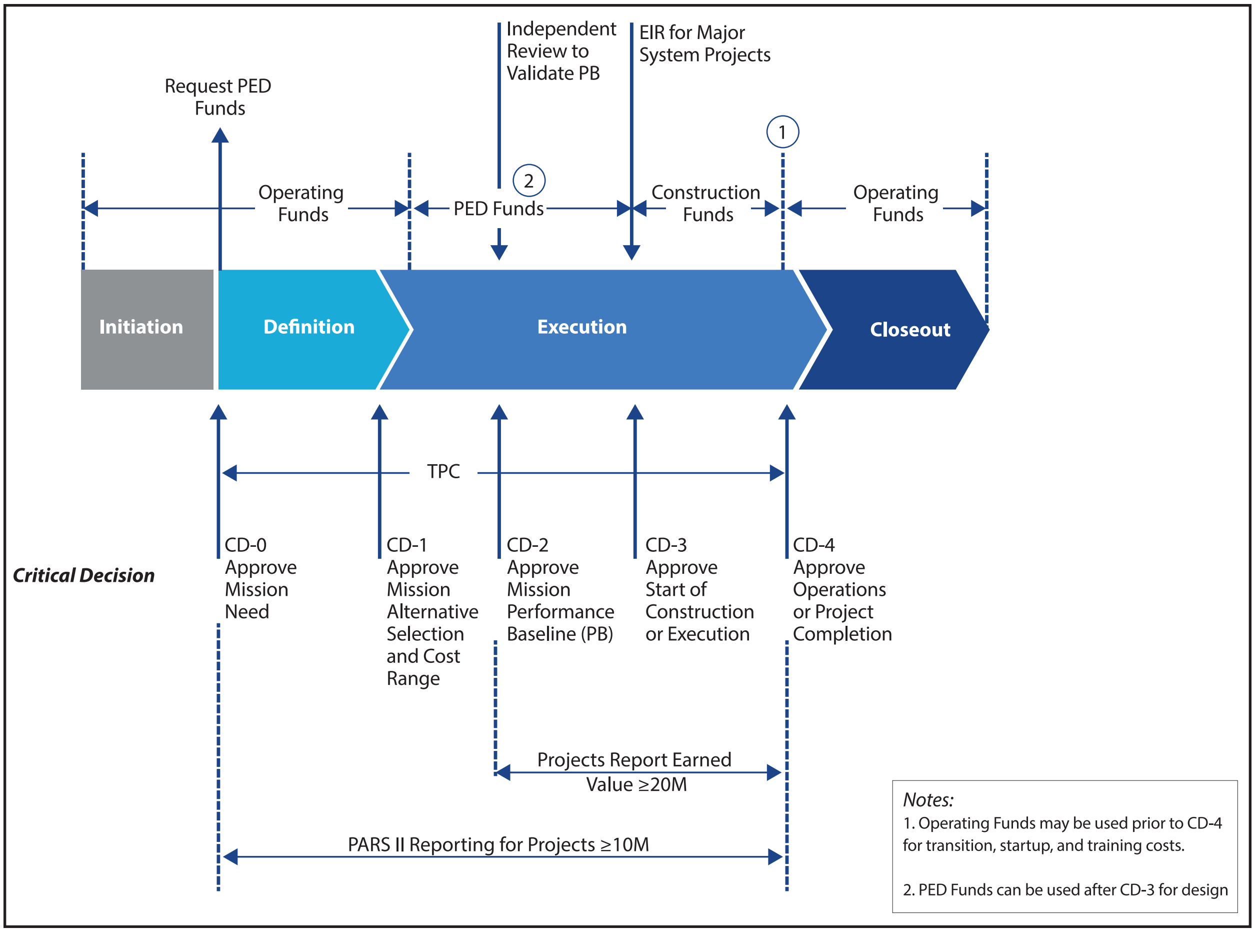


Figure 3.3: Typical DOE Acquisition Management System for Line Item Capital Asset Projects.
PED=project engineering and design; PB=performance baseline; EIR=external independent review: CD=critical decision; PARS=project assessment and reporting system

PMOA conducts external independent reviews and independent cost estimates/reviews (ICEs/ICRs). PMOA sponsors an annual workshop that seeks to bring the DOE project management community together to share best practices and lessons learned, hear talks by practitioners from other agencies and the private sector, and recognize DOE Project Management Award winners.

A focus of PMOA and representatives from all DOE project management support offices (PMSOs) over the past couple of years has been support of the Project Management Working Group that was organized to study areas in DOE project management needing improvement.

To address some of the significant management challenges associated with projects over the last two decades, the Department has taken several measures to improve the enterprise-wide perspective on individual capital asset projects, including sharing best practices and lessons learned. In December 2014, the Secretary took action to strengthen the Energy Systems Acquisition Advisory Board (ESSAB) and establish a Project Management Risk Committee (PMRC). He outlined the overarching aspects of his approach in January 2015 before the National Academy of Public Administration. As the Secretary noted, a core challenge is to bring together the Department's constituent pieces (and their various cultures and business methods) to adopt a common set of best practices while still allowing tailoring for specific problems and environments. The Department has also taken measures to ensure that each capital asset project has a clear project owner, i.e., an entity with the clear mission need and budgetary authority, and each Under Secretary establishes a project assessment office that does not have line management responsibility for project execution, if one does not already exist.

The purpose of the ESAAB is to support the Department's efforts in maintaining excellence in project management and advise the Deputy Secretary (the Chief Executive for Project Management (CEPM) and Departmental PMEs on enterprise-wide project management policy and issues and assist on CDs for major system projects with a TPC of $750 million or greater. The ESAAB and the PMRC are not responsible for project implementation or execution, which remains the responsibility of the PME, the project owner, and the FPD. As established by charter, the ESAAB now convenes at least quarterly to review all capital asset projects with a TPC of $100 million or greater, focusing in particular on projects at risk of not meeting their performance baselines. The ESAAB reviews major system projects before all CD and baseline change proposals are presented to the CEPM, and the ESAAB's review and recommendations are considered by the CEPM in deciding whether to approve a CD.

The PMRC was established to provide enterprise-wide project management risk assessment and expert advice to the Secretary, CEPM, Department PMEs, and the ESAAB on cost, schedule, and technical issues regarding capital asset projects with a TPC of $100 million or greater during CDs. The PMRC meets frequently, approximately biweekly, to carry out its functions and meets at least quarterly with the ESAAB. The PMRC will assess reviews that have been conducted at other levels, e.g., the Under Secretarial level. These assessments are to complement and not duplicate or replace ongoing peer review processes within the program offices. The PMRC may choose to conduct more frequent and detailed assessments of higher risk projects.

Project outcomes are directly related to the experience, competencies, and leadership abilities of DOE project personnel. Accountability for overall project performance must be accepted and shared by all responsible DOE line managers, the Federal project director, and the contractor project manager. Project authorities in DOE must be well defined, understood, and delineated in project execution plans. Advisory and independent oversight groups serve as an essential system of checks and balances. Ultimately, project outcomes depend on a success-oriented culture and a rigorous project management system implemented by DOE's project teams (Federal staff and contractors) that are aligned with the expectations established by DOE's senior managers. Over the years the Department has identified elements that have differentiated the successful projects from the failures (see text box on next page).

3.4.6.3 Project Management Practices across the Science and Energy Program Offices

Over the years, SC has demonstrated repeatedly its ability to bring projects for the construction of large-scale scientific facilities to completion on time and on budget. Success stories include, among other facilities, the Advanced Photon Source at ANL, the Spallation Neutron Source at ORNL, the Relativistic Heavy Ion Collider at BNL, the Linac Coherent Light Source at SLAC National Accelerator Laboratory, and the National Synchrotron Light Source II at BNL. These have generally been massive, football stadium-size installations of sophisticated facilities with total project cost approaching or exceeding $1 billion in today's dollars. These are complex, world-class projects that involved large technical components as well as civil construction. They are efforts to deliver new capabilities at the leading edge of scientific and technological advancement.

SC has embraced the elements of success called out above and considers effective implementation of project management and meeting project cost and schedule objectives to be as important as the scientific goals SC facilities are designed to achieve. SC's credibility with the scientific community, oversight agencies, and Congress is influenced by successful delivery of projects.

Elements of Successful Capital Asset Projects

- **A Culture of Project Management.** Projects are most likely to succeed when the organization is permeated by a culture of project management and this culture is fully assimilated by senior managers. At their best, senior managers are imbued with a project mentality, and concern about the ongoing management of projects is part of the day-to-day functioning of the office. The progress of critical or troubled projects is candidly reviewed by senior program management and project management personnel from both DOE headquarters and field offices on a regular basis.
- **Ownership and Leadership.** The Associate Director (AD) or Deputy Assistant Secretary (DAS) of an office with one or more major projects must take strong personal ownership of the project(s) as the manager ultimately responsible for the project outcome. There must be a close alignment and frequent and clear communication among the AD/DAS, the headquarters line manager for the project, and the Federal project director in the applicable DOE field office. The ability to present a unified voice on the project and to accept full responsibility for the project outcome are critical to effective management both of the organization undertaking the project (typically, though not always, a DOE Laboratory) and ultimately of the contractor(s) responsible for the actual work.
- **Alignment of Goals between HQ and Laboratory/Host Site.** A close alignment between the goals of the DOE headquarters program offices and of the Laboratory or other institution undertaking the project is also essential for success. Appropriate experience and sophistication of the project leadership at the Laboratory level is vital. At the foundation of the effort, there must be a clear shared understanding of the nature and objectives of the project and a willingness to exert and sustain the effort needed to reach the project finish line.
- **Stable Funding.** Careful front-end planning supported by realistic funding profiles is key to modeling actual project execution strategies and plans. While recognizing the degree of funding risk inherent in all Government projects, the best practice is to "baseline" the funding profile as early as practicable and then work diligently to ensure funds are available as planned. This stable funding, which is not always entirely in DOE control, is usually a requirement for success.
- **Peer Review.** Perhaps the biggest strategy for success in managing large projects has been the extensive use of peer review, through organizations such as the SC Office of Project Assessment (OPA). OPA conducts reviews, assembling teams of experts from the National Laboratories, universities, and abroad, at every critical stage of the project, and in the event a project begins to show signs of trouble.

As a key support organization within SC, OPA's mission is to ensure implementation of sound project management practices and to assist with successful execution of the projects. Through independent project peer reviews, conducted throughout all stages of a project, OPA provides project management advice to the project owner—the SC program office funding the project. SC's independent project peer review, typically including peer experts from DOE Laboratories, universities, and scientific facilities abroad, is recognized as a best practice in project management. The goal of OPA's reviews is to provide an outside evaluation of projects to ensure honesty, transparency, and realism that is needed to successfully execute a project. In addition to the review itself, management must be responsive to the findings and be willing to make the hard choices and take the often difficult steps needed to correct a situation that has begun to go awry.

For projects showing signs of trouble, additional ad hoc OPA or program-led reviews are employed.

NE currently manages two projects under DOE Order 413.3B: the Remote Handled Low Level Waste (RHLLW) Disposal Facility Project and the Sample Preparation Laboratory (SPL) Project at INL. The RHLLW Disposal Facility Project is a replacement waste disposal facility that is cofunded with Naval Reactors (NR). The TPC for the RHLLW Disposal Project is $77,576,000 and achieved CD-2/3 (Approve Performance Baseline/Start of Construction) in July 2014. The SPL Project will provide a new functionally focused laboratory, which when coupled with existing facilities and recapitalization efforts will fulfill near-term advanced post-irradiation examination capabilities needed to improve understanding of nuclear fuels and material performance. The TPC range is $60–$95M and is expected to achieve CD-1 in FY 2016.

Within EERE, project teams regularly monitor and manage risks throughout the project life to enhance project success. EERE currently does not have any capital asset projects that are subject to DOE Order 413.3B. For other major projects that do not fall under the requirements of the Order, once a project is underway, risk management is a shared responsibility of both EERE and the Performer. It is important to capture and log risks identified during the award process, as well as those identified throughout the life of the project. Project teams are expected to notify leadership as significant risks are identified. The EERE Assistant Secretary and the Deputy Assistant Secretaries are briefed on a monthly basis on the health of the project portfolio. Since March 2012, EERE has provided regular status updates on the project portfolio to Under Secretary offices during project review and market committee meetings.

As noted above, DOE Order 413.3B does not apply to activities supported under financial assistance agreements (grants and cooperative agreements), but there may be instances where it is in DOE's best interest to manage a large construction project or other capital asset project under the principles of the DOE Order 413.3B to ensure a rigorous framework is in place to deliver the project on schedule and within budget. One example of this is the construction of SC's Facility for Rare Isotope Beams (FRIB). FRIB will be a world-leading facility for the study of nuclear matter, providing intense beams of rare isotopes for a wide variety of studies in nuclear structure, nuclear astrophysics, and fundamental symmetries. The facility will create exotic nuclei that, until now, have existed only in nature's most spectacular explosion, the supernova. In 2007, the SC competitively awarded the construction of FRIB to Michigan State University (MSU), which will host the facility, under a cooperative agreement that falls under Federal financial assistance regulations. The FRIB cooperative agreement specifies that the construction project will be managed using the principles of DOE Order 413.3B, and SC has managed the project since its start, holding MSU to the similar CD milestone and review processes as it would for a construction project subject to the Order. Critical Decision-3b, approval of construction of the FRIB accelerator systems and the experimental systems, for the FRIB project was approved in August 2014, and the project is meeting its performance, cost, and schedule milestones.

FE's demonstration projects are funded under DOE's financial assistance regulations as cooperative agreements and thus are excluded from the requirements of DOE Order 413.3B. However, to maintain rigorous project oversight, FE follows the intent of the Order through its use of FE's "stage-gate" process (see section 3.4.3.2.) for structuring budget periods for the projects. NETL, as FE's principal implementing National Laboratory, executes sound project management principles in accordance with DOE Order 413.3, develops baselines and applies variance analysis and control of project costs, schedule, and performance on all projects in its portfolio, and diligently performs day-to-day management of its financial assistance awards. NETL's Federal Project Management Center (FPMC) has developed and issued written project management guidelines for extramural research, development, and demonstration. These guidelines serve as a reference manual that document the spirit of DOE Order 413.3. NETL's consistent application of financial management principles ensures that appropriated funds are properly invested and managed, and all budgeting, accounting, and internal control responsibilities are carried out in accordance with Government regulations and consistent with industry best practices. Projects are managed in phases with discreet budget periods, and a modified stage-gate process is used to assess progress made, project status, and to support go/no-go decision- making. An overview of FE/NETL's application of the project management principles found in DOE Order 413.3 is provided in table 3.1.

3.4.7 Department-Level Performance Reporting

The Department of Energy's overall performance management efforts encompass all of the activities the Department and program offices engage in to plan, execute, evaluate, and readjust their RDD&D portfolios. This comprehensive approach facilitates alignment of resources, processes, and people (Federal staff and performers) to ensure that the Department's strategic goals and priorities, as well as program-level goals, are being accomplished in an efficient and effective manner. The processes described throughout this chapter for program office planning, the various levels of evaluation, and program and project management accomplish the primary objectives of performance management: (1) to drive performance improvement; (2) to improve resource allocations by informing budget development, enactment, and execution; and (3) to demonstrate accountability to the taxpayer.

The Federal-wide efforts to formalize the measurement of Government performance and use the results in the Federal budget process have been guided by the statutes and Administrative initiatives that began in 1990 with the Chief Financial Officer's Act. The Chief Financial Officer's Act of 1990, the Government Performance and Results Act (GPRA) of 1993, the Federal Acquisition Streamlining Act of 1994, the Government Management Reform Act of 1994, and the Information Technology Management Reform Act of 1996 (the Clinger-Cohen Act) were the initial set of laws that required Federal agencies to strategically plan how they will deliver high-quality services and outcomes to their customers (and taxpayers), and specifically measure their programs' performance in meeting these commitments. In 2010, Congress amended GPRA with the enactment of the Government Performance and Results Act Modernization Act (GPRAMA). GPRAMA requires executive agencies to engage in setting goals, measuring results, and reporting their progress by:

1. developing strategic plans (GPRAMA requires an agency-level strategic plan that covers at least a four-year period);
2. developing annual performance plans;
3. reporting results via annual performance reports;
4. establishing the positions of Chief Operating Officer (COO) [if one did not exist previously] and Performance Improvement Officers (PIOs) within each agency tasked with improving the performance of his or her agency; and
5. requiring the agency COO to conduct data-driven quarterly reviews on agency priority goals and posting the results of these quarterly reviews on a public Web site. (OMB implementation of GPRMA requires the reviews to be published on the OMB Web site.)

The Director of the CFO's Budget Office is the DOE PIO. DOE uses a hierarchical relationship (referred to as the performance framework) from the Department's mission down to quarterly targets. Figure 3.4 illustrates the current DOE performance framework.

0.0 Establish IPT	An Integrated Project Team (IPT) is assigned to each project to oversee negotiations, and award. IPT membership is based on technology maturity, award type, project complexity, and visibility. IPT membership is comprised of the Federal Project Manager, Contract Specialist, Legal Counsel, NEPA Specialist, Property Manager and Cost Price Analyst.
1.0 Define Mission Need	Mission need is driven by national priorities set by the Administration, authorized via Congressional Appropriations, and charged by the Department's Strategic Plan. Within FE, Mission Need is defined by the Deputy Assistant Secretary for Coal consistent with the Clean Coal and Carbon Management Program Technology Roadmap and each respective program component's Annual Operating Plan.
2.0 Establish Requirements	RD&D projects are initiated by competitive Funding Opportunity Announcements (FOAs) based on solicitations constructed to achieve the Department's Technology Development Timelines, Annual Performance Measures and Quarterly GPRA Targets.
3.0 Consider Alternatives	Relevant programmatic, technical, NEPA, budget and procurement-related alternatives are considered during the planning process by FEHQ Program Managers and NETL Technology and Project Managers, with each area evaluated and addressed during development of solicitation specific Requirements and Procurement Strategy Documents.
4.0 Evaluate Risks	Both program and project related risks are evaluated and mitigation strategies developed. Program risks are assessed to establish pathways aimed at maximizing the opportunity to achieve Mission Need. Project risks are evaluated and formally point-scored in each of the following areas: financial; cost/schedule; technical scope; management, planning & oversight; ES&H; and external influences.
5.0 Develop WBS	A Work Breakdown Structure (WBS) is developed to fully describe planned work to be performed, assess work completed to date, and create logical interim decision points to support go/no-go decision making. The WBS is used as a project management and communication tool and is developed at the appropriate level based on the maturation level of the technology and the technical and programmatic complexity of the project.
6.0 Develop &Maintain Technical, Schedule, & Cost Baseline	Initial project awards include a Statement of Project Objectives (SOPO), WBS, project schedule, estimated cost, performance milestones, reporting requirements and a Project Management Plan. These portions of the award instrument set preliminary performance baselines at project initiation and are adjusted, when needed, to accommodate material variances and maintain realistic project management baselines.
7.0 Manage Baseline	A modified stage-gate process is used to manage project baselines. Formal go/no-go decision points are created and applied at the completion of discreet project phases and budget periods. Formal project management procedures and established practices are used to evaluate baseline performance and to track variance against baselines. Decision points typically coincide with large expenditures, major equipment purchases or significant project milestones.
8.0 Change Control	Given the nature of financial assistance, change control is typically a consensus driven process involving the mutual agreement of both the government and the participating entity. Agreements to change project terms are documented by a formal modification supported by NETL's Federal Project Manager and falling under the authority of the Contracting Officer.
9.0 Effective Reporting	Project deliverables are required pursuant to Title 2 CFR PART 200.328. Certain other deliverables are stipulated in the SOPO to ensure the level of reporting is commensurate with the type and complexity of the project being managed. Project information is shared by NETL's Federal Project Manager with the Department's HQ Program Managers and throughout the IPT.

Table 3.1: FE Application of DOE Order 413.3-Project Management Principles.
This table provides a typical DOE acquisition management system for line item capital asset projects using the example of an FE application of DOE Order 413.3 to its projects.

The higher-level goals (strategic goals and strategic objectives) direct the scope of the supporting performance elements (agency priority goals, performance goals, annual performance targets). The DOE mission, strategic goals, strategic objectives, and agency priority goals are presented in the DOE Strategic Plan. The program goals and annual performance targets are presented in the Annual Performance Plan, which is incorporated into the President's annual budget justification narrative. GPRAMA requires that every two years, each agency identifies agency priority goals from among the performance goals of the agency. The OMB determines the total number of agency priority goals across the Government, and the number to be used by each agency. Table 3.2 lists DOE's Agency Priority Goals for 2014–2015.

The Annual Performance Plans called for by GPRAMA are meant to provide a linkage between short- term (usually spanning 1–3 years) activities and associated performance goals to an agency's mission, strategic goals, and strategic objectives. The DOE Annual Performance Plan that is submitted within DOE's budget request to Congress covers a three-year period: the past, current, and next (budget request) fiscal years. The plans are specifically required to include (1) the annual performance goals for an agency's major programs and activities, (2) the indicators that will be used to gauge performance, (3) the strategies and resources required to achieve the performance goals, and (4) the procedures that will be used to verify and validate performance information.

Figure 3.4: DOE Performance Framework.
This figure demonstrates how specific goals and objectives flow down from the overall Departmental mission to provide a framework for ongoing evaluation of program performance.

DOE's various processes for implementing its performance management framework are anchored around the annual budget formulation and execution processes. Headquarters' program offices develop broad performance goals and related performance indicators. Then program offices develop annual budgets based on, and justified by, multiyear annual performance plans and well-documented, previously achieved results. DOE program and field elements carry forward the goals and performance indicators that are contained in the annual performance plans and add to those other goals and performance indicators necessary for their own programmatic and management proposes. Field elements work with DOE National Laboratories to develop performance goals relevant to Departmental, program, and field element performance goals, missions, and operations through the performance-based M&O contracts. Program offices conduct their regular portfolio peer reviews and other progress reviews throughout the fiscal year. Performance indicators and results are documented on a quarterly basis and used for local management and transmitted to Headquarters program offices.

Program	Area	DOE Goal Statement
EERE & LPO	Science & Energy	**Implement elements of the Climate Action Plan, including:** · Supporting the goal of reducing cumulative carbon pollution by 3 billion metric tons by 2030 through standards set since 2009 and promulgating new standards for consumer products and industrial equipment by the end of calendar year 2016. · Providing up to $8 billion in loan guarantees for advanced fossil energy technologies that reduce greenhouse gas emissions by the end of FY 2017.
EPSA	Science & Energy	**Enhance desirable characteristics and diminish vulnerabilities of the U.S. energy infrastructure to meet goals of economic competitiveness, national security, and environmental responsibility by:** · Supporting the first installment of the Quadrennial Energy Review (QER) through early 2015 and beginning implementation of relevant recommendations within DOE's existing authorities.
SC	Science & Energy	**Support and conduct basic research to deliver scientific breakthroughs and extend our knowledge of the natural world by capitalizing on the capabilities available at the National Laboratories, and through partnerships with universities and industry. In support of this goal, DOE will, by the end of FY 2015:** · Incorporate science user facility prioritization into program planning efforts. · Identify programmatic drivers and technical requirements in coordination with other Departmental mission areas to inform future development of high performance computing capabilities and in anticipation of capable exascale systems.
NNSA	Nuclear Security	**Maintain and modernize the U.S. nuclear weapons stockpile and dismantle excess nuclear weapons to meet the national security requirements, as assigned by the President, through the Nuclear Posture Review. In support of this goal, DOE will:** · Each year through FY 2015 and into the future, maintain 100% of the warheads in the stockpile as safe, secure, reliable, and available to the President for deployment. · Conduct activities necessary to complete planned W76-1 production in FY 2019 and achieve the first B61-12 production unit in FY 2020, as reported in the FY 2013 Selected Acquisition Reports.

Table 3.2: DOE Agency Priority Goals for 2014–2015.
This table provides the goal statements for the Offices of the Under Secretaries for Science and Energy, National Security, and Management and Performance.

Program	Area	DOE Goal Statement
NNSA	Nuclear Security	**Continue to make progress toward securing the most vulnerable nuclear materials worldwide. In support of this goal, DOE will:** · Remove or confirm disposition of an additional 315 kilograms of highly enriched uranium and plutonium for a cumulative total of 5,332 kilograms by the end of FY 2015.
EM/MA/ CIO	Management & Performance	**Increase the focus on efficient and effective management across the DOE enterprise and improve performance in the areas of environmental cleanup, construction project management, and cybersecurity. In support of this goal, DOE will:** · Retrieve tank waste, close tanks, and dispose of transuranic waste within cost and schedule through FY 2015. · On a three-year rolling basis, complete at least 90% of departmental projects baselined since the start of FY 2008 within the original scope baseline and not to exceed 110% of the cost as reflected in the performance baseline established at Critical Decision 2 through FY 2015. · Achieve full operational capability of the Joint Cybersecurity Coordination Center (JC3), including TS-SCI operations, by the end of FY 2015.
US Mgt & Perf.	Management & Performance	**Restructure the relationship and interactions between the Department and the National Laboratories and sites to ensure the continued status of the national laboratories as world-class research institutions best able to achieve DOE's mission, maximize the impact of federal R&D investment in the Laboratories, accelerate the transfer of technology into the private and government sectors, and better respond to opportunities and challenges. In support of this goal, DOE will:** · Establish the National Laboratory Policy Council to address high-level policy challenges and develop initiatives to build and focus the laboratory system on critical economic, research and national security priorities. · Establish the National Laboratory Operations Board to address operational and administrative issues and enhance the effectiveness and efficiency of DOE's management of the national laboratories. · Improve stewardship of national assets across the National Laboratories and DOE operating sites to assure that DOE physical plants and their operating practices comply with DOE Directives and achieve Administration priority initiatives by end of FY 2015.

Table 3.2 (continued from previous page)

In accordance with GPRAMA requirements, DOE issues an annual performance report that assesses DOE's actual performance compared to planned goals presented in the annual performance plan for the prior fiscal year, and discusses steps that are needed to improve performance in the future. Since OMB sets the total number of agency priority goals an agency may use, DOE's agency priority goals are not intended to cover every major research and development effort of the Science and Energy programs.

Special Feature—The Nonlinear Innovation Cycle and Feedback Loops: From Basic Research to Deployment

Innovation is the cornerstone of progress, and DOE has long recognized and encouraged the elements that foster technological innovation. Basic scientific research generates new ideas; applied research removes roadblocks and fine tunes early models; and field testing provides the proof of concept needed to facilitate commercialization. But these activities do not take place in strict sequence—progress is not linear—and multiple parties contribute to the process. Iterative feedback cycles and concurrent developments collectively shape a developing technology and move it toward commercialization. Collaboration between industry and Government accelerates this cycle and spawns secondary innovations. DOE's role is to support this process by funding the basic and applied research and development that opens doors to new technologies and by assisting when technological or financial obstacles threaten to stifle innovation of transformational energy technologies.

As an example, some of the earliest research supported by DOE focused on the development of particle accelerators and their application to nuclear and high energy physics. This research enabled the manufacture of semiconductors—the building block material of our electronic age—which makes heavy use of small particle accelerators developed on the coattails of DOE research accelerators. In addition, many major hospitals have at least one particle accelerator, since accelerators are also widely used in treatment of cancers. And particle accelerators are essential for the creation of key isotopes widely used in modern medicine for imaging and diagnosis. Another major spin-off of particle accelerators has been synchrotron x ray light sources. These large facilities use electron accelerators to produce beams of x ray light that are millions of times brighter and many times more focused than x rays in a typical doctor's office. These x rays permit us to "see" structures at the atomic and molecular level and even take "snapshots" of chemical reactions in real time. They are now the premier tools for studying matter at the atomic and molecular scales and are providing major new insights that are enabling us to create new materials, develop more effective batteries, and even find new cures for disease. Thus, DOE basic and applied research led to numerous and diverse innovations, while also paving the way for fundamental research in new directions.

The complexity and nonlinearity of technological innovation—and how DOE, the National Laboratories and industry have played complementary roles in its development— is visually portrayed in figure 3.5 for the polycrystalline diamond compact (PDC) drill bit used in subsurface drilling. As can be seen, through basic and applied research efforts, intermingled with field failures and successes, DOE and industry resolved technical problems and enabled widespread commercial use of PDC drill bits across the oil, natural gas, and geothermal industries.

The Story of Polycrystalline Diamond Cutter Innovation

PDC drill bits use thin, diamond layers bonded (brazed) to tungsten carbide-cobalt studs or blades. Introduced in the early 1970s by the General Electric Company, the first PDC bits were prone to premature braze joint failure, among other problems. DOE's research capabilities and brazing expertise—developed at Sandia National Laboratories during the weapons components program of the 1960s— assisted the oil and gas industry in moving PDC drilling technology forward over the next decade. DOE's interest in using PDC for geothermal applications overlapped with the oil and gas industry's interest in PDC for drilling in hard rock and other difficult environments.

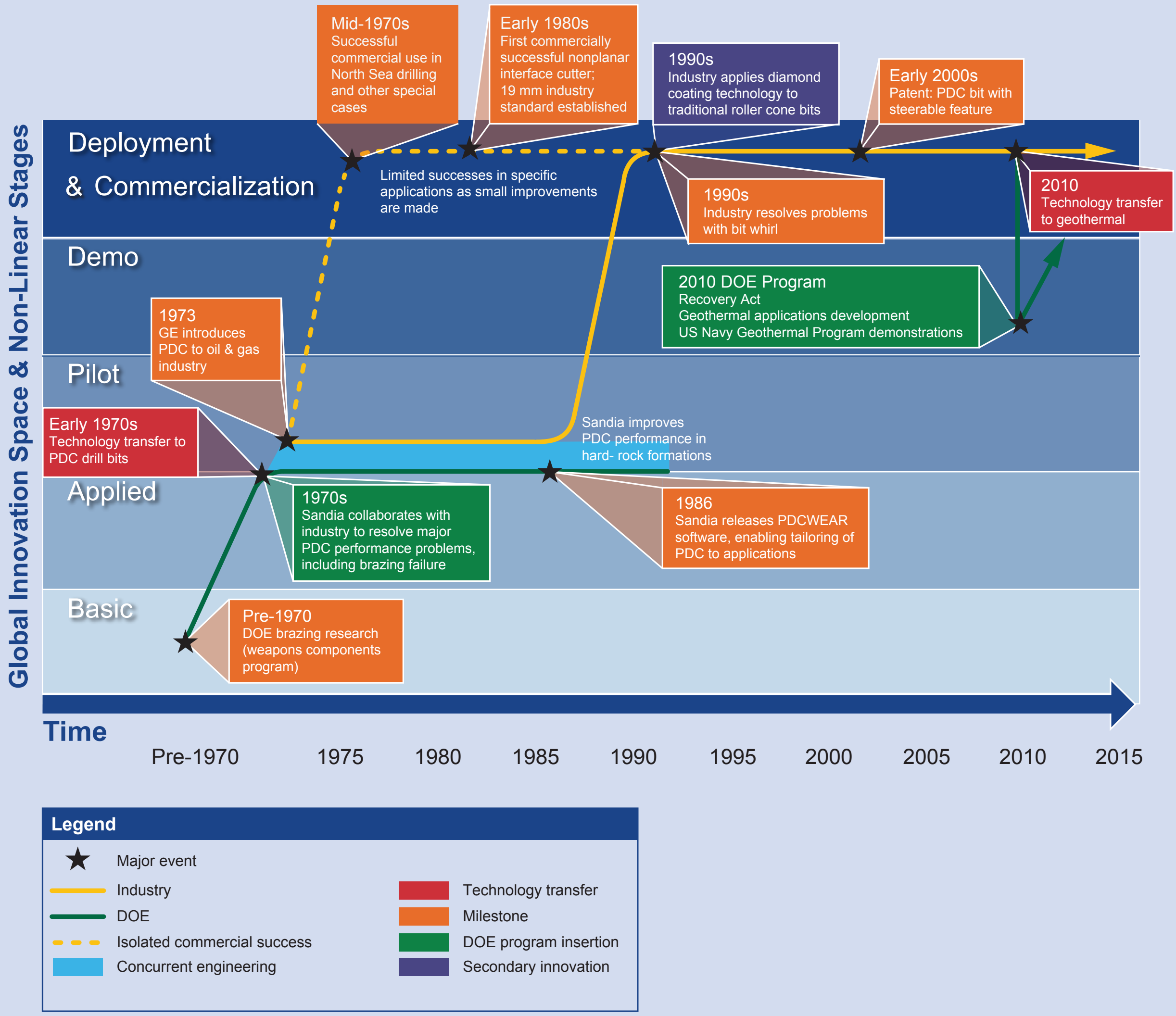


Figure 3.5: Innovation Cycle of the Polycrystalline Diamond Compact Drill Bit
This figure illustrates the nonlinear nature of the cycle of innovation for the PDC drill bit, from basic research through deployment and commercialization, including all the feedback loops throughout the development stages in between.

During the 1970s and early 1980s, improvements in PDC design led to limited commercial success in specific applications, such as drilling in the North Sea. But PDC bits did not perform satisfactorily in shale and similar rocks, and only a small percentage of drilling companies embraced the technology. Further research by Sandia in the mid-1980s led to a better understanding of basic rock-cutting actions, allowing researchers to model the performance and wear of PDC bit designs. A computer model (PDCWEAR) released by Sandia in 1986 enabled bit manufacturers to customize PDC bits to specific applications. As field performance of PDC bits improved, their use increased.

By the early 1990s, the drill-bit industry was applying diamonds to roller-cone bits, while PDC design continued to advance. Major improvements to PDC bits during the 1990s and 2000s included a new bit design to resist backward whirl (a phenomenon that leads to premature failure and reduced performance) and a patented steerable feature that allowed directional drilling. By 2004, PDC bits accounted for approximately 50 percent of the revenue in the bit industry and nearly 60 percent of the footage drilled. Formations previously considered undrillable by PDC could now be drilled economically and reliably. Diamond-enhanced, roller-cone bits were also a significant sector of the roller-cone bit market, with their acceptance continuing to grow.

In 2010, Sandia received American Recovery and Reinvestment Act funding to further improve PDC bits for better access to geothermal resources in the continental United States. Geothermal drilling requires bits that can withstand deeper, hotter geothermal conditions in hard, basement rock formations. Phase I of a Sandia/Navy demonstration project to test and evaluate PDC bits in a real-world drilling environment found that PDC test bits penetrated the rock nearly three times faster than standard roller bits. Today, ongoing work is focused on optimization of PDC design and materials for geothermal use.

4

Chapter 4: DOE National Laboratories, Universities, and Industry Partners

4.1 Overview

The National Laboratories, universities, and industry, along with other key stakeholders from the public and private sectors, are an integral part of the Department's mission to advance transformative science and technology innovation to meet our Nation's energy, nuclear security, and environmental challenges. These stakeholders play a vital role in virtually every facet of the Department's Science and Energy enterprise, providing expert input on strategic planning, helping to evaluate proposals, projects, and program activities, and engaging as performers and collaborators.

As DOE performers, the National Laboratories, universities, and industry push forward the frontiers of fundamental science, technology research, and commercialization. Innovation models ranging from the multi-investigator, multidisciplinary, and multi-institutional Energy Innovation Hubs and Energy Frontier Research Centers to team competitions for prizes and single-investigator awards, enable the Department to engage external performers in a manner tailored to the underlying RDD&D challenges. Further descriptions of these RDD&D innovation models are in Appendix E. This chapter discusses the role that National Laboratories, universities, and industry play in executing the Department's science and energy missions.

