Biological and Environmental Research

Funding Profile by Subprogram

(dollars in thousands)

	FY 2009 Current Appropriation	FY 2009 Current Recovery Act Appropriation[a]	FY 2010 Current Appropriation	FY 2011 Request
Biological and Environmental Research				
Biological Systems Science	0[b]	0	318,476	321,947
Climate and Environmental Sciences	0[b]	0	285,706	304,953
Biological Research	412,153[b]	+100,793	0	0
Climate Change Research	173,023[b]	+64,860	0	0
Total, Biological and Environmental Research	585,176[c]	+165,653	604,182	626,900

Public Law Authorizations:
Public Law 95–91, "Department of Energy Organization Act", 1977
Public Law 109–58, "Energy Policy Act of 2005"
Public Law 110–69, "America COMPETES Act of 2007"

Program Overview

Mission

The Biological and Environment Research (BER) program mission is to understand complex biological, climatic, and environmental systems across spatial and temporal scales ranging from sub-micron to global, from individual molecules to ecosystems, and from nanoseconds to millennia. This is accomplished by exploring the frontiers of genome-enabled biology; discovering the physical, chemical, and biological drivers of climate change; and seeking the geochemical, hydrological, and biological determinants of environmental sustainability and stewardship.

Background

The wonders of Earth, how it works, and how we can sustain it for future generations are the subject of discussion and debate from the classroom to the pages of scientific journals. We hear arguments about the threat and controversy of global warming, rising greenhouse gases, and increasing temperatures; about the promise of biofuels and concerns of whether we will be able to produce sufficient, affordable quantities in a manner that protects the environment; and about the challenge of protecting our rivers and aquifers from environmental contaminants left as a legacy of nuclear weapons development. These practical arguments and challenges are driven by a foundation of scientific knowledge and inquiry in atmospheric chemistry and physics, ecology, genetics, and subsurface science. Studies in these areas probe questions such as: What determines Earth's climate? How does a genome give life to microbes, plants, and ecosystems? What are the biological and physical forces that govern the behavior of Earth's

[a] The Recovery Act Current Appropriation column reflects the allocation of funding as of September 30, 2009.
[b] $313,688,000 of the FY 2009 funding for the Biological Research program is for activities funded in the Biological Systems Science subprogram in FY 2010 and FY 2011. $98,465,000 of the FY 2009 funding for the Biological Research subprogram and all of the $173,023,000 in the Climate Change Research subprogram is for activities funded in the Climate Change and Environmental Sciences subprogram in FY 2010 and FY 2011.
[c] Total is reduced by $16,364,000; $14,611,000 of which was transferred to the Small Business Innovation Research (SBIR) program; and $1,753,000 of which was transferred to the Small Business Technology Transfer (STTR) program.

subsurface environment? The BER program supports research addressing these questions to provide an understanding of Nature that enables DOE to discover and develop solutions to our energy and environmental challenges.

BER's origins date to 1946, the atomic bomb, concerns for health effects from exposure to radiation, and the promise of benefits from peaceful uses of nuclear energy. BER-funded health effects research provided breakthroughs in genetics and developments in nuclear medicine, such as radioisotopes for common medical tests and computed tomography (CT) and positron emission tomography (PET) scanners that still benefit millions of patients each year. Interest in the effects of radiation exposure led to the pursuit of an understanding of the most fundamental level of biology, DNA, and in turn led DOE's initiation of the Human Genome Project, spearheading today's biotechnology revolution. The need to understand the global distribution of fallout from weapons tests in the 1950s and 1960s led DOE to develop the first ecological research programs to understand clouds, models to predict the behavior of particles in the atmosphere, and today, models to understand and predict future climate.

Today, the BER science portfolio includes research programs and scientific user facilities that address some of the most exciting problems in biological, climatic, and environmental research. BER research uncovers Nature's secrets from the diversity of microbes and plants to understand how biological systems work, how they interact with each other, and how they can be manipulated to harness their processes and products. By starting with an organism's DNA, BER-funded scientists seek to understand whole biological systems as the systems respond to and modify their environments. The biological systems that BER scientists investigate range from individual proteins and other molecules, to groups of molecules that comprise molecular machines, to interconnected biological networks within whole cells, communities of cells and organisms, and ecosystems.

BER plays a vital role in supporting research on atmospheric processes, climate change modeling, interactions between ecosystems and greenhouse gases (especially carbon dioxide, CO_2), and analysis of impacts of climatic change on energy production and use. Understanding the Earth's radiant energy balance is the largest uncertainty in determining the rate of global climate change. BER supports research on the factors determining that balance—the role of different types of clouds, atmospheric particles, and greenhouse gases. BER also supports research to understand the impacts of climatic change—warmer temperatures, changes in precipitation, increased levels of greenhouse gases—on different ecosystems such as forests, grasslands, and farmland. In addition, the Earth's subsurface is a new frontier for discovering novel microorganisms and understanding important geochemical and hydrological processes, including the fate of environmental contaminants.

A common theme across BER's research portfolio, is the challenge and excitement of studying complex systems. The systems studied have their own unique complexity covering remarkable spatial and temporal scales. In living systems, the scales of interest can be as small as the interactions of individual proteins or fragments of DNA within a single cell or as large as an entire organism—a microbe or a person—or even an entire forest of trees used as the starting material for producing biofuels or responding to climate change. The range of critical time scales in living systems is equally vast, ranging from fractions of a second required for the interaction of biological molecules to decades or even centuries to understand the long-term ecological impacts of a changing climate or the sustained production of specific biofuel feedstock crops for production of biofuels. A unique complexity to the study of spatial or temporal scales in living systems is the genetic capacity of those systems to directly regulate their interactions with other systems and to replicate themselves, features not found in other systems studied by the Office of Science. The ranges of scales of interest are equally complex for studies of Earth's climate and subsurface. These range from particles in a cloud or the subsurface environment to the Earth's entire atmosphere or a regional aquifer. At the temporal scale they also range from

fractions of a second for interactions at the molecular level to decades or centuries to understand the long term effects of climate change or the behaviors of contaminants in the subsurface. Essential to BER supported research is the use of DOE's computational resources and the development of computational models that can be used to make experimentally testable predictions about climate, complex subsurface environments, or biological systems across the various spatial and temporal scales.

Major scientific goals for BER include:

- **Genomic Science** conducts explorations of microbes and plants at the molecular, cellular, and community levels. The goal is to gain insights about fundamental biological processes and, ultimately, a predictive understanding of how living systems operate. A 2006 National Research Council review of the Genomic Science activity[a] supports and encourages the focus on microbes and plants and states that "systems biology research is needed to develop models for predicting the behavior of complex biological systems."
- **Radiological Sciences** support research in radiochemistry and radiotracer development with the goal of developing new methodologies for real-time, high-resolution imaging of dynamic biological systems. This goal is supported by a 2008 community-based workshop, "New Frontiers of Science in Radiochemistry and Instrumentation for Radionuclide Imaging."[b] Radiobiology provides systems level research to understand radiation-induced perturbations of physiological processes.
- **Climate Research** supports research in atmospheric and environmental systems, and predictive climate and Earth system models. This research is guided by a 2008 report by the BER Advisory Committee entitled, "Identifying Outstanding Grand Challenges in Climate Change Research: Guiding DOE's Strategic Planning."[c] The report recommended that BER research "seek to understand Earth's climate system by characterizing current climate and its evolution over the last century to its present state, predicting regional climate change for the next several decades, and simulating Earth System changes and their consequences over centuries."
- **Subsurface Biogeochemistry** seeks to understand the role that subsurface biogeochemical processes play in determining the fate and transport of contaminants including heavy metals and radionuclides. Computational models of coupled biological, geochemical, and hydrological processes are needed to predict the rates and kinetics of transformation and sequestration of these critical DOE contaminants. This research is guided by an August 2009 community-based workshop, "Subsurface Complex System Science—with Relevance to Contaminant Fate and Transport."[d]

Subprograms

To accomplish its mission and address the scientific challenges described above, the BER program is organized into two subprograms, Biological Systems Science and Climate and Environmental Sciences.

- The *Biological Systems Science* subprogram explores the fundamental principles that drive the function and structure of living systems. The target systems range from microbes and microbial communities to plants and other whole organisms. Using the genome as a blueprint, Genomic Sciences provides the foundational biological understanding of microbial and plant systems in a range of natural and managed ecosystems. Three DOE Bioenergy Research Centers (BRCs)—led by Lawrence Berkeley National Laboratory, Oak Ridge National Laboratory, and the University of Wisconsin at Madison in partnership with Michigan State University—support multidisciplinary

[a] http://www.nap.edu/catalog/11581.html
[b] http://www.sc.doe.gov/ober/radiochem_2008workshop_report.pdf
[c] http://www.sc.doe.gov/ober/berac/Grand_Challenges_Report.pdf
[d] August 2009 workshop report to be available early 2010.

teams of leading scientists whose goal is to accelerate transformational breakthroughs needed to understand the conversion of cellulose (plant fibers) to biofuels. The Joint Genome Institute (JGI), a high-throughput DNA sequencing user facility, provides the basis for systems biology and unmatched capabilities to understand and predict the function of environmental and energy-related microbes and plants. Current sequencing capacity at the JGI is over 1,000 billion base pairs per year (compared to about 3 billion base pairs for the entire human genome) and growing rapidly. To understand the proteins encoded by DNA, the Structural Biology activity supports access to DOE's world-class synchrotron and neutron sources. The interface between biology and the physical sciences is explored in the Radiological Sciences with new methods for real-time high resolution imaging of dynamic biological processes and with molecular and genomic biology to underpin radiation risk policy.

- The *Climate and Environmental Sciences* subprogram advances science to understand, predict, and mitigate the impacts of energy production and use on climate change. Atmospheric System Research supports data collection and experimentation to help resolve the greatest uncertainties in climate change—the role of clouds and aerosols in Earth's radiation balance. The Atmospheric Radiation Measurement (ARM) Climate Research Facility (ACRF) provides key observational data to the climate research community on the radiative properties of the atmosphere, especially clouds. The facility includes highly instrumented ground stations, two mobile facilities, and an aerial vehicles program; it served 1000 users from around the world in FY 2009. Climate and Earth System Modeling supports some of the world's most powerful and sophisticated climate models that contribute to reports by the Intergovernmental Panel on Climate Change. In FY 2011, BER will initiate efforts for uncertainty quantification in climate models, incorporation of observational data sets, model development testbeds, and the development of numerical methods to enable climate models to use future computing architectures. Integrated Assessment research develops models to identify options for and costs of climate change mitigation. Environmental Systems Science supports research to understand the impact on and role of diverse ecosystems on climate change, as well as subsurface biogeochemical research to understand and predict subsurface contaminant fate and transport. The Environmental Molecular Sciences Laboratory (EMSL) serves 600–700 users annually and houses an unparalleled collection of state-of-the-art capabilities, including a supercomputer and over 60 major instruments, providing integrated experimental and computational resources for discovery and technological innovation in the environmental molecular sciences. EMSL also contributes to systems biology by providing leading edge capabilities in proteomics.

Benefits

BER science continues to have broad benefits for society and for science. BER's long history of biological discovery has advanced scientific discovery, improved human health, and revolutionized the field of biology. Perhaps the most revolutionizing event was BER's initiation of the Human Genome Project. Built on the strength in technology development at DOE's national laboratories, the Human Genome Project led to the determination of the complete DNA sequence of the human genome, information that has provided unprecedented opportunities for discovering and understanding fundamental principles of life. Today, DNA sequencing is the foundation for BER research on plants and microbes with an emphasis on organisms with energy and environmental relevance leading to the discovery of novel microorganisms with unanticipated biotechnological capabilities and provided new insights into a variety of plants including trees, legumes and grasses.

From research to understand the health effects of exposure to radiation we learned of the sensitivity of embryos to radiation, developed assays using mice and the bacteria to quantify the mutagenic potential of radiation and chemicals, and discovered the genes and mechanisms responsible for the repair of

damaged DNA. Today, BER research has shown that biological responses to low and high doses of radiation are both quantitatively and qualitatively different, suggesting that the traditionally used linear no-threshold model for assessing radiation risk is not scientifically justified.

Early DOE studies to understand the fate of radioactive fallout on land and in the oceans also had broad impacts, leading to the development of modern ecology and oceanography, tools to understand the intricacies of Earth's climate system, and modeling capabilities for predicting future climate. Today, our growing understanding of the climate system and our ability to more accurately predict future climate are essential to plan for future energy needs, water resources, and land use. BER research also provides new understanding of the biological, physical, and chemical mechanisms responsible for the natural sequestration of carbon dioxide in terrestrial ecosystems, knowledge that is useful in understanding the impacts of land use and land management decisions on carbon release or storage from various ecosystems.

Fundamental, hypothesis-driven research in both laboratories and the field has revealed new biogeochemical processes that influence the fate and transport of contaminants from a legacy of weapons production. Today, this knowledge has been translated into new strategies for cleaning up legacy contaminants based on understanding of the broad capabilities of naturally occurring subsurface microbes.

Program Planning and Management

BER uses broad input from scientific workshops and external reviews, such as those performed by the National Academies, to identify current and future scientific and technical needs and challenges in current national and international research efforts. BER also receives advice from the Biological and Environmental Research Advisory Committee (BERAC) on the management of its research programs (through Committee of Visitor [COV] reviews), on the direction and focus of its research programs, and on strategies for long-term planning and development of its research activities. A key focus of BERAC activities is to identify the greatest scientific challenges in biological, climate, and environmental systems science that BER should address in the long-term (20-year horizon) and how BER should be positioned to address those challenges; the continued or new fields of BER-relevant science that DOE will need to achieve its future mission challenges; and the future scientific and technical advances needed to underpin BER's complex systems science.

The BER program is coordinated with activities of other federal organizations supporting or conducting complementary research, e.g., the National Science Foundation, National Aeronautics and Space Administration, Department of Commerce/National Oceanic and Atmospheric Administration, Environmental Protection Agency, Nuclear Regulatory Commission, Department of Agriculture, National Institutes of Health, Department of State, and Department of Defense. BER Climate Change Research is coordinated with the U.S. Global Change Research Program, an interagency program codified by Public Law 101–606 and involving thirteen federal agencies and departments, and the U.S. Climate Change Technology Program.

BERAC conducts reviews of BER subprograms by COVs every three years. Results of these reviews and BER responses are posted on the Office of Science website.[a] Every three years, BER also conducts consolidated onsite merit, operational, management, and safety reviews of each of its user facilities, the Atmospheric Radiation Measurement Climate Research Facilities, the Joint Genome Institute, and the Environmental Molecular Sciences Laboratory. Results of these reviews are used to address management, scientific, operational, and safety deficiencies.

[a] http://www.science.doe.gov/SC-2/Committee_of_Visitors.htm

BER supports research at universities, research institutes, private companies, and DOE national laboratories. All BER-supported research undergoes regular peer review and merit evaluation based on procedures established in 10 CFR 605 for the external grant program and using a similar process for research at the national laboratories.

Basic and Applied R&D Coordination

BER research underpins the needs of DOE's energy and environmental missions. Fundamental research on microbes and plants to understand their biochemical pathways and the genetic mechanisms that control their interactions and behavior provides knowledge needed by DOE's Office of Energy Efficiency and Renewable Energy and the U.S. Department of Agriculture about new bioenergy crops and bioenergy production facilities that are cost effective and sustainable. BER research on the behavior and interactions of contaminants in the subsurface environment provides knowledge needed by DOE's Office of Environmental Management to develop new strategies for the remediation of weapons-related contaminants at DOE sites and by DOE's Office of Legacy Management to develop tools for monitoring the long-term status of contaminants at cleanup sites. Knowledge of the subsurface environment as a complete system will also be useful to the DOE Office of Fossil Energy in their efforts to predict the long-term behavior of carbon dioxide injected underground for long-term storage. Finally, BER research to understand Earth's climate system and to predict future climate and climate change is needed by DOE's Office of Policy and International Affairs as it develops strategies for our Nation's future energy needs and control of greenhouse gas emissions.

Budget Overview

BER's budget strategy is based on three mission priorities: exploring the frontiers of genome-enabled biology; discovering the physical, chemical, and biological drivers and environmental impacts of climate change; and seeking the geochemical, hydrological, and biological determinants of environmental sustainability and stewardship. The BER scientific user facilities are key to supporting these mission priorities.

Genomic science research supported in FY 2011, including the DOE Bioenergy Research Centers, will continue to advance our understanding of how plant and microbial system functions are specified by genome organization, expression, and regulation. This includes developing genomic, analytical, and computational approaches to study the structure, interdependence, and function of microbial communities and the identification of plant traits for improved bioenergy production or carbon sequestration. The JGI will continue to support sequencing needs of the Genomic Science program, especially the Bioenergy Research Centers. JGI activities will reflect the steady increase in production DNA sequencing as well as the resulting need for high-throughput, complex genome annotation and analysis.

Climate sciences research supported in FY 2011 will continue to improve understanding and quantification of the role of aerosols and clouds on climate change. New ARM sites and laboratory studies will support research in locations with different types of clouds, atmospheric conditions, and aerosol loadings to better address major outstanding questions in climate change research (clouds and aerosols). Results will be used to evaluate and improve performance of regional and global climate models. New efforts in FY 2011 will focus on uncertainty quantification in climate models, incorporation of observational data sets, and model development testbeds. Additional funding for Climate and Earth System modeling will support efforts to improve uncertainty quantification, streamline the translation of observational data sets, create model development testbeds, and develop new numerical methods to enable climate models to use future computing architectures. Efforts will continue on the development of an additional large-scale, manipulative experiment in the arctic tundra to

improve understanding of the impacts of climate change on ecosystem structure and function. Research will be expanded to improve understanding of the role of terrestrial ecosystems as sources and sinks of greenhouse gases focusing on the role of natural processes that control terrestrial carbon sequestration and how those processes might be managed to enhance carbon sequestration in terrestrial ecosystems.

Subsurface Biogeochemical Research will support basic research on the fate and transport of contaminants in the subsurface. This research addresses unique physical, chemical, and biological processes controlling the flux of contaminants across and within the root zone of soils and the flux of contaminants to surface water bodies. Processes in these critical zones influence fluxes of carbon and key nutrients between the atmosphere and terrestrial biosphere. The EMSL equipment refresh will continue to keep EMSL at the state of the art, including enhancement of leading capabilities in proteomics and advanced magnetic resonance.

Significant Program Shifts

In FY 2011, BER will initiate enhanced activities in climate modeling, including improving uncertainty quantification, streamlining the translation of observational data sets, creating model development testbeds, and developing new numerical methods. These activities will help to accelerate the advance of climate models. BER research on the development of the components of an artificial retina is completed in FY 2010. The BER effort will end in FY 2011 with the final testing of the assembled 240+ electrode device. In FY 2011, BER will continue to actively work with NIH and industry to identify an appropriate transition route that will move the artificial retina project from research into early development and application.

Annual Performance Targets and Results

Secretarial Priority: Innovation: Lead the world in science, technology, and engineering

GPRA Unit Program Goal: Biological and Environmental Research (BER) Program Goal: Harness the Power of Our Living World—Provide the biological and environmental discoveries necessary to clean and protect our environment, offer new energy alternatives, and facilitate the entrainment of physical science advances in biology.

Annual Performance Measure: Determine the dominant processes controlling the fate and transport of contaminants in subsurface environments and develop quantitative numerical models to describe contaminant mobility at the field scale.

FY 2006	T: Develop predictive model for contaminant transport that incorporates complex biology, hydrology, and chemistry of the subsurface. Validate model through field tests. A: Goal met
FY 2007	T: Implement a field-oriented, integrated experimental research program to quantify coupled processes that control reactive transport of at least one key DOE contaminant. A: Goal met
FY 2008	T: Identify the critical redox reactions and metabolic pathways involved in the transformation/ sequestration of at least one key DOE contaminant in a field environment. A: Goal met

FY 2009	T: Test geophysical techniques that measure parameters controlling contaminant movement under field conditions in at least two distinct subsurface environments. A: Goal met
FY 2010	T: Develop a reactive transport model for a complex field site that accounts for heterogeneity and objectively evaluate against field data. A: TBD
FY 2011	T: Refine subsurface transport models by developing computational methods to link important processes impacting contaminant transport at smaller scales to the field scale. A: TBD
FY 2012	T: Perform time-lapse geophysical experiments to monitor spatial and temporal dynamics of hydrogeological and biogeochemical parameters impacting contaminant transport processes. A: TBD
FY 2013	T: Use genomics-based methods to predict the activity of subsurface microbial communities and their influence on the transport of contaminants in the subsurface. A: TBD
FY 2014	T: Use geophysical signatures to locate and define key biogeochemical zones in subsurface environments that impact contaminant transport processes. A: TBD
FY 2015	T: Integrate genomic-based methods of predicting microbial community activity into computational models describing contaminant transport. A: TBD

Annual Performance Measure: Increase by at least 10% the number of high quality (less than one error in 10,000) bases of DNA from microbial and model organism genomes sequenced the previous year, and decrease by at least 10% the cost (billion base pair/dollar) to produce these base pairs from the previous year's actual results.[a]

FY 2007	T: Sequence 40 billion base pairs (bp) at a rate of 644 bp/$1. A: Goal not met
FY 2008	T: Sequence 42.8 billion base pairs at a rate of 785 bp/$1 A: Goal met

[a] This performance measure begins in FY 2007.

FY 2009	T: Sequence 253 billion base pairs at a rate of 4,600 bp/$1. A: Goal met
FY 2010	T: Sequence 1,100 billion base pairs at a rate of 15,942 bp/$1. A: TBD
FY 2011	T: TBD based on FY 2010 results A: TBD
FY 2012	T: TBD based on FY 2011 results A: TBD
FY 2013	T: TBD based on FY 2012 results A: TBD
FY 2014	T: TBD based on FY 2013 results A: TBD
FY 2015	T: TBD based on FY 2014 results A: TBD

Annual Performance Measure: Develop a coupled climate model with fully interactive carbon and sulfur cycles, as well as dynamic vegetation to enable simulations of aerosol effects, carbon chemistry, and carbon sequestration by the land surface and oceans and the interactions between the carbon cycle and climate.

FY 2006	T: Produce a new continuous time series of retrieved cloud properties at each ARM site and evaluate the extent of agreement between climate model simulations of water vapor concentration and cloud properties and measurements of these quantities on time scales of 1 to 4 days. A: Goal met
FY 2007	T: Provide new mixed-phase cloud parameterization for incorporation in atmospheric GCMs and evaluate extent of agreement between climate model simulations and observations for cloud properties in the arctic. A: Goal met
FY 2008	T: Report results of decade-long control simulation using geodesic grid coupled climate model and produce new continuous time series of retrieved cloud, aerosol, and dust properties, based on results from the ARM mobile facility deployment in Niger, Africa. A: Goal met

FY 2009	T: Provide improved climate simulations on subcontinental, regional, and large watershed scales, with an emphasis on improved simulation of precipitation and produce new continuous time series of retrieved cloud, aerosol, and radiation for Arctic region. A: Goal met
FY 2010	T: Provide a new parameterization for aerosol effects on cloud drizzle for incorporation into atmospheric models. A: TBD
FY 2011	T: Earth system model to be used in generating scenarios for the IPCC Fifth Assessment Report and provide integrated aerosol sub-model that includes direct and indirect forcing. A: TBD
FY 2012	T: Demonstrate coupled climate models at 20km resolution. A: TBD
FY 2013	T: Provide peer reviewed publications documenting effects of experimental warming on the regeneration of key plant species at a high-elevation and a high-latitude ecotone (i.e., boundary between two adjacent ecosystem types) in the United States. A: TBD
FY 2014	T: Provide a comparative analysis of measured and modeled biosphere atmosphere fluxes of carbon at the subcontinent scale using data products from the AmeriFlux Network and new versions of integrated terrestrial carbon cycle models. A: TBD
FY 2015	T: Provide progress report for scientific results from next generation ecosystem experiment. A: TBD

Annual Performance Measure: The achieved operation time of the JGI scientific user facility as a percentage of the total scheduled annual operating time is greater than 98%.

FY 2006	T: 98% of total scheduled operating time A: Goal met
FY 2007	T: 98% of total scheduled operating time A: Goal met
FY 2008	T: 98% of total scheduled operating time A: Goal not met

FY 2009	T: 98% of total scheduled operating time A: Goal met
FY 2010-FY2015	T: 98% of total scheduled operating time A: TBD

Annual Performance Measure: The achieved operation time of the ARM/ACRF scientific user facility as a percentage of the total scheduled annual operating time is greater than 98%.