4.2 The DOE National Laboratories

The core of DOE activities in pursuit of its science and energy missions resides in its National Laboratories, a network of 17 world-class research institutions largely operated by external contractors. Owned and stewarded by the Department, the National Laboratories constitute a unique national resource operating at the forefront of basic and applied science, research and development, national defense, and environmental management. The strategic engagement and oversight of the National Laboratories is thus one of the most important responsibilities of the Department.

Under Secretary for Science and Energy			NNSA Administrator		Under Secretary for Management & Performance
Single-Program Science Laboratories	**Energy Laboratories**	**Multi-Program Science Laboratories**	**National Security Laboratories**	**National Security Production Facilities**	**Environmental Management Laboratory**
Ames (SC)	INL (NE)	ANL (SC)	LLNL (NNSA)	Pantex (NNSA)	SRNL (EM)
Fermilab (SC)	NETL (FE)	BNL (SC)	SNL (NNSA)	Y-12 (NNSA)	
PPPL (SC)	NREL (EERE)	LBNL (SC)	LANL (NNSA)	KCP (NNSA)	
TJNAF (SC)		ORNL (SC)		NNSS (NNSA)	
		PNNL (SC)			
		SLAC (SC)			

Table 4.1: Laboratory Types and Stewardship Roles for DOE National Laboratories and NNSA Production Sites. The 17 National Laboratories are aligned with DOE's four missions: science, energy, nuclear security and environmental management. The DOE Office stewarding each laboratory is given in parentheses.

Founded during the immense investment in scientific research during and following World War II, the National Laboratories have served as leading institutions for bringing science to major national challenges in the United States for more than sixty years. DOE's National Laboratories tackle the critical scientific challenges of our time, from combating climate change to discovering the origins of our universe, and possess unique instruments and facilities, many of which are found nowhere else in the world. They address large-scale, complex R&D challenges with a multidisciplinary approach that places an emphasis on translating basic science to innovation. Specifically, the National Laboratories:

- conduct research of the highest caliber in physical, chemical, biological, and computational and information sciences that advances our understanding of the world around us;
- advance U.S. energy independence and leadership in clean energy technologies to ensure the ready availability of clean, reliable, and affordable energy;
- enhance global, national, and homeland security by ensuring the safety and reliability of the U.S. nuclear deterrent, helping to prevent the proliferation of weapons of mass destruction, and securing the Nation's borders; and
- design, build, and operate distinctive scientific instrumentation and facilities, and make these resources available to the research community.

4.2.1 The DOE Laboratory Management Model

The U.S. Government typically manages its National Laboratories under two general models: the GOGO (Government-owned, Government-operated) model and the GOCO (Government-owned, contractor-operated) model. GOGO laboratories are usually owned or leased by the Federal Government and are predominantly staffed by Federal employees and supported by non-Federal contract employees. GOCO laboratories are institutions where the facilities and equipment are owned by the Federal Government, but the staff is employed by a private or public contractor that operates the laboratory under a contract with the Federal Government. The type of laboratory management affects the responsibilities for laboratory oversight and can affect various aspects of the technology transfer mission at the laboratory, including intellectual property protection.

The underlying GOCO stewardship model, which dates to the Manhattan Project (and hence predates DOE), has proven to be remarkably adaptable. In the early days of the Manhattan Project, faced with the national imperative to develop an atomic bomb, the U.S. Government turned to academia and industry to quickly identify and organize the necessary scientific and engineering talent. Facilities were established at several locations, some near universities (to leverage talent) and others at remote locations (for security purposes). Although the Government originally intended to disband these efforts at the end of the war, it soon realized that the amassed talent and resources should be maintained in service of the Nation. In the ensuing years, the number of Laboratories grew, and it was necessary to put in place a more formal management structure. The GOCO management model was used because of the flexibility it afforded in the management and operation of the Laboratories.

Sixteen of the DOE National Laboratories are managed under the GOCO model, while one, National Energy Technology Laboratory (NETL), is operated under the GOGO model. While the GOGO model is unique to NETL among the 17 DOE National Laboratories, it is more often the standard across Federal research institutions outside of DOE. The GOCO management model now consists of DOE competitively awarding M&O contracts for its Laboratories. The sixteen National Laboratories that are managed as GOCOs have been designated as federally funded R&D centers (FFRDCs).

The FFRDC designation codifies a special relationship between the National Laboratories and the Federal Government. As an FFRDC, a National Laboratory must conduct business in a manner befitting their special relationship with the Government (e.g., nontypical contractor access to Government and supplier data [sensitive and proprietary], and to employees and Federal installations, equipment, and real property). DOE Laboratories may also perform work for agencies other than DOE and non-Federal sponsors when the work is not otherwise available from the private sector.

The GOCO model represents a partnership between the Government and private sector. The private sector contractor is expected to bring best practices, especially in personnel and R&D management, to the National Laboratories. The GOCO model is most effective when DOE specifies the mission and high-level objectives (the "what") and grants the contractor freedom to determine the best means to achieve them (the "how"). DOE evaluates contractor performance annually, and superior performance is incented through a variety of mechanisms, including contract term extensions.

The GOCO model affords the Government several benefits, including the flexibility needed to manage scientific institutions that must be able to recruit and retain world-class technical talent and adapt quickly to changing national research priorities and advances in science and technology (S&T). The consistent recognition of DOE National Laboratories as world-leading research institutions, with records of sustained scientific excellence and mission contributions, has often been attributed to the benefits of the GOCO model.

Many of the GOCO Laboratories are managed by universities, private sector organizations, or joint university-industry partnerships. For example, ANL is managed by UChicago Argonne, LLC, which is a partnership between the University of Chicago (which has managed ANL since its inception) and Jacobs Engineering Group

Inc. (which specializes in technical, professional, and construction services). The management contractor for ORNL is UT-Battelle, LLC, a partnership between the University of Tennessee and Battelle Memorial Institute.

The GOGO model used in the operation of NETL also affords unique benefits to the Department in the execution of NETL's mission. DOE GOCO Laboratories support DOE's mission by conducting R&D. NETL does the same with its ORD. However, consistent with its GOGO structure, NETL's Federal staff have a broader set of authorities than the Department's other National Laboratories. Staffed and managed by Federal employees, NETL performs the full range of inherently governmental functions, allowing it to support DOE's mission in ways the others cannot.

4.2.2 Overview of the DOE Laboratory System

DOE National Laboratories occupy a unique position inside the energy innovation system. As shown in Figure 4.1, on one end of the spectrum, universities have a predominant emphasis on early discovery and tend to focus on research associated with small groups of faculty members. At the other end of the spectrum, companies are responsive to market needs and competitive pressures and typically focus their R&D on near-term solutions or the integration of multiple technologies. In between the early discovery and the more near-term solutions, National Laboratories occupy the space where it is necessary to look at complex multidisciplinary problems that are long-time horizon and that span the fundamental to the applied. While there are areas of overlap—and universities and industry do engage directly with each other—each of these three entities has a region in which it is most dedicated.

The 17 DOE National Laboratories have evolved into distinctive institutions that are designed for creating strategic value for the DOE science and energy innovation system. Generally, National Laboratories can be either science-oriented or technology-oriented, and they can serve either multipurpose functions (multiple DOE missions) or single-program functions (primarily a single DOE program office mission).

Multipurpose science and energy Laboratories bring together a spectrum of facilities, expertise, and R&D programs to support the broad science and energy mission of the Department. While each Laboratory has distinctive capabilities, they often have several common features as well, such as infrastructure for doing science at scale.

Seven multipurpose science Laboratories—ANL, Lawrence Berkeley National Laboratory (LBNL), Brookhaven National Laboratory (BNL), Idaho National Laboratory (INL), ORNL, Pacific Northwest National Laboratory (PNNL), and SLAC National Accelerator Laboratory (SLAC)—provide combinations of facilities and programs that enable the broad science communities. For example, today, these seven Laboratories each have focused programs in materials and chemistry, nanoscience, and data science, and provide large-scale user facilities, but each Laboratory supports those activities in a way that provides distinct capabilities. These foundational areas of expertise form a toolbox of capabilities from which DOE draws in meeting its mission objectives. When these areas of expertise and facilities are developed within each Laboratory over time, they tend to reinforce each other. This helps scientists from universities and from industry that engage and collaborate with these Laboratories, by creating crosscutting value.

Single-program science Laboratories concentrate in a specific area, have a specialized set of expertise, and have a narrow Laboratory mission. Four single-program science Laboratories— Ames Laboratory (AMES), Fermi National Accelerator Laboratory (FNAL), Thomas Jefferson National Accelerator Facility (TJNAF), and Princeton Plasma Physics Laboratory (PPPL)—emphasize physics, focusing on the discovery of matter and force in the universe and on harnessing that knowledge for human benefit. Similarly, the energy mission of the Department is supported, in large part, by two single-program energy technology Laboratories—NETL and the National Renewable Energy Laboratory (NREL)—that serve as the focal point for research in the fossil and renewables sectors of the energy economy. While the capabilities of the energy technology laboratories are

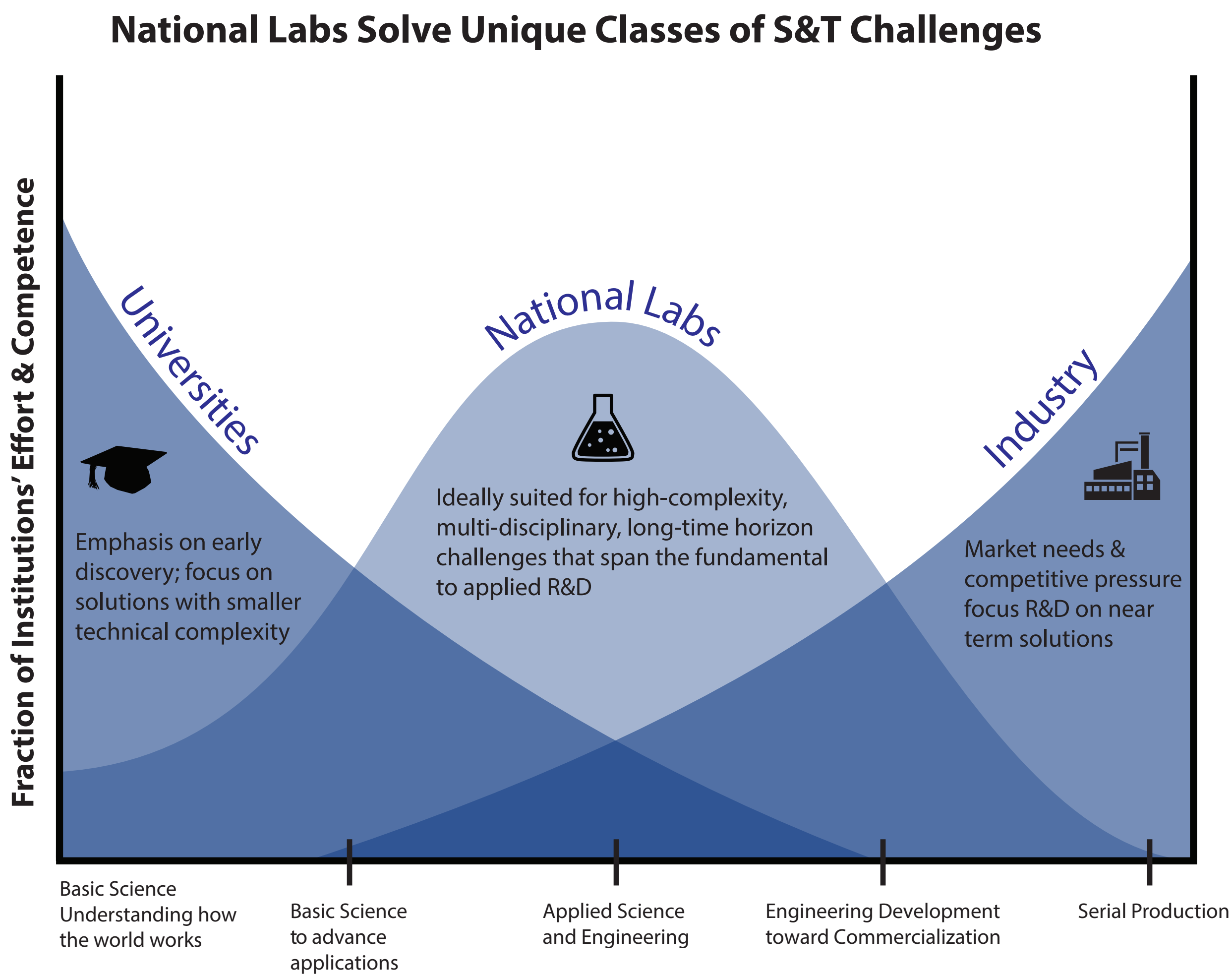


Figure 4.1: DOE National Laboratories' Relationship to Universities and Industry in the Energy Innovation System.

broad in that it spans multiple scientific and engineering disciplines, the targeted application of the R&D efforts are specific to their respective sectors. This allows the Department to explore different parts of an "all of the above" energy strategy.

The thirteen multipurpose and single-purpose Laboratories stewarded by the Office of the US/SE through the Office of Science (SC), Office of Fossil Energy (FE), Office of Energy Efficiency & Renewable Energy (EERE), and NE also engage in national security work; the expertise maintained by these Laboratories is an essential component of the Nation's security. Three multipurpose security Laboratories—Sandia National Laboratories (SNL), Los Alamos National Laboratory (LANL), and Lawrence Livermore National Laboratory (LLNL)—are dedicated to the science and technology of keeping the Nation safe and are stewarded by DOE's National Nuclear Security Administration (NNSA). One single-program Laboratory—Savannah River—serves as the focal point for the environmental mission of DOE, with ORNL, INL, PNNL, and LANL lending expertise to these efforts as well. Savannah River is the responsibility of DOE's Office of Environmental Management (EM). As demonstrated in figure 4.2, however, DOE's Science and Energy program offices engage directly with a number of National Laboratories, not just the Laboratories that they steward.

Although the Office of the US/SE does not have direct oversight over SNL, LANL, LLNL, and Savannah River, the Labs' scientific and technical expertise in this mission space contributes to the toolbox to achieve Science and Energy goals. Their scientific research and development, often supported by Science and Energy programs, adds to the greater body of knowledge in the science and energy fields.

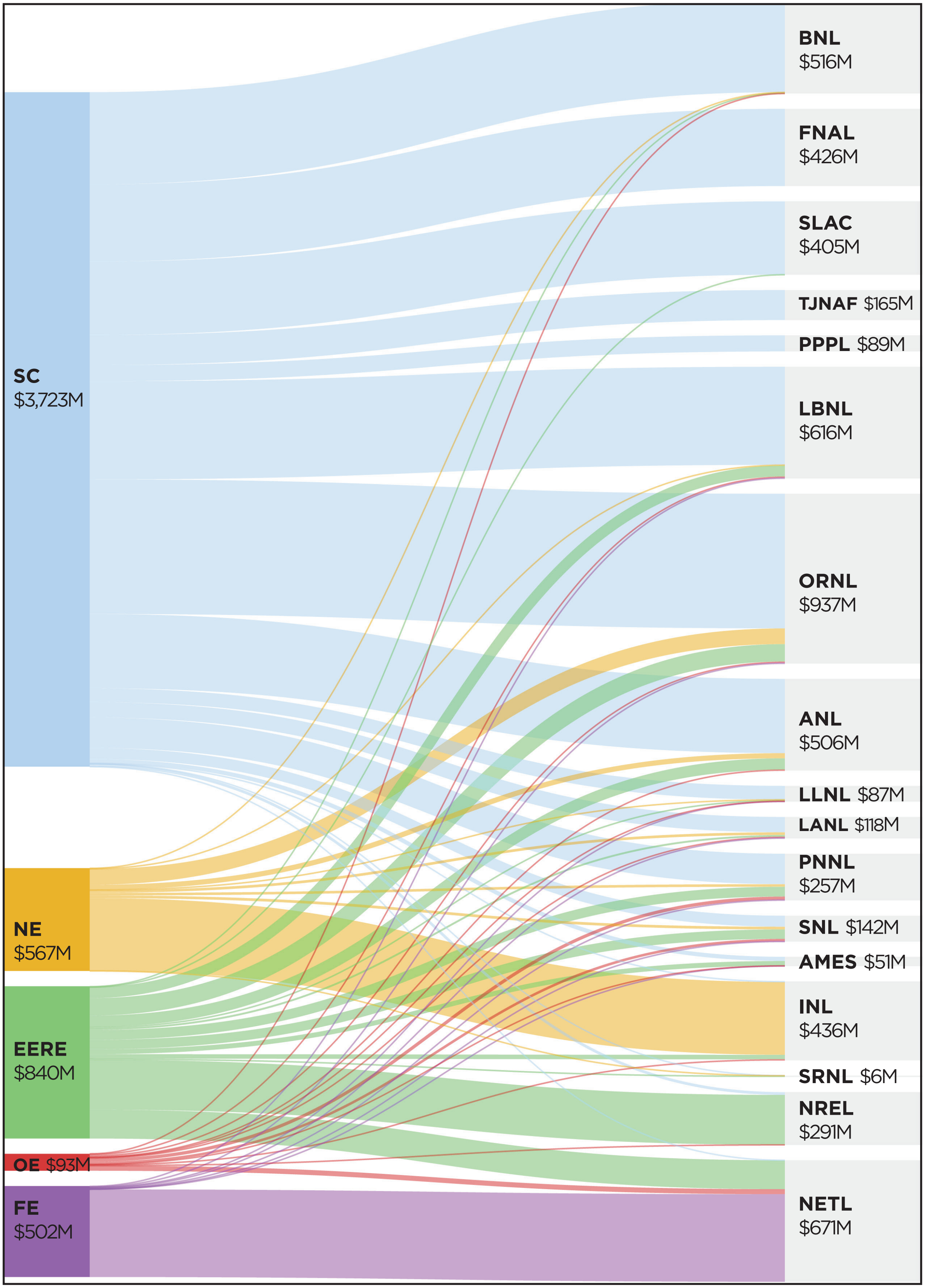


Figure 4.2: Flow of US/SE Program Funding to National Laboratories (FY 2014 Enacted).
This figure illustrates the flow of funding to each of 17 DOE National Laboratories from five of the six US/SE program offices. IE does not directly fund program work at the National Laboratories.

4.2.3 DOE Laboratory Coordination Groups

Overseeing and managing the DOE/National Laboratory contractor relationship involves strategic and oftentimes complex policies and issues. As described below, an evolving set of Laboratory governance committees and working groups are used to both navigate the environment and develop and sustain positive working relationships.

4.2.3.1 The National Laboratory Directors' Council and Working Groups

The National Laboratory Directors' Council (NLDC) consists of the Laboratory Directors from each of the 17 DOE Laboratories, and represents the scientific and technological leadership deployed across the DOE Laboratory complex. The NLDC, formed in 2007, provides one mechanism for coordinating the interactions across the whole DOE Laboratory complex. It is the mission of the NLDC to collaborate with DOE on strategic issues and concerns of broad interest and provide a forum for discussing matters that impact effective and efficient mission execution, and for presenting the Secretary and DOE senior management with consensus views on matters that affect the Laboratories and their ability to contribute to the DOE mission. The NLDC seeks to promote advances in the various DOE missions, and increase the effectiveness of DOE and the National Laboratories. An executive committee represents all Laboratory Directors and organizes and coordinates the activities of the NLDC. Membership consists of one representative from each of the four DOE mission areas: science, energy, nuclear security, and environment.

The NLDC meets twice a year with the Secretary of Energy and multiple times throughout the year in face-to-face meetings with all Laboratory Directors. Other interactions are organized as needed, such as interim meetings, working group meetings, ad hoc calls with all Laboratory Directors, etc. Various working groups under the NLDC provide insights on specific issues and impacts, and help work with the various DOE offices on implementation.

The NLDC has eight chartered working groups to support its activities:

- The National Laboratory Chief Research Officers working group advises on both technical and programmatic issues.
- The National Laboratory Chief Operating Officers working group advises on operational issues among the Laboratory complex.
- The National Laboratory Chief Information Officers working group advises on computing and information processing issues.
- The National Laboratory Chief Financial Officers working group advises on financial matters, budgets, and long-term financial risks.
- The National Laboratory General Counsels working group advises on legal issues.
- The National Laboratory Chief Communications Officers working group advises on public relations and communications issues.
- The National Laboratory Chief Human Resource Officers working group advises on human resource concerns, salary and benefits, and other personnel issues.
- The National Laboratory Environmental Safety and Health Directors working group advises on environmental and safety issues and requirements.

4.2.3.2 DOE-Led Councils and Working Groups

One of DOE's management and performance goals is to restructure the relationship and interactions between the Department and the National Laboratories and sites to ensure the continued status of the National Laboratories as world-class research institutions best able to achieve DOE's mission, maximize the impact of Federal R&D investment in the Laboratories, accelerate the transfer of technology into the private and Government sectors, and better respond to opportunities and challenges. In support of this, DOE established two councils: the Laboratory Policy Council (LPC) and Laboratory Operations Board (LOB).

4.2.3.2.1 Laboratory Policy Council

In July 2013, the Secretary established the Laboratory Policy Council (LPC) to bring the Laboratories into strategic-level discussions of the Department policy and program planning process and for the Department to provide strategic guidance on National Laboratory activities in support of Departmental missions. The LPC, which is chaired by the Secretary and is made up of senior DOE leadership and the NLDC executive committee, convenes three times a year and serves as an important forum for exploring nascent proposals related to new research directions, building human capacity, and improving communications; discussing progress and guidance on initiatives, such as technology transfer pilots and emergency response; and providing strategic guidance to the Laboratories.

4.2.3.2.2 Laboratory Operations Board

In October 2013, the Secretary established the LOB; its objectives are to strengthen and enhance the partnership between the Department and National Laboratories, and to improve management and performance in order to more effectively and efficiently execute the missions of the Department and the National Laboratories. The LOB meets monthly and is led by the Office of the Under Secretary for Management and Performance. The LOB membership includes four representatives from the National Laboratories (two Laboratory Chief Operating Officers and two Laboratory Chief Research Officers), the Chief Operating Officers of Departmental programs with Laboratories, the Director of the Office of Management, a Departmental field office representative, and an M&O contractor representative.

4.2.3.2.3 Office of Science: Operations Improvement Committee

The SC Operations Improvement Committee (OIC) was chartered in 2012 to collect, share, and report on operational efficiencies that will enhance the missions of the Office of Science. Membership rotates and is composed of five SC Laboratory Chief Operating Officers, site office managers, and one representative from the SC Deputy Director for Field Operations HQ office. The OIC has eight working groups that focus on operational improvements in the areas of acquisition optimization, requirements management, CFO-related issues, IT, human capital, infrastructure, and communications. Each working group is responsible for researching, implementing, and reporting on initiatives to either improve efficiency or reduce the cost of doing business within their area of responsibility. The OIC has successfully implemented operational efficiencies and continues to be a valuable tool for improving SC operations. OIC initiatives such as server virtualization, group purchasing of scientific literature, and integration of videoconferencing capabilities have improved the ability of SC Laboratories to fulfill their scientific missions while reducing the cost of operating these facilities.

4.2.3.2.4 Field Management Council

The Field Management Council (FMC) operationalizes interaction between senior executive field managers from DOE program offices and senior DOE leadership. Dedicated to the goal of maximizing DOE's mission successes, the FMC provides a conduit for DOE field managers to inform Departmental initiatives. This interaction provides a mechanism for knowledge-sharing throughout the Department, alignment and leveraging of program activities, and enhancement of decision-making through more informed programmatic activities.

4.2.3.2.5 Directives Review Board

DOE Order 251.1C, Departmental Directives Program, established the Directives Review Board (DRB) to ensure that directives are consistent with Departmental standards and to add value to the Department's business processes and operations. As stated in the Order, directives serve "as the primary means to set, communicate, and institutionalize policies, requirements, responsibilities, and procedures for Departmental elements and contractors." Of note, directives can result in contractor requirements documents (CRDs) that are incorporated into contracts, including M&O contracts.

The DRB is chaired by the Director, Office of Management (MA), who represents the interests of MA and organizations not otherwise represented on the DRB. Other members include representatives of the three Offices of the Under Secretaries; SC; EM; the Office of General Counsel; and the Office of Environment, Health, Safety and Security. Advisory members represent the National Laboratory Directors and the Field Management Council. Through serving as advisory members, the National Laboratories have the opportunity to inform DOE management of the specific implications of directives on their missions and operations.

4.2.4 DOE Laboratory Strategic Planning

The long-term stewardship of DOE National Laboratories is a shared responsibility between DOE and the Laboratories' M&O contractors (for GOCO Laboratories) or DOE program offices and Laboratory leadership (for NETL). This shared responsibility requires that DOE program offices and DOE Laboratories maintain a mutual understanding of DOE's evolving vision and long-term strategic plan and work together to address the necessary evolution of Laboratory capabilities—both research and facilities—to meet anticipated DOE mission and program office needs, as well as national needs.

This section discusses the annual program and strategic planning that the Science and Energy program offices carry out with their respective DOE Laboratories. These planning activities include collaboration on the near-term and longer term S&T directions of the program office, as well as the enabling facilities and required Laboratory infrastructure needs captured in ten-year site plans. This section also discusses the M&O contractors' responsibility for conducting their own strategic planning in order to make strategic investments internally with indirect resources.

4.2.4.1 Science and Energy Annual Laboratory Strategic Planning Processes

As part of meeting the requirements to operate a National Laboratory, the Laboratories undergo a common set of annual processes to produce strategic plans that are reviewed and approved by their DOE stewards. While these planning processes reflect the differences inherent among the Laboratories, they each address prioritization of RDD&D, aspirational and long-term directions, development and stewardship of core capabilities, and multiyear plans to address current RDD&D priorities.

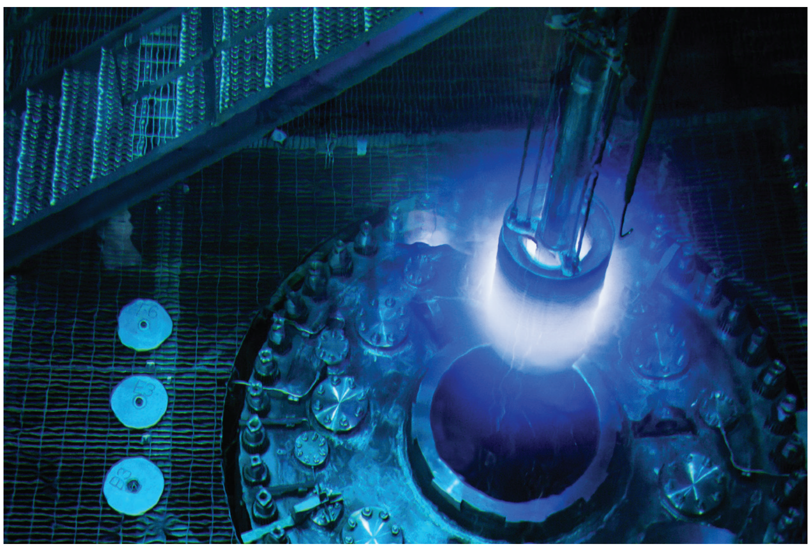
A common plan produced by each Laboratory is the ten-year site plan. As described in Chapter 3, each program office is required under DOE Order 430.1B (Real Property Asset Management) to establish a corporate, holistic, and performance-based approach to real property asset management that links asset planning, programming, budgeting, and evaluation to program mission projections and performance outcomes. The ten-year site plans must describe the site real property assets, including condition assessments, against program mission needs and define the infrastructure investments (e.g., line-item construction, general plant projects [GPPs]) required. The ten-year site plans are used by each program office to inform budget requests for the upcoming fiscal year.

The following subsections provide further detail on how the DOE Science and Energy program offices and the Laboratories they steward interact during the annual planning cycle.

4.2.4.1.1 SC's Annual Laboratory Strategic Planning

SC conducts a formal Laboratory strategic planning process annually whereby each of its ten National Laboratories prepares a written strategic ten-year plan that serves as the basis for detailed discussions during in-person meetings at DOE HQ between Laboratory leadership and SC leadership on the Laboratory's future direction, immediate and long-range challenges, and resource needs. The SC Annual Laboratory Plans, and the accompanying Campus Strategy documents, satisfy the ten-year site plan for SC Laboratories. This section provides a detailed description of the SC process. These written plans prepared by the SC Laboratories consist of the following sections and associated information that is developed by the Laboratories:

1. **Mission/Overview:** This section, which is for a public audience, comprises a top-level summary of the Laboratory that covers everything from the history and location of the Laboratory, to a list of its current core capabilities and a profile of its staff.
2. **Lab-At-A-Glance:** This section, which is intended for a public audience, outlines the Laboratory's major sources of funding and overall costs of operation and provides a snapshot of the Laboratory's human capital assets.
3. **Current Laboratory Core Capabilities:** SC has identified 17 categories of core capabilities—denoted as the SC Laboratory core capabilities—that constitute the scientific and technological foundation of its National Laboratories, and has identified the existence of these capabilities across the SC complex. This section, which is intended for a public audience, provides an overview of the Laboratory's current core capabilities. The list of SC Laboratory core capabilities is provided below.



Achieving the core capabilities and scientific vision for SC laboratories requires infrastructure site plans that identify activities and infrastructure investments. One such example is when ORNL's High Flux Isotope Reactor, pictured here, underwent routine refueling in July 2015. While submersed, the spent fuel emitted a luminescent blue glow due to Cherenkov radiation. Once removed from the reactor, spent fuel is then relocated into an adjacent holding pool for interim storage. *Photo credit: Genevieve Martin/ORNL*

4. **Science Strategy for the Future/Major Initiatives:** This section provides the basis for an in-depth discussion between the Laboratory and the SC leadership about the Laboratory's vision for the future. This discussion occurs in the context of a complete vision for a healthy, world-class Laboratory and the resource needs and risks associated with accomplishing that vision. With the exception of a two-paragraph summary, this section is for internal use only.
5. **Strategic Partnership Projects (SPP):** This section, which is for internal use only, asks the Laboratories to communicate their overall strategy and vision for the SPP program at the Laboratory and to articulate how SPP activities contribute to and strengthen the Laboratory's core capabilities and ability to deliver the DOE mission. As an appendix to the Laboratory plan, SC also asks the Laboratories to provide descriptions of their ongoing SPP activities and an SPP funding level ceiling request for the next fiscal year.
6. **Infrastructure/Mission Readiness:** This section ties mission readiness to Laboratory facilities and infrastructure by identifying gaps and plans to fill those gaps. In 2013, these infrastructure site plans evolved into the development of a Campus Strategy that identifies activities and infrastructure investments (e.g., line-item construction, GPPs) required to achieve the core capabilities and scientific vision for that Laboratory. The plan also serves as SC's equivalent of the ten-year site plan required by DOE Order 430.1b. This section, with the exception of a description on site sustainability, is intended for a public audience.
7. **Human Resources:** This section, which is for internal use only, requests the information needed to elucidate the Laboratory's perspective on the gap between its current human capital and an optimal one, the obstacles it is encountering with respect to developing a mission-ready workforce, and the actions it is taking to address these obstacles.
8. **Cost of Doing Business:** This section, for internal use only, allows the Laboratory to identify major cost drivers and to discuss methods of mitigating those factors.

The SC annual Laboratory strategic planning process occurs over an 8- to 9-month time frame, beginning with SC issuing the guidance for that fiscal year's planning process in December or January and concluding with the posting of the strategic ten-year plans for all SC-stewarded Laboratories on the SC Web site. Table 4.2 provides an overview of the annual process.

The SC Laboratory annual strategic plans and supplementary information provide the starting point for a discussion between the SC leadership—the SC Director and Deputy Directors, the Associate Directors and Office Directors, and respective site office managers—and the Laboratory leadership and parent M&O contractor. The annual strategic planning process and discussions enable DOE/SC to understand the directions in which the current contractor and Laboratory leadership wish to develop the Laboratory, and foster a shared understanding of how these plans fit or don't fit with DOE/SC's long-range scientific priorities and operational goals, taking into consideration reasonable budget outlooks. At SC's request, other major customers at the Laboratories, including the DOE applied energy programs, NNSA, and DHS, review the Laboratory plans of interest to them and participate in SC's annual planning meetings with the Laboratories to provide feedback. This annual Laboratory planning process, started in 2006, is now an integral part of the culture in which SC engages with its Laboratories to foster mutual success in delivering world-leading science and accomplishing the mission.

Planning Activities	Timeframe
The SC Director makes final decisions for Fiscal Year Laboratory planning and guidance.	December—January
SC convene meetings with the Associate Directors and Laboratory Chief Research Offices to review the list of core capabilities to ensure they are accurate and to make any changes.	January
SC issues draft guidance and holds calls with laboratories to discuss instructions and get feedback	February
SC releases final annual planning guidance for lab plans, including guidance on lab presentations.	Late February
Laboratories submit their draft written plans to SC.	Early May
SC holds internal meetings (Fed-only) to review and discuss Laboratories' proposed plans.	May
Annual Laboratory Planning Meetings occur: half-day meetings with the laboratories at DOE HQ are held with SC leadership and Labs receive real-time feedback from DOE	June
SC Publishes the Laboratory Plans on its website.	July—August

Table 4.2: SC Laboratory Planning Cycle.
This table describes the planning activities and associated time frames that make up the Office of Science's annual Laboratory strategic planning process.

4.2.4.1.2 SC Laboratory Core Capabilities

As noted above, SC has established 17 Laboratory core capabilities that constitute the scientific and technological foundation of its National Laboratories. The establishment of these core capabilities was done in collaboration with all of the SC Laboratories, and the existence of specific capabilities at each of the SC Laboratories must be endorsed by the sponsoring DOE office(s). SC uses three criteria to define their Laboratory core capabilities. They must (1) encompass a substantial combination of facilities and/or teams of people and/or equipment; (2) have a unique and/or world-leading component; and (3) be relevant to a discussion of the missions of DOE, NNSA, and Department of Homeland Security (DHS). These descriptions are intended to articulate the niche that each Laboratory holds in the SC complex relative to the other SC Laboratories so as to easily distinguish these institutions from one another. While several Laboratories may hold one or more of the same Laboratory core capabilities, when assessed at a deeper level, a Laboratory's core capability encompasses a unique, and complementary, set of facilities, equipment, and expertise. Table 4.3 illustrates the composition of SC Laboratory core capabilities across the ten SC Laboratories.