FY 2006	T: 98% of total scheduled operating time A: Goal met
FY 2007	T: 98% of total scheduled operating time A: Goal met
FY 2008	T: 98% of total scheduled operating time A: Goal met
FY 2009	T: 98% of total scheduled operating time A: Goal met
FY 2010-FY 2015	T: 98% of total scheduled operating time A: TBD

Annual Performance Measure: The achieved operation time of the EMSL scientific user facility as a percentage of the total scheduled annual operating time is greater than 98%.

FY 2006	T: 98% of total scheduled operating time A: Goal met
FY 2007	T: 98% of total scheduled operating time A: Goal met
FY 2008	T: 98% of total scheduled operating time A: Goal met
FY 2009	T: 98% of total scheduled operating time A: Goal met
FY 2010-FY 2015	T: 98% of total scheduled operating time A: TBD

Biological Systems Science

Funding Schedule by Activity

(dollars in thousands)

	FY 2009	FY 2010	FY 2011
Biological Systems Science			
Genomic Science	0	165,626	176,891
Radiological Sciences	0	46,615	42,327
Ethical, Legal, and Societal Issues	0	5,000	5,000
Medical Applications	0	8,226	4,000
Biological Systems Facilities and Infrastructure	0	84,300	84,950
SBIR/STTR	0	8,709	8,779
Total, Biological Systems Science	0[a]	318,476	321,947

Description

Systems biology is the holistic, multidisciplinary study of complex interactions that specify the function of an entire biological system—whether single cells or a multicellular organism—rather than the reductionist study of individual components. The Biological Systems Science subprogram focuses on understanding the functional principles that drive living systems, systems ranging in scale from microbes and microbial communities to plants and other whole organisms. Questions asked in the subprogram include: What information is contained in the genome sequence? How is information integrated and processed in a coordinated manner between the different subcellular constituents? What are the key molecular interactions that regulate the overall response of the living system and how can those interactions be understood in a dynamic and predictive way? The systems biology approaches employed include genome sequencing, proteomics, metabolomics, structural biology, high-resolution imaging and characterization, and integration of the resulting information into predictive computational models of biological systems that can be functionally tested and validated.

The subprogram supports multidisciplinary research primarily focused on microbial and plant systems, as well as operations of the subprogram's primary research facility, the DOE Joint Genome Institute, and access to structural biology facilities. Support is also provided for research at the interface between the biological and physical sciences and in radiochemistry and instrumentation research to develop new methodologies for real-time, high-resolution imaging of dynamic biological processes in energy- and environment-relevant contexts.

Selected FY 2009 Accomplishments

- The DOE Bioenergy Research Centers have pioneered a variety of new research and technological approaches designed to accelerate biofuels research. The Joint BioEnergy Institute combined carbohydrate arrays and nano-scale mass spectrometry to rapidly screen novel environmental microbes and identify new cellulose-degrading enzyme activities against a wide range of plant compounds. The Great Lakes Bioenergy Research Center used systems biology methods to identify microbial community interactions during biomass deconstruction in natural systems, with potential

[a] Associated FY 2009 funding of $313,688,000 is included within the previous Biological Research subprogram. Modifications were made to the budget structure to better reflect the subprogram's activities starting in FY 2010.

to augment development of novel approaches for biofuel production. Research on consolidated bioprocessing at the BioEnergy Science Center provided new insights on how microbes fine tune their enzyme systems to optimize efficiency while breaking down complex plant material. New analytical technologies were developed for characterizing biological processes in systems being studied for production of biofuels and for other DOE missions. Research in mass spectrometry enabled study of uncharged molecules, such as lipids, by state-of-the-art instrumentation and the rapid, accurate measurement of metabolites produced in essential pathways in microbial systems. Fourier Transform infrared spectromicroscopy at the Advanced Light Source (ALS) enabled continuous tracking of cellular chemistry within living microbes as they adapt to changing chemical environments. A high-throughput pipeline for small angle x-ray scattering was developed and implemented at another experimental station at the ALS that will allow the three dimensional shapes of proteins and protein complexes to be determined in large numbers. This information will provide significant insights into the function of a cell's proteins and complexes.

- The DOE Joint Genome Institute (JGI) significantly expanded its role in large-scale genome sequencing and analysis in support of DOE missions. Major accomplishments include the use of new sequencing technologies to sequence a trillion base pairs of DNA annually, the sequencing of the genome of sorghum (a major candidate biofuels crop with ability to withstand drought and prosper on marginal land), and substantial progress on sequencing the genome of a single microbial cell (critical to exploring the gene content of the huge majority of microbial species that cannot be easily cultivated). The JGI also developed enhanced data analysis tools for sequencing communities of organisms (metagenomes), providing fundamental insights into the behavior of microbes in natural environments.

Detailed Justification

(dollars in thousands)

	FY 2009	FY 2010	FY 2011
Genomic Science	**0**	**165,626**	**176,891**
▪ **Foundational Genomics Research**	**0**	**33,216**	**40,081**

The Foundational Genomics Research activity supports fundamental research on microbes and plants, with an emphasis on understanding biological systems across multiple scales of organization, ranging from subcellular protein-protein interactions to complex microbial community structures. At the subcellular level, this research focuses on the characterization and spatial organization of cellular components and the regulatory and metabolic networks of microbes and plants. It investigates how cells are able to balance dynamic needs for synthesis, assembly, and turnover of cellular machinery in response to changing signals from the environment. Foundational genomic research will increasingly focus on understanding how different organisms interact within a biological or environmental system to provide unique functions through mechanisms such as commensal nutrient flow or horizontal gene transfer. These systems-level capabilities allow a broad diversity of functions, ranging from microbial respiration and speciation of soil minerals to rhizosphere nutrient uptake and cell-cell communication, as well as a testable framework for development of genome-based models for systems biology. Research also includes the development of new biotechnological approaches specifically designed for systems biology, including methods to measure metabolites, proteins, and expressed genes for microbial communities. Research will also support the development of novel technologies to enable multi-modal chemical and biological measurements across broad spatial and temporal ranges, to provide insight into actively-occurring environmental

processes. The emphasis is on research that employs advanced molecular and computational biology approaches enabled by genome sequencing and emphasizes multidisciplinary efforts combining expertise in microbiology, plant biology, chemistry, biophysics, bioinformatics, metabolic engineering, and other fields.

In FY 2011, research is increased to advance the understanding of how complex biological system function is specified by genome organization, expression, and regulation, through the development of genomic and analytical technologies for multi-modal, dynamic measurements in actively-occurring environmental processes.

FY 2009 funding of $36,839,000 was funded in Molecular and Cellular Biology within the Biological Research subprogram.

- **Genomics Analysis and Validation** **0** **10,000** **10,000**

The Genomics Analysis and Validation activity develops the tools and resources needed to fully exploit the information contained in complete DNA sequences from microbes and plants for bioenergy, carbon sequestration, and bioremediation applications. This activity supports development of new strategies and tools capable of high-throughput, genome-wide experimental and analytic approaches for complex biological systems.

New high-throughput approaches for analyzing gene regulation and function, automated annotation tools for predicting genes and protein function from DNA sequence, and tools for identifying dynamic genome interactions within a biological or environmental system are essential for uncovering emergent properties of interacting genes. The ability to predict the function of an individual gene and sets of genes is essential for design and validation of strategies for bioenergy production, enhanced carbon sequestration, or environmental remediation.

In FY 2011, research supports innovative new approaches for the experimental validation and improvement of genome-scale annotation and gene models in microbes, plants, and complex biological systems.

FY 2009 funding of $10,000,000 was funded in Human Genome within the Biological Research subprogram.

- **Metabolic Synthesis and Conversion** **0** **39,127** **39,127**

This activity focuses on understanding biological pathway composition and regulation to effect conversion of carbon from simple precursor forms into advanced biomolecules. Fundamental research focuses on understanding carbon uptake, fixation, and storage in plants and soil microbes, strongly leveraging the increasing availability of information from whole organism genomes and community metagenomes. Research will also focus on understanding the role that microbial communities or plant-microbe associations play in the transfer of carbon between the roots and the soil to identify strategies that would lead to increased carbon storage in the rhizosphere and surrounding soil. Genome-based knowledge of metabolic functions and regulatory networks in microbial systems, plants, and plant-microbe associations can enable strategies to increase biomass formation for conversion into advanced biofuels or to increase the sequestration of carbon in terrestrial ecosystems.

(dollars in thousands)

FY 2009	FY 2010	FY 2011

While this activity draws upon the foundational research and technology development within the broader Genomic Sciences portfolio, it will specifically address challenges unique to advancing biofuels through understanding the metabolic conversion of simple sugars to ethanol and hydrogen. This will lead to improved understanding of environmental variables governing partitioning of energy precursors into different biomass, respiration, or energy producing pathways, or fixation into recalcitrant soil or marine carbon forms. Systems biology approaches are supported to understand how plant genomes can specify increased carbon fixation and biomass yield, improved feedstock characteristics, and sustainability.

In FY 2011, funds will continue to support research on carbon storage in plant biomass for conversion into advanced biofuels or for carbon sequestration. Funds will also support research focused on the characterization and regulation of carbon and nutrient cycling in plant and microbial systems, from subcellular or root-stem-leaf partitioning to flux within pathways or between networks of interacting organisms within a biological system.

FY 2009 funding of $43,814,000 was in Molecular and Cellular Biology within the Biological Research subprogram.

- **Computational Biosciences** **0** **8,283** **12,683**

Computational models and the necessary algorithmic and computational tools needed to describe the biochemical capabilities of microbial communities or plants are essential to the success of the BER Genomic Sciences activity. The models are needed to integrate diverse data types and data sets—from experiments using genomics, proteomics, and metabolomics—into single models, and they must accurately describe and predict the behavior of metabolic pathways and genetic regulatory networks. A systems biology knowledgebase is an integrated experimental framework for accessing comparing, analyzing, modeling, and testing systems biology data. The extension of capabilities beyond data generation and storage to data retrieval, data access, and cross-database comparative computational modeling forms the basic requirements of a systems biology knowledgebase. This will enable and provide support for progressively more precise and comprehensive predictive modeling of various catalytic and cellular processes, organisms, and communities. The systems biology knowledgebase dimensions and requirements were recently outlined in a community workshop. (see http://genomicscience.energy.gov/compbio/)

A knowledgebase framework is needed to compare and integrate mission critical data and information in a precise and comprehensive manner to develop bioenergy, carbon sequestration, or bioremediation strategies. This activity includes support for ongoing Scientific Discovery through Advanced Computing (SciDAC) research that develops multi-scale and multi-component mathematical and computational tools needed for modeling and analysis of complex data sets, such as mass spectrometry or metabolomics, and to develop predictive metagenomic models of complex microbial communities. The research is closely coordinated with Office of Science's Advanced Scientific Computing Research program.

In FY 2011, funding will support ongoing SciDAC research on the modeling of whole cellular processes that incorporate models of genomic information and protein production and function with metabolic, regulatory, and cellular signaling processes. Increased funding includes support to establish a system biology modeling framework, allowing open access to researchers to biological

data and analytical tools. The framework will include biological database research and development, new software and algorithm research for interoperability among databases and datasets, and will develop and test predictive models for microbial systems of DOE relevance with respect to physiological properties, behavior, and whole microbe and microbial community responses. The framework will enable broad, distributed access to a virtual computational environment, allowing integrated genome-scale modeling and reconstruction, using microbial experimental datasets from genome sequencing, biological networks and metabolic pathways, and transcriptional regulation and phenotypic data. The primary microbial experimental datasets for integration will be drawn from research conducted at the DOE Bioenergy Research Centers, the Joint Genome Institute, and from within the Genomic Science activity.

FY 2009 funding of $5,094,000 was in Molecular and Cellular Biology within the Biological Research subprogram.

- **Bioenergy Research Centers** **0** **75,000** **75,000**

In 2007, BER established three Bioenergy Research Centers to accelerate the transformational breakthroughs in basic science needed for the development of cost-effective technologies to make production of cellulosic (plant-fiber based) biofuels commercially viable on a national scale.