Categories of Core Capabilities	AMES	ANL	BNL	FNAL	LBNL	ORNL	PNNL	PPPL	SLAC	TJNAF
Accelerator Science		✓	✓	✓	✓	✓			✓	✓
Advanced Computer Science, Visualization, and Data		✓			✓	✓	✓			
Applied Materials Science and Engineering	✓	✓	✓		✓	✓	✓			
Applied Mathematics		✓			✓					
Applied Nuclear Science and Technology		✓	✓		✓	✓	✓			✓
Biological Systems Science			✓		✓	✓	✓			
Chemical and Molecular Science	✓	✓	✓		✓	✓	✓		✓	
Chemical Engineering		✓	✓		✓	✓	✓			
Climate Change Science			✓		✓	✓	✓			
Computational Science					✓	✓				
Condensed Matter Physics and Materials Science	✓	✓	✓		✓	✓			✓	
Environmental Subsurface Science					✓	✓	✓			
Large Scale User Facilities/Advanced Instrumentation		✓	✓	✓	✓	✓	✓	✓	✓	✓
Nuclear Physics		✓	✓		✓	✓				✓
Particle Physics		✓	✓	✓	✓				✓	
Plasma and Fusion Energy Science						✓		✓		
Systems Engineering and Integration		✓	✓		✓	✓	✓			

Table 4.3: Distribution of Core Capabilities across the SC Laboratories.
This table provides a list of categories that encompass SC's core capabilities and their alignment with the capabilities of each of the 10 National Laboratories that SC stewards.

4.2.4.1.3 EERE's Annual Laboratory Strategic Planning

Each year at the start of EERE's planning cycle, EERE holds the EERE Ideas Summit, which brings together NREL leadership and staff and EERE technology officers and program managers. The Summit is used to convey strategic priorities. The strategic planning from the Summit and the annual EERE strategic priorities are used as the basis for NREL's formulation of an NREL five-year plan.

The NREL five-year plan is developed collaboratively with the EERE programs and EERE's senior leadership. The plan focuses on priority research and technology directions and major initiatives, and the associated research infrastructure and strategic hiring needed. The plan identifies major aspirational directions for the Laboratories to increase their value and impact on their missions in the planning period and to sustain their value over the long term. Plans highlight key contributions that the Laboratories will make within their portfolios of mission goals and objectives, with more detailed discussions in the multiyear program and annual operating planning processes (such as the ten-year site plan). The NREL five-year plan is aligned with EERE-defined core and enabling capabilities (note that the EERE core capabilities are determined in a process distinct from that used by SC). NREL also uses this plan to help inform their annual Laboratory-directed research and development (LDRD) plan.

Close discussions among NREL and the EERE programs while the plan is being developed helps ensure alignment between EERE priorities and program goals and NREL's vision for the future.

In 2015, EERE developed its National Laboratory Guiding Principles to help ensure that its annual laboratory planning for the NREL, and planning with other DOE Laboratories where it has significant investments, involves a close collaboration between its programs and the Laboratories. Development of the National Laboratory Guiding Principles was coupled to EERE's efforts to establish more uniform, longer-term strategic planning for the EERE portfolio and improved stewardship of NREL and S&T capabilities and investments across DOE Laboratories.

As part of this effort, EERE has identified and defined core and enabling capabilities relevant to its core technology areas at each DOE Laboratory to help the EERE programs promote collaboration across the Laboratories and optimize investments. EERE has also established a new merit review process for direct Laboratory-funded work that emphasizes these core and enabling capabilities.

4.2.4.1.4 NE's Annual Laboratory Strategic Planning

As the Nation's lead Laboratory for nuclear energy, the INL is uniquely positioned to support NE's mission, and as such, NE and INL work closely on a number of strategic activities. NE's strategic vision is laid out in the NE Research and Development Roadmap, which was developed by NE with technical support from INL. The NE R&D Roadmap guides NE's program planning and forms the basis for much of INL's planning.

NE works with INL to develop an integrated priority list (IPL), which is an annual prioritization of work to be funded by NE in support of the NE R&D Roadmap. Working with the other DOE National Laboratories, INL leads the development and coordination of work proposed to NE as detailed in the annual INL IPL. The input provided by INL is presented to NE leadership and forms the basis for NE's annual work planning.

The annual update to the INL ten-year site plan is a collaborative effort between INL, NE, and the Idaho Operations Office. It is also informed by external recommendations (such as those by the NEAC) and NE's IPLs. The Plan focuses primarily on multiyear infrastructure planning but is also driven by and aligned with the NE R&D Roadmap to ensure capabilities will be in place to address research objectives, gaps are identified and addressed, and work is appropriately prioritized. The INL Ten-Year Site Plan also guides annual field work proposals from the Laboratory.

4.2.4.1.5 FE's Annual Laboratory Strategic Planning

As a GOGO Laboratory, the strategic priorities and future vision for NETL is integrally tied to the broader FE strategic planning and development of R&D roadmaps. FE program planning identifies the goals and priorities of the organization and determines the methods to achieve those goals. With respect to NETL, planning considers the goals and objectives established at the DOE organizational level, within the various technical programs and subprograms implemented at NETL, and throughout the NETL field organization. Typically, planning is conducted for three time horizons: strategic (10–20 years), multiyear programmatic (2–10 years, including a five-year resource plan), and annual/operational (one year). In addition, NETL, as FE's principal implementing National Laboratory, is also directly connected to, and responsible for, parts of FE's annual performance measures and quarterly reporting.

4.2.4.2 Laboratory General Purpose Infrastructure Planning

The Department is responsible for managing an infrastructure portfolio that stretches over 50 sites across the Nation. This portfolio of land, facilities, and other assets is the foundation of the Department's ability to conduct its mission. A long-term commitment to modernization of DOE Laboratory facilities and infrastructure supports mission-readiness of the Laboratories by ensuring that the Laboratories have state-of-the-art facilities and infrastructure that are flexible, reliable, and sustainable in support of scientific discovery and technology development.

Serving as a virtual nuclear control room, the Human Systems Simulation Laboratory at INL supports modernization of instrumentation and control systems by providing an operating model to safely test new technologies before they are implemented in real commercial reactor control rooms. *Photo credit: INL*

Additionally, DOE has major infrastructure dedicated to its responsibility for environmental remediation of a number of legacy sites contaminated during 50 years of nuclear weapons production and scientific research.

> ### DOE Inventory
>
> DOE's inventory of real property is the fifth largest in the Federal Government and includes over 18,000 buildings, trailers, utility systems, information technology networks, and roads covering an estimated 117 million square feet on 2.2 million acres of land—almost as large as Delaware and Rhode Island combined.

The DOE general purpose infrastructure portfolio has been developed over the past 70 years, with origins in the Manhattan Project. While it now represents one of America's premier assets for science, technology, innovation and security, the average age of DOE's facilities is nearing 40 years, and modernization has not kept up with evolving mission needs in S&T. As a result, much of this infrastructure cannot adequately support cutting edge science and highly technical operations as well as it could it if were modernized. The scientific and technological innovation at DOE Laboratories is significantly enhanced by funding and sustaining mission-ready infrastructure and fostering safe and environmentally responsible laboratory operations.

The Secretary formed the LOB in 2013 to provide an enterprise-wide forum to engage the Laboratories. Through the LOB, the Department's programs and Laboratories engage in a joint effort to identify opportunities to improve effectiveness and efficiency. One of the transformational opportunities identified by the LOB was the need to focus on revitalizing the general purpose infrastructure across the DOE enterprise. The LOB established an integrated plan to conduct for the first time a Laboratory-wide assessment of general purpose infrastructure across all 17 Laboratories as well as NNSA plants, using common metrics and an enterprise-wide approach.

> ### The DOE Infrastructure Portfolio
>
> - 10,660 buildings totaling 117 million square feet (owned and leased)
> - Average facility age: 35 years
> - Average utility age: 39 years
> - 2.2 million acres
> - $111 billion replacement plant value (excluding land)
> - $2 billion in annual operating costs
> - $6.1 billion in deferred maintenance (including inactive assets)

These assessments provided new insight into the condition of the infrastructure and formed the basis for the development of an infrastructure plan to ensure a sustainable infrastructure for the future. As part of the assessments, consistent definitions of functionality and utilization of the facilities were captured, enabling managers to understand where excess space exists and broadening the possibility of shared space use across DOE. The data show that the Department's infrastructure needs far exceed available funding. A comprehensive, strategic approach is needed to reverse the current decline in the state of DOE infrastructure. The infrastructure plan developed by the LOB effort is a first step in that direction. It will evolve as lessons are learned and results are evaluated.

The Department's strategy for making needed infrastructure investments consists of a two-pronged approach. First, in the 2016 budget request and beyond, the Department seeks to increase its investment in core general-purpose infrastructure while continuing to invest in infrastructure that is required to take advantage of emerging mission areas. Second, a broader set of investment tools is being explored. General purpose infrastructure investments include everything from line-item construction for modern laboratory research space; renovation of existing facilities; repair and upgrades to utilities; and demolition of dilapidated and unsafe infrastructure.

The Department is committed to using the full range of available financing strategies, including the best tool available for each type of project. The Department has adopted the following principles as it works to close the infrastructure gaps:

- Maintenance and repair funding will be at or above the National Academy recommended standard of 2 percent of each site's replacement plant value. If these investments are not made, infrastructure will continue to decline and the problem will grow. This fundamental level of investment is a foundational element of infrastructure stewardship.
- GPPs and Institutional GPP (IGPP) investments will be directed towards core-infrastructure gaps because these tools are best tailored for doing this type of work.
- Line-item funding will be typically reserved for transformative, focused, large-scale infrastructure projects to renovate and construct needed spaces.
- Alternative financing solutions will be used by the Department for new infrastructure that addresses emerging areas of research or is needed to perform our nuclear security and environmental missions of those facilities that satisfy the criteria for alternative financing. The Department and its Laboratories, plants, and sites will look for public and private sector partners as it works to revitalize its infrastructure. In addition, the Department will leverage other Federal initiatives to improve efficiencies and share costs (e.g., Energy Savings Performance Contracts [ESPCs] and Utility Energy Savings Contracts [UESCs]).

The enterprise-wide assessments initiated in 2013 resulted in a rigorous and consistent analysis of the condition, utilization, and functionality of the facilities and infrastructure that are the most important to mission accomplishment. Building on these assessments, in 2014 SC worked with each of its Laboratories to develop comprehensive Campus Strategies, integrated with the SC annual Laboratory planning process discussed above, which addresses the SC Laboratories' required ten-year site plans.

4.2.4.3 DOE Laboratory Internal Strategic Planning and Investments

The DOE Laboratory M&O contractors are active partners with DOE in ensuring that the Laboratory contractors maintain an understanding of DOE's Laboratory vision and DOE's strategic plan. The contractors are deeply engaged in the DOE program office strategic planning and RDD&D roadmapping and technology transfer efforts. They develop long-term strategic plans for their Laboratory in collaboration with DOE (as described above), and they may also develop their own long-term strategic plans that they present and discuss with their board of directors or advisory councils. Those internal strategic plans are tightly coupled to the long-term strategic plans developed for DOE, such as the SC, EERE, NE, and FE annual Laboratory plans and the ten-year site plans. An example of the process used by the Laboratories—in this instance, PNNL—is shown in Figure 4.3.

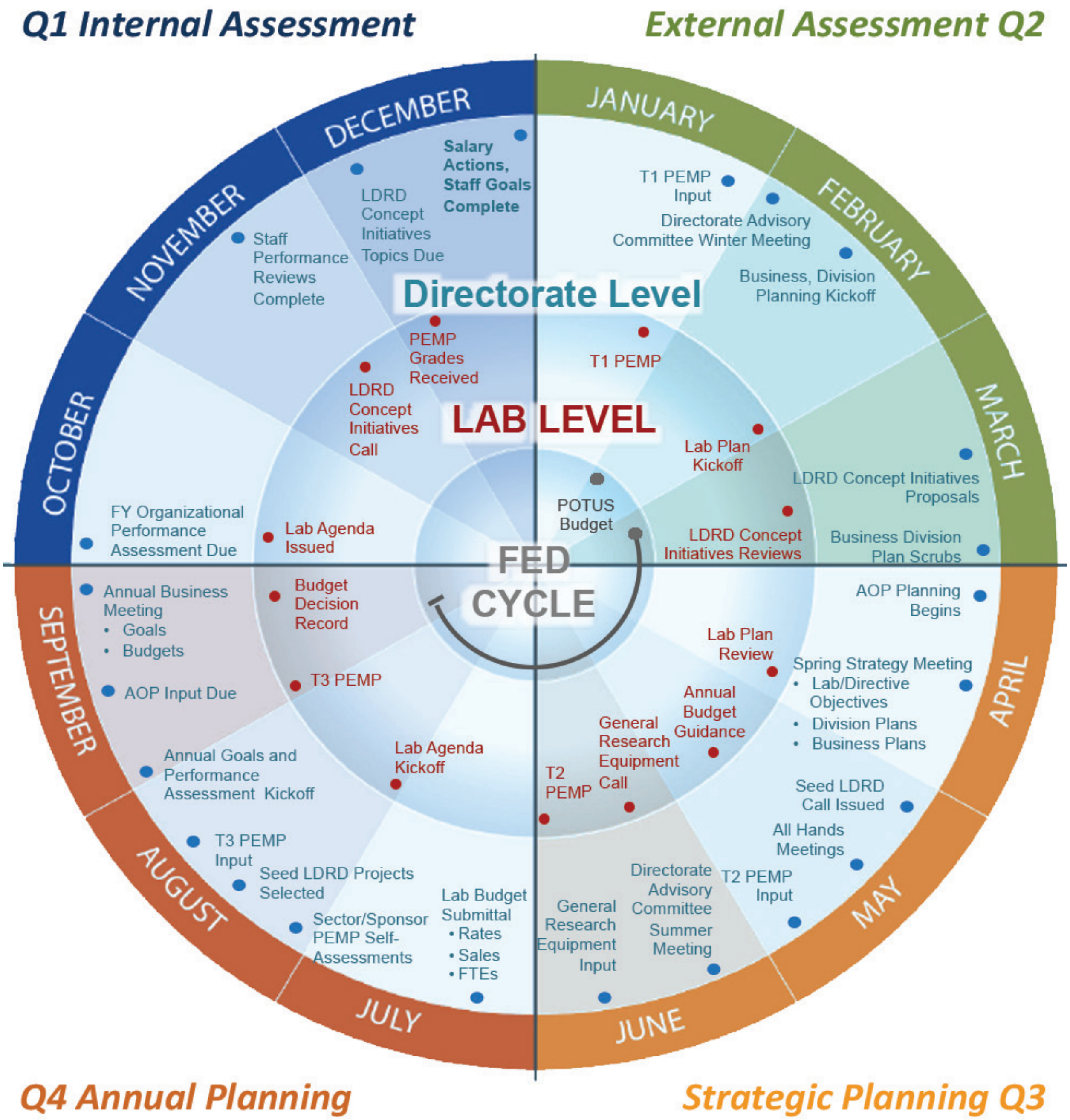


Figure 4.3: Laboratory Planning Cycle Example.

This diagram describes how the Energy and Environmental Directorate at PNNL executes their planning cycle. Q1, Q2, Q3, Q4 = 1st, 2nd, 3rd, 4th quarters, respectively; PEMP= performance evaluation and measurement plan; POTUS= President of the United States; see Appendix A for other acronyms.

As an active partner in the long-term stewardship of a DOE Laboratory, the M&O contractor has a responsibility not only for effective, efficient, and safe operation of the Laboratory and for delivering outstanding performance in S&T, but also to renew and enhance Laboratory systems, research facilities and equipment so the Laboratory remains state-of-the-art over time and is well-positioned to meet future DOE needs. The Laboratories work with DOE program offices on direct investments and are also allowed to and expected to use overhead to make the necessary and strategic investments to meet these responsibilities.

The M&O contractors also have a responsibility for making strategic investments in the Laboratory and do so in a number of ways: institutional general plant projects (GPP), LDRD, and investment of contractor resources.

4.2.4.3.1 Institutional General Plant Projects for Laboratory Infrastructure

One of the Laboratories' largest investments of overhead funds is maintenance of the Laboratory. This includes maintaining effective and efficient operation of Laboratory buildings and facilities, and utilities and grounds. Consistent with their ten-year site plans, Laboratories work with their cognizant DOE program offices to establish a prioritized list of needed infrastructure improvements and collaboratively identify direct GPP investments by the program office and IGPP to be made by the contractor through overhead.

GPPs are minor construction projects authorized by law for funds authorized by the national security authorization (i.e., the annual National Defense Authorization Act). These are new construction projects of a general nature, the total estimated costs of which may not exceed the congressionally established limit. GPPs are necessary to adapt facilities to new or improved production techniques, to effect economies of operations, and to reduce or eliminate health, fire, and security problems. These projects provide for design and/or construction, additions, improvements to land, buildings, and utility systems, and they may include the construction of small new buildings, replacements or additions to roads, and general area improvements.

IGPPs are similarly authorized but benefit multiple cost objectives and fulfill multiprogrammatic and/or interdisciplinary needs. IGPPs are funded through site overhead. Examples are multiprogrammatic/interdisciplinary scientific laboratories, institutional training facilities, cafeterias, guard houses, site-wide maintenance facilities and utilities, new roads, multiprogrammatic office space, and multiprogrammatic facilities required for "quality of life" improvements.

In November 2013, the LOB established an integrated plan to conduct an assessment of general purpose infrastructure to assess how it is meeting mission needs across all 17 Laboratories and NNSA sites and plants, using common standards and an enterprise-wide approach. These assessments, conducted over the course of 2014, provided new insight into the condition of the infrastructure. Data developed as a result of this initiative provided the basis for over $100 million in the Department's FY 2016 funding request, targeted for new investments in priority general purpose infrastructure projects. Through this enterprise-wide analysis and related infrastructure planning, the LOB identified a focus on excess facilities as an important second phase of this effort to establish a sustainable trajectory for DOE infrastructure.

4.2.4.3.2 Laboratory-Directed Research and Development

Laboratory contractors have a responsibility to deliver on their current S&T objectives for DOE program offices and other customers, but they are also charged with the responsibility to build and maintain a viable portfolio of R&D programs to renew and enhance Laboratory R&D capabilities over time, as well as attract, develop, and retain an outstanding work force, with the skills and capabilities to meet DOE's evolving mission needs. Laboratories may do this by competing for funding opportunities issued by DOE or other sources, but they may also use LDRD funds to make such investments.

DOE established the LDRD program in 1991 to give Laboratory directors the ability to allocate funding to scientists to support employee-initiated proposals that explore forefront areas of S&T. DOE-SC has been given responsibility for the Department's LDRD policy, codified in DOE Order 413.2B, Change 1, Laboratory Directed Research and Development.

The objectives of the LDRD program are to (1) maintain the scientific and technical vitality of the Laboratories; (2) enhance the Laboratories' ability to address current and future DOE/NNSA missions; (3) foster creativity and stimulate exploration of forefront S&T; (4) serve as a proving ground for new concepts in R&D; and (5) support high-risk, potentially high-value R&D.

In accordance with section 309 of the Consolidated Appropriations Act of 2014 (Public Law 113–76), the Secretary of Energy may authorize up to 6% of a Laboratory's total operating and capital equipment budget, including non-DOE funded work, for LDRD. This was a reduction from the previous cap of 8% set in 2006. DOE currently allows participating Laboratories to support their LDRD programs by including an LDRD change in the indirect costs for R&D performed for DOE, other Federal agencies, and non-Federal sponsors. The policy requires the Cognizant Secretarial Officer to approve the annual maximum funding level for LDRD at the Laboratories under his/her purview. Current actual LDRD funding levels vary across all DOE Laboratories and do not exceed 6 percent. To obtain approval of the maximum LDRD funding level, a Laboratory submits a request for the LDRD funding level to the Department as part of its required annual LDRD program plan, which is approved by the Cognizant Secretarial Officer. The LDRD program plan also provides the strategic areas of LDRD investment for the coming year and a general description of the LDRD program at the Laboratory. Table 4.4 provides an overview of LDRD funding levels at DOE National Laboratories in FY 2014.

Each DOE Laboratory has a process in which individual scientists and engineers propose projects that peer review panels and Laboratory managers prioritize on the basis of their assessment of potential S&T merit, potential strategic impact, and commercial potential. The Laboratory directors use these assessments to make their selections. In accordance with DOE policy, DOE concurs on each LDRD project. Each Laboratory establishes internal processes that cover the call for proposals, schedules, guidelines for what LDRD can be used to support, and what it is unable to support.

Each Laboratory provides DOE with an annual LDRD report, which provides information on each project funded that year. Consistent with the FY 2002 Energy and Water Development Appropriations Act, the Department submits an annual Report to Congress on LDRD expenditures. The report also affirms "that all LDRD activities derived from funds of other agencies have been conducted in a manner that supports science and technology development that benefits the programs of the sponsoring agencies and is consistent with the Appropriations Acts that provided funds to those agencies."

The LDRD program has been indispensable to DOE Laboratories in supporting scientific innovation. The overall LDRD programs of the Laboratories are well articulated and appropriately focused on DOE-defined mission and goals. However, DOE's mission has been and will continue to be dynamic, and the LDRD program has been and will continue to be a key mechanism for responding to new opportunities and scientific challenges. Given this dynamic context, LDRD also increases the ability of DOE Laboratories to respond to changing circumstances through the hiring and retention of new staff such as postdoctoral researchers.

4.2.4.3.3 Investment of Contractor Resources

DOE laboratory M&O contractors also make significant investments from their own resources into the Laboratories. Often, at the time a DOE Laboratory contract is re-competed, the commitments of a proposer's own organizational resources (people, property, infrastructure, equipment, business systems, or other

Laboratory	# of LDRD Projects	LDRD Certified Costs ($M)	Total Lab Certified Costs ($M)	LDRD as a % of Certified Cost Base
Ames Laboratory	9	1.0	**53.0**	1.89%
Argonne National Lab	107	29.2	**753.6**	3.87%
Brookhaven National Lab	40	9.6	**566.1**	1.70%
Fermi National Lab	7	.2	**324.1**	2.05%
Idaho National Lab	63	17.0	**827.7**	2.05%
Lawrence Berkley National Lab	83	23.6	**751.7**	3.14%
Lawrence Livermore National Lab	147	78.2	**1,411.7**	5.54%
Los Alamos National Lab	29	118.5	**2,068.0**	5.73%
National Energy Technology Lab*	0	0	**0**	0%
National Renewable Energy Lab	57	10.3	**356.3**	2.89%
Oak Ridge National Lab	174	36.3	**1,231.8**	2.95%
Pacific Northwest National Lab	182	38.9	**982.2**	3.96%
Princeton Plasma Physics Lab	15	2.0	**102.0**	1.96%
Sandia National Labs	419	151.3	**2,686.3**	5.63%
Savannah River National Lab	40	6.2	**188.4**	3.29%
SLAC National Accelerator Lab	20	4.4	**283.7**	1.55%
Thomas Jefferson National Accelerator Facility	3	.2	**107.9**	.19%
Total	**1,662**	**526.9**	**12,694.5**	**4.15%**

Table 4.4: FY 2014 Overall Laboratory Costs and LDRD Costs at DOE Laboratories.
This table provides an overview of LDRD charge rates at DOE National Laboratories in FY 2014. *As a GOGO laboratory, NETL is not eligible to fund LDRD.

resources) may be encouraged as part of the proposal and considered in the review of proposals. Those commitments become incorporated into the contract. The Laboratory contractor is further encouraged, and incentivized through the performance evaluation and measurement plans, to make their own investments in the Laboratory, and many of them do. Laboratory contractors have provided funding for everything from joint faculty appointments, modernizing Laboratory business systems and utilities, to the demolition of old excess buildings and the construction of modern Laboratory research buildings. The following are a few examples of some substantial investments.

Stanford University, the M&O contractor of SLAC National Accelerator Laboratory, owns the land that SLAC occupies and leases the land to DOE at no cost; the cost of leasing the land would be approximately $35 million per year. In addition, Stanford University sponsored the construction of several buildings on the SLAC campus over the past several years, which has significantly improved the research facilities and support buildings. The University of California (UC), the M&O contractor of LBNL, sponsors over 200 joint faculty appointments from the UC campus system with LBNL.

Several M&O contractors have been successful in working with their State Governments to secure State funds for Laboratory investments in infrastructure. ORNL worked with the University of Tennessee (UT) and the State of Tennessee over the past several years to construct three major research buildings on the ORNL campus: the Joint Institute for Computational Sciences, the Joint Institute for Biological Sciences, and the Joint Institute for Neutron Sciences. The nearly $30 million in Tennessee State investment provided for the construction of over 120,000 ft^2 of new research space to promote greater collaborations between ORNL and UT. ANL has worked with the State of Illinois, which is providing $35 million for the construction of the Energy Innovation

Center on the ANL campus to house the Laboratory's energy storage and battery research. The Commonwealth of Virginia has contributed $9 million to the Continuous Electron Beam Accelerator Facility (CEBAF) 12 GeV Upgrade project at TJNAF.

Over the last ten years, INL's M&O contractor, the Battelle Energy Alliance (BEA), invested in the Center for Advanced Energy Studies (CAES) as part of a consortium with Boise State University, Idaho State University, the University of Idaho, and the University of Wyoming. The CAES building is owned by the State of Idaho and maintained by Idaho State University. The facility enabled collaborative work with universities, industry, and other DOE Laboratories. BEA has also made upgrades to the Advanced Test Reactor that enables additional short-term irradiation testing.

4.2.5 Laboratory Quality Assurance and Oversight

The Department is both the owner and regulator of DOE sites, and as such, is ultimately responsible for ensuring that all DOE activities are performed safely—work is performed in a manner that is protective of the worker, the public, and the environment—and efficiently while achieving mission objectives. DOE work results must be of a high quality commensurate with its importance to the mission. This applies to work performed by both DOE Federal employees and DOE contractors. DOE requirements in this area are set forth primarily in two DOE Orders: DOE Order 414.1D, Quality Assurance, and DOE Order 226.1B, Implementation of Department of Energy Oversight Policy.

DOE Order 414.1D requires that contractors, including the M&O contractors of DOE Laboratories, establish a quality assurance program (QAP) to ensure the quality of their work, and a contractor assurance system (CAS) to provide DOE with reasonable assurance that they are meeting their contractor requirements. QAPs must implement the quality assurance (QA) criteria defined in DOE Order 414.1D and describe how the criteria are met, using a documented graded approach. DOE Order 226.1B defines specific requirements and formalized structure with respect to the DOE line management oversight of the operational subjects of environmental, health and safety, safeguards and security, cyber security, and emergency management. The oversight processes applied to those aspects of the operations are also applied to all other aspects of the Laboratory work, including business management functions, project management, facilities infrastructure operations and maintenance, and scientific research.

In an effective QAP and CAS, the M&O contractor implements management systems that include performance metrics, internal oversight, internal independent assessment, management/self-assessment, inspection and testing, and a broad array of quality improvement activities including deficiency identification, occurrence reporting, lessons learned, trending analyses, causal analyses, corrective actions, and issues management. An effective CAS also provides for oversight of the M&O contractor by its corporate parent.

The DOE program office with line management responsibility for the Laboratory conducts oversight of the Laboratory, first relying on the contractor's own QAP and CAS practices. Only when there is reason to believe implementation of areas of the QAP or CAS have been deficient does DOE line management take a more in-depth look at an issue, conducting its own reviews, to ensure that problems are evaluated and corrected on a timely basis.

4.2.5.1 Responsibilities of a DOE Laboratory Contractor

The DOE Laboratory M&O contractor's internal management assurance programs work together in conjunction with the DOE oversight processes to form a comprehensive strategic governance and oversight framework, defined in the QAPs and CAS, based on prime contract requirements, DOE orders, other national consensus standards, and prudent management of risk, accountability, transparency, and renewed trust. Assurance for the M&O contractor includes important elements such as CAS implementation; a Laboratory governance structure; strategic planning, resourcing, and implementation of CAS performance improvement tools; and internal assessment and oversight programs. The goal is to ensure performance and risks are understood, managed, and support mission accomplishment. Internal assurance processes incorporate the following:

- Resourcing decisions informed by performance/risk
- Performance that is understood, trended, and aligned to mission outcomes
- Issues/conditions that are self-identified, prioritized, and corrected
- Identified and managed risks
- Independent/external oversight to improve performance
- Root cause analysis of events to ensure they are understood and recurrence and impacts are minimized
- Rigorous and credible assessments that drive improvements
- Sharing and learning from mistakes and successes

The elements of regular contractor management assurance reviews include input from sponsors (DOE and other sponsors of work at the Laboratory), results of Laboratory-initiated peer reviews and Laboratory advisory boards, results of internally conducted self-assessments, reports from functional management reviews, and standard performance metrics (e.g., data related to publication of scientific results, establishing and protecting intellectual property, and safety and security statistics).

An important element of Laboratory assurance is peer reviews by review and advisory boards/committees. Rigorous peer review is a fundamental tenet of scientific and engineering research and an essential element of planning and assessment at the organizational level. These reviews, which may be coupled with or are complementary to those reviews organized by DOE program offices, are essential to examining, assessing, and maintaining the quality of the Laboratory's R&D efforts, productivity of the technical workforce, internal investments (discussed above), Laboratory strategic planning, and relevance of the research efforts to important DOE and Laboratory missions.

4.2.5.2 DOE Oversight and Role of the Site Office

DOE line management conducts oversight of its contractors to maintain awareness of the adequacy of the contractors' performance. Since the M&O contractor, through its QAP and CAS, is conducting a broad array of internal oversight and quality improvement activities, DOE line management can, once it establishes confidence in the contractor's management systems, take advantage and make use of the output of the contractor's QAP and CAS. Therefore much of the focus of DOE line management oversight of M&O contractor operations is to establish and maintain confidence in the credibility of the M&O contractor's internal oversight results. Upon establishment of DOE line management confidence in the effectiveness of the M&O contractor's QAP and CAS outputs, DOE line management oversight continues in order to maintain the level of confidence.

DOE line management uses numerous oversight activities to maintain awareness of Laboratory site operations and the effectiveness of the M&O contractor's QAP and CAS. Operational awareness activities include assessments, surveillances, inspections, facility tours and walkthroughs, work observations, document and records reviews, meeting attendance and participation, and continual interactions with contractor workers, support staff, and management. DOE line management oversight may include a mix of independent DOE oversight of contractor activities; joint DOE–contractor oversight of contractor activities; and DOE observation of contractor oversight of contractor activities. The level and/or mix of DOE line management oversight of M&O contractor activities may be adjusted commensurate with the effectiveness of the M&O contractor's QAP and CAS. DOE line management oversight activities must include review of the relevant output/results generated by the M&O contractor's QAP and CAS. This enables the ongoing verification of the credibility of the M&O contractor's QAP and CAS results.

The DOE site office manager at each DOE site office serves as the DOE line manager accountable for the management of the M&O contract and oversight of the day-to-day activities at the Laboratory under their cognizance. The site office manager also serves as DOE's principal point of contact to the M&O contractor management. The contracting officer (CO) within the site office has the legal contracting responsibility for contract administration. Science or Energy program office staff at the respective site office, supporting field sites (such as the SC ISC) and HQ carry out a variety of oversight activities outlined above and other requirements that are prescribed by DOE regulations, DOE directives (e.g., DOE Orders, DOE policy documents), and other requirements included in the prime contract between DOE and the M&O contractor. This staff consists of, but is not limited to, COs, contract specialists, safety and operations specialists, and project management, business, environmental, and finance specialists.

4.2.6 Measuring Laboratory Performance

As noted above, DOE is ultimately responsible for ensuring that all DOE activities, regardless of whether they are performed by DOE Federal employees or by DOE contractors, are performed safely and efficiently while achieving mission objectives. DOE embraces a performance-based management approach to the overall evaluation of the M&O contractor's management of the DOE Laboratory and establishes requirements in the M&O contract for standards of performance, self-assessment by the contractor, and comprehensive performance evaluation.

DOE program office line management evaluates Laboratory contractor performance in meeting the applicable regulatory and contractual requirements and expectations, including but not limited to laws, regulations, DOE directives, DOE technical standards, contractors' assurance system outcomes, national/international consensus standards, the goals and objectives set forth in the performance evaluation and measurement plans (PEMPs), and DOE-approved plans and program/system documents.

More specifically, the Science and Energy program offices conduct the comprehensive evaluations of Laboratory performance for their respective Laboratories on an annual basis. The US/SE program offices that have stewardship responsibilities for DOE National Laboratories operated as FFRDCs under M&O contracts are also required to establish defined processes and protocols for meeting the line management oversight responsibilities conveyed in DOE Order 226.1B, Implementation of Department of Energy Oversight Policy, with respect to environmental, safety, and health; safeguards and security; cybersecurity; and emergency management. In addition, as required under DOE Order 414.1D, Quality Assurance, program offices oversee other aspects of work at the Laboratory, including facilities and infrastructure maintenance, program and project management, finance and budget, and human resources.

SC, NE, and EERE have established standard processes by which they evaluate how their respective DOE Laboratories are performing and meeting the requirements of the M&O contract. Each program office establishes an annual PEMP for each of its respective DOE Laboratories that is put into effect (that is, appended to the contract) at the beginning of the fiscal year, and each program office has established a formal process by which it conducts its annual evaluation of the Laboratory. The PEMP defines the performance goals for the year as well as the evaluation methodology that will be used. The PEMP may also define the availability and conditions for a performance-based fee, and for award term eligibility (if allowed under the M&O contract).

The following provides an overview of the SC, EERE, and NE processes for annual Laboratory performance evaluation. This section closes with a discussion of how NETL, as a Government-operated laboratory, is evaluated by FE through a different set of merit review processes.

4.2.6.1 Annual Laboratory Appraisal Process for Office of Science Laboratories

Each year, SC conducts an evaluation of the scientific, technological, managerial, and operational performance of the contractors who manage and operate its ten National Laboratories. The performance evaluation provides a standard by which to determine whether the contractor is managerially and operationally in control of the Laboratory and is meeting the mission requirement and performance expectations/objectives of the Department as stipulated within the M&O contract. These evaluations provide the basis for determining annual performance fees and the possibility of winning additional years on the contract through an "Award Term" extension. They also serve to inform the decisions the Department makes regarding whether to extend or to compete the M&O contracts when they expire.

The current SC Laboratory appraisal process has been in place since FY 2006. It was designed to improve the transparency of the process, raise the level of involvement by the SC leadership, increase consistency in the way the Laboratories are evaluated, and more effectively incentivize contractor performance by tying performance to fee earned, contract length, and the public release of grades. The SC Office of Laboratory Policy coordinates the Laboratory appraisal process on behalf of the Director of the Office of Science, working closely with the SC program office Associate Directors, Office Directors, and Site Office managers, as well as soliciting input from other major sponsors of Laboratory work, such as DOE's applied technology offices, NNSA, and DHS. The schedule of the annual appraisal cycle is described in Table 4.5.

4.2.6.1.1 Performance Goals and Objectives

The SC Laboratory appraisal process uses a common structure and scoring system across all ten of its Laboratories. Structured around eight performance goals, it emphasizes the importance of delivering the science and technology necessary to meet the missions of DOE; of operating the Laboratories in a safe, secure, responsible, and cost-effective way; and of recognizing the leadership, stewardship, and value-added provided by the contractor managing the Laboratory. The eight performance goals are:

1. mission accomplishment (delivery of S&T, transfer, and deployment);
2. design, construction and operation of research facilities;
3. science and technology project/program management;
4. leadership and stewardship of the Laboratory;
5. integrated environment, safety and health protection;
6. business systems;
7. facilities maintenance and infrastructure; and
8. security and emergency management.

Each performance goal is composed of a small number of objectives. Within each objective, SC science programs and site offices can further identify a small number of notable outcomes that illustrate or amplify important features of the Laboratory's performance for the coming year. The performance goals, objectives, and notable outcomes are documented at the beginning of each year in a PEMP that is appended to the respective Laboratory contract.

4.2.6.1.2 Performance Evaluation and Measurement Plan

The PEMP that is developed for each SC Laboratory and appended to the M&O contract at the beginning of each fiscal year formally holds the Laboratory contractor accountable for the performance goals and objectives and the notable outcomes, and also describes the methodology for determining the amount of fee that can be earned by the contractor for that fiscal year, and the basis for determining the contractor's award term eligibility.

Planning Activities	Timeframe
SC Associate Directors (ADs) and Site Offices (SOs) develop draft Notable Outcomes for Goals 1.0-3.0 and Goals 5.0 -8.0, respectively. Also provide suggested Notable Outcomes for Goal 4.0.	April—June
ADs meet with the Deputy Director for Science Programs and SOs meet with the Deputy Director for Field Operations to discuss Notable Outcomes.	July—August
PEMP details, including Notable Outcomes are finalized and sent to the SC Director for Approval.	August—September
The approved PEMP is legally included as part of M&O contract as an appendix for each SC Laboratory for the start of the new Fiscal Year.	October 1st
At the end of the Fiscal Year (subject to the previous PEMP), SC's Office of Laboratory Policy and gets input and grades from ADs on Goals 1.0-3.0 and SOs on Goals 5.0-8.0. Input on Goal 4.0 is also collected.	October
ADs meet with the Deputy Director for Science Programs and SOs meet with the Deputy Director for Field Operations to discuss inputs and grades.	November
Deputy Directors meet with SC-1 to review input and approve final grades and evaluations.	November—December
SC Director meets with Laboratory leadership to discuss overall performance of the Laboratory.	December
Annual Laboratory Report Card posted on SC website and evaluation report made available.	December

Table 4.5: Laboratory Appraisal Cycle.
This table provides the significant milestones within SC's Laboratory appraisal cycle that occur throughout the calendar year.

Since FY 2010, SC has included notable outcomes in the PEMP for each Laboratory every year. This is in response to a 2009 review of SC's annual appraisal process, which recommended that measures be focused more on outcomes for improved performance and less on compliance measures or process steps that duplicate requirements in the DOE Orders and regulations.

The notable outcomes are a short list of the most important things SC wants the contractor to focus on in the coming year, above and beyond sound management of the contract and across all the eight evaluation categories. The notable outcomes do not cover all that the Laboratory has to accomplish, but rather identify a "notable few" things that the Laboratory must achieve or improve in the coming year. Achievement of the notable outcomes is required for the Laboratory to be rated at least a B+ in the cognizant objective. Initial draft notables are often identified by science program associate directors and site office managers at the time of the annual Laboratory strategic planning presentations, and further refined before the PEMP for each Laboratory is finalized and added to the contract before the beginning of the next fiscal year.

4.2.6.1.3 Overview of the Annual Process and Conducting the Appraisals

At the conclusion of each fiscal year, the S&T (Goals 1–3) performance of the Laboratory is evaluated by the organizations that fund work at the Laboratory. In addition to the SC science programs, SC solicits input from all organizations that spend more than $1 million at the Laboratory. This S&T input is weighted according to the dollars spent at the Laboratory. Each site office evaluates the Laboratory's performance against the M&O objectives (Goals 5–8). Each evaluating office provides a proposed grade and corresponding numerical score for each objective. Site offices and science programs provide input regarding the contractor's performance with respect to Goal 4 to the SC leadership who subsequently determine the Laboratory's score in this area.

In determining these grades, the SC science programs and site offices consider the Laboratory's performance against the notable outcomes, defined in the PEMP, as well as other sources of performance information that becomes available to DOE throughout the year. These include independent scientific program and project reviews; external operational reviews conducted by the Government Accountability Office (GAO), DOE Inspector General (IG), and other parts of DOE; and the results of SC's own oversight activities. The evaluation process includes end-of-year normalization meetings for all the goals, during which rating organizations report their proposed scores/grades and work to ensure a consistent and fair scoring/grading approach across all ten Laboratories.

The current SC appraisal process uses a five-point (0–4.3) scoring system with corresponding grades for the performance goals and objectives. A grade of "B+" is awarded for performance at the objective level that meets SC's expectations for performance. SC intentionally set its expectations associated with a B+ very high, and does not equate performance below a B+ as necessarily unsatisfactory, but as offering opportunity for improvement. The grade for each of the performance goals is based on a weighted computation of the scores of the individual performance objectives identified for each goal, and SC uses the resultant performance goal grades to create annual "report cards" for each Laboratory that are publicly available on the SC Web site.

4.2.6.1.4 Outcomes of the Evaluation Process

Prior to making the annual Laboratory appraisal grades public on the SC Web site, the SC Director meets in person with each SC Laboratory separately to review the evaluation feedback for each goal by the Laboratory's primary DOE sponsors. A summary of written evaluation comments and scores are provided to the Laboratory. As mentioned earlier, these evaluations provide the basis for determining annual performance fees and the possibility of winning additional years on the contract. Over the past decade, as DOE/SC has re-competed the M&O contracts for its Laboratories, a contract award has often been an award of a base five-year contract plus the ability to earn up to 15 years of award term determined on an annual basis through the annual Laboratory appraisal process. The terms and performance requirements and the formula for calculating the earned fee based on the level of performance is defined in the PEMP. For SC Laboratories, a maximum fee is available and the actual award fee is determined by applying a set of multipliers associated with the PEMP scores. The annual appraisal process also informs the decisions the Department makes regarding whether to extend or to compete the M&O contracts when they expire.

4.2.6.2 Performance Evaluation Process for Energy Laboratories

EERE and NE use similar processes to SC in measuring the performance of their Laboratories. FE, however, employs a performance management process that derives from NETL's status as a GOGO. These processes are explained below.

EERE determines the performance management process for NREL and negotiates and approves the NREL PEMP annually. NREL is operated under a performance-based contract that was awarded to the Alliance for Sustainable Energy, LLC, in 2008. EERE's National Laboratory Oversight Office (NLOO) manages the annual performance planning process between EERE and NREL. The PEMP for the Alliance is an integrated document that establishes the planning context for the upcoming fiscal year and the key priorities, and provides the specific objectives and measures of performance for the Alliance in meeting DOE's requirements for managing and operating the Laboratory. Under the performance-based contract, EERE and the Alliance work together to establish the performance framework that is defined in the PEMP. NLOO evaluates the NREL M&O contractor's PEMP operational performance objectives periodically and provides an official midyear review of performance to the contractor.

The PEMP for NREL is structured around eight goals, which are overarching statements of the desired outcome (see text box). Goals 1–4 carry more weight than the other goals in determining the M&O contractor's performance. Each goal has an objective, e.g., Goal 1 has the objective "advancing science and technology." For each objective, major outcomes are identified, and these assist DOE in grading performance at the objective level. In addition, at the end of each fiscal year, the Alliance prepares a "self-assessment" to assist DOE in evaluating the M&O contractor's performance. At midyear, EERE prepares a report and meets with the Alliance to provide performance feedback. EERE solicits feedback from all sponsors of NREL to prepare an end-of-year report that determines the Alliance's performance in managing and operating the Laboratory and the fee earned. Full details of the appraisal process are detailed in the PEMP.

The annual evaluation process includes three primary steps: (1) the self-assessment of performance by the NREL management, (2) DOE's evaluation of performance, and (3) DOE determination of award fee. DOE's evaluation of performance considers input from EERE staff, who also evaluate the Alliance performance with respect to the performance measurement framework defined in the PEMP (addressing both mission and operational performance). DOE's performance evaluation also considers feedback on NREL's performance from other non-EERE customers (SC, OE, and NREL strategic partnership projects). An EERE initiative to implement consistent principles for engaging the National Laboratories is being implemented in FY 2015. A diagram that illustrates the timing and alignment of EERE's annual planning and evaluation processes for NREL is provided in Appendix D.

NE follows a Laboratory performance appraisal process for INL that is very similar to SC's process. The PEMP for INL includes a similar goals, objectives, and notable outcomes structure. The goals and objectives remain constant each year. The notable outcomes change each year and are specific, high-importance measures. NE conducts bimonthly DOE reviews and bimonthly reviews with INL management. NE also conducts a joint DOE-INL midyear review of PEMP performance. A final review is done at the end of the fiscal year; the outcome of the review and overall ratings on performance against the PEMP determine award fee for the Laboratory contractor, Battelle Energy Alliance, LLC. The end-of-year DOE ratings of the INL PEMP and fee determination cover ietter are available to the public.

NREL's Annual PEMP Goals

Goals 1–4, overseen by DOE Headquarters

1. Efficient and effective mission accomplishment
2. Efficient and effective stewardship and operation of research facilities
3. Provide effective and efficient program management
4. Provide sound and competent leadership and stewardship of the Laboratory operations,

Goals 5–8, overseen by the Golden Field Office

5. Environment, safety, and health management
6. Business operations
7. Infrastructure development and site operations
8. Security and emergency management

A construction goal (Goal 9) is used when appropriate and is also overseen by Golden Field Office.

As a GOGO Federal Laboratory, NETL's performance evaluation is unique in DOE and is carried out by FE through a different process. FE evaluates the performance of the NETL Office of Research and Development (ORD), which is the Laboratory's component that performs on-site research by Federal employee scientists and engineers and manages contract research performed on-site by URS, Inc. under an existing research and engineering services (RES) contract. FE conducts routine and periodic DOE reviews of its Laboratories' acquisition and assistance, finance, information technology, and human resource functions. FE, EERE, and OE sponsor external peer reviews on the R&D projects and programs that are managed by NETL. NETL, as FE's principal implementing National Laboratory, is directly connected to the achievement of the Fossil Energy portion of DOE's annual performance measures and quarterly targets. To this end, NETL reports on the assessment of FE program achievements against targeted cost and performance measures on a quarterly and annual basis as required by the GPRA. Milestones at risk are identified and corrected, or reasons for not accomplishing milestones are identified, explained, and justified.

The contributions of NETL's on-site ORD research are an integral part of achievement of FE's performance objectives. FE has established ORD performance metrics and evaluates NETL ORD/URS progress towards these metrics on a quarterly and annual basis. NETL's Enterprise Performance Assessment System (EPAS) is designed to help NETL managers identify, monitor, and update the results of each of its office's performance measures, and enable NETL managers to readily evaluate their organization's success in meeting its performance objectives. The NETL EPAS system is administered by NETL's Internal Review and Quality Assurance Division.

4.2.6.3 Improving DOE's Performance Management Model for the National Laboratories

In November 2014, the Office of the US/SE chartered a DOE-wide working group to enhance the Department's performance management model. The purpose of the DOE Lab Performance Management Working Group (LPMWG) is to ensure the Department's performance management model enables:

- achievement of the best possible outcomes related to national grand challenges and Departmental priorities,
- consistent approach to evaluating Laboratories' stewardship/utilization of core capabilities and strategic contributions (FFRDC role), and
- crosscutting, multi-Laboratory, and multi-sponsor programs and partnerships.

The LPMWG evaluated and recommended best practices previously established from sponsoring offices (e.g., SC) and developed new recommendations for consistent DOE-wide processes that are more strategic and outcome-based as opposed to a transactional-based approach in managing Laboratory performance. A working group goal was to launch a corporate process for ensuring that high-priority DOE crosscutting activities are included in Laboratory performance plans or for judging Laboratories' performance on collaboration, Laboratory-specific deliverables, and on managing such consortia.

The LPMWG focused on three objectives: (1) champion a consistent evaluation model that is strategic and outcome-based; (2) ensure that evaluation processes account for and encourage crosscutting, multi-Laboratory, and multi-sponsor programs and partnerships; and (3) enhance business management tools for establishing program level expectations and to facilitate efficient collaboration between sponsoring programs and Laboratories performing work.

The LPMWG developed a framework for managing Laboratories' performance on inter-Laboratory collaboration and crosscutting activities, with performance evaluation objectives added to reflect a Laboratory's role not only in performing a specific task, but more importantly, its role in providing S&T leadership, strategic planning, and collaboration amongst and with other Laboratories.

Further work by the LPMWG is anticipated in a second phase that would enhance the work done under each of the above objectives and focus on creating standard business tools at the project level between DOE and the National Laboratories.

4.2.7 DOE Laboratories' Strategic Partnerships

Forming strategic partnerships is essential to each Laboratory in fulfilling its mission. The incentives are compelling—commercializing new technologies, expanding opportunities for R&D, and developing a future workforce, to name just a few. This section describes why DOE's National Laboratories pursue partnerships with each other and non-DOE Federal agencies and industrial and academic partners, as well as the mechanisms they use to formalize those relationships.

4.2.7.1 Overview of Laboratory Partnerships

The Department's National Laboratories do not pursue their RDD&D activities solely for DOE program offices or in isolation. They are involved in a broad range of partnerships with each other, other Federal agencies, and with a number of academic and private sector entities. On the one hand they collaborate with universities in fundamental and applied research, as well as support the training of thousands of future scientists and engineers; on the other hand, the Laboratories partner with industry in technology development and deployment to ensure the transfer of their R&D to the marketplace.

The drivers for engaging entities beyond DOE include:

- reaching subject matter experts and specialized equipment that do not exist within the Laboratory enterprise but can help achieve DOE's mission;
- assisting Federal agencies and non-Federal entities in accomplishing goals that may be otherwise unattainable, and to avoid the need to duplicate Federal facilities;
- providing access for non-DOE entities to highly specialized or unique Laboratories and facilities, services, or technical expertise when private sector facilities with those capabilities are not available;
- increasing R&D interaction between DOE Laboratories and industry to transfer technology originating at the Laboratories to industry for further development or commercialization; and
- maintaining and advancing core capabilities, enhancing the S&T base at DOE Laboratories, and continuing to accomplish the DOE mission.

In engaging with each other, the National Laboratories can adopt a variety of collaborative models. In some instances, they team with each other and other organizations in developing proposals for work to be performed for DOE and other agencies. They may subcontract work to their partners, which is facilitated through DOE's processes for inter-entity work such as the inter-entity work order. DOE Laboratories also collaborate through cooperative mechanisms (e.g., charters and MOUs) to collaborate in managing activities that are spread among the Laboratory enterprise. The Grid Modernization Laboratory Consortium (discussed in section 2.3) is one such example. Different and more formal mechanisms are required when DOE Laboratories collaborate with non-DOE and non-National Laboratory entities. The mechanisms through which non-DOE entities can engage with the Laboratories are described in section 4.2.7.2.

Another example of a multi-Laboratory collaborative arrangement is the National Risk Assessment Partnership (NRAP)—an initiative within DOE's FE and led by NETL—which applies DOE's expertise in science-based prediction for engineered–natural systems to the long-term storage of carbon dioxide (CO_2). The science-based prediction of engineered–natural systems is a core competency that crosscuts many of today's energy challenges. LBNL, LLNL, LANL, and PPNL are members of the team. The NRAP collaborative keeps abreast of international developments by participating in collaborations such as the International Energy Agency Greenhouse Gas Research and Development Programme's Risk Assessment Network.

Using these various partnership agreement mechanisms, the Laboratories often participate in collaborations that involve not just bilateral arrangements with academic or industrial institutions, but mixtures of both. An illustrative example of this type of arrangement is FE and NETL's Carbon Capture Simulation Initiative (CCSI). This effort is developing and deploying state-of-the-art computational modeling and simulation tools to accelerate the commercialization of carbon capture technologies from discovery to development, demonstration, and ultimately the widespread deployment for advanced power generation. The CCSI toolset will provide end users in industry with a comprehensive, integrated suite of scientifically validated models, with uncertainty quantification, optimization, risk analysis and decision-making capabilities. The project leverages DOE National Laboratories' core strengths in modeling and simulation, bringing together capabilities at NETL, LANL, LBNL, LLNL, and PNNL. The CCSI's industrial partners provide representation from the power generation industry, equipment manufacturers, technology providers, engineering and construction firms, and software vendors. The CCSI's academic participants (Carnegie Mellon University, Princeton University, West Virginia University, Boston University, and the University of Texas) bring expertise in multiphase flow reactors, combustion, process synthesis and optimization, planning and scheduling, and process control techniques for energy processes.

The National Laboratories also engage in partnerships to leverage their capabilities and facilities to support the missions of Federal agencies besides DOE and DHS. One such example is the NASA Space Radiation Laboratory (NSRL) at BNL. Commissioned in 2003, the NSRL is funded by the National Aeronautics and Space Administration (NASA) and operated by BNL. The Booster Accelerator at BNL that feeds the Office of Science's Relativistic Heavy Ion Collider (RHIC) with heavy ions and protons for nuclear physics research also serves as the energetic heavy ion source for the NSRL. NASA-funded scientists use the beams of ions at NSRL to simulate cosmic rays and assess the risks of space radiation to human space travelers and equipment.

One more example of DOE programs and Laboratories supporting another Federal agency mission is the partnership among the Office of Science, the DOE Laboratories hosting synchrotron light sources, and the National Institutes of Health to make the x ray crystallography capabilities created by the light sources available to the structural biology community. For example, NIH has made direct investments at the Advanced Photon Source at ANL such as the construction of two insertion devices and one bending magnet beamline. These provide world-leading microcrystallography capabilities and enabled the structure determination work on G-protein-coupled receptors by Brian Kobilka that resulted in the 2012 Nobel Prize in Chemistry.

4.2.7.2 Partnership Agreement Mechanisms

Non-DOE entities can partner with the National Laboratories in numerous ways to engage in collaborative research efforts and access the Laboratories' unique capabilities: Strategic Partnership Project (SPP) agreements (formerly Work for Others [WFO] agreements), CRADAs, Agreements for Commercializing Technology (ACT), user agreements, technology licensing agreements, technical assistance (TA) agreements, and material transfer agreements (MTA). Each of these contractual mechanisms is discussed below, as well as in the Technology Transfer Working Group's Guide to Partnering with DOE's National Laboratories.

Strategic Partnership Project Agreements

SPP agreements permit DOE Laboratories and facilities to conduct work for other Federal agencies and non-Federal entities on a 100 percent reimbursable basis. This work uses Laboratory personnel and/or facilities; pertains to the mission of the Laboratory; does not conflict or interfere with the achievement of DOE program objectives; does not place the Laboratory in direct competition with the domestic private sector; and does not create a potential future burden on DOE resources. An SPP agreement typically allows the non-Federal customer to own any inventions made by the Laboratory under the SPP agreement (i.e., subject inventions) and to mark as proprietary and obtain ownership of data that is generated under the SPP agreement, subject to certain terms and conditions. Although the Government typically will retain a royalty-free license in subject inventions for use by or on behalf of the Government (i.e., Government Use License), a more limited Government research license may be applied to SPP subject inventions with DOE patent counsel approval. The Government Research License permits the Government to use and enable others to use the SPP subject inventions for research purposes only. If a limited research license is applied, then the Government retains expanded rights in data.

SPP agreements require the non-Federal customer to (1) maintain at least sixty days of advance funding for activities the Laboratory conducts under the SPP agreement and (2) in certain circumstances, indemnify the Government and the Laboratory for certain specified risks, intellectual property infringement, and product liability. The Laboratory recovers its costs of performing activities under an SPP agreement to a non-Federal customer and is prohibited from charging any fee in excess of the Laboratory's costs. SPP agreements are "best efforts" contract, and the customer receives no warranties for work performed under an SPP agreement.

In FY 2013, the 17 National Laboratories received $2.43 billion in work for non-DOE/non-DHS Federal agencies. Of that, the U. S. Department of Defense (DOD) was the primary partner, providing $1.49 billion in funding. Other Federal partners (in order) were Health and Human Services (including the National Institutes of Health), NASA, and the Nuclear Regulatory Commission (NRC). SNL engaged in the largest volume of SPP work in FY 2013, with $900 million of SPP funds; PNNL was the second largest volume of SPP work, with $271 million. In FY 2014, the 17 National Laboratories received $235.2 million in direct partner funds through 2,021 active SPPs for non-Federal Government work.

Cooperative Research and Development Agreements

A Cooperative Research and Development Agreement (CRADA) is a collaborative, legal agreement that allows the Federal Government, through its Laboratories, and non-Federal partners to optimize their resources, share technical expertise in a protected environment, access intellectual property emerging from the effort, and advance the commercialization of Federally developed technologies. The participants collaborate by providing personnel, services, facilities, or equipment and pool the results from a particular R&D program. The non-Federal parties must provide funds or in-kind contributions. A CRADA allows the participant to own the subject inventions it conceives or first reduces to practice under the CRADA. Data produced under the CRADA may also be protected from public disclosure for up to five years. The participant receives an option for a limited period of time to negotiate a field of use limited exclusive license agreement to the subject inventions made by the Laboratory under the CRADA.

As with SPP agreements, certain terms and conditions such as the Government license apply to all CRADA subject inventions and data generated under the CRADA. Unless the CRADA is a "100 percent funds-in" CRADA, the participant provides actual or in-kind funding for its contributions to the CRADA activities, and the Laboratory obtains funding from a DOE programmatic source. The Laboratory does not charge a fee to the participant for the Laboratory's CRADA activities. CRADA work begins after the Laboratory receives its funding, the CRADA is executed by the Laboratory and the participant, and the DOE contracting officer approves the CRADA. The CRADA participant indemnifies the Government and the Laboratory for product liability, and the Government and the Laboratory disclaim all warranties to work performed under a CRADA. In FY 2014, there were 702 active CRADAs across the 17 National Laboratories, which accounted for $64.3M in direct private sector partner funds-in.

Agreement for Commercializing Technology

The Agreement for Commercializing Technology (ACT) is a pilot program running through October 2017. ACT agreements, which may be used when DOE Laboratories conduct R&D for a business or other non-Federal entity, have terms and conditions that are negotiated between the participant and the Laboratory M&O contractor. In contrast to SPP and CRADAs, the M&O contractor negotiates the ACT agreement acting in a private capacity, and thus may share in certain risks (e.g., indemnity) that the Federal Government generally cannot. ACT agreements allow more flexible intellectual property arrangements and allow the participants to mark generated data as proprietary and obtain ownership of the data. If a limited research license is applied, then the Government retains expanded rights in data. Terms requiring advance funding and indemnification, normally required under CRADAs and SPPs, are negotiable. Unlike SPPs or CRADAs, the Laboratory may charge the participant a fee in excess of its actual costs for ACT activities. Other terms and conditions also apply to ACT agreements depending on the business circumstances of a given transaction, including the availability of performance measures or guarantees when appropriate. In FY 2014 there were already 67 active ACT partnerships, which accounted for $29.0M in direct private sector partner funds-in.

User Agreements

User agreements are specialized, standard agreements to expedite user access to DOE designated user facilities (discussed in section 2.1.7). Each facility manages its allocation of facility resources, typically granting access through merit review of submitted research proposals. Prospective nonproprietary users may propose independent or collaborative research. In most cases, there is no charge for users who are doing nonproprietary work, with the understanding that they are expected to publish their results; access is also typically available on a full cost recovery basis for proprietary research that is not intended for publication.

Technology Licensing Agreements

A technology licensing agreement typically provides commercialization rights to patented and/or copyrighted intellectual property (IP) developed at DOE's National Laboratories. IP developed by DOE's National Laboratories is typically held and licensed by the contractor for the Laboratory where the technology was developed. Because of the unique set of laws and policies governing the licensing of Federally funded research and DOE policies regarding intellectual property, licensing agreements for technology developed at DOE Laboratories have some provisions that may not be present in a license agreement between private entities, including march-in-rights, Government use rights, and indemnification provisions.

Technical Assistance Agreements

Many Laboratories offer a technical assistance agreement, which leverages the expertise of Laboratory scientists and engineers to help members of the small business community solve important challenges free of charge. Examples of assistance include advising on existing or emerging products, providing advanced technology for hardware and software applications, improving production and manufacturing processes, resolving technical problems, performing scientific peer reviews, and recommending energy conservation and environmental technologies. Funds for technical assistance are limited and are available only at certain DOE National Laboratories.

Material Transfer Agreements

A material transfer agreement (MTA) protects biological materials and tangible research products provided either to, or by, the Laboratory. This is an agreement that biological materials and tangible research products provided by one party to another will be protected from further transmittal. The agreement normally requires return or destruction of materials and products at the end of the agreement.

4.3 Universities and Colleges

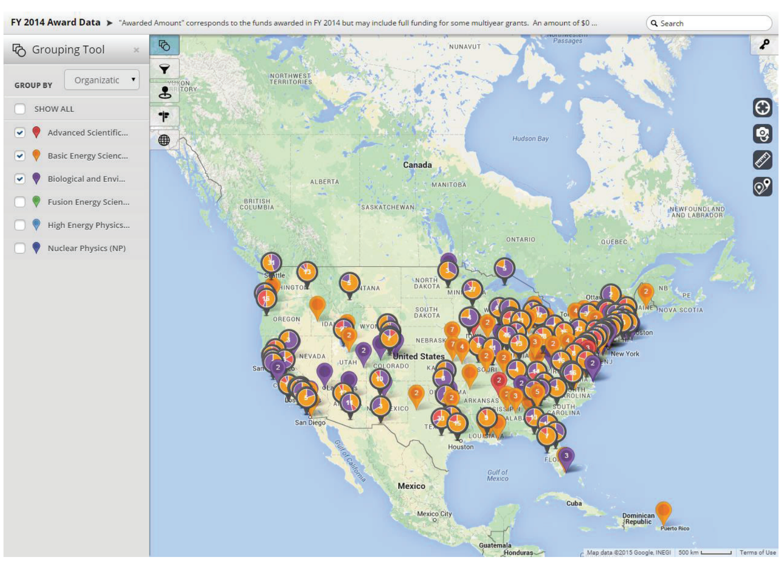
While the Department has a unique relationship with, and responsibility for, DOE National Laboratories, its mission success is also dependent on the innovative and systemic contributions of the Nation's academic institutions. The missions of S&T research and STEM education and training are inextricably linked and squarely intersect at U.S. universities and colleges.

U.S. academic institutions serve a substantial role in conducting discovery-oriented research and basic science, with growing efforts in long-term applied R&D, and are often charged with new ideas from the constant influx of young talent. Their scientists and engineers pursue fundamental and applied R&D that complements the RD&D conducted by DOE Laboratories. Likewise, as degree-granting institutions, U.S. colleges and universities create a pipeline of highly skilled STEM professionals who will be the next generation to carry out DOE's mission, whether at a DOE Laboratory, a university, a public or private sector organization, or as a program or project manager within DOE.

Chapter 3 discussed the many ways in which scientists and engineers from academia, along with those from Laboratories and industry, engage with the Science and Energy program offices in broader program planning efforts such as S&T workshops. This section discusses the role that U.S. academic institutions play in executing the portfolio of the science and energy programs, and also discusses the engagement between DOE National Laboratories and universities.

4.3.1 Universities and Colleges in the Science and Energy Portfolio

U.S. academic institutions are key partners across the full spectrum of the Department's S&T development activities. In FY 2014, SC provided nearly $813 million in funding to support research at over 300 colleges and universities located across all 50 U.S. States and Puerto Rico. These university-led efforts range from single-investigator awards and small-group research projects, to mid-sized research efforts such as Energy Frontier Research Centers and major university programs or centers of excellence in high energy physics and nuclear physics, to large multidisciplinary efforts such as a Bioenergy Research Center. In FY 2014, SC had over 3,000 active grants with academic institutions. Information about these awards can be found on the SC interactive grants map page, where grants and cooperative agreements can be searched for by SC Program, by State, by research topic, and by institution type.



The interactive map above contains information regarding FY 2014 grants and cooperative agreements categorized by SC Program, by State, by research topic, and by institution type.

Colleges and universities are also responsible for training the next generation of scientists and engineers who will lead the Nation in discovery and innovation and who will tackle the complex missions of the Office of Science. SC is committed to this next generation, including supporting early-career scientists at universities and DOE Laboratories through the SC Early Career Research Program. Since the launch of the Early Career Research Program in 2010, SC has made over 230 awards to early career researchers at universities. SC also currently supports nearly 4,000 graduate students per year on its research awards. In addition, through programs such as the Visiting Faculty Program (VFP), SC supports research collaborations between faculty at minority-serving institutions, and other academic institutions historically underrepresented in the DOE research portfolio, and DOE Laboratory scientists to help faculty build a research capacity that they can maintain and further grow from their home institution. SC also supports the Science Undergraduate Laboratory Internships (SULI) and the Community College Internships (CCI) programs, which provide research internships for nearly 1000 undergraduate students per year who participate in projects at a DOE National Laboratory under the mentorship of DOE Laboratory scientists.

The university research communities are actively engaged in SC's designated scientific user facilities. In fact, the largest portion of the users of SC's facilities comes from academic institutions. In targeted areas, universities have also been hosts to major research facilities and capabilities that support the research program mission areas, and in a few instances are the lead institutions for designing, constructing, and operating scientific user facilities. Of the more than 33,600 individuals who used SC's scientific user facilities in FY 2014, approximately 60 percent of them came from academic institutions from all 50 U.S. States and Washington, DC, and from academic institutions abroad, as described in Tables 4.6 and 4.7. The user statistics for FY 2014 for SC's user facilities are fully searchable on its interactive statistics Web page, where one can search for the users by facility, by sponsoring SC program office, and by facility host site.

User Type	Quantity
University users	20,163 (59.90%)
Non-university users*	13,508 (40.1%)
Total	33,671

Table 4.6: FY 2014 Users of SC Designated User Facilities—University and Non-University Users.
This table breaks down the number of university and non-university users of SC designated user facilities in FY 2014. **Non-university users include users from industry, non-academic research institutes, Government agencies, and Government Laboratories.*

User Type	Quantity from U.S.	Quantity from Non-U.S.*
University users	16,245 (80.6%)	3,918 (19.4%)
Unique university institutions	429	668
States/countries	50 states plus D.C.	68 countries

Table 4.7: FY 2014 University Users of SC Designated User Facilities—U.S. and Non-U.S. Users.
This table breaks down the number of university users of SC designated user facilities in FY 2014, shown as those from the U.S. and those from other countries. **This is a lower bound. Further detailed analysis and research would be required to determine which non-U.S. entities identified as "Institutes" or "Centers" are actually academic institutions.*

SC draws upon the expertise of the science community at universities and colleges to support the SC mission areas in a number of capacities, and their contribution is substantial. Scientists from academia serve as peer reviewers of proposals; this is significant, as SC receives nearly 5,000 research proposals each year. They also serve on advisory committees of the SC programs and of its National Laboratories. Their volunteer service is essential to upholding SC's commitment to scientific excellence and integrity. It is worth noting that 9 of the 10 DOE National Laboratories stewarded by SC are managed either by a university, a consortium of universities, or a university or university consortium in partnership with a nonprofit research organization. All of SC's National

Laboratories support joint faculty appointments with universities, and many of the Laboratories are colocated with or near major universities. University researchers not only take advantage of the research capabilities at DOE Laboratories, but the strategic partnerships that DOE Laboratories make with universities at both the institutional level and at the individual level contribute to the overall strength of the DOE research enterprise.

Universities and colleges are also essential to achieving the mission of the applied energy technology offices. For example, universities are a key to executing OE's mission to modernize the Nation's electric infrastructure. OE funds two university-led consortiums:

- The Center for Ultra-Wide-Area Resilient Electric Energy Transmission Networks (CURENT) is an NSF engineering research center that is jointly supported by NSF and DOE. A collaboration among academia, industry, and National Laboratories, CURENT is led by the University of Tennessee, Knoxville. Partner institutions include Northeastern University, Rensselaer Polytechnic Institute, and Tuskegee University. The goal of CURENT is to (1) support the development of a Nation-wide or continent-wide transmission grid that is fully monitored and dynamically controlled in real-time for high-efficiency, high-reliability, low-cost, better accommodation of renewable energy sources, full utilization of energy storage, and accommodation of responsive load, and (2) develop a new generation of electric power and energy systems engineering leaders with global perspectives and diverse backgrounds.
- The Trustworthy Cyber Infrastructure for the Power Grid (TCIPG) consortium is a unique partnership of four academic institutions formed to meet increasing cyber threats and challenges to the grid's underlying computing and communication network infrastructure that is at serious risk from malicious attacks on grid components and networks, as well as from accidental causes, such as natural disasters, misconfiguration, or operator errors. TCIPG continually collaborates with National Laboratories and the utility sector to protect the U.S. power grid by significantly improving the way the power grid infrastructure is designed, making it more secure, resilient, and safe. TCIPG comprises several dozen researchers, students, and staff from four partner universities: the University of Illinois at Urbana-Champaign, Dartmouth College, the University of California–Davis, and Washington State University. TCIPG faculty, students, and research staff have developed interdisciplinary expertise essential to the operation and public adoption of current and future grid systems. TCIPG brings together recognized leaders in power engineering; computer science and engineering; advanced communications and networking; smart grid markets and economics; and STEM education.

Twenty percent of the R&D funding provided by NE is dedicated to university research through its Nuclear Energy University Programs (NEUP). One approach to using universities is through integrated research projects (IRPs). IRPs are significant three-year awards for projects that address specific research issues and capability gaps identified and defined by the NE R&D programs, and are intended to develop a capability within each specified area. These projects are multidisciplinary and require multi-institutional partners. NEUP also provides funding for smaller university-led projects that support research areas identified by NE as well as transformative "blue sky" efforts. And NEUP provides funding for general scientific infrastructure to support enhanced research and educational capabilities at universities and reactor upgrades to ensure the Nation's university research reactors are maintained to the highest standards. When funded by Congress, NE also supports undergraduate scholarships and graduate-level fellowships through the Integrated University Program (IUP). Since 2009, NE has invested more than $400M to over 100 schools in 39 States and the District of Columbia through NEUP and IUP.

EERE also relies on universities to execute its RDD&D portfolio as well as to prepare the Nation's workforce for EERE-related fields of work. For example, in RDD&D execution, the Vehicle Technologies Office (VTO) currently funds the university-based NSF/DOE Partnership on Advanced Combustion Engines ($12M cost-shared 50/50 with NSF). In addition, VTO plans to issue a university-based combustion and emission control R&D FOA topic in FY 2016. VTO also funds 19 universities in the battery materials research activity, including 6 awards from the FY 2014 VTO program-wide FOA Topic on beyond lithium ion battery research. VTO plans an FY 2016 battery materials research topic to solicit project applications from universities focused on advanced battery cathode materials, modeling, and diagnostics.

In Wind research, WWPTO has funded the National Marine Renewable Energy Centers (NMRECs). Established in 2008, NMRECs facilitate the development of marine renewable energy technologies via research, education, and outreach. These facilities focus on evaluating marine renewable energy technologies from technical, environmental, and social perspectives. DOE funds three regional centers, one each in the Northwest, Southeast, and Hawaii. The Northwest university partners include Oregon State University, the University of Washington, and the University of Alaska–Fairbanks. The other two regional centers are based at Florida Atlantic University and the University of Hawaii.

In terms of workforce development activities relevant to the university community, EERE has ongoing university-focused activities across its portfolio, such as the following examples:

- The Collegiate Wind Competition challenges interdisciplinary teams of undergraduate students to develop a unique solution to a complex wind energy project, providing each student with real-world experience as they prepare to enter the wind industry workforce. The inaugural competition at the 2014 American Wind Energy Association Annual Conference and Expo in Las Vegas, Nevada, was supported by General Electric, Vestas, AWEA, and Blattner Energy. More than 150 students from 10 institutions across the country participated in the public event. Pennsylvania State University, the University of Kansas, and the University of Massachusetts were first, second, and third place champions, respectively.