The Centers each represent a multidisciplinary, multi-institutional partnership between universities, national laboratories, and the private sector. The Centers take scientific approaches that are complementary and synergistic. Areas of fundamental research include the identification, characterization, and systems-level regulation of genetic traits for cell wall composition of model plants such as Arabidopsis and rice, for which detailed genome sequence and phenotypic information are available, as well as second-generation bioenergy crops such as poplar and switchgrass for which there are more limited genomic resources. Other studies focus on understanding the metabolic pathways in individual microbes or microbial consortia that carry out efficient degradation of cell wall material and conversion into ethanol, hydrocarbons, diesel, and even jet fuel. The Centers also focus on modeling structure-function relationships in enzymes and proteins important in the synthesis, turnover, and remodeling of plant cell wall biomass, as well as subsequent metabolic and enzymatic conversion.

Annual progress of each center is evaluated by an on-site review of science and management activities and progress against stated milestones. The external review teams are comprised of scientists from universities, DOE national laboratories, and industry, with expertise in systems biology, microbial physiology and genetics, plant genomics and bioinformatics, genomic database management and informatics, and analytical chemistry. All three centers are evaluated for progress against milestones and for the planned science programs.

The Centers are using the advanced, genomics-based techniques of modern systems biology to re-engineer both plants and microbes for more efficient biologically-based conversion of plant fiber into carbon-neutral biofuels. This capability addresses critical DOE mission needs in the area of secure and sustainable bioenergy production.

In FY 2011, funds will support the continued work of the three DOE Bioenergy Research Centers to pursue fundamental research focused on improving breakdown of plant biomass, discovery and

(dollars in thousands)

FY 2009	FY 2010	FY 2011

bioengineering of new microbes and enzymes capable of degrading lignocellulose, and conversion of cellulose-derived sugars to carbon-neutral biofuels.

FY 2009 funding of $75,000,000 was in Molecular and Cellular Biology within the Biological Research subprogram.

Radiological Sciences	**0**	**46,615**	**42,327**
▪ **Radiochemistry and Imaging Instrumentation**	**0**	**20,688**	**18,400**

The activity supports fundamental research in radiochemistry and radiotracer development activities that include development of new methodologies for real-time, high-resolution imaging of dynamic biological processes in energy- and environment-relevant contexts. Radionuclide imaging continues to stand out as a singular tool for studying living organisms in a manner that is highly quantitative, three dimensional, temporally dynamic, and non-perturbative of the natural biochemical processes under study.

Radiotracer imaging methods provide new opportunities for quantitative measurement of *in situ* chemical reactions in living systems. The activity encompasses applications of new innovative technologies for biological systems with primary benefits for DOE mission needs while also providing fundamental research and tool development that may translate to nuclear medicine diagnostic and therapeutic research.

In FY 2011, funds will support improvements in synthetic radiochemical methods, new radiotracer design, and the development of multimodality tracers. These new approaches will be combined with advanced imaging instrumentation and detectors, to expand the opportunities for non-perturbative study of microbial and plant metabolism, and for tracking dynamic processes in the environment. Funding will also continue to support integrative training opportunities in radiochemistry to ensure the future availability of human resources for important radiochemistry applications. Two year activities funded in FY 2010 to develop new radiochemistry synthetic and detection methods will not require additional funding and will be completed in FY 2011.

FY 2009 funding of $22,811,000 was in the Radiochemistry and Instrumentation activity within the Biological Research subprogram.

▪ **Radiobiology**	**0**	**25,927**	**23,927**

The Radiobiology activity supports research that will help determine health risks from exposures to low levels of ionizing radiation, information critical to adequately and appropriately protect radiation workers and the general public. Research investigations include a number of critical biological phenomena induced by low dose exposure including adaptive responses, bystander effects, genomic instability, and genetic susceptibility. This activity includes support for understanding the role of epigenetics in integrated gene function and response of biological systems to environmental conditions, including low dose radiation.

This activity will provide a scientific basis for informed decisions regarding remediation of contaminated DOE sites and for determining acceptable levels of human health protection, both for cleanup workers and the public in the most cost-effective manner.

(dollars in thousands)

FY 2009	FY 2010	FY 2011

In FY 2011, funds will support the development of models that integrate responses to low dose radiation at the tissue or whole organism level with available epidemiological and epigenetic data to contribute to developing safe and appropriate radiation protection standards and the development of systems genetic strategies for integrated gene function and response to the environment. Research on DNA damage from low dose radiation exposure is completed in FY 2011, requiring no FY 2011 funding.

FY 2009 funding of $20,667,000 and $5,937,000 was in Molecular and Cellular Biology and Health Effects, respectively, within the Biological Research subprogram.

Ethical, Legal, and Societal Issues	**0**	**5,000**	**5,000**

ELSI research supports activities applicable to Office of Science interests in bioenergy, synthetic biology, and nanotechnology, including exploration and communication of the societal implications arising from these programs. The ecological and environmental impacts of nanoparticles resulting from nanotechnology applied to energy technologies will be studied. The research will be coordinated across the Office of Science and with other relevant Federal agencies and offices, such as the Environmental Protection Agency, National Science Foundation, and Office of Science and Technology Policy.

The ELSI program takes a proactive stance to anticipate societal benefits and implications of science and contributes to the informed choices society makes to implement scientific knowledge.

In FY 2011, funding is provided to support explorations of the potential societal implications arising from scientific research in areas of systems microbiology, synthetic genomics, sustainable bioenergy crop production, and nanotechnology in the environment.

FY 2009 funding of $5,000,000 was in Human Genome within the Biological Research subprogram.

Medical Applications	**0**	**8,226**	**4,000**

Research continues to utilize resources of the national laboratories in material sciences, engineering, microfabrication, and microengineering to develop an artificial retina to restore sight to the blind. DOE's goal for the artificial retina project is to develop the technology underpinning the ultimate fabrication of a 1,000+ electrode intraocular device that will allow a blind person to read large print, recognize faces, and move around without difficulty.

The Artificial Retina activity enables scientists to work together across disciplines and promotes scientific and technological innovation at the interface between biology and the physical sciences. The results will benefit not only human health but also other DOE-relevant areas such as sensor development for environmental monitoring. BER research on the development of the components of the 240+ electrode artificial retina device is completed in FY 2010.

In FY 2011, BER continues to actively work with NIH and industry to identify an appropriate transition route that will move the artificial retina project from research into early development and application. Funding is provided to support device integration, quality assurance and quality control, and preparation for pre-clinical trials.

FY 2009 funding of $8,226,000 was in Medical Applications within the Biological Research subprogram.

(dollars in thousands)

	FY 2009	FY 2010	FY 2011
Biological Systems Facilities and Infrastructure	**0**	**84,300**	**84,950**
▪ **Structural Biology Infrastructure**	**0**	**15,300**	**15,683**

The Structural Biology Infrastructure activity continues to develop and support access to beamlines and instrumentation at DOE's national user facilities for the Nation's structural biologists. BER coordinates, with the NIH and NSF, the management and maintenance of 22 experimental stations at several DOE synchrotrons (Advanced Photon Source [APS], Advanced Light Source [ALS], and Stanford Synchrotron Radiation Laboratory [SSRL]) and neutron sources (High Flux Isotope Reactor [HFIR] and Los Alamos Neutron Science Center [LANSCE]). User statistics for all BER structural biology user facilities are included in the Basic Energy Sciences (BES) facility user reports. BER continually assesses the quality of the instrumentation at its experimental stations and supports upgrades to install the most effective instrumentation for taking full advantage of the facility capabilities.

The Structural Biology infrastructure enables a broad user community to conduct the high-resolution study of biological molecules involved in cellular architecture, biocatalysis, environmental sensing, and carbon capture. It advances and promotes scientific and technological innovation in support of the DOE mission.

In FY 2011 funds will continue to support biological community access to structural biology beamlines and instrumentation at DOE national user facilities.

FY 2009 funding of $15,300,000 was in Structural Biology within the Biological Research subprogram.

▪ **Joint Genome Institute**	**0**	**69,000**	**69,267**

The Joint Genome Institute (JGI) is the only federally-funded large genome center focusing on genome discovery and analysis in plants and microbes for energy and environmental applications. This unique status has enabled it to contribute valuable information through the large-scale genome sequencing of bioenergy crops such as sorghum, maize, poplar, and soybean, as well as targeted sequencing of gene expression sets for switchgrass, cotton, wheat, and conifers. The JGI provides the genomic blueprint which is the basis for systems biology of plants and environmental microbes. Through the development of genome assembly algorithms, tools for comparative gene and pathway analysis, and systems-level integration of data from multiple sequencing technology and functional genomic platforms, the JGI has enabled researchers and plant breeders to identify key traits and genes for specific bioenergy applications or environmental conditions. In addition to a broad reference set of laboratory cultured microbes, the JGI has pioneered approaches for sequencing uncultured, environmental microbial isolates and microbial communities. These metagenomic capabilities will eventually allow elucidation of the functional potential of all the biological organisms that comprise a specific environmental system.

The JGI provides DOE mission-relevant genome sequencing, genome data acquisition, and genome analysis to the broad scientific user community, DOE national laboratories, and the Bioenergy Research Centers. This suite of high-throughput tools, technologies, and comparative analytical capabilities serve as a discovery platform for understanding the organization and function of

(dollars in thousands)

complex genomes. This genomic-level understanding is vital to the predictive design and engineering of microbial and plant systems for mission capabilities in bioenergy, carbon cycling and biosequestration, and environmental remediation and stewardship.

In FY 2011, funding will continue to support access by the scientific user community and the DOE Bioenergy Research Centers to integrative large-scale genome data acquisition and analysis of biological systems at the JGI. Funding will also support a greater emphasis on metagenome expression and sequencing of environmental microbial communities or the plant-microbe rhizosphere, improved genome annotation, and functional analysis and verification of genome-scale models.

FY 2009 funding of $65,000,000 was in Human Genome within the Biological Research subprogram.

(estimated)

	FY 2009	FY 2010	FY 2011
Achieved Operating Hours	8,400	N/A	N/A
Planned Operating Hours	8,400	8,400	8,400
Optimal hours	8,400	8,400	8,400
Percent of Optimal Hours	100%	100%	100%
Unscheduled Downtime	0	N/A	N/A
Number of Users[a]	780	940	940

SBIR/STTR	**0**	**8,709**	**8,779**

FY 2010 and FY 2011 amounts shown for the SBIR and STTR programs are the estimated requirements for continuation of these congressionally mandated programs.

Total, Biological Systems Science	**0**	**318,476**	**321,947**

[a] All JGI users are remote. Primary users are individuals associated with approved projects being conducted at the JGI in a reporting period. Each user is counted once per year regardless of how many proposals their name may be associated with. Different users may utilize vastly differing levels of JGI resources.

Explanation of Funding Changes

	FY 2011 vs. FY 2010 ($000)
Genomic Science	
▪ **Foundational Genomics Research**	
Funding is increased to advance the understanding of how complex biological system function is specified by genome organization, expression and regulation, through the development of genomic and analytical technologies for multi-modal, dynamic measurements in actively-occurring environmental processes.	+6,865
▪ **Computational Bioscience**	
Funding is increased to develop a systems biology modeling framework to integrate microbiological experimental data sets from research conducted at the DOE Bioenergy Research Centers, the Joint Genome Institute, and the Genomic Science activity.	+4,400
Total, Genomic Science	**+11,265**
Radiological Sciences	
▪ **Radiochemistry and Imaging Instrumentation**	
The decrease reflects the completion in FY 2011 of multi-year activities initiated in FY 2010 (and funded for two years) in development of new radiochemistry synthetics and detection methods.	-2,288
▪ **Radiobiology**	
Research on DNA damage from low dose radiation exposure is completed in FY 2011 and requires no FY 2011 funding.	-2,000
Total, Radiological Sciences	**-4,288**
Medical Applications	
BER funding for the components of the Artificial Retina effort is completed with integration and pre-clinical testing of a 240 electrode retinal device as a basis for fabrication of the 1,000 electrode device. In FY 2011, BER will actively work with NIH and industry to identify a transition route that will move the artificial retina project from research into early development and application.	**-4,226**

	FY 2011 vs. FY 2010 ($000)
Biological Systems Facilities and Infrastructure	
▪ **Structural Biology Infrastructure**	
In FY 2011 funds will continue to support biological community access to structural biology beamlines and instrumentation at DOE national user facilities.	+383
▪ **Joint Genome Institute**	
Funding will support a greater emphasis on metagenome expression and sequencing of environmental microbial communities or the plant-microbe rhizosphere, improved genome annotation, and functional analysis and verification of genome-scale models.	+267
Total, Biological Systems Facilities and Infrastructure	**+650**
SBIR/STTR	
▪ SBIR/STTR increases as the funding for research increases.	+70
Total Funding Change, Biological Systems Science	**+3,471**

Climate and Environmental Sciences

Funding Schedule by Activity

(dollars in thousands)

	FY 2009	FY 2010	FY 2011
Climate and Environmental Sciences			
Atmospheric System Research	0	26,452	28,396
Environmental System Science	0	82,558	81,531
Climate and Earth System Modeling	0	69,775	85,622
Climate and Environmental Facilities and Infrastructure	0	99,479	101,333
SBIR/STTR	0	7,442	8,071
Total, Climate and Environmental Sciences	0[a]	285,706	304,953

Description

The Climate and Environmental Sciences subprogram focuses on a predictive, systems-level understanding of the fundamental science associated with climate change and DOE's environmental challenges—both key to support the DOE mission. The subprogram supports an integrated portfolio of research ranging from molecular to field scale studies with emphasis on the use of advanced computer models and multidisciplinary experimentation. Climate and Environmental Sciences supports three research activities and two national scientific user facilities. The Atmospheric System Research activity seeks to resolve the two major areas of uncertainty in climate change projections: the role of clouds and the effects of aerosol emissions on the atmospheric radiation balance. The Environmental System Science activity provides scientific understanding of the effects of climate change on terrestrial ecosystems, the role of terrestrial ecosystems in global carbon cycling, and the role of subsurface biogeochemical processes on the fate and transport of DOE-relevant contaminants including heavy metals and radionuclides. Climate and Earth System Modeling focuses on development, evaluation, and use of large scale climate change models to determine the impacts, and possible mitigation, of climate change. Two scientific user facilities—the Atmospheric Radiation Measurement (ARM) Climate Research Facility (ACRF) and the Environmental Molecular Sciences Laboratory (EMSL)—provide the broad scientific community with technical capabilities, scientific expertise, and unique information to facilitate science in areas of importance to DOE.

Selected FY 2009 Accomplishments

- In 2009, the ACRF hosted approximately 1,200 users, resulting in over 185 publications in the scientific literature. ACRF completed experiments in several climatically important regions including at the fixed sites (mid-continental U.S, Tropical Western Pacific, and the North Slope of Alaska) and by mobile facilities deployed at Graciosa Island in the Azores, a mountain top in Chile, and in China. Several strong collaborations with other agencies and countries were developed for the conduct of these experiments. These peer reviewed experiments addressed critical science questions including carbon cycling, marine clouds, low-altitude liquid-water clouds, and climatic effects of aerosols.

[a] Associated FY 2009 funding of $271,488,000 is included in the Biological Research ($98,465,000) and Climate Change Research ($173,023,000) subprograms.

- DOE scientists found that statistics for cloud radiative impacts are almost the same for low-level clouds whether cloud-radiative interactions are represented by one-dimensional or three-dimensional approaches. This result resolves a longstanding question, demonstrating that the simplified approach taken by state-of-the-art global climate models (GCMs) provides a realistic representation of low-level cloud properties. This is an important and useful result as climate models continue to increase in complexity and computational intensity
- Genome-scale models of microbial metabolism have been coupled with reactive transport models to better describe biogeochemical processes affecting uranium transport in groundwater. In a groundbreaking effort, BER investigators have integrated genome science with environmental science to provide a mechanistic basis on which to build a predictive understanding of environmentally relevant microbial processes influencing contaminant transport.
- The Environmental Molecular Sciences Laboratory (EMSL) enabled a multidisciplinary team of scientists to combine mass spectrometry capabilities and the computational chemistry software, NWChem, running on the EMSL supercomputer for molecular simulations to demonstrate that a very short segment of a protein fragment in the membrane of a microorganism is all that binds the microbe to a mineral surface. This finding enables scientists to understand how microbial interactions influence geochemical processes important for bioremediation.

Detailed Justification

(dollars in thousands)

	FY 2009	FY 2010	FY 2011
Atmospheric System Research	**0**	**26,452**	**28,396**

The emphasis for Atmospheric System Research is on understanding the radiation balance from the surface of the Earth to the top of the atmosphere and how this balance is affected by clouds, aerosols, and increases in the concentration of greenhouse gases in the atmosphere. In the presence of clouds and aerosols, the current state of radiative transfer modeling is inaccurate, limiting our ability to predict future climates with a high degree of confidence.

The Intergovernmental Panel on Climate Change (IPCC) fourth assessment report establishes that cloud simulation is poor in all climate models. With regard to aerosols, the problem is more severe; we are less sure of the magnitude of its forcing on the climate. Supported research seeks to increase the fidelity of process representations (and interactions among processes) that are needed inputs to the development of the next-generation of climate models, both in the U.S. and internationally. In FY 2011, research will continue to focus on improving the understanding of the relationship of clouds and radiative transfer processes in the atmosphere and the characterization of aerosol physical, chemical, and optical properties and their effects on the Earth's energy balance. Specific focus areas include life cycle of marine boundary layer clouds and their impacts on radiation; aerosol-cloud-precipitation interactions; polar clouds and their interactions with aerosols; high altitude clouds (cirrus) and their life cycles and impacts on radiation budget; and processes and atmospheric transformations involving biogenic aerosols. Analyses will continue on recent campaigns in the Azores, Alaska, Chile, and California. Research will use atmospheric measurements from laboratories, ACRF, and other sources in this effort. Research also will be coordinated with BER's Earth System Modeling activity to quickly and effectively incorporate results into climate models. In FY 2011, increased funding will use data from the new Recovery Act-funded instruments at the ARM sites to support expanded research, specifically the development of three-dimensional representation of clouds in the climate models.

(dollars in thousands)

FY 2009	FY 2010	FY 2011

FY 2009 funding of $15,079,000 and $10,334,000 was in Atmospheric Radiation Measurement (ARM) Research and Atmospheric Science in the Climate Change Research subprogram.

Environmental System Science **0** **82,558** **81,531**

- **Terrestrial Ecosystem Science** **0** **27,913** **28,633**

  The Terrestrial Ecosystem Science activity advances the fundamental science concerning the effects of climate change on terrestrial ecosystems and the role of terrestrial ecosystems in global carbon cycling. The research focuses on determining the effects of climate change on the structure and functioning of terrestrial ecosystems, understanding the processes controlling exchange rate of carbon dioxide between atmosphere and terrestrial biosphere, and improving reliability of global carbon cycle models for predicting future atmospheric concentrations of carbon dioxide.

  Although climate change is expected to cause changes in many terrestrial ecosystems, present correlations between climate and ecosystems do not provide the requisite cause-and-effect understanding needed to forecast effects of future climate changes on terrestrial ecosystems. Experiments involving controlled manipulations of climate factors, and atmospheric carbon dioxide (CO_2) concentration, are needed to establish cause-and-effect relationships between climate changes and effects on ecosystems. While a significant fraction of the CO_2 released to the atmosphere during fossil fuel combustion is apparently now being taken up by terrestrial ecosystems, future impacts of the timing and magnitude of climate change, particularly warming, on the uptake of CO_2 by the terrestrial biosphere remains a mystery. The significant sensitivity of climate models to a terrestrial carbon cycle feedback, and the uncertain sign of that feedback, makes resolving the role of the terrestrial biosphere in the global carbon cycle a high priority.

  In FY 2011, the activity will continue ongoing research and initiate new research to understand important potential effects of climate change and increasing atmospheric CO_2 concentration on terrestrial ecosystems and the terrestrial carbon cycle. Continuing research will support AmeriFlux, the network of CO_2 flux measurement sites, for directly estimating net ecosystem production and carbon storage by terrestrial ecosystems. Continuing research on data analysis and model development will support the activity goals. The new activities will include, as recommended by a BERAC subcommittee and a subsequent workshop, continuing development of a next-generation ecosystem-climate change experiment, with a focus on an ecosystem that is of importance at the regional or global scales, is expected to be sensitive to climate change, and has been poorly studied to date. The increased funding will support the development of the novel experimental framework needed to conduct this research.

  FY 2009 funding of $13,979,000 and $13,962,000 was in Ecosystem Function and Response, and Terrestrial Carbon Processes within the Climate Change Research subprogram.

- **Terrestrial Carbon Sequestration Research** **0** **4,747** **3,000**

  Terrestrial Carbon Sequestration research supports efforts to identify, understand, and predict the fundamental physical, chemical, biological, and genetic mechanisms controlling carbon sequestration in terrestrial ecosystems including soils. These challenges are addressed by identifying the physical, biological, and chemical processes controlling soil carbon input, distribution, and longevity; developing models of these systems to predict future scenarios and to inform larger-scale

coupled earth systems models; and seeking ways to exploit these processes to enhance carbon sequestration in terrestrial ecosystems. Current research focuses on switchgrass (*Panicum virgatum*) ecosystems associated with DOE's cellulosic ethanol research. Preliminary results indicate that switchgrass' extensive rooting system could be managed for enhanced soil carbon sequestration.

In FY 2011, the focus of this program will be to complete the research objectives of the current field research with an emphasis on the synthesis of data and knowledge collected over the history of the program. Funding is reduced with the completion of a series of research projects focused on the cycling of carbon associated with agriculture and forestry.

FY 2009 funding of $5,104,000 was in the Climate Change Research subprogram.

- **Subsurface Biogeochemical Research** **0** **49,898** **49,898**

The Subsurface Biogeochemical Research activity addresses fundamental science questions at the intersection of biology, geochemistry, and physics to describe complex processes in key subsurface environments. The activity builds on BER advances in genome science and promotes cross-disciplinary research to link interdependent relationships between microbial metabolism, geochemical reactions, and physical transport processes with computational modeling to advance a predictive understanding of environmental processes. The current focus of the activity is to predict the impact of biogeochemical processes on the fate and transport of contaminants in the subsurface. This activity supports research at many scales and includes field research sites at Oak Ridge, Tennessee; Hanford, Washington; and Rifle, Colorado (a uranium mill tailings site). These field sites provide researchers opportunities to obtain samples of environmental media from DOE sites for further evaluation in the laboratory and to test laboratory-derived hypotheses regarding subsurface biogeochemical transport at the field scale. These field sites also are important for testing and evaluating computer models that describe contaminant mobility in the environment. Strong ties have been developed between the Environmental Molecular Sciences Laboratory and subsurface biogeochemical researchers. This activity includes support for SciDAC research on advanced models to predict the mobility of subsurface contaminants.

This fundamental research provides the scientific foundation for the solution of key environmental challenges within DOE and other agencies. These challenges include nuclear waste cleanup, carbon sequestration, and monitoring of contaminants in groundwater around existing and future radionuclide waste disposal and storage sites. These efforts also will assist the Department's research on using deep geological formations to store carbon dioxide taken from the atmosphere.

In FY 2011, the activity will adopt a complex systems approach to environmental research. The approach builds on the findings of a recent workshop and frames the current scope of environmental research across scales as a broad continuum of complex interdependent processes. The approach relies on integrated, multi-disciplinary, multi-scale research efforts to advance a predictive understanding of processes controlling the mobility of radionuclides in the environment. This activity advances innovative scientific approaches to understanding environmental systems providing the basis for DOE's strategic goals for cleanup of legacy nuclear wastes and nuclear energy applications.

FY 2009 funding of $48,702,000 was in Environmental Remediation Sciences Research within the Biological Research subprogram.

(dollars in thousands)

	FY 2009	FY 2010	FY 2011
Climate and Earth System Modeling	**0**	**69,775**	**85,622**
▪ **Regional and Global Climate Modeling**	**0**	**27,856**	**34,351**

Regional and Global Climate Modeling focuses on the research application of regional and global climate models to develop climate change projections on temporal scales of decades to centuries and spatial scales from regional to global. Core research areas are climate model diagnosis and intercomparison through the use of appropriate metrics, detection and attribution of climate change, analysis of multi-model climate change simulations and projections, and understanding of natural and forced variability of the climate system.