Students reach into a wind tunnel in preparation for the Turbine Testing subcontest during the Collegiate Wind Competition where each team's wind turbine was tested for 5 seconds at 1 m/s interval wind speeds from 5–14 m/s. The experience provided student participants with real-world experience as they prepare to enter the workforce.

- The annual Better Buildings Case Competition engages the next generation of engineers, entrepreneurs, and policymakers to develop creative solutions to real-world energy efficiency problems for businesses and other organizations across the marketplace. Through the competition, interdisciplinary teams of university students gain critical skills and experience to start careers in clean energy, while supporting the Obama Administration's Better Buildings Initiative goal of reducing energy consumption by at least 20 percent by 2020 in commercial and industrial buildings across the United States.
- The Race to Zero Student Design Competition is an annual competition open to both undergraduate and graduate students and faculty from any interested collegiate institution in the United States and Canada. The competition is based on a real-world scenario where a builder needs to update an existing product line (house plan) to a high-performance house design or is developing a new high-performance home product line. Teams are presented a specific design problem and are asked to either redesign an existing floor plan or create a new house design that satisfies the project requirements.
- DOE Industrial Assessment Centers (IACs), managed by AMO, are located at 24 universities around the country and house teams that conduct the energy audits for small- and medium-sized manufacturers to identify opportunities to improve productivity, reduce waste, and save energy. IACs train the next generation of energy savvy engineers, more than 60 percent of which pursue energy-related careers upon graduation. IAC assessments are in-depth evaluations of a facility conducted by engineering faculty with upper class and graduate students from a participating university. Each year, about 300 engineering students at IACs receive hands-on assessment training at operating industrial facilities and gain substantive experience performing evaluations of industrial processes and energy systems. Alumni report the training sets them apart in the job market.

The designated user facilities of the applied energy technology offices also engage with university users. While NETL does not currently have any user facilities, all of its experimental and computational facilities can be accessed by academia and the private sector through contributed funds agreements (CFAs) and for collaborative R&D through CRADAs. The ESIF user facility at NREL currently has 6 of its 45 partners from universities and colleges that represent a $9M investment by those institutions in research activities.

4.3.2 Academic Partnerships with DOE Laboratories

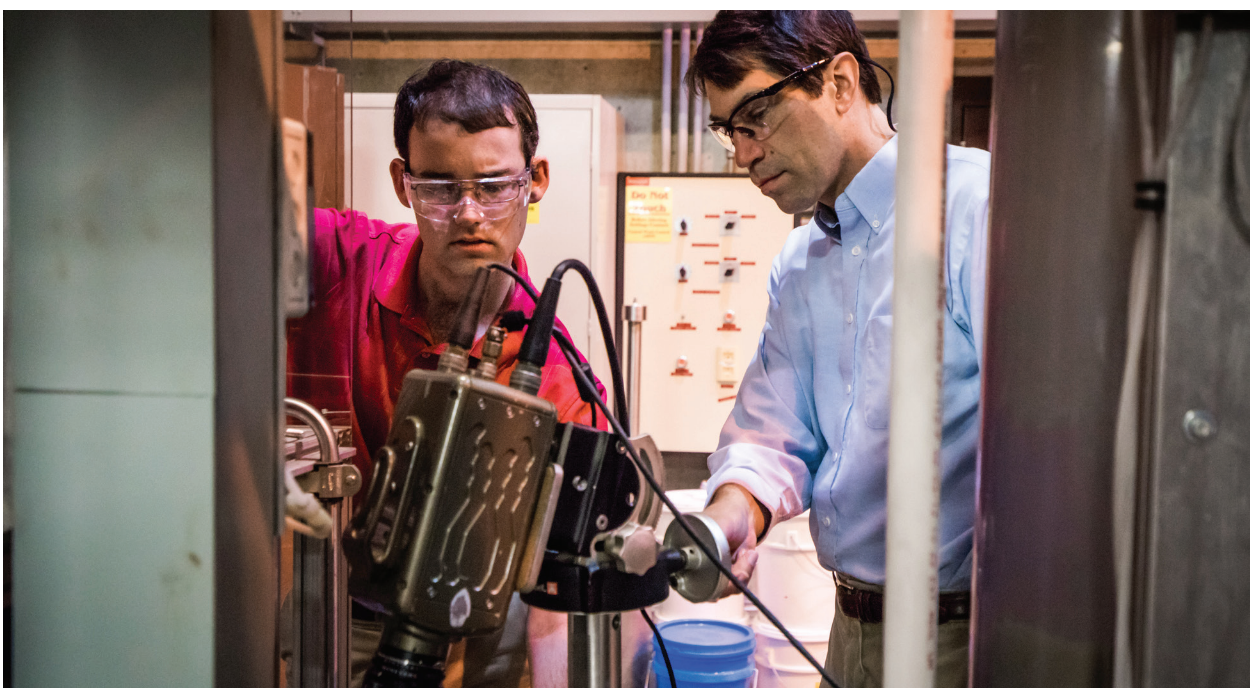
The partnerships between academic institutions and DOE National Laboratories are substantial and varied. Universities and consortia of universities are integrally involved in the management of DOE Laboratories. Experts from academia serve on the Laboratories' boards of directors, on Laboratories' advisory committees, and on Laboratories' own review panels. Universities are strategic partners in R&D, as well as in training of the next generation of skilled researchers and S&T professionals. It is a part of the mission of DOE Laboratories to operate the designated user facilities to support research of the broader S&T communities, the universities of which make up the majority of the facility users.

Productive collaborations between university and National Laboratory researchers take place through personnel exchanges, research collaborations at the individual investigator level, joint research programs established to develop and take advantage of DOE user facilities and unique capabilities, and strategic institutes established to focus on new areas of scientific endeavor. There are nearly 1,000 joint faculty appointments across DOE Laboratories. DOE Laboratories are also encouraged to partner with academic institutions and industry and compete for RD&D awards through open and competitive solicitations. As documented in a 2005 report from the National Research Council, collaborating with National Laboratories can provide universities with the ability to conduct R&D requiring large, complex facilities and teams trained in their safe and effective operation; science requiring substantial engineering and instrument development; or science requiring specialized facilities that are costly to maintain. These collaborations also provide for expansive opportunities for interdisciplinary research, professional development, and training. In FY 2014, U.S. and foreign universities accounted $97.2M in direct partner funds-in to the National Laboratories through SPPs and CRADAs.

DOE National Laboratories will collaborate with academic institutions to subcontract work where focused areas of expertise of researchers at universities can provide for productive outcomes. DOE Laboratory subcontracts with academic institutions not only provide an additional avenue for education and training, but also represent a substantial flow of DOE resources to the academic research community. The National Laboratories collectively subcontract over $500M to universities and employed more than 8,600 students, postdocs, and faculty. This is in addition to the more than $900M that DOE directly funds through academic research grants. This demonstrates how tightly interwoven the Laboratories and universities are within the national research ecosystem supported by DOE.

The following are some examples of the extensive partnering in R&D by DOE Laboratories with universities. In FY 2014, PNNL executed 173 subcontracts to universities and colleges in 37 States at a total value of more than $11 million. In FY 2014, INL funded activities in 72 universities and colleges across 25 States. The NNSA Laboratories also engage with academic partners, including for work that they perform for Science and Energy program offices. For example, in FY 2014, LLNL funded $1.8 million in subcontracts to 23 universities across 14 states, with most of the funding ($1.4 million) provided to LLNL for SC-supported projects.

NETL provides an illustrative example of how partnerships with universities are fundamental to the Laboratory's success. Early stage R&D at NETL is conducted in close collaboration with a suite of university partners. This collaboration with academia brings a broad perspective for transformative concepts to NETL's research portfolio and supports NETL's education mission by providing fossil-energy research opportunities to undergraduate, master's, and PhD students. At present, NETL's implementation of the Department's FE programs includes an R&D portfolio of approximately 230 active partnership agreements with academia totaling $905 million, of which the combined university cost share investment is 27 percent, an amount equal to $245 million.



A Mickey Leland intern and his NETL mentor work with the Chemical Looping Reactor at NETL in Morgantown, WV. The Mickey Leland Energy Fellowship provides students with opportunities to gain hands-on research experience with FE. *Photo credit: NETL*

For example, the Carbon Capture Simulation Initiative (CCSI) is a partnership of National Laboratories, industry, and universities led by NETL that includes researchers from Carnegie Mellon, Princeton, West Virginia, Boston, and the University of Texas. CCSI's mission is to nurture innovations and hasten the commercialization of carbon capture technologies. To date, the CCSI has produced a software toolset that lends credence to carbon capture designs, makes it easier to distinguish favorable concepts from unfavorable ones, shortens the time it takes to design and troubleshoot a new device or process, and more accurately represents the risk associated with scaling-up the technology. The tool set was originally released in 2012, updated and expanded in 2013, with a final completed version made available to technology developers in January 2015.

NREL and University of Colorado (CU) have several ongoing collaborations, including participation in the Renewable and Sustainable Energy Institute (RASEI), a joint research institute dedicated to addressing complex problems in energy that require a multidisciplinary, multi-institutional approach. Additional NREL collaborations with CU include the Center for Research and Education in Wind (CREW), Center for Revolutionary Solar Photoconversion (CRSP), Colorado Center for Biorefining and Biofuels (C2B2), and current study of emerging markets in the western power grid. Georgia Institute of Technology and NREL have a number of joint projects. Current work involves the development of kinetics and mathematical models for high-pressure gasification of lignite-switchgrass blends, and overcoming silicon solar cell bottlenecks.

As noted above, Laboratories also collaborate with universities and colleges through establishing joint appointments of faculty, and such appointments are extensive—totaling nearly 1,000—across the DOE Laboratory complex. For example, INL has staff members with nine formal joint appointments with nine different universities in seven States. LLNL has two official joint appointments with two universities (that is, where the Laboratory employee is also a university employee), but has nine employees in five universities that perform nonsalaried work that is reimbursed to LLNL by the universities. In addition to these joint appointments, Laboratory employees serve on advisory committees and review boards at universities.

4.4 Industry and Private Sector Entities

The Department works with a broad array of industrial and private sector entities, such as technology developers, utility companies, trade groups, and many others, throughout the technology development life cycle. As noted in figure 4.1, industry and private sector stakeholders are a critical part of the Department's activities. While these stakeholders primarily engage with the Department at the latter stages of the technology lifecycle, they play an important role throughout every stage of the technology development process.

Because of industry's essential role in commercializing and bringing new energy technologies to scale in the marketplace, the Department's Science and Energy programs routinely engage with industry partners. Industry representatives sit on advisory committees, participate in reviews of DOE programs and projects, and help the Department refine its activities to those areas where a Federal role is most appropriate. As technologies near commercialization, industry plays an increasingly important role in accelerating the adoption of these technologies, sharing the cost of demonstrations, helping address market barriers, and helping ensure that public sector investments yield positive returns to the taxpayer.

The Department and the National Laboratories also help industry partners to bring innovative technologies to the market that would otherwise be cost-prohibitive to develop. Many such collaborative efforts are performed through the Department's shared R&D facilities.

Section 4.4 discusses a variety of ways in which the Department and the National Laboratories interact with industry, with specific attention given to small businesses, through knowledge sharing, technology development, and industry use of shared R&D facilities.

4.4.1 Knowledge Sharing

Overall, the Nation's energy sector consists of large corporations with significant market share and a diverse network of smaller companies. As a result, the strategic role of the Federal Government in RDD&D activities must be balanced to avoid redundancy with private sector initiatives and to meaningfully enhance the market competitiveness of the Nation's energy suppliers, consumers, and manufacturers. Fluctuating market conditions, evolving regulatory environments, and private sector investments in new technologies complicate the challenge of defining the appropriate Federal role.

To this end, the Department's strategic direction is informed early in the program development phase by accessing the business acumen and technical expertise of industry stakeholders through partnerships, workshops, conferences, public meetings, and requests for information. These interactions assist the Department in identifying technology gaps, industry research needs, and emerging market trends. Industry plays a significant role in all of the stakeholder engagement activities described in section 3.3.2.,including not only scientific and technical workshops, but also the following:

- **Advisory Committees**—Industry participation in Federal advisory committees helps the Department leverage industry expertise to identify opportunities for investment. Industry helps inform the appropriate role for Government RDD&D activities in their sector and provides input into strategic direction. The members of the committees can be found on DOE's Web pages describing each of the committees.
- **Merit Reviews**—Industry expertise plays an important role in evaluating the merit of proposals submitted to the Department, particularly for the applied technology offices. Industry professionals' perspective and subject matter expertise help inform the Department's decisions on projects with the most strategic and technical merit.
- **Peer Reviews**—Regular review of DOE programs is an essential part of program management (as discussed in Chapter 3), and industry expertise in evaluating ongoing work helps refine the scope and direction of DOE programs.

Another key aspect of the knowledge sharing that occurs between the Department and industry relates to the development of regulatory codes and standards. In developing codes and standards, the Department works closely with industry and other stakeholders to determine what is possible, and engages in an open process to solicit input from all stakeholders prior to promulgating codes or standards. In doing so, the Department encourages industry consensus agreements and voluntary agreements, as in the recent negotiated rulemaking promulgated by the Building Technologies Office on rooftop air conditioners and warm air furnaces. In this case, DOE established a working group comprising industry, energy efficiency, and environmental advocates, contractors, and Agency representatives, that reached consensus and provided recommendations for energy conservation standards, test procedures, and metrics.

In addition to formalized knowledge sharing, the Department and industry exchange information regularly through informal forums.

4.4.2 Department and Laboratory Partnerships with Industry

It is industry, and not the Department or National Laboratories, that ultimately manufactures, markets, commercializes, and operates new technologies, making industry support integral to achieving Departmental goals.

The primary objectives of DOE's activities in advanced energy-related production, delivery, and utilization technologies are to (1) accelerate the development and manufacture of new and revolutionary technologies beyond the pace that would otherwise be dictated by normal market or regulatory forces; (2) expand the slate of beneficial energy options beyond those likely to be developed solely by the private sector; and (3) facilitate the creation and production of disruptive "breakthrough" technologies that achieve environmental, efficiency, and/or cost goals well beyond those currently of interest and pursued by the private sector.

Partnerships with industry that go beyond knowledge-sharing activities ensure that DOE's science and energy RDD&D portfolio is relevant, market barriers are identified and reduced, investment risk is shared with our private sector participants, solutions are informed by industry practice, and clear responsibility to take advanced technology to market is established. This dynamic is exemplified by the Department's cost-sharing practices, as prescribed in Section 988 of the Energy Policy Act of 2005. This cost-sharing model is designed to ensure that industry is engaged at some level even in the earliest stages of technology development, while requiring significant industry engagement and guidance as technologies near commercialization.

DOE engages with its industrial partners to execute activities primarily through contracts, grants, and cooperative agreements awarded by competitive funding opportunity announcements (FOAs). These financial agreements help ensure the continued vitality of the Nation's broad-based research capabilities. The intellectual and cost-sharing involvement by the private sector throughout the RDD&D process not only provides an intrinsic technology transfer mechanism that accelerates the deployment of new technologies, but also assists industrial partners in leveraging funding from the investment community, which further amplifies the public sector investment. Industrial partners' understanding of end-user needs also helps ensure that new technologies will gain rapid acceptance in the marketplace and within the financial community. Overall, by means of these public-private RDD&D partnerships, the cost, reliability, and environmental benefits offered by new technologies can be more quickly realized.

The applied energy technology offices and the National Laboratories they steward rely upon partnerships with industry to accomplish their missions. The reliance upon industry is driven by the fact that the Science and Energy programs do not own or operate the Nation's energy infrastructure. A prime example of this is the Nation's electrical grid. As noted in Chapter 2, the Department funds a large portfolio of RDD&D activities to improve and modernize the grid. To leverage this portfolio of activities, DOE and the National Laboratories partner with industry to both share information and jointly develop next-generation grid technologies that can benefit consumers and industry, while meeting the Department's strategic goals.

Another example is with NE's work on the continued development of small modular rectors (SMR). NE initiated the SMR Licensing Technical Support program in 2012 with a focus on partnering with the first movers in the SMR industry to support, on a cost-shared basis, the upfront costs for design, certification, and licensing. This effort will result in the completion of design certifications for at least one U.S. SMR vendor in the 2019–2020 time frame and up to two combined construction and operating licenses 12–18 months following the approval of the design certification.

FE's Carbon Capture Program has been supporting industry, academia, and several National Laboratories through a portfolio of cooperative agreements and Laboratory-directed activities that are focused on developing technologies that can significantly reduce the cost of CO2 capture for coal-fired power plants. Over the past decade, these technologies have progressed from the laboratory scale to the small pilot scale with several National Laboratories supporting materials and process developments. In addition, NETL has been leading a team of National Laboratories to develop and apply the CCSI toolset, which can optimize the design of future commercial-scale capture plants. DOE's integration of the National Laboratories with the RD&D portfolio has accelerated the development of novel materials, manufacturing processes, and advanced simulation capabilities, which will support DOE's efforts to meet its strategic goals and industry's need for technology solutions.

While the applied energy technology offices engage regularly with industry partners on late-stage energy technology development, SC programs, particularly though their DOE Laboratories, also have a long and diverse history of industrial engagement beneficial to both the Department and the industrial partner.

PNNL researchers work in the Laboratory's Electricity Infrastructure Operations Center to develop new technologies that are transferable across the industry and address the national need for a more reliable and effective electricity grid. *Photo credit: PNNL*

For example, out of mission need, SC invested heavily in accelerator technology and high-performance computing at DOE Laboratories. These investments became signal examples in which sustained partnerships produced major technological transformations and created new industries, which in turn propagated into broad commercial application. In the 1970s, Fermi National Accelerator Laboratory (FNAL), Supercon, Magnetic Corporation of America, and Intermagnetics General Corporation worked jointly to develop a manufacturing process capable of supplying the 5,000,000 feet of Nb-Ti 23-strand cable required to build the Fermilab Tevatron. Special 23-strand cable was developed to support the high current density, high field Tevatron application. Manufacturing techniques were jointly developed with industry and the required tonnage of Nb-Ti conductor produced. The construction of the Tevatron required introduction of rigorous quality control and significant improvements in manufacturing processes, several of which were developed by FNAL and transferred to industry.

One example of a broader application is the diverse contributions from accelerator science to human health, including the development of new irradiation therapies, pharmaceuticals, and diagnostics. The development of proton therapy, which occurred over several decades and involved multiple DOE Laboratories and other international research institutions, is a particularly revealing story of the long-term nature of some problems, and the commitment required to overcome them. As early as the dawn of nuclear science in the 1940s, scientists had speculated that protons and neutrons could be used to attack diseased tissue. The first attempts to use protons in therapy for human subjects occurred in the 1950s, but it was not until the late 1970s, in large part due to major engineering achievements at FNAL, that accelerator technology became remotely affordable for deployment in a clinical setting. When the Loma Linda University Medical Center's Proton Treatment Center began treating patients in 1989, it realized a more-than-40-year vision. Today, with continual engineering advances, proton therapy, while still costly, is emerging as a key resource at preeminent regional cancer treatment facilities. These achievements required a number of strong collaborations between DOE Laboratories and clinical institutions.

Last, through the DOE Isotope Program, managed since 2009 by SC's Office of Nuclear Physics, SC engages dozens of companies every year that are in need of isotopes not widely commercially available. The DOE Isotope Development and Production for Research and Applications subprogram (IDPRA or DOE Isotope Program) supports the production, distribution, and development of production techniques for radioactive and stable isotopes in short supply and critical to the Nation. Isotopes are commodities of strategic importance and are essential for energy exploration and innovation, medical applications, national security, manufacturing, and basic research. Both stable isotopes and radioisotopes have applications across the physical sciences and engineering sectors. Two of the largest sectors for isotope applications are medicine and national security. The Isotope Program produces and/or distributes approximately 30 radioisotopes (the number varies year-to-year depending on demand) and has 244 enriched stable isotopes available for distribution. The program typically serves over 400 customers a year, a majority from the private sector. The program engages industry on a regular basis, through customer meetings and annual customer surveys. The program also makes available its capabilities and resources for public-private partnerships with industry to assist industry in R&D challenges related to isotope production.

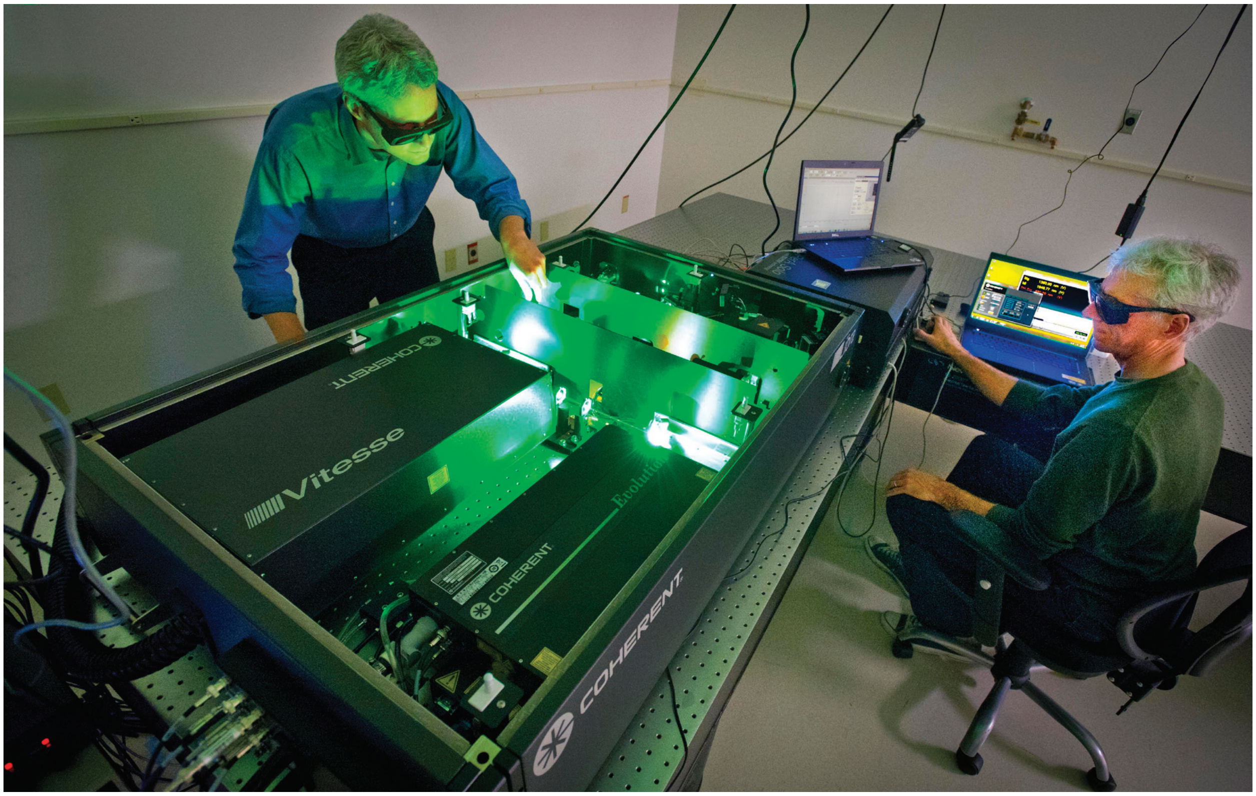
Likewise, SC and NNSA's unique partnerships with leading U.S. companies to develop first-of-its-kind high-performance computers (HPCs) have driven major advancements in HPCs in the United States over the past several decades. The seemingly continuous improvements in high-performance computing over decades belies critical moments of discrete technological advances that hinged on collaboration between DOE and the handful of U.S. processor manufacturers. Design and fabrication of the processors and memory at the heart of every computer is costly, with large capital expenditures required by industry to invest in the "fab lines" that produce the chips and the engineering controls for design assurance. At several times in the history of computing, a major technological roadblock existed in the prevailing design architectures; progress beyond incremental improvement was unclear. Driven by mission need for more powerful supercomputers, DOE has—multiple times—led successful R&D partnerships with U.S. semiconductor vendors to explore new paradigms in processor and memory design. Today, the exascale computing initiative (discussed in section 2.3) to achieve the next thousand-fold improvement in computational power is the most recent example.

SC's FOAs are generally open to industry as well as academia and National Laboratories to submit proposals as the lead or as a partner. Industry organizations also engage in several of SC's major research efforts such as the Energy Frontier Research Centers, the Bioenergy Research Centers, the Batteries and Energy Storage Hub—the Joint Center for Energy Storage Research (JCESR), and the Sunlight to Fuels Hub—the Joint Center for Artificial Photosynthesis (JCAP).

4.4.3 Industry Engagement with DOE's Unique Facilities

As discussed in previous chapters, DOE National Laboratories maintain cutting-edge experimental and computational capabilities that provide unique opportunities for partners from the commercial sector to develop and test new technologies. Shared R&D facilities at the National Laboratories available to the public typically fall into three broad classes depending on the mode of access: designated user facilities, shared R&D facilities, and the facilities at NETL.

- *Designated user facilities* meet broad mission need by enabling a range of S&T research, characterization, and analysis, with operational costs fully supported by DOE. Access to time on these facilities is managed by a peer-reviewed proposal process. To encourage innovative technical proposals



The Joint Center for Artificial Photosynthesis (JCAP)-North, a DOE energy innovation hub aimed at developing the technology to commercially generate fuels directly from sunlight. JCAP is operated as a partnership between the California Institute of Technology and Berkeley Laboratory.

and the exploration of new scientific knowledge, user fees are not charged for nonproprietary work if the user intends to publish the research results in the open literature. Full cost recovery is required for proprietary work.

- *Shared R&D facilities* meet specific mission needs and typically are used primarily by DOE Laboratory staff, but may have additional time available for external users. Access to time on these facilities is most often managed by the development of research agreements with the facilities' staff. In these facilities, operational costs are supported by DOE for mission activities, but operational costs for external use must be supported by cost recovery. Work at such facilities is most often supported by technology partnering arrangements using contractual mechanisms described below. Shared R&D facilities include a broad spectrum of DOE Laboratory assets such as technology benchmarking test beds (a.k.a. "test facilities"), large-scale collaborative R&D centers, and specialized materials processing capabilities, among others.
- The *facilities* at NETL are essentially shared R&D facilities, but the contractual mechanism for accessing them is slightly different than for the other Laboratories because NETL is a GOGO lab.

In addition to engaging industry through cooperative agreements and contracts, NE works closely with industry through the nuclear scientific user facilities (NSUF), which provides industry, academia, Government, and international research entities access to its unique, highly capable, and otherwise generally unavailable research facilities, equipment, and expertise to support fundamental and applied nuclear energy research. NSUF offers significant support through all phases of a research project, including planning, design, fabrication, experiment transport, irradiation, and post-irradiation examination, by leveraging its collective capabilities at INL and its 11 partners (ORNL, Massachusetts Institute of Technology, North Carolina State University, Illinois

Institute of Technology's beam line capabilities at the Advanced Photon Source, PNNL, Westinghouse, the University of Wisconsin, the University of Michigan, the University of California–Berkeley, Purdue University , and the University of Nevada–Las Vegas).

In 2007, NSUF began working directly with representatives from the nuclear energy industry to ensure the capabilities offered addressed specific needs of industry. Benefits of this interaction to date include the development of the irradiation assisted stress corrosion cracking (IASCC) test capability and the re-start of Loop 2A in the Advanced Test Reactor at the INL. Furthermore, in 2015 NE expanded eligibility for competitive access of all NSUF capabilities, previously limited to university-led teams, to now include industry and National Laboratories.

For SC, the most common mode of engagement with industry is through the SC designated scientific user facilities, which provide unique research tools on a competitive open-access basis. Each of SC's six research program offices sponsors scientific user facilities that serve their respective scientific missions, and many facilities are of significant interest to industry. Each year hundreds of industrial concerns use the facilities to advance their research goals. In FY 2014, 1,692 users from 430 industrial institutions were among the users of SC's scientific user facilities. The x ray light sources, neutron sources, supercomputers, nanoscience research centers, genomic sequencing, environmental science, and atmospheric monitoring user facilities each have diverse industrial user populations. Tables 4.8 and 4.9 provide a summary the total domestic and international industry users of the SC facilities, and a breakdown of industry users by the SC sponsor of user facilities, respectively.

User Type	Quantity from U.S.	Quantity from Non U.S.*	Total
Industry Users	1,396 (82.7%)	294 (17.3%)	1692
Unique Industry Institutions	333	97	430
States/Countries	37	21	-

Table 4.8: FY 2014 Industry Users of SC Designated User Facilities—U.S. and Non-U.S. Users.
This table details the number of industry users of SC designated user facilities in FY 2014, shown as those from the U.S. and those from other countries. **This is a lower bound. Further analysis would be required to determine which non-U.S. entities identified as "Institutes" or "Centers" are actually industrial institutions.*

Program	U.S. Industry Users	Non U.S. Industry Users*	Line Total
Advanced Scientific Computing Research	391	56	447
Basic Energy Sciences	646	130	776
Biological and Environmental Research	73	34	107
Fusion Energy Sciences	252	24	276
High Energy Physics	18	4	22
Nuclear Physics	16	46	62
Grand Total	**1,396**	**294**	**1,690**

Table 4.9: FY 2014 Industry Users of SC Programs' Scientific User Facilities—U.S. and Non-U.S. Users.
This table breaks down the number of industry users of SC programs' scientific user facilities in FY 2014, shown as those from the U.S. and those from other countries. **This is a lower bound. Further detailed analysis would be required to determine which non-U.S. entities identified as "Institutes" or "Centers" are actually industrial institutions.*

DOE Laboratories that host and operate these designated user facilities work continuously to improve the processes for developing and executing user partnerships. Several facilities have industrial liaisons on staff that are practiced in discussing the research needs of the prospective partner, introducing them to the technical capabilities available at the facility, and facilitating negotiation of partnership agreements. In the aggregate, these scoping interactions are labor-intensive, as each industrial user approaches the facility with a unique set of problems, goals, and constraints.

Dedicated Laboratory staff work to connect prospective users with the knowledge and expertise necessary to illuminate potential technical approaches to the problem. Several user facilities offer a rapid-access mode that allows prospective industrial users an opportunity to gain short-term access quickly on a provisional basis to make preliminary measurements and investigate the viability of a notional project; to gain further access, the industrial user submits a full proposal to the facility.

Several facilities offer a variety of standardized partnership agreements to facilitate negotiation of intellectual property rights and the level of collaboration. Many industrial users elect to employ a non-proprietary user agreement or SPP agreement to enable active collaboration with Laboratory scientists.

There are numerous examples of high-impact, industrial partnerships at SC scientific user facilities. SEMATECH, the semiconductor industry's private research consortium, has a longstanding collaboration at LBNL's Advanced Light Source to support SEMATECH's extreme ultraviolet (EUV) nanolithography research. SEMATECH has made substantial investments in recent years to create world-class lithography and metrology instrumentation, including the Microfield Exposure Tool, the world's highest resolution EUV lithography tool.

Perhaps the most prevalent class of industrial partnerships at SC user facilities is that of pharmaceutical companies, who rely on SC's x ray light sources to conduct rapid, precise structure measurements of novel biomolecules for drug discovery. The two structural biology beamlines at ANL's Advanced Photon Source, one operated by Lily Research Laboratories and a second by a consortium of Merck, AbbVie, Pfizer, Bristol-Myers Squibb, and Novartis, have pioneered high-throughput automated protein crystallography sample environments. The Lily beamline alone processes over 10,000 individual samples each year, and typically completes measurements on a next-day schedule. Collectively, molecular structure measurements at the light sources have played a significant role in the development of new pharmaceutical therapies for a variety of diseases.

The Argonne and Oak Ridge Leadership Computing Facilities supercomputers—among the most powerful computing resources in the world for open science—have enabled a variety of advances for industry users. Industry researchers have used the resources at SC's Leadership Computing Facilities to conduct both proof-of-concept and validation simulations to advance fundamental understanding in their R&D efforts. These users have praised Government support for such cutting edge resources and state that their results have helped them gain a competitive advantage by demonstrating the benefits of high-performance computing to their companies. Industry applications are held to the same peer review and readiness criteria as academic and National Laboratory applications and have come from a broad range of industry areas.

SC FES's largest experimental facility, DIII-D National Fusion Facility (DIII-D), is hosted at and operated by the private company General Atomics in San Diego, CA, under a cooperative agreement. To FES and to a researcher, DIII-D has the look and feel of a National Laboratory, with a significant number of graduate students and early career scientists conducting research there, and scientists from U.S. universities and National Laboratories as well as scientists from abroad carrying out research at the facility.

Outside of the user facility context, there is a broad portfolio of industrial partnerships linked to SC's funded research programs. SNL's Combustion Research Facility, a collaborative research center, originally an SC designated user facility and now a shared R&D facility cofunded by SC and EERE, has worked with dozens of manufacturers over thirty years to expand the scientific understanding of internal combustion. These results have led directly to significant improvements in commercial internal combustion engine efficiency and performance. These partnerships are typically framed under CRADAs and SPP agreements.

4.4.4 DOE Program and Laboratory Engagement with Small Business

Both domestic and international competition is compelling energy companies to reduce development and production cycle costs in order to satisfy investors, whose time horizons are increasingly measured in quarters, not years. In addition, business consolidation and the resultant demand for higher investment returns and shorter payback periods are more often attached to incremental process improvements than to longer term shifts in technology that offer step-change gains in economics, efficiency, and environmental quality. The result is fewer RDD&D dollars available per dollar of company revenue. These factors represent a particularly challenging environment for the small business community.

The Federal Government has long recognized the essential role that small business plays in any market, bringing new approaches to national challenges, maintaining a competitive commercial marketplace, and offering consumers more choices to meet their needs. SBIR and STTR are U.S. Government programs in which Federal agencies with large research and development budgets set aside a fraction of their funding to be competitively awarded to small businesses. The small businesses that win awards through these programs are encouraged to commercialize the technology, and they retain the rights to technology that they develop. The Department solicits proposals on a set of specified topics on an annual basis (typically in September), inviting small businesses to apply for SBIR/STTR grants.

Though the Department's SBIR and STTR programs are overseen by SC (as discussed in Chapter 2), all of the applied energy technology programs contribute funding and submit research topics that support their mission spaces and in which successful applications will help meet their R&D needs. DOE supports a large portfolio of nearly $200 million per year in SBIR/STTR awards to small businesses. SC's SBIR/STTR portfolio largely supports the development of instrumentation and enabling technologies for mission areas in SC's six research program offices.

The National Laboratories also engage heavily with small businesses to both support their operations and further their missions. In FY 2014, more than $2.1 billion of the National Laboratories' subcontracts were directed to small businesses. Of the science and energy Laboratories, ORNL supported the most small business contracts in terms of total dollars spent (nearly $213 million).

Subcontracting with Small Businesses

The partnership with Membrane Technology and Research, Inc. (MTR), a small business centered in Newark, CA, serves as an excellent example of how NETL works with small business to facilitate the development of high-risk, high-reward technologies. Over the past decade, with early stage funding first made available via the Department's SBIR program, MTR has collaborated with NETL in the development of a novel membrane for separating carbon dioxide from power plant flue gas. Following positive results from the SBIR program, MTR was able to successfully compete for funding from NETL to advance the scale of its capture technology. This promising technology is now ready for pilot-plant–scale proof-of-concept testing.

1 MWe MTR CO_2 Membrane Test Facility

The Department strives to involve small businesses in all activities and has put in place a number of activities that are either targeted at small business or lend themselves particularly well to small business participation, such as the following:

- The Small Businesses Vouchers (SBV) program: SBV aims to improve the industry's awareness of National Laboratory capabilities, and to provide affordable and easy access to the Laboratories' intellectual and physical assets to advance DOE's clean energy mission. The SBV concept is based on successful models of technology assistance provided by DOE Laboratories that allow regional small businesses to tap into the Laboratories' vast scientific and engineering expertise to overcome technical challenges, often free of charge.
- EERE incubator programs: Incubator programs, run by individual EERE programs to ensure alignment with that Office's mission, have been created to allow each EERE program to use a small fraction of its annual budget for an open solicitation that explicitly targets R&D technology approaches that are within its mission space, but not significantly represented in the current portfolio or plans. Incubators facilitate identification and on-ramping of highly promising emerging approaches into EERE programs' MYPPs and main-line project portfolios, and their small size makes them well suited for small business applications.

These efforts enable the R&D research areas to utilize the innovation, cost competitiveness, and productivity consistently demonstrated by successful small businesses.

A

Appendix A
Acronyms and Abbreviations

Appendix A: Acronyms and Abbreviations

AAAS	American Association for the Advancement of Science
ACT	Agreements for Commercializing Technology
AD	Associate Director
AEC	Atomic Energy Commission
ALCC	ASCR Leadership Computing Challenge
AMES	Ames Laboratory
AMO	Advanced Manufacturing Office
ANL	Argonne National Laboratory
AOP	annual operating plan
APM	Office of Acquisition and Project Management
ARM	Atmospheric Radiation Measurement
ARPA-E	Advanced Research Projects Agency – Energy
ASCR	Advanced Scientific Computing Research
ATF	Accelerator Test Facility
ATLAS	A Toroidal LHC Apparatus (at LHC/CERN)
ATVM	Advanced Technology Vehicle Manufacturing
AWE	Atomic Weapons Establishment
BEA	Battelle Energy Alliance
BECCS	Bioenergy with Carbon Capture and Sequestration
BER	Biological and Environmental Research
BES	Basic Energy Sciences
BESAC	Basic Energy Sciences Advisory Committee
BETO	Bioenergy Technologies Office
BIRD	Binational Industrial R&D
BIS	Big Ideas Summit
BLC	Bilateral Commission
BNL	Brookhaven National Laboratory
BRC	Bioenergy Research Center
BRN	Basic Research Needs
C2B2	Colorado Center for Biorefining and Biofuels
CAES	Center for Advanced Energy Studies
CAS	Contractor Assurance System
CASL	Consortium for Advanced Simulation of LWRs
CCI	Community College Internship
CCPI	Clean Coal Power Initiative
CCS	carbon capture and storage
CCSI	Carbon Capture Simulation Initiative
CCUS	carbon capture, utilization, and storage
CD	critical decision
CEBAF	Continuous Electron Beam Accelerator Facility
CEDS	Cybersecurity for Energy Delivery Systems
CEPM	Chief Executive for Project Management
CERC	Clean Energy Research Center
CERN	European Organization for Nuclear Research
CETR	Clean Energy Transmission and Reliability
CFA	Contributed Funds Agreement
CFIUS	Committee on Foreign Investment in the U.S.
CFO	Office of the Chief Financial Officer
CFR	Code of Federal Regulations

CFS	Comprehensive Fuel Services
CIPAC	Critical Infrastructure Partnership Advisory Council
CMS	Compact Muon Solenoid
CO	Contracting Officer
COO	Chief Operating Officer
COV	committee of visitors
CR	Continuing Resolution
CRADA	cooperative research and development agreement
CRD	Contractor Requirements Document
CREW	Center for Research and Education in Wind
CRF	Combustion Research Facility
CRSP	Center for Revolutionary Solar Photoconversion
CSLF	Carbon Sequestration Leadership Forum
CTBTO	Comprehensive Nuclear-Test-Ban Treaty Organization
CU	University of Colorado
CURENT	Center for Ultra-Wide-Area Resilient Electric Energy Transmission Networks
DARPA	Defense Advanced Research Projects Agency
DAS	Deputy Assistant Secretary
DESI	mid-scale dark energy spectroscopic instrument
DHS	Department of Homeland Security
DNN	Office of Defense Nuclear Nonproliferation
DOE IG	DOE Office of the Inspector General
DOE	Department of Energy
DPC	Director of the Domestic Policy Council
DRB	Directives Review Board
EAC	Electricity Advisory Committee
ECI	Exascale Computing Initiative
EERE	Office Energy Efficiency and Renewable Energy
EFRC	Energy Frontier Research Center
EIA	Energy Information Administration
EISA 2007	Energy Independence and Security Act of 2007
EM	Office of Environmental Management
EPA	Environmental Protection Agency
EPAct 2005	Energy Policy Act of 2005
EPCA	Energy Policy and Conservation Act
EPSA	Energy Policy and Systems Analysis
EPSCoR	Experimental Program to Stimulate Competitive Research
ERDA	Energy Research and Development Administration
ESAAB	Energy Systems Acquisition Advisory Board
ESC	executive steering committee
ESCC	Energy Sector Government Coordinating Council
ESIF	Energy Systems Integration Facility
ESPC	Energy Savings Performance Contract
ESRPC	energy systems risk and predictive capability
ET	Emerging Technologies
EUV	extreme ultraviolet
FACA	Federal Advisory Committee Act
FACAs	committees formed under the Federal Advisory Committee Act
FAR	Federal Acquisition Regulations
FCEV	fuel cell electric vehicle
FCTO	Fuel Cell Technologies Office
FE	Office of Fossil Energy
FEMA	Federal Emergency Management Agency
FEMP	Federal Energy Management Program

FERC	Federal Energy Regulatory Commission
FES	Fusion Energy Sciences
FFRDC	Federally funded research and development center
FMC	Field Management Council
FNAL	Fermi National Accelerator Laboratory
FOA	Funding Opportunity Announcements
FORGE	Frontier Observatory for Research in Geothermal Energy
FPD	Federal project director
FPMC	Federal Project Management Center
FRIB	Facility for Rare Isotope Beams
FTE	full-time employee
FWP	field work proposal
FY	fiscal year
GAO	Government Accountability Office
GHG	greenhouse gas
GIF	Generation IV International Forum
GOCO	Government-owned and contractor-operated
GOGO	Government-owned and Government-operated
GPP	General Plant Project
GPRA	Government Performance and Results Act
GPRAMA	Government Performance and Results Act Modernization Act
GSA	General Services Administration
GTO	Geothermal Technologies Office
HEP	high energy physics
HEU	highly enriched uranium
HPC	high-performance computing (or computers)
HQ	headquarters
IA	Office of International Affairs
IAC	Industrial Assessment Center
IAEA	International Atomic Energy Agency
IASCC	Irradiation Assisted Stress Corrosion Cracking
ICCS	Industrial Carbon Capture & Storage
ICE/ICR	Independent Cost Estimate/Review
IDPRA	Isotope Development and Production for Research and Applications
IE	Office of Indian Energy
IEA	International Energy Agency
IFM	Idaho Facilities Management
IFNEC	International Framework for Nuclear Energy Cooperation
IG	Inspector General
IGPP	Institutional General Plant Project
INC	International Nuclear Cooperation
INERI	International Nuclear Energy Research Initiative INERI
INL	Idaho National Laboratory
IP	intellectual property
IPA	Intergovernmental Personnel Act
IPL	Integrated Priority List
IPNS	Intense Pulsed Neutron Source
IRP	Integrated Research Project
ISC	Integrated Support Center
ISER	Infrastructure Security and Energy Restoration
ISGAN	International Smart Grid Action Network
ITER	ITER Project, formerly International Thermonuclear Experimental Reactor
IUP	Integrated University Program
JC	Joint Convention
JCAP	Joint Center for Artificial Photosynthesis
JCESR	Joint Center for Energy Storage Research

LBNL	Lawrence Berkeley National Laboratory
LDRD	Laboratory Directed Research and Development
LEU	low enriched uranium
LHC	Large Hadron Collider
LLNL	Lawrence Livermore National Laboratory
LOB	National Laboratory Operations Board
LPC	Laboratory Policy Council
LPMWG	Lab Performance Management Working Group
LPO	Loan Programs Office
LSST	Large Synoptic Survey Telescope
LTS	long-term stewardship
M&O	Management & Operating
MA	Office of Management
MEC	Mission Executive Council
METI	Ministry of Economy, Trade, and Industry
MHK	marine and hydrokinetic
MIE	Major Items of Equipment
MOD	Ministry of Defence (in the UK)
MOE	Ministry of Environment
MOU	Memorandum of Understanding
MTA	Material Transfer Agreements
MTR	Membrane Technology and Research, Inc.
MYPP	multi-year program plans
NAAC	White House Council on Native American Affairs
NAPA	National Academy of Public Administrators
NE	Office of Nuclear Energy
NEA	Nuclear Energy Agency
NEAC	Nuclear Energy Advisory Committee
NEAMS	Nuclear Energy Advanced Modeling and Simulation Program
NED	National Electricity Delivery
NEET	Nuclear Energy Enabling Technologies
NERC	North American Electric Reliability Corporation
NETL	National Energy Technology Laboratory
NEUP	Nuclear Energy University Programs
NIPP	National Infrastructure Protection Plan
NITRD	Networking and Information Technology Research and Development
NLDC	National Laboratory Directors' Council
NLOO	National Laboratory Oversight Office
NMREC	National Marine Renewable Energy Center
NNSA	National Nuclear Security Administration
NP	Nuclear Physics
NPS	Nuclear Power Station
NR	Naval Reactors
NRAP	National Risk Assessment Partnership
NREL	National Renewable Energy Laboratory
NRO	National Reconnaissance Office
NSET	Nanoscale Science, Engineering, and Technology
NSF	National Science Foundation
NSLS-II	National Synchrotron Light Source II
NSTC	National Science and Technology Council
NSUF	nuclear scientific user facilities
ODNI	Office of the Director of National Intelligence

OE	Office of Electricity Delivery and Energy Reliability
OECD	Organization for Economic Cooperation and Development
OIC	Operations Improvement Committee
OMB	Office of Management and Budget
OPA	Office of Project Assessment
OPR	Office of Petroleum Reserves
ORD	Office of Research and Development
ORNL	Oak Ridge National Laboratory
OSP	Office of Strategic Programs
OSTP	Office of Science and Technology Policy
OTT	Office of Technology Transitions
PBR	President's Budget Request
PCAST	President's Council of Advisors on Science and Technology
PEMP	Performance Evaluation and Measurement Plan
PI	Principal Investigator
PICS:NE	Program Information and Collection System (Office of Nuclear Energy)
PIO	Performance Improvement Officer
PMA	Power Marketing Administrations
PME	Project Management Executive
PMRC	Project Management Risk Committee
PNNL	Pacific Northwest National Laboratory
POTUS	President of the United States
PV	photovoltaics
QA	Quality Assurance
QAP	Quality Assurance Program
QCD	quantum chromodynamics
QER	Quadrennial Energy Review
R&D	research and development
RASEI	Renewable and Sustainable Energy Institute
RCSP	Regional Carbon Sequestration Partnerships
RD&D	research, development, and demonstration
RDD&D	research, development, demonstration, and deployment
REE	rare earth elements
RERF	Radiation Effects Research Foundation
RES	Research and Engineering Services
RFI	Request for Information
RHLLW	Remote Handled Low Level Waste
RRI	Research Reactor Infrastructure
S&S	safeguards and security
S&T	science and technology
SBIR	Small Business Innovation Research
SBTT	Small Business Technology Transfer
SBV	Small Businesses Vouchers
SC	Office of Science
SCGSR	Office of Science Graduate Student Research
SciDAC	Scientific Discovery through Advanced Computing
SEP	Science and Energy Plan
SETO	Solar Energy Technologies Office
SLAC	SLAC National Accelerator Laboratory, formerly Stanford Linear Accelerator Center
SLI	Science Laboratories Infrastructure
SMR	small modular reactor
SNL	Sandia National Laboratories
SNM	special nuclear materials
SNS	Spallation Neutron Source
SOI	statement of intent
SPP	Strategic Partnership Project
SSL	solid state lighting

START	Strategic Technical Assistance and Response Team
STEAB	State Energy Advisory Board
STEM	science, technology, engineering, and mathematics
SubTER	Subsurface Technology and Engineering RD&D
SULI	Science Undergraduate Laboratory Internship
TA	technical assistance
TCIPG	Trustworthy Cyber Infrastructure for the Power Grid
TELGP	Tribal Indian Energy Loan Guarantee Program
TEP	Tribal Energy Program
TJNAF	Thomas Jefferson National Accelerator Facility
TPC	total project cost
TRAC	transformer resilience and advanced components
TTC	Technology Transfer Coordinator
TTWG	Technology Transfer Working Group
UESC	Utility Energy Savings Contract
UNF	used nuclear fuel
US/MP	Under Secretary for Management and Performance
US/NS	Under Secretary for National Security
US/SE	Under Secretary for Science and Energy
USAF	U.S. Air Force
USDA	U.S. Department of Agriculture
USG	U.S. Government
UT	University of Tennessee
VFP	Visiting Faculty Program
VTC	video teleconference
VTO	Vehicle Technologies Office
WAP	Weatherization Assistance Program
WDTS	Workforce Development for Teachers and Scientists
WDTS	Workforce Development for Teachers and Scientists
WFO	Work for Others
WIPO	Weatherization and Intergovernmental Programs Office
WWTP	Wind and Water Technologies Program Office
WWTPO	Wind and Water Technologies Program Office

B

Appendix B
Merit Review Process

Appendix B: Merit Review Process

The primary purpose of a merit review is to provide an independent assessment of the technical/scientific merit of an application for financial assistance. Merit reviews are performed by person(s) who have knowledge and expertise in the technical/scientific fields identified or presented in the applications submitted to DOE.

Merit reviews may be designed in several formats and completed in different manners. For example, a merit review panel can consist of qualified Federal personnel that evaluate the technical/scientific merit of individual applications in accordance with the evaluation criteria and also rate the applications in accordance with the pre-established rating plan. Alternatively, the technical/scientific merit of individual applications can be evaluated by multiple teams of qualified non-Federal personnel that provide strengths and weaknesses in accordance with the merit review criteria. These strengths and weaknesses would then be provided to the merit review panel of Federal personnel that determine consensus strengths and weaknesses and rate the applications in accordance with the pre-established rating plan. In either case, the Federal personnel provide the consensus rating for each application to be considered by the Selecting Official in determining which applications are selected to potentially fund.

Program offices may also develop their own merit review procedures through a program rule. The program rule should include procedures that minimize the administrative burden on reviewers and be stated as clearly and succinctly as possible.

All persons involved in the evaluation and selection process will be required to protect the confidentiality of any specifically identified trade secrets and/or privileged or confidential commercial or financial information obtained as a result of their participation in the evaluation.

C

Appendix C

Acronyms for SC User Facilities (Current and Terminated)

Appendix C: Acronyms for SC User Facilities (Current and Terminated)

Advanced Scientific Computing Research (ASCR) facilities:

- National Energy Research Scientific Computing Center (NERSC)
- Energy Sciences Network (ESNet)
- Argonne Leadership Computing Facility (ALCF)
- Oak Ridge Leadership Computing Facility (OLCF)

Biological and Environmental Research (BER) facilities:

- Environmental Molecular Sciences Laboratory (EMSL)
- Joint Genomics Institute (JGI)
- Atmospheric Radiation Measurement Climate Research Facility (ARM)

Basic Energy Sciences (BES) facilities:

- Stanford Synchrotron Radiation Lightsource (SSRL)
- Advanced Light Source (ALS)
- Advanced Photon Source (APS)
- Linac Coherent Light Source (LCLS)
- High Flux Isotope Reactor (HFIR)
- Spallation Neutron Source (SNS)
- Nanoscale Science Research Centers (NSRCs)
- National Synchrotron Light Source II (NSLS-II)
- Los Alamos Meson Physics Facility (LAMPF) [T]
- High Flux Beam Reactor (HFBR) [T]
- Radiochemical Engineering & Development Center (REDC) [T]
- Intense Pulsed Neutron Source (IPNS) [T]
- Manuel Lujan Jr. Neutron Scattering Center (Lujan) [T]
- National Synchrotron Light Source (NSLS) [T]

[T] Indicates the user facility is terminated

Fusion Energy Sciences (FES) facilities:

- Alcator C-Mod
- DIII-D
- National Spherical Torus Experiment (NSTX)
- Neutralized Drift Compression Experiment-I (NDCX)
- Tokamak Fusion Test Reactor (TFTR) [T]

High Energy Physics (HEP) facilities:

- Contributions to the Large Hadron Collider (LHC)
- NuMI Off-Axis Neutrino Appearance (NOvA) Experiment
- Neutrinos at the Main Injector (NuMI)-Main Injector Neutrino Oscillation Search (MINOS)
- Facility for Advanced Accelerator Experimental Tests (FACET)
- Daya Bay
- Stanford Positron Electron Accelerating Ring (SPEAR) [T]
- Alternate Gradient Synchrotron (AGS-HEP) [T]
- SLAC Linac (LINAC) [T]
- Stanford Linear Collider (SLC) [T]
- Main Ring[T]
- BEVALAC/Bevatron (Bevatron) [T]
- Positron-electron project (PEP) [T]
- PEP-II, BaBar B Factory experiment (B Factory) [T]
- Tevatron Collider (Tevatron) [T]

Nuclear Physics (NP) facilities:

- Relativistic Heavy Ion Collider (RHIC)
- 88-Inch Cyclotron
- Argonne Tandem Linac Accelerator System (ATLAS)
- Continuous Electron Beam Accelerator Facility (CEBAF)
- Alternate Gradient Synchrotron (AGS-NP) [T]
- Holifield Heavy Ion Research Facility (HHIRF) [T]
- Bates Linear Accelerator Center (Bates) [T]
- Holifield Radioactive Ion Beam Facility (HRIBF) [T]

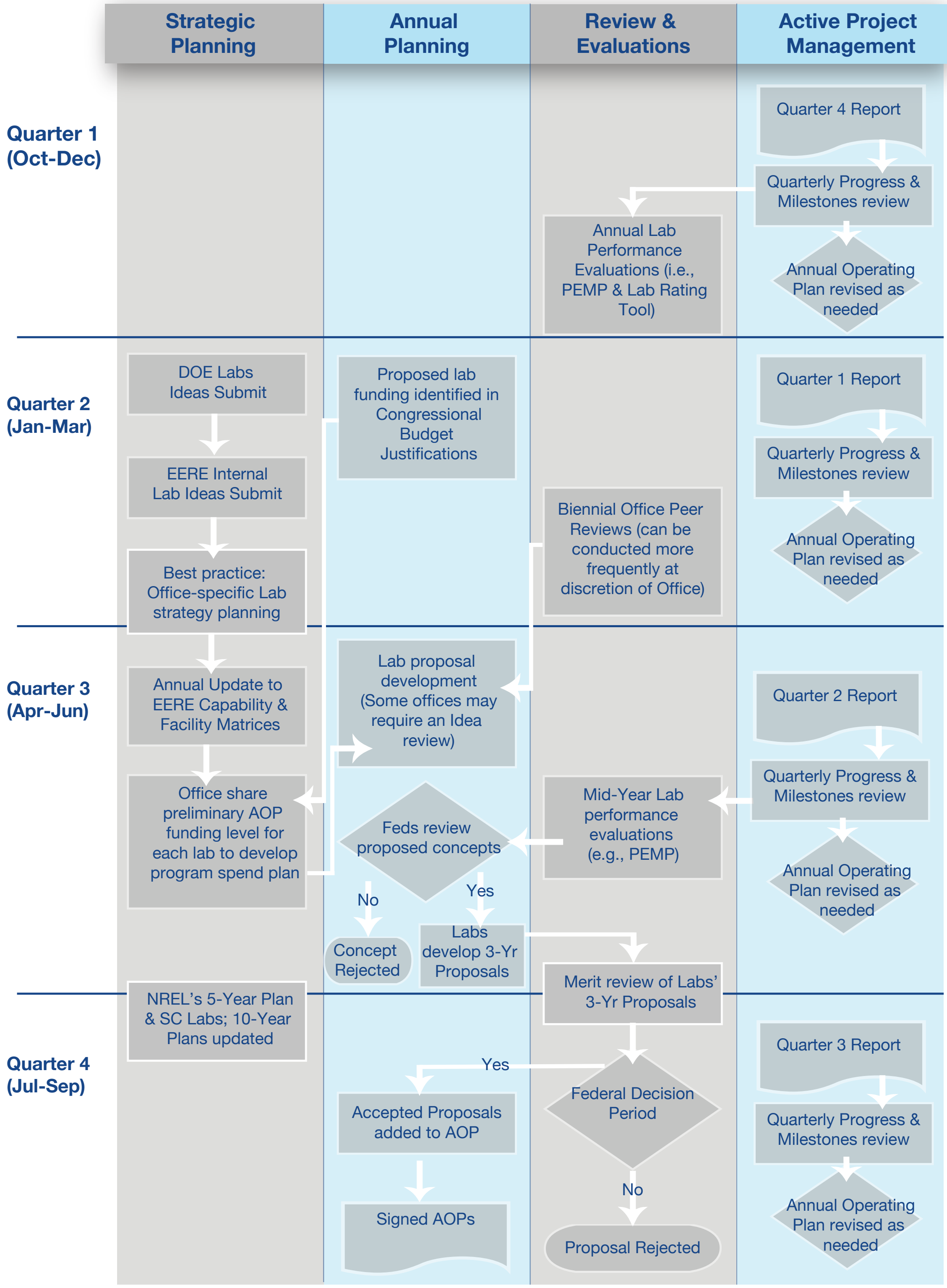
[T] Indicates the user facility is terminated

D

Appendix D

Diagram of EERE Annual Lab Planning and Management Timeline and Business Processes

Appendix D: Diagram of EERE Annual Lab Planning and Management Timeline and Business Processes



Appendix E

Descriptions of DOE's RDD&D Innovation Models

Appendix E: Descriptions of DOE's RDD&D Innovation Models

The Department of Energy invests significant resources to explore, develop, and advance new scientific discoveries and energy technologies. The Department has broad authorities to pursue its work through a variety of mechanisms that fit the scope and nature of the challenge. In choosing implementation mechanisms, DOE seeks and supports innovation broadly while at the same time making these investments as efficient and cost- effective as possible. This requires a combination of innovation, risk tolerance, and disciplined project management to identify and support projects that are risky and exploratory and also to support projects focused on delivering innovative products into real applications.

Over the years DOE has evolved a number of funding mechanisms to address the broad range of required investments. These modalities range from the funding for single investigators at universities to teams of scientists at universities and labs to form Energy Frontier Research Centers to funding multi-institutional, multi-location Innovation Hubs much larger in scope and size. This section provides an overview of some of the more common RDD&D mechanisms selected by DOE's Science and Energy programs.

Single Investigators and Small Groups of Investigators: These investigators conduct discovery science with the goal of understanding the world around us. Their agility and risk-tolerance are critical to the broader portfolio. Individual investigators may propose research activities in any topical area supported by SC. For many fields such as chemistry, biology, and materials sciences, understanding how nature works is the key to ultimately predicting and controlling materials properties and transformations. Yet there is no requirement for this research to link to applications. There is no funding limit, but awards are typically $150K/year per PI in the university sector and more in the Laboratory sector where we must accommodate FTE costs. Activities are typically reviewed every 3 years, and there is no sunset provision.

Energy Frontier Research Centers: The Energy Frontier Research Centers are composed of a set of self-assembled investigators, often spanning several science and engineering disciplines, who will address fundamental science questions that must be solved in order to remove roadblocks to transformational energy technologies. This research is "use inspired" discovery science motivated by the need to solve a specific problem, such as energy storage, photoconversion, and CO2 sequestration. The funding range is $2M–$5M/year. Activities are reviewed every 4–5 years.

Energy Innovation Hubs: The Energy Innovation Hubs are composed of a large set of investigators that span many science, engineering, and public policy/economics disciplines, focused on a critical national need. By bringing together top talent across the full spectrum of R&D performers—including universities, private industry, nonprofits, and National Laboratories—it is envisioned that each Hub will become a world-leading R&D center in its topical area. The research at the Hubs is purpose-driven towards rapid scientific and technological advances that lead to commercially feasible energy technologies. The highly integrated Hubs bridge the gap between basic scientific breakthroughs and industrial commercialization through proof-of-concept prototyping, modeling, measurement, and verification of the potential for major impacts. Like the Bioenergy Research Centers, the initial award is openly competed among performers. Activities are reviewed every 5 years.

Manufacturing Innovation Institutes: DOE partners with several other Federal agencies, including Commerce, Defense, and Agriculture to establish a national network of manufacturing institutes that bring together industry, academia, DOE Labs, and State and local economic and workforce development stakeholders to revitalize America's manufacturing industry. The National Network of Manufacturing Institutes (NNMIs) is a network of local "ecosystems" that (1) combines public and private resources to develop advanced technologies that help U.S. manufacturers achieve a competitive advantage in global markets, (2) makes it attractive for private industry to site future manufacturing facilities in the United States, and (3) creates a talent pipeline needed to support the growth of manufacturing in the United States. NNMIs focus on several objectives: reducing the energy intensity of manufacturing, developing technological advances to increase product value and/or reduce manufacturing costs, and improving the sustainability of the manufacturing supply chain. Each NNMI is competitively awarded $50M–$70M of DOE funding for an initial period of 5 years, matched by a level of private and State investments that meet or exceed the Federal investment. Every NNMI includes a business plan to have the institute sustain its operation with private, State, and local funding even after the initial five-year period of Federal funding.

Bioenergy Research Centers: The concept and rationale of the Bioenergy Research Centers (BRCs) is to accelerate the transformational scientific breakthroughs necessary for cost-effective production of biofuels and bioenergy, including cellulosic ethanol. These centers conduct comprehensive, multidisciplinary research programs on microbes and plants to develop innovative biotechnology solutions to energy production. The three BRCs are:

- Joint BioEnergy Institute (JBEI; lead institution LBNL),
- Great Lakes Bioenergy Research Center (GLBRC; lead institution University of Wisconsin-Madison), and
- BioEnergy Science Center (BESC; lead institution ORNL).

Annual Operating Plans & Laboratory Calls: The applied energy technology offices use their AOPs to directly fund core and enabling S&T capabilities that have long-term value in advancing strategic and programmatic objectives. Any FOA funding obtained should be supplementary, meaning the funds are not necessary to sustain core or enabling capabilities. The Science and Energy program offices expect that it will generally continue to allow National Laboratories to submit applications as primes and sub-awardees through competitive FOAs to support activities that build on, are complementary to, and/or are differentiated from core and enabling capability work funded through AOPs. Program offices may conduct inter-lab competitions or lab calls; these may be appropriate for new or emerging capabilities and for determining capabilities that may exist at National Laboratories but are not currently recognized. Lab calls may also be a good tool to encourage inter-lab collaboration and bigger consortia-like projects where labs synergistically combine enabling capabilities to accomplish a challenging multiyear goal in one project.

Appendix F
Chapter Resources

Appendix F: Chapter Resources

A Message from the Under Secretary and Deputy Under Secretary for Science and Energy

Title	Hyperlink
About Us: Dr. Ernest Moniz - Secretary of Energy	http://www.energy.gov/contributors/dr-ernest-moniz
About Us: Dr. Michael Knotek - Deputy Under Secretary for Science and Energy	http://www.energy.gov/contributors/michael-knotek
About Us: Franklin (Lynn) Orr - Under Secretary for Science and Energy	http://www.energy.gov/contributors/franklin-lynn-orr
Department of Energy National Laboratories	http://www.energy.gov/maps/doe-national-laboratories
Department of Energy Offices	http://www.energy.gov/offices
Secretary Moniz at Town Hall Forum on Departmental Reorganization	http://www.energy.gov/videos/secretary-moniz-town-hall-forum-departmental-reorganization
U.S. Department of Energy Strategic Plan 2014-2018 (Mission)	http://energy.gov/sites/prod/files/2014/04/f14/2014_dept_energy_strategic_plan.pdf#page=8

Executive Summary

Title	Hyperlink
Department of Energy FY 2016 Congressional Budget Request (Cybersecurity)	http://www.energy.gov/sites/prod/files/2015/02/f19/FY2016BudgetVolume2.pdf#page=259
Department of Energy FY 2016 Congressional Budget Request (Energy-Water Nexus)	http://www.energy.gov/sites/prod/files/2015/02/f19/FY2016BudgetVolume2.pdf#page=215
Department of Energy FY 2016 Congressional Budget Request (Exascale Computing)	http://www.energy.gov/sites/prod/files/2015/02/f19/FY2016BudgetVolume2.pdf#page=225
Department of Energy FY 2016 Congressional Budget Request (Grid Modernization)	http://www.energy.gov/sites/prod/files/2015/02/f19/FY2016BudgetVolume2.pdf#page=231
Department of Energy FY 2016 Congressional Budget Request (Subsurface Technology and Engineering RD&D)	http://www.energy.gov/sites/prod/files/2015/02/f19/FY2016BudgetVolume2.pdf#page=243
Department of Energy FY 2016 Congressional Budget Request (Supercritical Dioxide)	http://www.energy.gov/sites/prod/files/2015/02/f19/FY2016BudgetVolume2.pdf#page=253
Department of Energy National Laboratories	http://www.energy.gov/maps/doe-national-laboratories
Department of Energy Offices	http://www.energy.gov/offices
Deputy Director for Field Operations	http://science.energy.gov/sc-3/oversight/contractor-assurance-systems/
DOE Designated User Facilities	http://energy.gov/gc/downloads/doe-designated-user-facilities
Energy-Saving Homes, Buildings, and Manufacturing	http://www.energy.gov/eere/efficiency
Federal Advisory Committee Management	http://energy.gov/management/office-management/operational-management/federal-advisory-committee-management
Heating Oil Reserve	http://www.energy.gov/fe/services/petroleum-reserves/heating-oil-reserve
Laboratory Planning Process	http://science.energy.gov/lp/laboratory-planning-process/
Map: Explore the National Labs	http://www.energy.gov/articles/map-explore-national-labs
National Laboratory Directors' Council	http://nldc.nationallabs.org/
National Nuclear Security Administration	http://nnsa.energy.gov/
Office of Electricity Delivery and Energy Reliability	http://www.energy.gov/oe/office-electricity-delivery-and-energy-reliability

Title	Hyperlink
Office of Energy Efficiency & Renewable Energy	http://www.energy.gov/eere/office-energy-efficiency-renewable-energy
Office of Fossil Energy	http://www.energy.gov/fe/office-fossil-energy
Office of Indian Energy Policy and Programs	http://www.energy.gov/indianenergy/office-indian-energy-policy-and-programs
Office of Nuclear Energy	http://www.energy.gov/ne/office-nuclear-energy
Office of Science	http://science.energy.gov/
Office of Technology Transitions	http://www.energy.gov/technologytransitions/office-technology-transitions
Office of the Under Secretary for Management and Performance	http://www.energy.gov/office-under-secretary-management-and-performance
Office of the Under Secretary for Science and Energy	http://www.energy.gov/office-under-secretary-science-and-energy
Operations Improvement Committee	http://science.energy.gov/sc-3/oic/
Quadrennial Energy Review (Full Report)	http://energy.gov/epsa/downloads/quadrennial-energy-review-full-report
Quadrennial Technology Review	http://energy.gov/qtr
Renewable Electricity Generation	http://www.energy.gov/eere/renewables
Small Business Innovation Research and Small Business Technology Transfer	http://science.energy.gov/sbir/
Strategic Petroleum Reserve	http://www.energy.gov/fe/services/petroleum-reserves/strategic-petroleum-reserve
Sustainable Transportation	http://www.energy.gov/eere/transportation
Technology Transition Facilities Database	http://energy.gov/technologytransitions/technology-transitions-facilities-database
Ten Year Site Plans	http://energy.gov/management/office-management/operational-management/facilities-and-infrastructure/ten-year-site
The Department of Energy	http://www.energy.gov/
U.S. Department of Energy Strategic Plan 2014-2018	http://www.energy.gov/sites/prod/files/2014/04/f14/2014_dept_energy_strategic_plan.pdf

Chapter 1

Title	Hyperlink
About EIA	http://www.eia.gov/about/
About Us Franklin (Lynn) Orr - Under Secretary for Science and Energy	http://www.energy.gov/contributors/franklin-lynn-orr
About Us: Dr. Elizabeth Sherwood-Randall - Deputy Secretary of Energy	http://www.energy.gov/contributors/dr-elizabeth-sherwood-randall
About Us: Dr. Ernest Moniz - Secretary of Energy	http://www.energy.gov/contributors/dr-ernest-moniz
Advanced Research Projects Agency-Energy	http://arpa-e.energy.gov/
Advanced Scientific Computing Research	http://science.energy.gov/ascr/
Ames Laboratory	https://www.ameslab.gov/
Argonne National Laboratory	http://www.anl.gov/
Atomic Energy Act of 1946	http://science.energy.gov/~/media/bes/pdf/Atomic_Energy_Act_of_1946.pdf
Atomic Energy Act of 1954	http://science.energy.gov/~/media/bes/pdf/nureg_0980_v1_no7_june2005.pdf#page=14
Atomic Energy Commission	http://energy.gov/sites/prod/files/AEC%20History.pdf
Basic Energy Sciences	http://science.energy.gov/bes/
Biological and Environmental Research	http://science.energy.gov/ber/
Bonneville Power Administration	http://www.bpa.gov/Pages/home.aspx
Brookhaven National Laboratory	https://www.bnl.gov/world/
Clean Coal Power Initiative	http://energy.gov/fe/science-innovation/clean-coal-research/major-demonstrations/clean-coal-power-initiative
Department of Energy	http://www.energy.gov/
Department of Energy FY 2016 Congressional Budget Request	http://energy.gov/sites/prod/files/2015/02/f19/FY2016BudgetinBrief.pdf
Department of Energy FY 2016 Congressional Budget Request (Supercritical Dioxide)	http://www.energy.gov/sites/prod/files/2015/02/f19/FY2016BudgetVolume2.pdf#page=253
Department of Energy FY 2016 Congressional Budget Request (Cybersecurity)	http://www.energy.gov/sites/prod/files/2015/02/f19/FY2016BudgetVolume2.pdf#page=259