Regional and Global Climate Modeling supports the basic research needed to achieve the goals of the core areas and support for national and international climate modeling research and assessments. Currently gaps exist in our knowledge of how modes of climate variability (e.g., the El Niño Southern Oscillation, Pacific Decadal Oscillation, and Northern Annular Mode) change as atmospheric greenhouse gas concentrations continue to increase.

In FY 2011, the focus will be on improving the accuracy of climate predictions at higher resolution. The results of a new set of coordinated experiments from about 20 modeling groups world-wide will be available as part of the Climate Model Intercomparison Project (CMIP5) archive. These model simulations will facilitate the continued development and improvement of the diagnostic tools and metrics used to evaluate the reliability of climate change projections and the multiscale natural modes of variability. Studies on understanding climate extremes, reducing the uncertainty in model predictions, and detection and attribution, and using the newly developed models will continue, as well as efforts to understand feedback processes—such as high latitude ocean-ice interaction and carbon cycle feedbacks—that are important for understanding climate change. The funding increases will provide for enhanced efforts to better represent the feedbacks produced by the indirect effect of aerosols and enhanced efforts in uncertainty quantification for climate model simulations and predictions. Current models have an unacceptably large range of uncertainty, due to differences in the simulation of feedbacks and insufficient information to properly constrain model parameters. Advanced methods coupled with leadership computing resources and integrated observational data sets can reduce these uncertainties.

FY 2009 funding of $34,820,000 was in Climate Change Modeling within Climate Change Research subprogram.

▪ **Earth System Modeling**	**0**	**30,596**	**39,611**

Earth System Modeling develops the components and the mechanisms needed to couple atmosphere-ocean-land-sea ice models for simulating climate variability and change over decadal to centennial time scales, and thus provides the research results that underpin the Regional and Global Climate Modeling research activities. Research focuses on the incorporation of improved physical presentations in the specific modules of the coupled model. The focus is on incorporation and testing of various schemes for aerosol, convection, ice sheets, and land surface in the coupled models, and evaluation using innovative metrics that span a variety of climate time scales. Research to increase model resolution and computational performance is also conducted. The latter effort is closely coordinated with BER's SciDAC Climate Change Research activities and enhances BER's partnerships with the Advanced Scientific Computing Research program. This partnership

specifically addresses scaling and other computational issues, so that needed high throughput is achieved. The Earth System Modeling research has been informed by workshops attended by national and international modeling experts.

During the past decade, considerable advances have been made in the detection, understanding, and attribution of past climate change and in projecting future changes in climate using state-of-the-art climate models. However, uncertainties due to climate forcings and feedbacks have not yet been resolved; for example, current coupled atmosphere-ocean-land-sea ice models still have systematic precipitation biases. Improvements are needed before models can accurately simulate regional climate variability and change.

In FY 2011, the focus will be to continue the development of a comprehensive coupled earth system model at high resolution that will be the foundation for understanding climate change at regional and global scales. Improvement of the representation of the physical, chemical, and biogeochemical processes crucial for climate change prediction, such as cloud-aerosol and carbon cycle-climate, are an important part of this program. Development and testing of these processes and their incorporation into high resolution models will continue as part of this program. The program also continues development of software tools that enhance the ability to analyze high resolution model output and observational data in a single framework. This modeling program will also continue its support of Data Visualization which was initiated in 2010. FY 2008 multiyear research awards on abrupt climate change have been completed and no FY 2011 funding is required. In FY 2011, the funding increase will support three activities. First, enhanced research will focus on converting observational datasets into specialized, multi-variable datasets for model testing and improvement. This will seamlessly link and provide integration of existing and new data resources for the purpose of model development and evaluation and advancement. In addition, the increased funding supports establishment of model development testbeds in which model components can be rapidly prototyped and evaluated using integrated observational datasets, like those described above. Thirdly, the enhanced funding will also focus on the development of numerical methods to enable climate models to effectively use future computer architectures.

FY 2009 funding of $26,258,000 was in Climate Change Modeling within Climate Change Research subprogram.

- **Integrated Assessment** **0** **11,323** **11,660**

Integrated Assessment research provides scientific insights into options for mitigation of an adaptation to climate change through multi-scale models of the entire climate system, including human processes responsible for greenhouse gas emissions, land use, and combined impacts on and feedbacks from changing human and natural systems, including the energy system. Importantly, Integrated Assessment research develops advanced quantitative tools for exploring the implications of science and technology decisions and innovations on our energy, environmental, and economic futures.

(dollars in thousands)

FY 2009	FY 2010	FY 2011

Research focuses on improving the fundamental knowledge and methodologies for analysis of climate change impacts and adaptations within integrated assessment frameworks; innovative general approaches to modeling impacts and adaptation; developing different measures of impacts; and developing approaches to addressing probabilities and uncertainties. Understanding the role of present and possible future energy technologies remains a central focus of the research, leading to improved understanding of potential emissions trajectories and the environmental costs and benefits of stabilization options.

In FY 2011, BER will continue research on several key research challenges identified in the Integrated Assessment Research Workshop held in November of 2008. In particular, Integrated Assessment will continue to provide the scientifically rigorous, quantitative basis from which policy makers and researchers may assess the impacts of the Nation's scientific and engineering enterprise, improve their understanding of its dynamics, and assess likely outcomes for decision-making on our climate, energy, economic futures. The Integrated Assessment activity will continue to benefit from Recovery Act investments made in FY 2009 that provided the resources to develop open source, community-based approaches to modeling; improve capacity to conduct inter-model comparisons and multi-model studies; improve capacity to enhance convergence of models and collaborations across the Integrated Assessment, Earth System Modeling, and Impacts, Adaptation, and Vulnerability research communities, especially for regional-scale and multi-scale questions; and enhance transparency and accessibility for both data and models by the Integrated Assessment research community, their collaborators, and other user communities. Funding for this activity was increased significantly in FY 2010 to take full advantage of Recovery Act investments. The Recovery Act investments included software upgrade and development as well as short-term efforts to integrate the Recovery Act computing resources into the Integrated Assessment activity.

FY 2009 funding of $9,713,000 was in Integrated Assessment within Climate Change Research subprogram.

Climate and Environmental Facilities and Infrastructure	**0**	**99,479**	**101,333**

- **Atmospheric Radiation Measurement Climate Research Facility** — **0** | **41,809** | **45,770**

The Atmospheric Radiation Measurement Climate Research Facility (ACRF) is a multi-platform national scientific user facility, with stationary and mobile platforms and instruments at fixed and varying locations around the globe. ACRF provides continuous field measurements of climate data to promote the advancement of atmospheric process understanding and climate models through precise observations of atmospheric phenomena. The stationary sites provide scientific testbeds in three different climate regions (mid-latitude, polar, and tropical); the operating paradigm of continuous measurement of atmospheric and surface properties at long-term sites is well suited to climate studies. The two mobile facilities provide a capability to address high priority scientific questions in other regions. The ACRF aerial capability provides *in situ* cloud and radiation measurements that complement the ground-based measurements.

(dollars in thousands)

FY 2009	FY 2010	FY 2011

ACRF provides unparalleled continuous, long-term observations needed to develop and test understanding of the central role of clouds in the Earth's climate and to determine the effects of aerosol emissions on the atmospheric radiation balance. The role of clouds and the effects of aerosols are the two largest uncertainties in climate change research.

In FY 2011, ACRF will continue its long-term observations from the fixed sites and will provide data from the new instruments acquired under the Recovery Act funding. These new data include 3-D cloud evolution and properties, a broader geographic coverage of aerosol measurements, and enhanced surface characterization measurements. ACRF will conduct field experiments to study questions on aerosols and various cloud types—cirrus, marine, and mixed-phase (ice and water)—to improve process understanding as well improving regional and Earth System Models that simulate climate change. The first mobile facility will support an experiment in India to examine the impact of aerosols on the Indian monsoon. The second mobile facility will continue to examine liquid and mixed-phase clouds in Colorado. These measurements support research efforts designed to address the largest uncertainties in the climate models. ACRF will support a field experiment at the North Slope of Alaska site to study cloud and aerosol properties in the Arctic lower troposphere. The increased funding in FY 2011 will support operations of the new Recovery Act instruments resulting in new capabilities for users and new data for improving representation of clouds and aerosols in the climate models.

FY 2009 funding of $40,339,000 was in Atmospheric Radiation Measurement (ARM) Infrastructure within the Climate Change Research subprogram.

(estimated)

	FY 2009	FY 2010	FY 2011
Achieved Operating Hours	8,219	N/A	N/A
Planned Operating Hours	7,884	7,884	7,884
Optimal hours	7,884	7,884	7,884
Percent of Optimal Hours	104%	100%	100%
Unscheduled Downtime	0	N/A	N/A
Number of Users[a]	1,186	1,000	1,000

- **Environmental Molecular Sciences Laboratory** **0** **52,021** **51,340**

The William R. Wiley Environmental Molecular Sciences Laboratory (EMSL), a scientific user facility located at the Pacific Northwest National Laboratory, provides integrated experimental and computational resources for discovery and technological innovation in the environmental molecular sciences for DOE and the Nation. With more than fifty leading-edge instruments and a supercomputer, EMSL enables users to undertake molecular-scale experimental and theoretical

[a] ARM users are both onsite and remote. A user is an individual who accesses ARM databases or uses equipment at an ARM site. Individuals are only counted once per year at an individual site but may be counted at different ARM sites if they are a user at more than one site.

(dollars in thousands)

FY 2009	FY 2010	FY 2011

research on aerosol chemistry, biological systems, biogeochemistry, and interfacial and surface science.

EMSL encourages the use of multiple experimental systems to provide fundamental understanding of the physical, chemical, and biological processes that underlie DOE's energy and environmental mission areas, including alternative energy sources, improved catalysts and materials for industrial applications, insights into the factors influencing climate change and carbon sequestration processes, and an understanding of subsurface biogeochemistry at contaminated sites. For example, EMSL's nuclear magnetic resonance spectrometers; high resolution mass spectrometers; ultra-high vacuum scanning, tunneling, cryogenic and atomic force microscopy capabilities; and the 160 teraflop supercomputer are all used to study microbial and plant species important for bioenergy and other energy sources. The EMSL capability for proteomics is unique and essential for advances in the field of systems biology.

In FY 2011, EMSL operations funding is increased to provide users with enhanced access to new EMSL capabilities obtained with the FY 2009 Recovery Act funding. Capital equipment support for EMSL enables instrument upgrades and modifications as well as the development and procurement of unique state-of-the-art capabilities needed by external users and EMSL staff to conduct innovative and leading-edge science. A multi-year effort to acquire a High Magnetic Field Mass Spectrometer, a major item of equipment with a total estimated cost of $17,500,000 was initiated in FY 2010 at $ 3,000,000 and is continued in FY 2011 at $7,250,000. This transformational instrument will enable users to undertake world-leading proteomics, metabolomics and lipidomics of plant, animal and microbial cells, communities and other complex systems that will have application to biofuels, systems biology, bioremediation, aerosol particle characterization, catalysis and fossil fuel analysis. A suite of integrated imaging capabilities (advanced data processing, image correlation, and remote operational capabilities) will be developed to better understand biological transformations and energy and materials transport in complex environments and to support systems biology research, particularly proteomics.

FY 2009 funding of $48,953,000 was in the EMSL activity within the Biological Research subprogram.

(estimated)

	FY 2009	FY 2010	FY 2011
Achieved Operating Hours	4,376	N/A	N/A
Planned Operating Hours	4,365	4,352	4,365
Optimal hours	4,365	4,365	4,365
Percent of Optimal Hours	100%	100%	100%
Unscheduled Downtime	0	N/A	N/A
Number of Users[a]	750	750	750

[a] EMSL users are both onsite and remote. Individual users are counted once per year.

(dollars in thousands)

	FY 2009	FY 2010	FY 2011
▪ **Data Management and Education**	**0**	**4,199**	**2,773**

The role of climate data management is to facilitate full and open access to quality-assured carbon cycle data for climate change research. Data holdings include records of the concentrations of atmospheric CO_2 and other greenhouse gases; the role of the terrestrial biosphere and the oceans in biogeochemical cycles of greenhouse gases; emissions of CO_2 to the atmosphere; long-term climate trends; the effects of elevated CO_2 on vegetation; and the vulnerability of coastal areas to rising sea level. Data management support for major projects, such as the AmeriFlux network, measurements of CO_2 taken aboard ocean research vessels, and DOE-supported Free-Air CO_2 Enrichment (FACE) experiments, are also included.