Title	Hyperlink
Department of Energy FY 2016 Congressional Budget Request (Exascale Computing)	http://www.energy.gov/sites/prod/files/2015/02/f19/FY2016BudgetVolume2.pdf#page=225
Department of Energy FY 2016 Congressional Budget Request (Grid Modernization)	http://www.energy.gov/sites/prod/files/2015/02/f19/FY2016BudgetVolume2.pdf#page=231
Department of Energy FY 2016 Congressional Budget Request (Subsurface Technology and Engineering RD&D)	http://www.energy.gov/sites/prod/files/2015/02/f19/FY2016BudgetVolume2.pdf#page=243
Department of Energy Organization Act of 1977	http://www.gpo.gov/fdsys/pkg/STATUTE-91/pdf/STATUTE-91-Pg565.pdf
DOE Bioenergy Research Centers	http://genomicscience.energy.gov/centers/
DOE History	http://energy.gov/management/office-management/operational-management/history
DOE Mission	http://energy.gov/mission
DOE Offices	http://energy.gov/offices
DOE Organization Chart	http://energy.gov/leadership/organization-chart
Energy Efficiency and Renewable Energy (EERE)	http://energy.gov/eere/office-energy-efficiency-renewable-energy
Energy Frontier Research Centers	http://science.energy.gov/bes/efrc/
Facility For Rare Isotope Beams	http://www.frib.msu.edu/
Fermi National Accelerator Laboratory	http://www.fnal.gov/
Fusion Energy Sciences	http://science.energy.gov/fes/
Heating Oil Reserve	http://www.energy.gov/fe/services/petroleum-reserves/heating-oil-reserve
High Energy Physics	http://science.energy.gov/hep/
High Energy Physics Advisory Panel (HEPAP)	http://science.energy.gov/hep/hepap
History of the Energy Research and Development Administration	http://energy.gov/sites/prod/files/ERDA%20History.pdf
Idaho National Laboratory	https://www.inl.gov/
ITER	https://www.iter.org/
Jefferson Lab	https://www.jlab.org/
Launch of the Grid Modernization Laboratory Consortium	http://energy.gov/articles/launch-grid-modernization-laboratory-consortium

Title	Hyperlink
Lawrence Berkeley National Laboratory	http://www.lbl.gov/
Lawrence Livermore National Laboratory	https://www.llnl.gov/
Lieutenant General Frank G. Klotz, USAF (Ret)	http://www.nnsa.energy.gov/aboutus/ourleadership/klotz
Loan Program Office	http://energy.gov/lpo/loan-programs-office
Long-Baseline Neutrino Facility (LBNF)	http://lbnf.fnal.gov/
Management & Operating (M&O) Contracts	http://science.energy.gov/lp/management-and-operating-contracts/
Manhattan Project	http://energy.gov/management/office-management/operational-management/history/manhattan-project
National Academies Press: Rising Above the Gathering Storm	http://www.nap.edu/catalog/11463/rising-above-the-gathering-storm-energizing-and-employing-america-for
National Energy Technology Laboratory	http://www.netl.doe.gov/
National Labs	http://energy.gov/national-labs
National Nuclear Security Administration	http://nnsa.energy.gov/
National Renewable Energy Laboratory	http://www.nrel.gov/
Nuclear Physics	http://science.energy.gov/np/
Oak Ridge National Laboratory	https://www.ornl.gov/
Office of Electricity Delivery and Energy Reliability	http://energy.gov/oe/office-electricity-delivery-and-energy-reliability
Office of Environmental Management	http://energy.gov/em/office-environmental-management
Office of Fossil Energy	http://energy.gov/fe/office-fossil-energy
Office of Indian Energy Policy and Programs	http://www.energy.gov/indianenergy/office-indian-energy-policy-and-programs
Office of International Affairs	http://energy.gov/ia/office-international-affairs
Office of Nuclear Energy	http://energy.gov/ne/office-nuclear-energy
Office of Science	http://science.energy.gov/
Office of the Under Secretary for Management and Performance	http://energy.gov/office-under-secretary-management-and-performance
Office of the Under Secretary for Science and Energy	http://energy.gov/office-under-secretary-science-and-energy
Pacific Northwest National Laboratory	http://www.pnnl.gov/

Title	Hyperlink
Petroleum Reserves	http://energy.gov/fe/services/petroleum-reserves
Presidential Memorandum -- Accelerating Technology Transfer and Commercialization of Federal Research in Support of High-Growth Business	https://www.whitehouse.gov/the-press-office/2011/10/28/presidential-memorandum-accelerating-technology-transfer-and-commerciali
President's Climate Action Plan	https://www.whitehouse.gov/sites/default/files/image/president27sclimateactionplan.pdf
Princeton Plasma Physics Laboratory	http://www.pppl.gov/
Quadrennial Technology Review	http://energy.gov/qtr
Sandia National Laboratories	http://www.sandia.gov/
Savannah River National Laboratory	http://srnl.doe.gov/
SLAC National Accelerator Laboratory	https://www6.slac.stanford.edu/
Small Business Innovation Research (SBIR) and Small Business Technology Transfer	http://science.energy.gov/sbir/
Southeastern Power Administration	http://energy.gov/sepa/southeastern-power-administration
Southwestern Power Administration	http://www.swpa.gov/
Strategic Petroleum Reserve	http://energy.gov/fe/services/petroleum-reserves/strategic-petroleum-reserve
Strategy for the Management and Disposal of Used Nuclear Fuel and High-Level Radioactive Waste	http://energy.gov/sites/prod/files/Strategy%20for%20the%20Management%20and%20Disposal%20of%20Used%20Nuclear%20Fuel%20and%20High%20Level%20Radioactive%20Waste.pdf
U.S. Department of Energy Strategic Plan 2014-2018	http://energy.gov/sites/prod/files/2014/04/f14/2014_dept_energy_strategic_plan.pdf
Western Area Power Administration	https://www.wapa.gov/Pages/Western.aspx
Workforce Development for Teachers and Scientists	http://science.energy.gov/wdts/

Chapter 2

Title	Hyperlink
About CERN	http://home.web.cern.ch/about
About Field Offices	http://science.energy.gov/about/field-offices/
About SBIR	http://science.energy.gov/sbir/about
About the Appliance and Equipment Standards Program	http://energy.gov/eere/buildings/about-appliance-and-equipment-standards-program
About the National Labs	http://energy.gov/about-national-labs
Access to High Technology User Facilities at DOE National Laboratories	http://energy.gov/gc/access-high-technology-user-facilities-doe-national-laboratories
Advance Light Source	http://www-als.lbl.gov/
Advance Photon Source	https://www1.aps.anl.gov/
Advanced Grid Integration (AGI)	http://energy.gov/oe/mission/advanced-grid-integration-agi
Advanced Manufacturing Office	http://energy.gov/eere/amo/advanced-manufacturing-office
Advanced Manufacturing Office FY 2016 Budget at-a-glance	http://energy.gov/eere/downloads/advanced-manufacturing-office-fy-2016-budget-glance
Advanced Modeling Grid Research Program	http://energy.gov/oe/services/technology-development/advanced-modeling-grid-research-program
Advanced Reactor Technologies	http://energy.gov/ne/nuclear-reactor-technologies/advanced-reactor-technologies
Advanced Scientific Computing Research	http://science.energy.gov/ascr
American Recovery and Reinvestment Act of 2009	http://www.recovery.gov/arra/About/Pages/The_Act.aspx
Ames Site Office	http://science.energy.gov/amso/
ANL Atlas	http://www.phy.anl.gov/atlas/
APEC Energy Working Group Expert Group on Clean Fossil Energy	http://www.egcfe.ewg.apec.org/
Appliance and Equipment Standards Program	http://energy.gov/eere/buildings/appliance-and-equipment-standards-program
Argonne Leadership Computing Facility	http://www.alcf.anl.gov/
Argonne National Laboratory	http://www.anl.gov/
Argonne Site Office	http://science.energy.gov/aso/
ARM Climate Research Facility	http://www.arm.gov/

Title	Hyperlink
ASCR Leadership Computing Challenge	http://science.energy.gov/ascr/facilities/accessing-ascr-facilities/alcc/
Assisting Federal Facilities with Energy Conservation Technologies (AFFECT) Funding Opportunity	http://energy.gov/eere/femp/assisting-federal-facilities-energy-conservation-technologies-affect-funding-opportunity
Atmosphere to Electrons	http://energy.gov/eere/wind/atmosphere-electrons
Atomic Energy Act of 1946	http://science.energy.gov/~/media/bes/pdf/Atomic_Energy_Act_of_1946.pdf
Atomic Energy Commission	http://energy.gov/sites/prod/files/AEC%20History.pdf
AWE	http://www.awe.co.uk/
Bayh-Dole Act of 1980 (Public Law 96-517)	http://www.gpo.gov/fdsys/pkg/USCODE-2011-title35/pdf/USCODE-2011-title35-partII-chap18.pdf
Berkeley Lab Computing Science - Energy Sciences Network	http://cs.lbl.gov/about/divisions-and-facilities/energy-sciences-network/
Berkeley Site Office	http://science.energy.gov/bso/
Better Plants	http://energy.gov/eere/amo/better-plants
Bilateral Agreements with China	http://energy.gov/fe/services/international-cooperation/bilateral-agreements-china
Bilateral Cooperation	http://energy.gov/ne/nuclear-reactor-technologies/international-nuclear-energy-policy-and-cooperation/bilateral
Bioenergy Technologies Office	http://www.energy.gov/eere/bioenergy/bioenergy-technologies-office
Bioenergy Technologies Office FY 2016 Budget at-a-glance	http://energy.gov/eere/downloads/bioenergy-technologies-office-fy-2016-budget-glance
Biological and Environmental Research	http://science.energy.gov/ber/
Brookhaven Site Office	http://science.energy.gov/bhso/
Building Technologies Office	http://energy.gov/eere/buildings/building-technologies-office
Building Technologies Office FY 2016 Budget at-a-glance	http://energy.gov/eere/downloads/building-technologies-office-fy-2016-budget-glance
Carbon Capture, Utilization & Storage	http://www.energy.gov/carbon-capture-utilization-storage
Carbon Sequestration Leadership Forum	http://www.cslforum.org/
CCS Regional Partnerships	http://energy.gov/fe/science-innovation/carbon-capture-and-storage-research/regional-partnerships
Center for Functional Nanomaterials	https://www.bnl.gov/cfn/
Center for Integrated Nanotechnologies	http://cint.lanl.gov/

Title	Hyperlink
Center for Nanophase Materials Sciences	http://www.cnms.ornl.gov/
CERN Compact Muon Solenoid	http://cms.web.cern.ch/
CERN The Large Hadron Collider	http://home.web.cern.ch/topics/large-hadron-collider
Clean Coal Research	http://energy.gov/fe/science-innovation/clean-coal-research
Clean Energy Manufacturing Initiative	http://energy.gov/eere/cemi/clean-energy-manufacturing-initiative
Commercial Buildings Integration	http://energy.gov/eere/buildings/commercial-buildings-integration
Community College Internships	http://science.energy.gov/wdts/cci/
Consortium for Advanced Simulation of LWRs	http://www.casl.gov/
Critical Infrastructure Partnership Advisory Council	http://www.dhs.gov/critical-infrastructure-partnership-advisory-council
Crosscutting Technology Development	http://energy.gov/ne/nuclear-energy-enabling-technologies/crosscutting-technology-development
Cybersecurity	http://energy.gov/oe/services/cybersecurity
Cybersecurity Capability Maturity Model (C2M2) Program	http://energy.gov/oe/services/cybersecurity/cybersecurity-capability-maturity-model-c2m2-program
Defense Nuclear Security	http://nnsa.energy.gov/aboutus/ourprograms/nuclearsecurity
Defense Programs	http://nnsa.energy.gov/aboutus/ourprograms/defenseprograms
Department of Energy FY 2016 Congressional Budget Request (Advanced Scientific Computing Research)	http://science.energy.gov/~/media/budget/pdf/sc-budget-request-to-congress/fy-2016/FY_2016_Office_of_Science-ASCR.pdf
Department of Energy FY 2016 Congressional Budget Request (Basic Energy Science)	http://science.energy.gov/bes
Department of Energy FY 2016 Congressional Budget Request (Biological and Environmental Research)	http://science.energy.gov/~/media/budget/pdf/sc-budget-request-to-congress/fy-2016/FY_2016_Office_of_-Science-BER.pdf
Department of Energy FY 2016 Congressional Budget Request (Energy Efficiency and Renewable Energy)	http://www.energy.gov/sites/prod/files/2015/02/f19/FY2016BudgetVolume3_7.pdf#page=15
Department of Energy FY 2016 Congressional Budget Request (Exascale Computing)	http://www.energy.gov/sites/prod/files/2015/02/f19/FY2016BudgetVolume2.pdf - page=225
Department of Energy FY 2016 Congressional Budget Request (Fossil Energy Research and Development)	http://www.energy.gov/sites/prod/files/2015/02/f19/FY2016BudgetVolume3_7.pdf#page=573

Title	Hyperlink
Department of Energy FY 2016 Congressional Budget Request (Fusion Energy Science)	http://science.energy.gov/~/media/budget/pdf/sc-budget-request-to-congress/fy-2016/FY_2016_Office_of_Science-FES.pdf
Department of Energy FY 2016 Congressional Budget Request (Grid Modernization)	http://www.energy.gov/sites/prod/files/2015/02/f19/FY2016BudgetVolume2.pdf#page=231
Department of Energy FY 2016 Congressional Budget Request (High Energy Physics)	http://science.energy.gov/~/media/budget/pdf/sc-budget-request-to-congress/fy-2016/FY_2016_Office_of_Science-HEP.pdf
Department of Energy FY 2016 Congressional Budget Request (Isotope Production and Distribution Program Fund)	http://science.energy.gov/~/media/budget/pdf/sc-budget-request-to-congress/fy-2016/FY_2016_Office_of_Science-Isotope.pdf
Department of Energy FY 2016 Congressional Budget Request (Nuclear Energy)	http://www.energy.gov/sites/prod/files/2015/02/f19/FY2016BudgetVolume3_7.pdf#page=425
Department of Energy FY 2016 Congressional Budget Request (Nuclear Physics)	http://science.energy.gov/~/media/budget/pdf/sc-budget-request-to-congress/fy-2016/FY_2016_Office_of_Science-NP.pdf
Department of Energy FY 2016 Congressional Budget Request (Office of Indian Energy Policy and Programs)	http://www.energy.gov/sites/prod/files/2015/02/f19/FY2016BudgetVolume3_7.pdf - page=753
Department of Energy FY 2016 Congressional Budget Request (Office of Science)	http://www.energy.gov/sites/prod/files/2015/02/f19/FY2016BudgetVolume4_5.pdf#page=15
Department of Energy FY 2016 Congressional Budget Request (Safeguards and Security)	http://science.energy.gov/~/media/budget/pdf/sc-budget-request-to-congress/fy-2016/FY_2016_Office_of_Science-SS.pdf
Department of Energy FY 2016 Congressional Budget Request (Science and Energy)	http://www.energy.gov/sites/prod/files/2015/02/f19/FY2016BudgetinBrief.pdf#page=26
Department of Energy FY 2016 Congressional Budget Request (Science Laboratories Infrastructure)	http://science.energy.gov/~/media/budget/pdf/sc-budget-request-to-congress/fy-2016/FY_2016_Office_of_Science--SLI.pdf
Department of Energy FY 2016 Congressional Budget Request (Subsurface Technology and Engineering RD&D)	http://www.energy.gov/sites/prod/files/2015/02/f19/FY2016BudgetVolume2.pdf#page=243
Department of Energy FY 2016 Congressional Budget Request (Supercritical Carbon Dioxide)	http://www.energy.gov/sites/prod/files/2015/02/f19/FY2016BudgetVolume2.pdf#page=253
Department of Energy Organization Act of 1977	http://www.gpo.gov/fdsys/pkg/STATUTE-91/pdf/STATUTE-91-Pg565.pdf
DOE History	http://science.energy.gov/about/history/

Title	Hyperlink
DOE Nobel Laureates	http://science.energy.gov/about/honors-and-awards/doe-nobel-laureates/
DOE Office of Science Graduate Student Research (SCGSR) Program	http://science.energy.gov/wdts/scgsr/
DOE Order 413.2B	https://www.directives.doe.gov/directives-documents/400-series/0413.2-BOrder-b-admchg1
DOE Order 413.3B	https://www.directives.doe.gov/directives-documents/400-series/0413.3-BOrder-b
DOE Public-Private Consortia	http://energy.gov/technologytransitions/downloads/doe-public-private-consortia
EERE FY 2016 Budget Request	http://energy.gov/eere/downloads/eere-fy-2016-budget-request
Electricity Delivery and Energy Reliability	http://www.energy.gov/sites/prod/files/2015/02/f19/FY2016BudgetVolume3_7.pdf#page=337
Emergency Support Function #12; Energy Annex	http://energy.gov/oe/downloads/emergency-support-function-12-energy-annex
Emerging Technologies	http://energy.gov/eere/buildings/emerging-technologies
Energy and Water Development Appropriations Act, 1998	http://www.gpo.gov/fdsys/pkg/PLAW-105publ62/pdf/PLAW-105publ62.pdf
Energy Delivery Systems Cybersecurity	http://energy.gov/oe/services/technology-development/energy-delivery-systems-cybersecurity
Energy Frontier Research Centers (EFRCs)	http://science.energy.gov/bes/efrc/
Energy Infrastructure Modeling and Analysis (EIMA)	http://energy.gov/oe/mission/energy-infrastructure-modeling-and-analysis-eima
Energy Policy Act of 2005	http://energy.gov/sites/prod/files/2013/10/f3/epact_2005.pdf#page=360
Energy Policy Act of 2005, Title V, Sec. 502	http://energy.gov/sites/prod/files/2013/10/f3/epact_2005.pdf - page=171
Energy Policy and Conservation Act (EPCA)	http://www.gpo.gov/fdsys/pkg/STATUTE-89/pdf/STATUTE-89-Pg871.pdf
Energy Storage	http://energy.gov/oe/services/technology-development/energy-storage
Energy Storage Safety Strategic Plan	http://energy.gov/sites/prod/files/2014/12/f19/OE%20Safety%20Strategic%20Plan%20December%202014.pdf
Energy Systems Integration Facility	http://www.nrel.gov/esif/
Energy-Saving Homes, Buildings, and Manufacturing	http://energy.gov/eere/efficiency

Title	Hyperlink
Environmental Molecular Sciences Laboratory	https://www.emsl.pnl.gov/emslweb/
EV Everywhere Grand Challenge: DOE's 10-Year Vision for Plug-In Electric Vehicles	http://energy.gov/eere/vehicles/ev-everywhere-grand-challenge-does-10-year-vision-plug-electric-vehicles
Experimental Program to Stimulate Competitive Research (EPSCoR)	http://science.energy.gov/bes/epscor/
Export-Import Bank of The United States	http://www.exim.gov/authority-has-lapsed/
Facilities Management	http://energy.gov/ne/nuclear-reactor-technologies/nuclear-facility-operations/facilities-management
Facility for Advanced Accelerator Experimental Tests (FACET) and Test Beam Facilities	https://www6.slac.stanford.edu/facilities/facet.aspx
Facility for Rare Isotope Beams	http://www.frib.msu.edu/
Fact Sheet: U.S.-Japan Bilateral Cooperation	https://www.whitehouse.gov/the-press-office/2014/04/25/fact-sheet-us-japan-bilateral-cooperation
FE FY 2016 Budget Request Presentation	http://energy.gov/fe/downloads/fe-fy-2016-budget-request-presentation
Federal Energy Efficiency Fund (FEEF)	http://energy.gov/eere/femp/energy-incentive-programs
Federal Energy Management Program	http://energy.gov/eere/femp/federal-energy-management-program
Federal Energy Management Program FY 2016 Budget at-a-glance	http://energy.gov/eere/downloads/federal-energy-management-program-fy-2016-budget-glance
Federally Supported Innovations: 22 Examples of Major Technology Advances That Stem From Federal Research Support	http://www2.itif.org/2014-federally-supported-innovations.pdf
Fermi Site Office	http://science.energy.gov/fso/
Fermilab's Accelerator Complex	http://www.fnal.gov/pub/science/particle-accelerators/accelerator-complex.html
Frontier Observatory for Research in Geothermal Energy	http://energy.gov/eere/forge/forge-home
Fuel Cell Electric Vehicle	http://energy.gov/eere/fuelcells/downloads/infographic-fuel-cell-electric-vehicle
Fuel Cell Technologies Office	http://energy.gov/eere/fuelcells/fuel-cell-technologies-office
Fuel Cell Technologies Office FY 2016 Budget at-a-glance	http://energy.gov/eere/downloads/fuel-cell-technologies-office-fy-2016-budget-glance
Fuel Cycle Technologies	http://energy.gov/ne/nuclear-reactor-technologies/fuel-cycle-technologies

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Fuel Economy	http://www.fueleconomy.gov/
Fuels From Sunlight Hub	http://energy.gov/articles/fuels-sunlight-hub
Fusion Energy Sciences (FES)	http://science.energy.gov/fes
General Atomic Fusion Energy Research	https://fusion.gat.com/global/DIII-D
Generation IV International Forum	https://www.gen-4.org/gif/jcms/c_9260/public
Genomic Science Program	http://genomicscience.energy.gov/centers/
Genomics Programs of the DOE	http://genomics.energy.gov/
Geothermal Energy at the U.S. Department of Energy	http://energy.gov/eere/geothermal/geothermal-energy-us-department-energy
Geothermal Technologies Office FY 2016 Budget at-a-glance	http://energy.gov/eere/downloads/geothermal-technologies-office-fy-2016-budget-glance
Global Carbon Capture and Sequestration Institute	http://www.globalccsinstitute.com/
Grid Energy Storage - December 2013	http://energy.gov/oe/downloads/grid-energy-storage-december-2013
GridEx	http://www.nerc.com/pa/CI/CIPOutreach/Pages/GridEX.aspx
High Energy Physics (HEP)	http://science.energy.gov/hep
History of the Energy Research and Development Administration	http://energy.gov/management/downloads/history-energy-research-and-development-administration
HydroNEXT Fact Sheet	http://energy.gov/eere/water/downloads/hydronext-fact-sheet
Idaho Operations Office	http://www.id.doe.gov/
IEA Clean Coal Centre	http://www.iea-coal.org.uk/site/2010/home
IEA Greenhouse Gas R&D Programme	http://ieaghg.org/
IEA International Smart Grid Action Network	http://www.iea-isgan.org/
IEAE Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management	https://www.iaea.org/publications/documents/conventions/joint-convention-safety-spent-fuel-management-and-safety-radioactive-waste
Industrial Assessment Centers	http://energy.gov/eere/amo/industrial-assessment-centers-iacs
Infrastructure Security and Energy Restoration (ISER)	http://energy.gov/oe/mission/infrastructure-security-and-energy-restoration-iser
Integrated Support Center	http://science.energy.gov/isc/
International Atomic Energy Agency	https://www.iaea.org/

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International Framework For Nuclear Energy Cooperative	http://www.ifnec.org/
International Fuel Services and Commercial Engagement	http://energy.gov/ne/international-nuclear-energy-policy-and-cooperation/international-fuel-services-and-commercial
International Nuclear Energy Policy and Cooperation	http://energy.gov/ne/nuclear-reactor-technologies/international-nuclear-energy-policy-and-cooperation
International Nuclear Energy Research Initiative (I-NERI) Annual Reports	http://energy.gov/ne/listings/international-nuclear-energy-research-initiative-i-neri-annual-reports
ITER	https://www.iter.org/
Jefferson Lab	https://www.jlab.org/
Jefferson Lab Visitor's Center	https://www.jlab.org/visitors/science/
Joint Center for Artificial Photosynthesis (JCAP)	http://solarfuelshub.org/
Joint Center for Energy Storage Research	http://www.jcesr.org/
Joint Genome Institute	http://jgi.doe.gov/
Laboratory Directed Research and Development Annual Reports	http://energy.gov/cfo/reports/laboratory-directed-research-and-development-annual-reports
Laboratory for Laser Energetics	http://www.lle.rochester.edu/
Labs at-a-Glance: Ames Laboratory	http://science.energy.gov/laboratories/ames-laboratory/
Labs at-a-Glance: Argonne National Laboratory	http://science.energy.gov/laboratories/argonne-national-laboratory/
Labs at-a-Glance: Brookhaven National Laboratory	http://science.energy.gov/laboratories/brookhaven-national-laboratory/
Labs at-a-Glance: Fermi National Accelerator Laboratory	http://science.energy.gov/laboratories/fermi-national-accelerator-laboratory/
Labs at-a-Glance: Lawrence Berkeley National Laboratory	http://science.energy.gov/laboratories/lawrence-berkeley-national-laboratory/
Labs at-a-Glance: Oak Ridge National Laboratory	http://science.energy.gov/laboratories/oak-ridge-national-laboratory/
Labs at-a-Glance: Pacific Northwest National Laboratory	http://science.energy.gov/laboratories/pacific-northwest-national-laboratory/
Labs at-a-Glance: Princeton Plasma Physics Laboratory	http://science.energy.gov/laboratories/princeton-plasma-physics-laboratory/
Labs at-a-Glance: SLAC National Accelerator Laboratory	http://science.energy.gov/laboratories/slac-national-accelerator-laboratory/

Title	Hyperlink
Labs at-a-Glance: Thomas Jefferson National Accelerator Facility	http://science.energy.gov/laboratories/thomas-jefferson-national-accelerator-facility/
Launch of the Grid Modernization Laboratory Consortium	http://energy.gov/articles/launch-grid-modernization-laboratory-consortium
Lawrence Berkeley National Lab	http://www.lbl.gov/
Light Water Reactor Sustainability (LWRS) Program	http://www.energy.gov/ne/nuclear-reactor-technologies/light-water-reactor-sustainability-lwrs-program
Linac Coherent Light Source	https://portal.slac.stanford.edu/sites/lcls_public/Pages/Default.aspx
Loan Program Office ATVM	http://energy.gov/lpo/advanced-technology-vehicles-manufacturing-atvm-loan-program
Loan Program Office Title XVII	http://energy.gov/lpo/innovative-clean-energy-projects-title-xvii-loan-program
Loan Programs Office	http://energy.gov/lpo/loan-programs-office
Market Transformation	http://energy.gov/eere/fuelcells/market-transformation
Ministry of Economy, Trade and Industry, Japan	http://www.meti.go.jp/english/
Ministry of the Environment, Japan	https://www.env.go.jp/en/
Molecular Foundry	http://foundry.lbl.gov/
National Carbon Capture Center	http://www.nationalcarboncapturecenter.com/
National Electric Transmission Congestion Study	http://energy.gov/oe/services/electricity-policy-coordination-and-implementation/transmission-planning/national-2
National Energy Research Scientific Computing Center	https://www.nersc.gov/
National Ignition Facility & Photon Science	https://lasers.llnl.gov/
National Nuclear Security Administration	http://nnsa.energy.gov/
National Response Framework	https://www.fema.gov/media-library/assets/documents/32230
National Risk Assessment Partnership	http://www.netl.doe.gov/research/coal/crosscutting/national-risk-assessment-partnership
National Science Bowl®	http://science.energy.gov/wdts/nsb/
National Security Council	https://www.whitehouse.gov/administration/eop/nsc/
National Spherical Torus Experiment	http://nstx.pppl.gov/overview.html
National Strategy for the Arctic Region	https://www.whitehouse.gov/sites/default/files/docs/nat_arctic_strategy.pdf

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Natural Gas Act of 1938	http://www.energy.gov/sites/prod/files/2013/04/f0/2011usc15.pdf
Naval Petroleum and Oil Shale Reserves	http://energy.gov/fe/downloads/naval-petroleum-and-oil-shale-reserves
Naval Petroleum Reserves	http://energy.gov/fe/services/petroleum-reserves/naval-petroleum-reserves
NDEMC Final Report	http://www.compete.org/publications/all/2938
NETL Cooperative Research and Development Agreement (CRADA)	http://www.netl.doe.gov/business/tech-transfer/partnerships-and-licensing
NETL On-Site Research Facilities	http://www.netl.doe.gov/research/on-site-research/research-capabilities/research-facilities
NETL's Energy Data eXchange	https://edx.netl.doe.gov/
New View of The Universe	https://str.llnl.gov/str/pdfs/07_99.2.pdf
NNSA Nonproliferation	http://nnsa.energy.gov/aboutus/ourprograms/nonproliferation-0
NNSA Supercomputing	http://nnsa.energy.gov/category/related-topics/supercomputing
Northeast Gasoline Supply Reserve	http://energy.gov/fe/services/petroleum-reserves/northeast-regional-refined-petroleum-product-reserve
NRC: Issued Design Certification - Economic Simplified Boiling-Water Reactor (ESBWR)	http://www.nrc.gov/reactors/new-reactors/design-cert/esbwr.html
NREL Research Facilities - Test and User Facilities	http://www.nrel.gov/research_facilities/user_facilities.html
Nuclear Energy Advanced Modeling and Simulation (NEAMS) Program Plan	http://energy.gov/ne/downloads/nuclear-energy-advanced-modeling-and-simulation-neams-program-plan
Nuclear Energy Agency	http://www.oecd-nea.org/
Nuclear Energy Enabling Technologies	http://energy.gov/ne/nuclear-reactor-technologies/nuclear-energy-enabling-technologies
Nuclear Energy University Program	http://energy.gov/ne/nuclear-reactor-technologies/nuclear-energy-university-program
Nuclear Facility Operations	http://energy.gov/ne/nuclear-reactor-technologies/nuclear-facility-operations
Nuclear Nonproliferation Program Offices	http://nnsa.energy.gov/aboutus/ourprograms/nonproliferation/programoffices
Nuclear Physics	http://science.energy.gov/np/
Nuclear Science User Facilities	https://atrnsuf.inl.gov/
Oak Ridge Leadership Computing Facility	https://www.olcf.ornl.gov/

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Oak Ridge National Laboratory	https://www.ornl.gov/
Oak Ridge Site Office	http://science.energy.gov/oso/
Office of Civilian Radioactive Waste Management	http://www.energy.gov/downloads/office-civilian-radioactive-waste-management
Office of Electricity Delivery and Energy Reliability	http://energy.gov/oe/office-electricity-delivery-and-energy-reliability
Office of Electricity Delivery and Energy Reliability	http://www.energy.gov/oe/office-electricity-delivery-and-energy-reliability
Office of Energy Efficiency & Renewable Energy	http://energy.gov/eere/office-energy-efficiency-renewable-energy
Office of Energy Policy and Systems Analysis	http://energy.gov/epsa/office-energy-policy-and-systems-analysis
Office of Environment, Health, Safety & Security	http://energy.gov/ehss/environment-health-safety-security
Office of Environmental Management	http://energy.gov/em/office-environmental-management
Office of Fossil Energy	http://energy.gov/fe/office-fossil-energy
Office of Indian Energy Policy and Programs	http://www.energy.gov/indianenergy/office-indian-energy-policy-and-programs
Office of Laboratory Policy	http://science.energy.gov/lp/
Office of Multilateral Cooperation	http://energy.gov/ne/international-nuclear-energy-policy-and-cooperation/multilateral-cooperation
Office of Nuclear Energy	http://energy.gov/ne/office-nuclear-energy
Office of Nuclear Energy Leadership	http://energy.gov/ne/leadership
Office of Project Assessment	http://science.energy.gov/opa/
Office of Safety and Security Policy	http://science.energy.gov/ssp/
Office of Science	http://science.energy.gov
Office of Science Designation Process	http://science.energy.gov/user-facilities/policies-and-processes/designation-process/
Office of Science Laboratories	http://science.energy.gov/laboratories/
Office of Science Policies and Processes Definition	http://science.energy.gov/user-facilities/policies-and-processes/definition/
Office of Strategic Programs	http://energy.gov/eere/about-us/office-strategic-programs

Title	Hyperlink
Office of Technology Transfer Coordinator	http://energy.gov/technologytransitions/office-technology-transitions
Office of Technology Transitions	http://techtransfer.energy.gov/
Office of the Chief Human Capital Officer - Overseas Assignments	http://energy.gov/hc/policy-and-guidance/employment-and-staffing/overseas-assignments
Office of the Under Secretary for Science and Energy	http://energy.gov/office-under-secretary-science-and-energy
Offshore Wind Advanced Technologies Demonstration Projects	http://energy.gov/eere/wind/offshore-wind-advanced-technology-demonstration-projects
Oil & Gas Research	http://energy.gov/fe/science-innovation/oil-gas-research
Operations Program Management (OPM)	http://science.energy.gov/opm/
ORNL Manufacturing Demonstration Facility	http://web.ornl.gov/sci/manufacturing/mdf/
Pacific Northwest Site Office	http://science.energy.gov/pnso/
Petra Nova - W.A. Parish Project	http://energy.gov/fe/petra-nova-wa-parish-project
Petroleum Reserves	http://energy.gov/fe/services/petroleum-reserves
Pittsburgh Supercomputing Center	http://www.psc.edu/
Plasma Science and Fusion Center MIT	https://www.psfc.mit.edu/research/alcator/intro/info.html
Play Fairway Analysis FOA Selections	http://www.energy.gov/eere/geothermal/downloads/play-fairway-analysis-foa-selections
Power America	http://energy.gov/eere/amo/power-america
Power Purchase Agreements	http://energy.gov/eere/slsc/power-purchase-agreements
Power Systems Engineering Research and Development (PSE R&D)	http://energy.gov/oe/mission/power-systems-engineering-research-and-development-pse-rd
Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treat Organization	https://www.ctbto.org/
Presidential Memorandum -- Accelerating Technology Transfer and Commercialization of Federal Research in Support of High-Growth Business	https://www.whitehouse.gov/the-press-office/2011/10/28/presidential-memorandum-accelerating-technology-transfer-and-commerciali
Presidential Policy Directive -- Critical Infrastructure Security and Resilience	https://www.whitehouse.gov/the-press-office/2013/02/12/presidential-policy-directive-critical-infrastructure-security-and-resil
President's Climate Action Plan	https://www.whitehouse.gov/sites/default/files/image/president27sclimateactionplan.pdf

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Prevent, Counter, and Respond—A Strategic Plan to Reduce Global Nuclear Threats (FY 2016—2020)	http://nnsa.energy.gov/aboutus/ourprograms/dnn/npcr
Princeton Site Office	http://science.energy.gov/pso/
Public Law 112-81	http://www.gpo.gov/fdsys/pkg/PLAW-112publ81/html/PLAW-112publ81.htm
Recovery Act: Smart Grid Investment Grants	http://energy.gov/oe/technology-development/smart-grid/recovery-act-smart-grid-investment-grants
Relativistic Heavy Ion Collider	https://www.bnl.gov/rhic/
Renewable Electricity Generation	http://energy.gov/eere/renewables
Research, Development, Test, and Evaluation (NNSA)	http://www.nnsa.energy.gov/aboutus/ourprograms/defenseprograms/stockpilestewardship
Residential Buildings Integration	http://energy.gov/eere/buildings/residential-buildings-integration
Roadmap to Achieve Energy Delivery Systems Cybersecurity - 2011	http://www.energy.gov/oe/downloads/roadmap-achieve-energy-delivery-systems-cybersecurity-2011
Sandia National Laboratories Combustion Research Facility	http://crf.sandia.gov/
Sandia National Laboratories Combustion Research Facility Engine Combustion	http://crf.sandia.gov/combustion-research-facility/engine-combustion/
SBIR Funding Opportunity Announcements (FOAs)	http://science.energy.gov/sbir/funding-opportunities/
Science Undergraduate Laboratory Internships	http://science.energy.gov/wdts/suli/
Scientific Discovery through Advanced Computing	http://www.scidac.gov/
Scientific Grand Challenges: Crosscutting Technologies for Computing at the Exascale	http://science.energy.gov/~/media/ascr/pdf/program-documents/docs/Crosscutting_grand_challenges.pdf
Scientific User Facilities (SUF) Division	http://science.energy.gov/bes/suf/user-facilities/nanoscale-science-research-centers/
SLAC National Accelerator Laboratory	https://www6.slac.stanford.edu/
SLAC Site Office	http://science.energy.gov/sso/
Small Business Innovation Research (SBIR) and Small Business Technology Transfer	http://science.energy.gov/sbir
Small Modular Nuclear Reactors	http://www.energy.gov/ne/nuclear-reactor-technologies/small-modular-nuclear-reactors
Smart Grid	http://energy.gov/oe/services/technology-development/smart-grid