BER's Global Climate Education Program (GCEP) is completed in FY 2010. BER will meet the outyear commitments for prior year awards. This program has achieved its goals of supporting graduate and undergraduate students with interest in climate change. BER will continue to support students with interest in climate change science through its on-going research at universities and DOE national laboratories. The Office of Science Graduate Fellowship program initiated in FY 2010 within the Workforce Development for Teachers and Scientists (WDTS) program supports graduate students pursuing advanced degrees in areas of research supported by the Office of Science, including climate change research. Likewise the Summer Undergraduate Laboratory Internship program supported by WDTS continues to support undergraduate research opportunities at the national laboratories in areas including climate science.

In FY 2011, the data management activity will continue to support data users with tools for identifying and accessing those data needed to address important climate change research questions. The activity will also implement information technology advances to meet evolving data sharing needs of researchers. These include user interfaces, visualization capabilities, and customized data extractions from large, often complex, data files.

FY 2009 funding of $2,013,000 and $1,422,000 was in Information and Integration, and Education within the Climate Change Research subprogram.

▪ **General Purpose Equipment (GPE)**	**0**	**750**	**750**

GPE funding provides general purpose equipment for Pacific Northwest National Laboratory (PNNL) and Oak Ridge Institute for Science and Education (ORISE), such as information system computers and networks and instrumentation that support multi-purpose research.

FY 2009 funding of $112,000 was in Environmental Remediation Sciences Research activity within the Biological Research subprogram.

▪ **General Plant Projects (GPP)**	**0**	**700**	**700**

GPP funding supports minor construction, capital alterations, and additions, such as replacing utility systems in 30 to 40 year old buildings. Funding of this type is essential for maintaining the productivity and usefulness of Department-owned facilities and meeting the requirements for safe and reliable facilities operation. This activity includes stewardship GPP funding for ORISE. The total estimated cost of each GPP project will not exceed $5,000,000 in FY 2011.

(dollars in thousands)

	FY 2009	FY 2010	FY 2011
FY 2009 funding of $698,000 was in Environmental Remediation Sciences Research activity within the Biological Research subprogram.			
SBIR/STTR	**0**	**7,442**	**8,071**
FY 2010 and FY 2011 amounts shown for the SBIR and STTR programs are the estimated requirements for continuation of these congressionally mandated programs.			
Total, Climate and Environmental Sciences	**0**	**285,706**	**304,953**

Explanation of Funding Changes

	FY 2011 vs. FY 2010 ($000)
Atmospheric System Research	
The increased funding will support the development of the next generation 3D cloud parameterizations.	**+1,944**
Environmental System Science	
▪ **Terrestrial Ecosystem Science**	
The increased funding will support development of the next-generation of large-scale, long-term manipulative field experiments, with a focus on an ecosystem that has to date been poorly studied, is expected to be sensitive to climate change, and is of significant importance at the regional or global scales.	+720
▪ **Terrestrial Carbon Sequestration Research**	
Funding is reduced with the completion of a series of research projects focused on the cycling of carbon sequestration associated with agriculture and forestry.	-1,747
Total, Environmental System Science	**-1,027**
Climate and Earth System Modeling	
▪ **Regional and Global Climate Modeling**	
Funding increases to enhance efforts to better represent the feedbacks produced by the indirect effect of aerosols and enhanced efforts in uncertainty quantification.	+6,495
▪ **Earth System Modeling**	
Funding increases to support focused efforts for converting observational datasets, the establishment of model development testbeds, and new numerical capabilities for transitioning climate models to new computing architectures.	+9,015

	FY 2011 vs. FY 2010 ($000)
▪ **Integrated Assessment**	
In FY 2011 Integrated Assessment will continue to provide the scientifically rigorous, quantitative basis from which policy makers and researchers may assess the impacts of the Nation's scientific and engineering enterprise, improve their understanding of its dynamics, and assess likely outcomes for decision-making on our climate, energy, economic futures.	+337
Total, Climate and Earth System Modeling	**+15,847**
Climate and Environmental Facilities and Infrastructure	
▪ **ARM Climate Research Facility**	
The increase will support operations of the new Recovery Act instruments resulting in new capabilities for users and new data for improving representation of clouds and aerosols in the climate models.	+3,961
▪ **Environmental Molecular Sciences Laboratory**	
Funding is held near FY 2010 levels. Operations funding increases are offset by reductions in capital equipment funding.	-681
▪ **Data Management and Education**	
Support for BER's Global Climate Education Program is completed in FY 2010. The Workforce Development for Teachers and Scientists program will support graduate climate science education in the DOE Office of Science Graduate Fellowship program.	-1,426
Total, Climate and Environmental Facilities and Infrastructure	**+1,854**
SBIR/STTR	
SBIR/STTR increases as the funding for research increases.	+629
Total Funding Change, Climate and Environmental Sciences	**+19,247**

Biological Research

Funding Schedule by Activity

(dollars in thousands)

	FY 2009	FY 2010	FY 2011
Biological Research			
Life Sciences	305,462	0	0
Medical Applications	8,226	0	0
Environmental Remediation	98,465	0	0
Total, Biological Research	412,153[a]	0	0

Description

The BER program has continued its investments in core fundamental science and technologies needed to address the interfaces between scientific disciplines such as biology, physics, chemistry, engineering, and information science. Within the Biological Research subprogram, the highest priority has been the Genomics: GTL program which develops an understanding of the fundamental principles underlying the function and control of biological systems.

Modifications were made to the budget structure to better reflect the subprogram's activities starting in FY 2010. The Conference report for the FY 2010 Energy and Water Development Appropriations Bill reflected this new structure.

Detailed Justification

(dollars in thousands)

	FY 2009	FY 2010	FY 2011
Life Sciences	**305,462**	**0**	**0**
▪ **Structural Biology**	**15,300**	**0**	**0**

The Structural Biology program develops and supports access to beamlines and instrumentation at DOE's national user facilities for the Nation's structural biologists. BER coordinates, with the NIH and the NSF, the management and maintenance of 22 experimental stations at several DOE synchrotrons (Advanced Photon Source [APS], Advanced Light Source [ALS], and Stanford Synchrotron Radiation Laboratory [SSRL]).

In FY 2010 and 2011, funding is shown in the Biological Systems Facilities and Infrastructure activity in the Biological Systems Science subprogram.

[a] $313,688,000 is associated with activities funded in the Biological Systems Science subprogram in FY 2010 and FY 2011, and $98,465,000 with activities funded in the Climate and Environmental Science subprogram.

(dollars in thousands)

	FY 2009	FY 2010	FY 2011
▪ **Molecular and Cellular Biology**	**191,391**	**0**	**0**
• **Carbon Sequestration Research**	**7,817**	**0**	**0**

Carbon sequestration research seeks to understand the fundamental mechanisms of carbon fixation, conversion and cycling in microbes, microbial communities, and plants. The program initiated a new focus on carbon sequestration and utilization for biofuels, with genomics-based research that will lead to the improved use of plant feedstocks for the production of carbon-neutral fuels such as ethanol or renewable chemical feedstocks.

In FY 2010 and 2011, funding is shown in the Metabolic Synthesis and Conversion activity in the Biological Systems Science subprogram.

• **Genomics: GTL**	**162,847**	**0**	**0**
► **Genomics: GTL Foundational Research**	**41,850**	**0**	**0**

The Foundational Research activity supports fundamental research and technology development that underpins all microbial and plant research conducted in the Genomics: GTL program overall and in the GTL Bioenergy Research Centers. GTL Foundational Research also develops the robust computational infrastructure needed to understand, predict, and ultimately use the genomic potential, cellular responses, biological regulation, and behaviors of complex biological systems of interest to the DOE mission.

In FY 2010 and 2011, funding is shown in the Foundational Genomics Research and Computational Biosciences activities in the Biological Systems Science subprogram.

► **Genomics: GTL Sequencing**	**10,000**	**0**	**0**

DNA sequence data underpins and is the starting point for all aspects of the Genomics: GTL program. The vast majority of high-throughput DNA sequencing of plants, microbes, and microbial communities conducted at the Joint Genome Institute (JGI) user facility is directly relevant to the Genomics: GTL program. Research continued within Genomics: GTL to generate DNA sequence data of individual genes as they are expressed, whole genomes, and metagenomes in order to provide essential information needed to formulate genetic engineering strategies for microbes and plants, to understand plant and microbe molecular machines, to determine the composition of complex microbial communities, and to dissect plant-microbe associations.

In FY 2010 and 2011, funding is shown in the Genomics Analysis and Validation activity in the Biological Systems Science subprogram.

► **Genomics: GTL Biohydrogen Research**	**15,661**	**0**	**0**

This activity supports innovative systems biology research with a specific emphasis on biological hydrogen production, such as the discovery and development of improved or oxygen-tolerant hydrogenases, characterization of specific cellular architecture to facilitate electron transfer for optimum hydrogen production, and the redirection of metabolic

(dollars in thousands)

FY 2009	FY 2010	FY 2011

pathways and metabolite flow into hydrogen production. While this activity draws upon the foundational research and technology development within the broader GTL portfolio, it is specifically directed towards scientific issues and challenges unique to biological hydrogen production.

In FY 2010 and 2011, funding is shown in the Metabolic Synthesis and Conversion activity in the Biological Systems Science subprogram.

- **Genomics: GTL Bioethanol Research** **20,336** **0** **0**

Cellulosic ethanol is a carbon-neutral fuel that can already be used within today's energy infrastructure. Microbes or microbial processes are used to produce ethanol from residues such as corn plants left after a corn harvest or energy crops such as poplar trees that are specifically grown as biomass for energy production. While this activity draws upon the foundational research and technology development within the broader GTL portfolio it is specifically directed towards scientific issues and challenges unique to understanding the metabolic conversion of 5- and 6-carbon sugars to ethanol.

In FY 2010 and 2011, funding is shown in the Metabolic Synthesis and Conversion activity in the Biological Systems Science subprogram.

- **Genomics: GTL Bioenergy Research Centers** **75,000** **0** **0**

The three DOE Bioenergy Research Centers, all involving academic, industrial, and national laboratory scientists, are designed to accomplish the GTL program objectives more effectively. The centers serve as catalysts for innovation and change, by concentrating appropriate technologies and scientific expertise to go from the genome sequence to an integrated systems understanding of the pathways and internal structures of plants and microbes most relevant to the steps required to develop bioenergy compounds.

In FY 2010 and 2011, funding is shown in the Bioenergy Research Centers within the Biological Systems Science subprogram.

- **Low Dose Radiation Research** **20,727** **0** **0**

The Low Dose Radiation Research activity supports research that will help determine health risks from exposures to low levels of ionizing radiation; information critical to adequately and appropriately protecting individuals, and to making more effective use of our national resources. Information developed in this program will provide a better scientific basis for making decisions with regard to remediating contaminated DOE sites and for determining acceptable levels of human health protection, both for cleanup workers and the public, in the most cost-effective manner. Some research in this program is jointly funded with NASA's Office of Biological and Physical Research.

In FY 2010 and 2011, funding is shown in the Radiobiology activity in the Biological Systems Science subprogram.

(dollars in thousands)

	FY 2009	FY 2010	FY 2011
▪ **Human Genome**	**70,000**	**0**	**0**
• **Joint Genome Institute, Production Genomics Facilities**	**55,000**	**0**	**0**

The Joint Genome Institute's (JGI) high-throughput DNA sequencing factory, the Production Genomics Facility (PGF) is focused on helping to meet the demand for DNA sequencing in the broader energy and environment scientific community.

In FY 2010 and 2011, funding is in Joint Genome Institute within the Biological Systems Science subprogram.

• **Tools for DNA Sequencing and Sequence Analysis**	**10,000**	**0**	**0**

BER develops the tools and resources needed by the scientific, medical, and industrial sector communities to fully exploit the information contained in complete DNA sequences, from energy-relevant microbes to low dose radiation effects.

In FY 2010 and 2011, funding is in the Joint Genome Institute activity in the Biological Systems Science subprogram.