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Solar Energy Technologies Office	http://energy.gov/eere/renewables/solar
Solar Energy Technologies Office FY 2016 Budget at-a-glance	http://energy.gov/eere/downloads/solar-energy-technologies-office-fy-2016-budget-glance
START Program	http://energy.gov/indianenergy/resources/start-program
State and Local Energy Assurance Planning	http://energy.gov/oe/services/energy-assurance/emergency-preparedness/state-and-local-energy-assurance-planning
State Energy Program	http://energy.gov/eere/wipo/state-energy-program
Stevenson-Wydler Technology Innovation Act of 1980 (Public Law 96-480)	http://www.gpo.gov/fdsys/pkg/STATUTE-94/pdf/STATUTE-94-Pg2311.pdf
Strategic Petroleum Reserve	http://energy.gov/fe/services/petroleum-reserves/strategic-petroleum-reserve
Subsurface Tech Team	http://energy.gov/subsurface-tech-team
Sunshot Initiative	http://energy.gov/eere/sunshot/sunshot-initiative
Super Energy Performance	http://www.energy.gov/eere/amo/superior-energy-performance
Supercritical CO2 Tech Team	http://energy.gov/supercritical-co2-tech-team
Supernova Cosmology Project	http://supernova.lbl.gov/
Sustainable Transportation	http://energy.gov/eere/transportation
System Engineering and Integration	http://energy.gov/ne/fuel-cycle-technologies/systems-engineering-and-integration
Technology Transfer Working Group	http://energy.gov/technologytransitions/technology-transfer-working-group-ttwg
Technology Transitions Facilities Database	http://energy.gov/technologytransitions/technology-transitions-facilities-database
Technology Transitions Facilities Database	http://energy.gov/technologytransitions/technology-transitions-facilities-database
Thomas Jefferson Site Office	http://science.energy.gov/tjso/
Transmission Reliability	http://energy.gov/oe/services/technology-development/transmission-reliability
Tribal Energy Program	http://apps1.eere.energy.gov/tribalenergy/
U.S. Department of Energy Strategic Plan 2014-2018	http://energy.gov/sites/prod/files/2014/04/f14/2014_dept_energy_strategic_plan.pdf
U.S.-China Clean Energy Research Center	http://www.us-china-cerc.org/
U.S.-China Climate Change Working Group Fact Sheet	http://www.state.gov/r/pa/prs/ps/2013/07/211768.htm

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UK Ministry of Defense	https://www.gov.uk/government/organisations/ministry-of-defence
United Nations Economic Commission for Europe (UNECE)	http://www.unece.org/info/ece-homepage.html
USEA 15th U.S. - China Oil and Gas Industry Forum	http://www.usea.org/event/15th-us-china-oil-and-gas-industry-forum
USEA 2015 U.S.-China Clean Coal Industry Forum (CCIF)	http://www.usea.org/event/2015-us-china-clean-coal-industry-forum-ccif
Used Fuel Disposition Research & Development	http://energy.gov/ne/fuel-cycle-technologies/used-fuel-disposition-research-development
User Facilities at a Glance	http://science.energy.gov/user-facilities/user-facilities-at-a-glance/
Vehicle Technologies Office	http://energy.gov/eere/vehicles/vehicle-technologies-office
Vehicle Technologies Office FY 2016 Budget at-a-glance	http://energy.gov/eere/downloads/vehicle-technologies-office-fy-2016-budget-glance
Visiting Faculty Program	http://science.energy.gov/wdts/vfp/
Water Energy Tech Team	http://www.energy.gov/water-energy-tech-team
Water Power Program at-a-glance	http://energy.gov/eere/downloads/water-power-program-fy-2016-budget-glance
Water Power Technologies Office	http://energy.gov/eere/renewables/water
Water-Energy Nexus: Challenges and Opportunities	http://www.energy.gov/sites/prod/files/2014/06/f16/Water Energy Nexus Report June 2014.pdf
Weatherization and Intergovernmental Programs Office	http://energy.gov/eere/wipo/weatherization-and-intergovernmental-programs-office
Weatherization and Intergovernmental Programs Office FY 2016 Budget at-a-glance	http://energy.gov/eere/downloads/weatherization-and-intergovernmental-programs-office-fy-2016-budget-glance
Weatherization Assistance Program	http://energy.gov/eere/wipo/weatherization-assistance-program
Western Area Power Administration	http://www.wapa.gov/Pages/Western.aspx
Wind Energy Technologies Office	http://energy.gov/eere/renewables/wind
Wind Program FY 2016 Budget at-a-glance	http://energy.gov/eere/downloads/wind-program-fy-2016-budget-glance
Workforce Development for Teachers and Scientists	http://science.energy.gov/wdts/
Z Pulsed Power Facility	http://www.sandia.gov/z-machine/

Chapter 3

Title	Hyperlink
2 CFR 200	http://www.gpo.gov/fdsys/pkg/CFR-2014-title2-vol1/pdf/CFR-2014-title2-vol1-part200.pdf
2 CFR 910.126 (a)	http://webapps.dol.gov/federalregister/PdfDisplay.aspx?DocId=27995#page=158
2 CFR 910	http://webapps.dol.gov/federalregister/PdfDisplay.aspx?DocId=27995#page=158
41 CFR 102-3.30	http://www.gpo.gov/fdsys/granule/CFR-2012-title41-vol3/CFR-2012-title41-vol3-sec102-3-30
88-Inch Cyclotron	http://cyclotron.lbl.gov/
AAAS Science & Technology Policy Fellowships	http://www.aaas.org/program/science-technology-policy-fellowships
About the National Labs	http://energy.gov/about-national-labs
Acquisition and Project Management Glossary of Terms Handbook	http://energy.gov/sites/prod/files/2014/10/f18/DOE APM Glossary of Terms Handbook_FINAL_Sep_30_2014.pdf
Advanced Manufacturing Office	http://energy.gov/eere/amo/advanced-manufacturing-office
Advanced Research Projects Agency-Energy	http://arpa-e.energy.gov/
All-of-the-above Energy Strategy as a Path to Sustainable Economic Growth	https://www.whitehouse.gov/sites/default/files/docs/aota_energy_strategy_as_a_path_to_sustainable_economic_growth.pdf
Alternating Gradient Synchrotron	https://www.bnl.gov/rhic/AGS.asp
American Recovery and Reinvestment Act of 2009	http://www.gpo.gov/fdsys/pkg/BILLS-111hr1enr/pdf/BILLS-111hr1enr.pdf
Annual Performance Reports	http://energy.gov/cfo/reports/annual-performance-reports
Appliance Standards and Rulemaking Federal Advisory Committee	http://energy.gov/eere/buildings/appliance-standards-and-rulemaking-federal-advisory-committee
Basic Energy Sciences (BES)	http://science.energy.gov/bes/
Basic Energy Sciences Advisory Committee (BESAC)	http://science.energy.gov/bes/besac/
Basic Research Needs to Assure a Secure Energy Future	http://science.energy.gov/~/media/bes/besac/pdf/Basic_research_needs_to_assure_a_secure_energy_future_feb_2003.pdf
Basic Research Needs Workshop Series	http://science.energy.gov/~/media/bes/pdf/reports/files/brn_workshops.pdf
Bioenergy Technologies Office	http://www.energy.gov/eere/bioenergy/bioenergy-technologies-office
Bioenergy Technologies Office Multi-Year Program Plan	http://www.energy.gov/sites/prod/files/2015/03/f20/mypp_beto_march2015.pdf
Bioenergy with Carbon Capture and Sequestration Workshop	http://energy.gov/eere/bioenergy/events/bioenergy-carbon-capture-and-sequestration-workshop

Title	Hyperlink
Biological and Environmental Research (BER)	http://science.energy.gov/ber/
Biomass Research & Development	http://biomassboard.gov/committee/committee.html
Biomass Research and Development Act of 2000	http://energy.gov/eere/bioenergy/downloads/biomass-research-and-development-act-2000
Blue Ribbon Commission on America's Nuclear Future Report to the Secretary of Energy	http://energy.gov/ne/downloads/blue-ribbon-commission-americas-nuclear-future-report-secretary-energy
BR&D Advancing Bioenergy Technologies	http://www.biomassboard.gov/
Building Technologies Office	http://energy.gov/eere/buildings/building-technologies-office
Building Technologies Office 2015 Program Peer Review	http://energy.gov/eere/buildings/building-technologies-office-2015-program-peer-review
Carbon Capture and Storage from Industrial Sources	http://energy.gov/fe/science-innovation/carbon-capture-and-storage-research/carbon-capture-and-storage-industrial
Carbon Capture and Storage Research	http://energy.gov/fe/science-innovation/carbon-capture-and-storage-research
Chief Financial Officers Act a Mandate for Federal Financial Management Reform	http://www.gao.gov/special.pubs/af12194.pdf
Clean Coal Power Initiative	http://energy.gov/fe/science-innovation/clean-coal-research/major-demonstrations/clean-coal-power-initiative
Committee Management Secretariat	http://www.gsa.gov/portal/content/247369
Council on Environmental Quality	https://www.whitehouse.gov/administration/eop/ceq
Critical Decision 2 (CD-2) Approval Template	http://energy.gov/management/downloads/critical-decision-2-cd-2-approval-template
Dark Energy Spectroscopic Instrument	http://desi.lbl.gov/
Department of Energy Acquisition Regulation	http://www.energy.gov/sites/prod/files/2013/07/f2/EDEAR July 2 2013 final.pdf
Deputy Director for Science Programs: Committees of Visitors	http://science.energy.gov/sc-2/committees-of-visitors/
Diamond-Cutter Drill Bits	http://www.nrel.gov/docs/fy00osti/23692.pdf
Directing Matter and Energy: Five Challenges for Science and the Imagination	http://science.energy.gov/~/media/bes/pdf/reports/files/gc_rpt.pdf
DOE Leadership	http://www.energy.gov/leadership
DOE Mission	http://energy.gov/mission
DOE O 413.3B, Program and Project Management for the Acquisition of Capital Assets	https://www.directives.doe.gov/directives-documents/400-series/0413.3-BOrder-b

Title	Hyperlink
DOE O 430.1B, Real Property Asset Management	https://www.directives.doe.gov/directives-documents/400-series/0430.1-BOrder-b
DOE Office of Science	http://science.energy.gov/
DOE Offices	http://energy.gov/offices
DOE Order 130.1	http://www.lm.doe.gov/Office_of_Business_Operations/Solicitations/RFP_Support/DOE_Directives/002_DOE_O_130_1.aspx?__taxonomyid=791
DOE Organization Act of 1977	http://www.gpo.gov/fdsys/pkg/STATUTE-91/pdf/STATUTE-91-Pg565.pdf
DOE Organization Chart	http://energy.gov/leadership/organization-chart
DOE Timeline of Events: 1971 to 1980	http://energy.gov/management/office-management/operational-management/history/doe-history-timeline/timeline-events-1
EFRCs Grand Challenges	http://science.energy.gov/bes/efrc/research/grand-challenges/
Electric Power Supply Association	https://www.epsa.org/forms/documents/DocumentFormPublic/
Electricity Advisory Committee (EAC)	http://energy.gov/oe/services/electricity-advisory-committee-eac
Energy Frontier Research Centers (EFRCs)	http://science.energy.gov/bes/efrc/
Energy Independence and Security Act of 2007	http://www.gpo.gov/fdsys/pkg/BILLS-110hr6enr/pdf/BILLS-110hr6enr.pdf
Energy Policy Act of 2005	http://energy.gov/sites/prod/files/2013/10/f3/epact_2005.pdf
Energy Storage Safety Strategic Plan - December 2014	http://energy.gov/oe/downloads/energy-storage-safety-strategic-plan-december-2014
Energy Systems Acquisition Advisory Board (ESAAB) Members – July 2014	http://www.energy.gov/management/downloads/energy-systems-acquisition-advisory-board-esaab-members-july-2014
Energy Systems Integration Facility	http://www.nrel.gov/esif/
Executive Order -- Establishing the White House Council on Native American Affairs	https://www.whitehouse.gov/the-press-office/2013/06/26/executive-order-establishing-white-house-council-native-american-affairs
External Independent Review (EIR) Standard Operating Procedure (SOP)	http://energy.gov/management/downloads/external-independent-review-eir-standard-operating-procedure-sop
FACA Database Committees	http://www.facadatabase.gov/committee/committees.aspx?aid=42
Facility for Rare Isotope Beams	http://www.frib.msu.edu/
Federal Acquisition Regulation (FAR)	https://www.acquisition.gov/?q=browsefar
Federal Acquisition Streamlining Act of 1994	http://www.gpo.gov/fdsys/pkg/BILLS-103s1587enr/pdf/BILLS-103s1587enr.pdf
Federal Advisory Committee Act	http://www.gsa.gov/portal/content/100916
Federal Energy Management Program	http://energy.gov/eere/femp/federal-energy-management-program

Title	Hyperlink
Fermi National Accelerator Laboratory	http://www.fnal.gov/
Fermilab Muon g-2 Experiment	http://muon-g-2.fnal.gov/
Financial Management Handbook	http://energy.gov/cfo/downloads/financial-management-handbook
Giant electromagnet completes its journey, moves into its new home at Fermilab	http://www.fnal.gov/pub/presspass/press_releases/2014/Muon-g-2-Move-20140730.html
Government Management Reform Act of 1994	http://www.fasab.gov/pdffiles/newsroom_ind_articles_2008winter_dacey.pdf
Government Performance Results Act of 1993	https://www.whitehouse.gov/omb/mgmt-gpra/gplaw2m
GPRA Modernization Act of 2010	http://www.gpo.gov/fdsys/pkg/BILLS-111hr2142enr/pdf/BILLS-111hr2142enr.pdf
H.R.3547 - Consolidated Appropriations Act, 2014	https://www.congress.gov/bill/113th-congress/house-bill/3547
H.R.5116 - America Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science Reauthorization Act of 2010	https://www.congress.gov/bill/111th-congress/house-bill/5116/
High Energy Physics (HEP)	http://science.energy.gov/hep/
Hiring Authorities Intergovernment Personnel Act OPM	http://www.opm.gov/policy-data-oversight/hiring-authorities/intergovernment-personnel-act/ - url=Overview
Hydrogen and Fuel Cell Technical Advisory Committee	http://www.hydrogen.energy.gov/advisory_htac.html
Idaho National Laboratory	https://www.inl.gov/
Idaho Operations Office	http://www.id.doe.gov/
Improving Project Management	http://energy.gov/sites/prod/files/2014/12/f19/Project Mgt Working Group Report Final final.pdf
Improving Project Management at the Department of Energy	http://energy.gov/articles/improving-project-management-department-energy
Improving the Assessment of the Proliferation Risk of Nuclear Fuel Cycles	http://www.nap.edu/catalog/18335/improving-the-assessment-of-the-proliferation-risk-of-nuclear-fuel-cycles
Independent Cost Review (ICR) and Independent Cost Estimate (ICE) Standard Operating Procedures	http://energy.gov/management/downloads/independent-cost-review-icr-and-independent-cost-estimate-ice-standard
Information Technology Management Reform	http://govinfo.library.unt.edu/npr/library/misc/s1124.html
Intense Pulsed Neutron Source	http://www.neutron.anl.gov/ipns/
Large Synoptic Survey Telescope	http://www.lsst.org/
Linac Coherent Light Source	https://portal.slac.stanford.edu/sites/lcls_public/Pages/Default.aspx

Title	Hyperlink
Major Facilities for Materials Research and Related Disciplines	http://www.aps.anl.gov/Science/Reports/1984/rf002.pdf
Memorandum of Understanding Between U.S. Department of Energy and U.S. Department of Defense	http://energy.gov/sites/prod/files/edg/news/documents/Enhance-Energy-Security-MOU.pdf
Methane Hydrate Advisory Committee	http://energy.gov/fe/services/advisory-committees/methane-hydrate-advisory-committee
National Coal Council	http://www.nationalcoalcouncil.org/
National Energy Technology Laboratory	http://www.netl.doe.gov/
National Infrastructure Protection Plan	http://www.dhs.gov/national-infrastructure-protection-plan
National Nanotechnology Initiative	http://www.nano.gov/
National Petroleum Council Washington, DC	http://energy.gov/downloads/national-petroleum-council-washington-dc
National Science and Technology Council	https://www.whitehouse.gov/administration/eop/ostp/nstc
National Security Strategy	https://www.whitehouse.gov/sites/default/files/docs/2015_national_security_strategy.pdf
National Synchrotron Light Source II	https://www.bnl.gov/ps/
Networking and Information Technology Research and Development (NITIRD) Program	https://www.nitrd.gov/
NSET Subcommittee	http://www.nano.gov/nset
NSTC Executive Order	https://www.whitehouse.gov/administration/eop/ostp/nstc/about/executiveorder
Nuclear Energy Advisory Committee	http://www.energy.gov/ne/services/nuclear-energy-advisory-committee
Nuclear innovation workshops	https://nuclearinnovationworkshop.inl.gov/SitePages/Home.aspx
Office of Chief Financial Officer	http://energy.gov/cfo/office-chief-financial-officer
Office of Electricity Delivery and Energy Reliability	http://energy.gov/oe/office-electricity-delivery-and-energy-reliability
Office of Energy Efficiency & Renewable Energy	http://energy.gov/eere/office-energy-efficiency-renewable-energy
Office of Environmental Management Project Management	http://energy.gov/em/services/program-management/project-management
Office of Fossil Energy	http://energy.gov/fe/office-fossil-energy
Office of Inspector General	http://energy.gov/ig/office-inspector-general
Office of Inspector General Performance Plans	http://energy.gov/ig/calendar-year-reports/performance-plans
Office of Nuclear Energy	http://www.energy.gov/ne/office-nuclear-energy

Title	Hyperlink
Office of Science and Technology Policy	https://www.whitehouse.gov/administration/eop/ostp
Office of Technology Transitions	http://energy.gov/technologytransitions/office-technology-transitions
Office of the Director of National Intelligence	http://www.dni.gov/index.php
Office of the Under Secretary for Science and Energy	http://energy.gov/office-under-secretary-science-and-energy
Office of the Under Secretary for Science and Energy	http://www.energy.gov/office-under-secretary-science-and-energy
Phased Retirement OPM	http://www.opm.gov/retirement-services/phased-retirement/
Policy Flash 2013-38 Revised Merit Review Guide for Financial Assistance	http://energy.gov/management/downloads/policy-flash-2013-38-revised-merit-review-guide-financial-assistance
President's Climate Action Plan	https://www.whitehouse.gov/sites/default/files/image/president27sclimateactionplan.pdf
Presidential Management Fellows Program	http://www.pmf.gov/
Presidential Memorandum -- Accelerating Technology Transfer and Commercialization of Federal Research in Support of High-Growth Businesses	https://www.whitehouse.gov/the-press-office/2011/10/28/presidential-memorandum-accelerating-technology-transfer-and-commerciali
Presidential Policy Directive -- Critical Infrastructure Security and Resilience	https://www.whitehouse.gov/the-press-office/2013/02/12/presidential-policy-directive-critical-infrastructure-security-and-resil
President's Budget for Fiscal Year 2016	https://www.whitehouse.gov/omb/budget
President's Council of Advisors on Science and Technology	https://www.whitehouse.gov/administration/eop/ostp/pcast
Procurement and Acquisition	http://energy.gov/management/office-management/operational-management/procurement-and-acquisition
Project Assessment and Reporting System (PARS II)	http://energy.gov/management/project-assessment-and-reporting-system-pars-ii
Quadrennial Energy Review (QER)	http://energy.gov/epsa/quadrennial-energy-review-qer
Quadrennial Technology Review	http://www.energy.gov/qtr
Sandia National Laboratories Combustion Research Facility	http://crf.sandia.gov/
Science & Technology	http://www.energy.gov/science-innovation/science-technology
Secretary Moniz's Remarks on Project Management Reform at the National Academy of Public Administration -- As Delivered	http://energy.gov/articles/secretary-monizs-remarks-project-management-reform-national-academy-public-administration
Secretary of Energy Advisory Board	http://www.energy.gov/seab/secretary-energy-advisory-board
SLAC National Accelerator Laboratory	https://www6.slac.stanford.edu/

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Spallation Neutron Source	https://neutrons.ornl.gov/sns
State Energy Advisory Board	http://www.steab.org/
Strategic Petroleum Reserve	http://energy.gov/fe/services/petroleum-reserves/strategic-petroleum-reserve
Strategy for the Management and Disposal of Used Nuclear Fuel and High-Level Radioactive Waste	http://www.energy.gov/downloads/strategy-management-and-disposal-used-nuclear-fuel-and-high-level-radioactive-waste
Technology Transfer Working Group (TTWG)	http://energy.gov/technologytransitions/technology-transfer-working-group-ttwg
Title 48—Federal Acquisition Regulations System	http://www.gpo.gov/fdsys/pkg/CFR-2003-title48-vol1/pdf/CFR-2003-title48-vol1-chap1.pdf
U.S. Department of Energy Strategic Plan 2014-2018	http://energy.gov/sites/prod/files/2014/04/f14/2014_dept_energy_strategic_plan.pdf
U.S. Global Change Research Program	http://www.globalchange.gov/
Ultra-Deepwater Advisory Committee	http://energy.gov/fe/services/advisory-committees/ultra-deepwater-advisory-committee
Unconventional Resources Technology Advisory Committee	http://energy.gov/fe/services/advisory-committees/unconventional-resources-technology-advisory-committee
United States Department of Agriculture	http://www.usda.gov/wps/portal/usda/usdahome
United States Department Of Agriculture	http://www.usda.gov/wps/portal/usda/usdahome

Chapter 4

Title	Hyperlink
Funding Opportunity Announcements (FOAs)	http://science.energy.gov/grants/foas/open/
12 GeV Upgrade Technical Scope Jefferson Lab	https://www.jlab.org/12GeV/
About: UT-Battelle	http://www.ut-battelle.org/about.shtml
Advanced Photon Source ANL	https://www1.aps.anl.gov/
Advanced Photon Source LBNL	http://www-als.lbl.gov/
Ames Laboratory	https://www.ameslab.gov/
Argonne National Laboratory	http://www.anl.gov/
ASAP, AHRI, and ACEEE applaud successful negotiated rulemaking for commercial air conditioners and warm air furnaces	http://www.appliance-standards.org/documents/asap-press-releases/asap-ahri-and-aceee-applaud-successful-negotiated-rulemaking-comercial?utm_source=RTU+agreement+press+release&utm_campaign=Rooftop+AC+agreement&utm_medium=email
AWEA WINDPOWER	http://www.windpowerexpo.org/
Battelle	http://www.battelle.org/
Berkeley Microfield Exposure Tool (MET)	http://www.cxro.lbl.gov/MET
Better Buildings Case Competition	http://www1.eere.energy.gov/buildings/betterbuildings/casecompetition/
BNL Relativistic Heavy Ion Collider	https://www.bnl.gov/rhic/
Brookhaven National Laboratory	https://www.bnl.gov/nsrl/
Brookhaven National Laboratory	https://www.bnl.gov/world/
Building New Ways to Work Together Report of a Workshop	http://www.nap.edu/openbook.php?record_id=11190
Building Technologies Office	http://energy.gov/eere/buildings/building-technologies-office
Carbon Capture and Storage Research	http://energy.gov/fe/science-innovation/carbon-capture-and-storage-research
Carbon Capture Simulation Initiative	https://www.acceleratecarboncapture.org/
Center for Advanced Energy Studies	https://inlportal.inl.gov/portal/server.pt/community/caes_home/
Center for Revolutionary Solar Photoconversion	http://www.crspresearch.org/
Center for Ultra-Wide-Area Resilient Electric Energy Transmission Networks	http://curent.utk.edu/
Collegiate Wind Competition	http://energy.gov/eere/collegiatewindcompetition
Colorado Center for Biorefining and Bioproducts	http://www.c2b2web.org/

Title	Hyperlink
Colorado Renewable Energy Collaboratory	http://crew.colorado.edu/
Community College Internships	http://science.energy.gov/wdts/cci/
Consolidated Appropriations Act, 2014	https://www.congress.gov/bill/113th-congress/house-bill/3547
Department of Homeland Security	http://www.dhs.gov/
Deputy Director for Field Operations - Contractor Assurance Systems	http://science.energy.gov/sc-3/oversight/contractor-assurance-systems/
DOE Bioenergy Research Centers	http://genomicscience.energy.gov/centers/
DOE Designated User Facilities	http://energy.gov/sites/prod/files/2015/06/f24/DOE Designated User Facilities 26MAY2015.pdf
DOE Innovation Hubs	http://energy.gov/science-innovation/innovation/hubs
DOE Mission	http://energy.gov/mission
DOE O 430.1B	https://www.directives.doe.gov/directives-documents/400-series/0430.01-BOrder-b-chg2/view
DOE O 4700.3	https://www.directives.doe.gov/directives-documents/4700-series/4700.3-BOrder-c1
DOE Order 226.1B	https://www.directives.doe.gov/directives-documents/200-series/0226.1-BOrder-b
DOE Order 226.1B	https://www.directives.doe.gov/directives-documents/200-series/0226.1-BOrder-b/view
DOE Order 251.1C	https://www.directives.doe.gov/directives-documents/200-series/0251.001-BOrder-c
DOE Order 413.2B	https://www.directives.doe.gov/directives-documents/400-series/0413.2-BOrder-b-admchg1
DOE Order 414.1B	https://www.directives.doe.gov/directives-documents/400-series/0414.1-BOrder-d
DOE Order 414.1D	http://energy.gov/sites/prod/files/em/DOEOrder414.1D.pdf
DOE Order 481.1B	https://www.directives.doe.gov/directives-documents/400-series/0481.1-BOrder-c-admchg2
DOE Order 483.1B	https://www.directives.doe.gov/directives-documents/400-series/0483.1-BOrder-A
Early Career Research Program	http://science.energy.gov/early-career/
EERE-National Laboratory Guiding Principles	http://energy.gov/sites/prod/files/2015/04/f22/National Laboratory Impact Initiative Guiding Principles.pdf
Energy and Water Development Appropriations Act, 2002	http://science.energy.gov/~/media/budget/pdf/sc-congressional-appropriations/fy-2002/enacted-bill-public-law/FY02_PL_107_66_v2.pdf

Title	Hyperlink
Energy Department Presents FY16 Budget Request	http://energy.gov/articles/energy-department-presents-fy16-budget-request
Energy Frontier Research Centers (EFRCs)	http://science.energy.gov/bes/efrc/
Energy Innovation Center	http://www.anl.gov/energy-innovation-center
Energy Policy Act of 2005	http://www.gpo.gov/fdsys/pkg/PLAW-109publ58/pdf/PLAW-109publ58.pdf
Energy Savings Performance Contracts for Federal Agencies	http://energy.gov/eere/femp/energy-savings-performance-contracts-federal-agencies
FACA Database Committees	http://www.facadatabase.gov/committee/committees.aspx?aid=42
Fermi National Accelerator Laboratory	http://www.fnal.gov/
Fermilab Tevatron Accelerator	http://www.fnal.gov/pub/tevatron/tevatron-accelerator.html
Fusion Energy Research DIII-D	https://fusion.gat.com/global/DIII-D
FY 2014 LDRD Report	http://energy.gov/cfo/downloads/fy-2014-ldrd-report
Guide to Partnering with DOE's National Laboratories	http://www2.lbl.gov/tt/industry/Doing Business_lr.pdf
Hawaii National Marine Renewable Energy Center	http://hinmrec.hnei.hawaii.edu/
Idaho National Laboratory	https://www.inl.gov/
Idaho Operations Office	http://www.id.doe.gov/
IEA Greenhouse Gas R&D Programme	http://ieaghg.org/
Industrial Assessment Centers (IACS)	http://energy.gov/eere/amo/industrial-assessment-centers-iacs
Interactive Grants Map	http://science.energy.gov/universities/interactive-grants-map/
Inter-Entity Transactions	http://energy.gov/sites/prod/files/AH-Chap12.pdf
Investigating Extreme Ultraviolet Lithography Mask Defects	http://www-als.lbl.gov/index.php/holding/408-investigating-extreme-ultraviolet-lithography-mask-defects.html
Isotope Development & Production for Research and Applications (IDPRA)	http://science.energy.gov/np/research/idpra/
Jefferson Laboratory	https://www.jlab.org/
Joint Center for Artificial Photosynthesis (JCAP)	http://solarfuelshub.org/
Joint Center for Energy Storage Research	http://www.jcesr.org/
Joint Institute for Biological Sciences	http://rcc.utk.edu/joint-institute-for-biological-sciences/
Joint Institute for Computational Sciences	http://www.jics.utk.edu/
Joint Institute for Neutron Sciences	http://jins.tennessee.edu/

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Laboratory Appraisal Process FY2014	http://science.energy.gov/lp/laboratory-appraisal-process/fy-2014/
Laboratory Directed Research and Development Annual Reports	http://energy.gov/cfo/reports/laboratory-directed-research-and-development-annual-reports
Laboratory Planning Process	http://science.energy.gov/lp/laboratory-planning-process/
Laboratory Policy: Laboratory Appraisal Process	http://science.energy.gov/lp/laboratory-appraisal-process/
Launch of the Grid Modernization Laboratory Consortium	http://energy.gov/articles/launch-grid-modernization-laboratory-consortium
Lawrence Berkeley National Lab	http://www.lbl.gov/
Lawrence Livermore National Laboratory	https://www.llnl.gov/
Los Alamos National Laboratory	https://www.lanl.gov/
Manhattan Project	http://energy.gov/management/office-management/operational-management/history/manhattan-project
NASA	http://www.nasa.gov/
National Academy of Sciences	http://www.nasonline.org/
National Defense Authorization Act	http://armedservices.house.gov/index.cfm/ndaa-home?p=ndaa
National Energy Technology Laboratory	http://www.netl.doe.gov/
National Institutes of Health	http://www.nih.gov/
National Laboratories Chief Information Officers	http://nlcio.nationallabs.org/
National Laboratories Chief Operations Officers	http://nlcoo.nationallabs.org/
National Laboratories Chief Research Officers	http://nlcro.nationallabs.org/
National Laboratory Directors' Council	http://nldc.nationallabs.org/
National Labs Environment Safety and Health Directors	https://sites.google.com/a/nationallabs.org/nleshd/
National Nuclear Security Administration	http://nnsa.energy.gov/
National Renewable Energy Laboratory	http://www.nrel.gov/
National Risk Assessment Partnership	http://www.netl.doe.gov/research/coal/crosscutting/national-risk-assessment-partnership
NETL Partnerships and Licensing Options	http://www.netl.doe.gov/business/tech-transfer/partnerships-and-licensing
Northwest National Marine Renewable Energy Center	http://nnmrec.oregonstate.edu/
NSF/DOE Partnership on Advanced Combustion Engines	https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=504782

Title	Hyperlink
Nuclear Energy Research and Development Roadmap	http://energy.gov/sites/prod/files/NuclearEnergy_Roadmap_Final.pdf
Nuclear Energy Research and Development Roadmap	http://www.energy.gov/ne/downloads/nuclear-energy-research-and-development-roadmap
Nuclear Energy University Program	http://energy.gov/ne/nuclear-reactor-technologies/nuclear-energy-university-program
Nuclear Science User Facilities	https://atrnsuf.inl.gov/
Oak Ridge National Laboratory	http://www.ornl.gov/
Office of Efficiency	http://energy.gov/eere/office-energy-efficiency-renewable-energy
Office of Environment, Health, Safety & Security	http://energy.gov/ehss/environment-health-safety-security
Office of Environmental Management	http://energy.gov/em/office-environmental-management
Office of Fossil Energy	http://energy.gov/fe/office-fossil-energy
Office of Science	http://science.energy.gov/
Office of Science Laboratories	http://science.energy.gov/laboratories/
Office of the General Counsel	http://energy.gov/gc/office-general-counsel
Office of the Inspector General	http://energy.gov/ig/office-inspector-general
Office of the Under Secretary for Management and Performance	http://energy.gov/office-under-secretary-management-and-performance
Office of the Under Secretary for Science and Energy	http://energy.gov/office-under-secretary-science-and-energy
Pacific Northwest National Laboratory	http://www.pnnl.gov/
Performance Evaluation and Measurement Plans for Cost-Reimbursement, Non-Management and Operating Contracts	http://energy.gov/sites/prod/files/DOE Acq Guide Chapter 16- 2.pdf
Princeton Plasma Physics Laboratory	http://www.pppl.gov/
Quality Assurance Program Plan	http://energy.gov/lm/downloads/quality-assurance-program-plan
Renewable and Sustainable Energy Institute	http://www.colorado.edu/rasei/
Sandia National Laboratories	http://www.sandia.gov/
Sandia National Laboratories Combustion Research Facility	http://crf.sandia.gov/
Savannah River National Laboratory	http://srnl.doe.gov/
Science Undergraduate Laboratory Internships	http://science.energy.gov/wdts/suli/
SEMATECH	http://public.sematech.org/
SLAC National Accelerator Laboratory	https://www6.slac.stanford.edu/

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Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR)	http://science.energy.gov/sbir/
Small Business Vouchers Documents DOE	http://energy.gov/eere/lab-impact/downloads/small-business-vouchers-documents-0
Small Modular Nuclear Reactors	http://www.energy.gov/ne/nuclear-reactor-technologies/small-modular-nuclear-reactors
Southeast National Marine Renewable Energy Center	http://snmrec.fau.edu/
STEM Education	http://energy.gov/diversity/services/stem-education
Ten Year Site Plans	http://energy.gov/management/office-management/operational-management/facilities-and-infrastructure/ten-year-site
Trustworthy Cyber Infrastructure for the Power Grid	https://tcipg.org/
U.S. Department of Defense	http://www.defense.gov/
U.S. Department of Energy Race to Zero Student Design Competition	http://energy.gov/eere/buildings/us-department-energy-race-zero-student-design-competition
U.S. Department of Health and Human Services	http://www.hhs.gov/
U.S. Government Accountability Office	http://www.gao.gov/
U.S. Nuclear Regulatory Commission	http://www.nrc.gov/
UChicago Argonne	http://www.uchicagoargonnellc.org/about/
University of Chicago	http://www.uchicago.edu/
University of Tennessee, Knoxville	http://www.utk.edu/
User Facilities at a Glance	http://science.energy.gov/user-facilities/user-facilities-at-a-glance/
User Facilities User Statistics	http://science.energy.gov/user-facilities/user-statistics/
Utility Energy Service Contracts for Federal Agencies	http://energy.gov/eere/femp/utility-energy-service-contracts-federal-agencies
Vehicle Technologies Office	http://energy.gov/eere/vehicles/vehicle-technologies-office
Visiting Faculty Program	http://science.energy.gov/wdts/vfp/
Water Power Program	http://energy.gov/eere/water/water-power-program