• **Ethical, Legal, and Societal Issues (ELSI)**	**5,000**	**0**	**0**

BER ELSI research supports activities applicable to Office of Science issues in bioenergy, synthetic biology, and nanotechnology, including exploration of, and communication of, the societal implications arising from these programs.

In FY 2010 and 2011, funding is in the Ethical, Legal, and Societal Issues (ELSI) activity in the Biological Systems Science subprogram.

▪ **Health Effects**	**5,937**	**0**	**0**

Health effects research in functional genomics provides a link between human genomic sequencing and the development of information that is useful in understanding normal human development and disease processes including susceptibility to low doses of ionizing radiation.

In FY 2010 and 2011, funding is in the Radiobiology activity in the Biological Systems Science subprogram.

▪ **Radiochemistry and Instrumentation**	**22,834**	**0**	**0**

BER supports basic research that builds on unique DOE capabilities in physics, chemistry, engineering, and computational science. It supports fundamental imaging research, maintains core infrastructure for imaging research and development, including innovative imaging technology with respect to new radiochemistry and radiotracer methodologies for precise and dynamic metabolic imaging of biological organisms.

In FY 2010 and 2011, funding is in Radiochemistry and Imaging Instrumentation within the Biological Systems Science subprogram.

(dollars in thousands)

	FY 2009	FY 2010	FY 2011
Medical Applications			
▪ **Artificial Retina**	**8,226**	**0**	**0**
BER utilized the resources of the national laboratories in material sciences, engineering, microfabrication, and microengineering to develop unique neuroprostheses and continue development of an artificial retina to restore sight to the blind.			
In FY 2010 and 2011, funding is in the Medical Applications activity within the Biological Systems Science subprogram.			
Environmental Remediation	**98,465**	**0**	**0**
▪ **Environmental Remediation Sciences Research**	**48,702**	**0**	**0**
Environmental Remediation Sciences research activities address questions of fundamental environmental remediation science at the interfaces of biology, chemistry, geology, and physics. The research will help to provide the scientific foundation for the solution of key environmental challenges within DOE's cleanup mission at scales ranging from molecular to the field, including issues of fate and transport of contaminants in the environment; novel strategies for *in situ* remediation; and long-term monitoring of remediation strategies.			
In FY 2010 and 2011, Environmental Remediation Sciences Research funding is in Subsurface Biogeochemical Research within the Climate and Environmental Sciences subprogram.			
▪ **General Purpose Equipment (GPE)**	**112**	**0**	**0**
GPE funding will increase to provide general purpose equipment for Pacific Northwest National Laboratory (PNNL) and Oak Ridge Institute for Science and Education (ORISE) such as information system computers and networks, and instrumentation that support multi-purpose research.			
In FY 2010 and 2011, GPE funding is in Climate and Environmental Facilities and Infrastructure within the Climate and Environmental Sciences subprogram			
▪ **General Plant Projects (GPP)**	**698**	**0**	**0**
GPP funding continued for minor new construction, other capital alterations and additions, and for buildings and utility systems, such as replacing infrastructure in 30- to 40-year old buildings. Funding of this type is essential for maintaining the productivity and usefulness of Department-owned facilities and meeting the requirements for safe and reliable facilities operation. This activity included stewardship GPP funding for ORISE.			
In FY 2010 and 2011, GPP funding is in Climate and Environmental Facilities and Infrastructure within the Climate and Environmental Sciences subprogram.			
▪ **Facility Operations**	**48,953**	**0**	**0**
The William R. Wiley Environmental Molecular Sciences Laboratory (EMSL), a national scientific user facility located at the Pacific Northwest National Laboratory, provides integrated experimental and computational resources for discovery and technological innovation in the environmental molecular sciences to support the needs of DOE and the Nation.			

(dollars in thousands)

	FY 2009	FY 2010	FY 2011
• **EMSL Operating Expenses**	**34,223**	**0**	**0**

Operating funds are used for: staff support for users; maintenance of instruments and buildings; utilities; environmental safety and health compliance activities; and communications. With over 55 leading-edge instruments and a supercomputer system, EMSL annually supports approximately 700 users. The core EMSL science team networks with the broader academic community as well as with DOE national laboratories and other agencies. EMSL users have access to unique expertise and instrumentation for environmental research, including a high performance computer; a 900 MHz nuclear magnetic resonance (NMR) spectrometer that highlights a suite of NMRs in EMSL; a collection of mass spectrometers, including an 11.5 Tesla high performance mass spectrometer; laser desorption and ablation instrumentation; ultra-high vacuum scanning, tunneling and atomic force microscopes; and controlled atmosphere environmental chambers.

In FY 2010 and 2011, funding for EMSL Operating Expenses is in EMSL Operations and Infrastructure within the Climate and Environmental Sciences subprogram.

• **Capital Equipment**	**5,987**	**0**	**0**

Capital equipment support for the EMSL enables instrument modifications needed by collaborators and external users of the facility as well as the ability to make upgrades to existing instrumentation and to provide additional capabilities in order to maintain EMSL capabilities for environmental molecular scientific research.

In FY 2010 and 2011, funding for EMSL Capital Equipment is in EMSL Operations and Infrastructure within the Climate and Environmental Sciences subprogram.

• **EMSL GPP**	**8,743**	**0**	**0**

GPP is provided to initiate development and construction of an addition to EMSL.

In FY 2010 and 2011, funding for EMSL GPP is in EMSL Operations and Infrastructure within the Climate and Environmental Sciences subprogram.

Total, Biological Research	**412,153**	**0**	**0**

Climate Change Research

Funding Schedule by Activity

(dollars in thousands)

	FY 2009	FY 2010	FY 2011
Climate Change Research			
Climate Forcing	81,727	0	0
Climate Change Modeling	61,078	0	0
Climate Change Response	25,114	0	0
Climate Change Mitigation	5,104	0	0
Total, Climate Change Research	173,023[a]	0	0

Description

BER priorities within the Climate Change Research subprogram are to develop the ability to predict climate on global and regional scales; to explore the impacts of excess atmospheric CO_2 on the Earth system; to develop strategies for its removal and sequestration from the atmosphere; and, provide the science to underpin the prediction of the impacts of climate change. These priorities will depend on the continued development of novel research tools and a close integration of experimental, observational, and computational research.

Modifications were made to the budget structure to better reflect the subprogram's activities starting in FY 2010. The Conference report for the FY 2010 Energy and Water Development Appropriations Bill reflected this new structure.

Detailed Justification

(dollars in thousands)

	FY 2009	FY 2010	FY 2011
Climate Forcing	**81,727**	**0**	**0**
▪ **Atmospheric Radiation Measurement (ARM) Research**	**15,079**	**0**	**0**

A major emphasis in the Climate Forcing area of the Climate Change Research subprogram is on understanding the radiation balance from the surface of the Earth to the top of the atmosphere and how this balance is affected by clouds, aerosols, and increases in the concentration of greenhouse gases in the atmosphere.

In FY 2010 and 2011, funding is shown in Atmospheric System Research within the Climate and Environmental Sciences subprogram.

[a] Associated FY 2010 and 2011 activities are funded in the Climate and Environmental Sciences subprogram.

(dollars in thousands)

	FY 2009	FY 2010	FY 2011
▪ **Atmospheric Radiation Measurement (ARM) Infrastructure**	**40,339**	**0**	**0**

The ARM infrastructure activity will continue to support and upgrade the operation of the ARM Climate Research Facility (ACRF). The ACRF consists of three stationary facilities, an ARM Mobile Facility (AMF), and the ARM Aerial Vehicles Program (AAVP). The stationary sites provide scientific testbeds in three different climatic regions (mid-latitude, polar, and tropical); the operating paradigm of continuous measurement of atmospheric and surface properties at long-term sites is well suited to climate studies. The AMF provides a capability to address high priority scientific questions in regions other than the stationary sites. The AAVP provides a capability to obtain *in situ* cloud and radiation measurements that complement the ground-based measurements.

In FY 2010 and 2011, funding is shown in ARM Operations and Infrastructure within the Climate and Environmental Sciences subprogram.

▪ **Atmospheric Science**	**10,334**	**0**	**0**

The Atmospheric Science Program is focused on the radiative effects of atmospheric aerosols, the greatest source of uncertainty in global radiative forcing of climate change over the last century. To enable more reliable and accurate simulations of direct and indirect aerosol climate forcing, the program conducts research on the atmospheric processes that control the formation, transport, transformations, and removal of atmospheric aerosols as these affect their distribution, radiative, and cloud nucleating properties.

In FY 2010 and 2011, funding is shown in the Atmospheric System Research activity within the Climate and Environmental Sciences subprogram.

▪ **Terrestrial Carbon Processes**	**13,962**	**0**	**0**

BER continues support of AmeriFlux, a network of research sites where the net exchange of carbon dioxide, energy, and water between the atmosphere and major terrestrial ecosystems in North America is continuously measured.

The AmeriFlux Network research sites provided extensive measurements of terrestrial carbon sink properties, including biological and soil carbon processes. This research is important for evaluating what happens to carbon dioxide emissions from combustion of fossil fuels, and provides scientific information needed for prognostic modeling of the rate of atmospheric carbon dioxide increase, which is a key forcing factor of climate.

In FY 2010 and 2011, funding is shown in Terrestrial Ecosystem Science within the Climate and Environmental Sciences subprogram.

▪ **Information and Integration**	**2,013**	**0**	**0**

The Information and Integration element of Climate Forcing research continued to store, evaluate, quality assure, and disseminate a broad range of climate change related data, especially data on atmospheric concentrations and industrial emissions of greenhouse gases, greenhouse gas fluxes from terrestrial systems, ocean CO_2 data, and air quality data. This is accomplished by supporting the Carbon Dioxide Information and Analysis Center (CDIAC). CDIAC's data holdings include records of the concentrations of carbon dioxide and other radiatively active gases in the atmosphere;

the role of the terrestrial biosphere and the oceans in the biogeochemical cycles of greenhouse gases; emissions of carbon dioxide to the atmosphere; long-term climate trends; the effects of elevated carbon dioxide on vegetation; and the vulnerability of coastal areas to rising sea level.

In FY 2010 and 2011, funding is shown in Data Management and Education within the Climate and Environmental Sciences subprogram.

Climate Change Modeling **61,078** **0** **0**

BER's Climate Change Modeling program addresses uncertainty in simulating Regional and Global Climate Change. The focus is on incorporation and testing of various aerosol schemes, convection schemes, ice sheets, and land surface schemes in the coupled models, and evaluation using innovative metrics that span a variety of climate time scales.

BER's SciDAC for Climate Change Research continued partnerships with the Advanced Scientific Computing Research program.

In FY 2010 and 2011, funding is shown in the Climate and Earth System Modeling activity within the Climate and Environmental Sciences subprogram.

Climate Change Response **25,114** **0** **0**

- **Ecosystem Function and Response** **13,979** **0** **0**

  The goal of the Ecosystem Function and Response research activity is to understand the potential effects of climatic change anticipated during the coming 50-100 years on the health of important terrestrial ecosystems in the United States. The primary focus is experimental studies of the potential effects of warming on the abundance and geographic distribution of plant and animal species in several ecosystem types. The experiments will be conducted to fill specific critical knowledge gaps. In particular, experiments will determine linkages between warming and the possibility of species migrations, the expansion of species into areas that are presently too cool for their success, and the decline of species or ecosystems presently at the warm edge of their ranges.

  In FY 2010 and 2011, funding is shown in Terrestrial Ecosystem Science within the Climate and Environmental Sciences subprogram.

- **Integrated Assessment** **9,713** **0** **0**

  BER's Integrated Assessment (IA) Research supports underlying research and development of the basic methods and models for estimating costs and benefits of global climate change and possible actions to mitigate such change. Understanding the underlying and complex human-earth systems dynamics are a priority for IA research.

  In FY 2010 and 2011, funding is shown in Integrated Assessment within Climate and Earth System Modeling in the Climate and Environmental Sciences subprogram.

- **Education** **1,422** **0** **0**

  BER's Global Change Education Program continues to support both undergraduate and graduate studies in FY 2009 through the DOE Summer Undergraduate Research Experience (SURE) and the DOE Graduate Research Environmental Fellowships (GREF).

(dollars in thousands)

	FY 2009	FY 2010	FY 2011
In FY 2010 and 2011, funding is shown in Data Management and Education within the Climate and Environmental Sciences subprogram.			
Climate Change Mitigation	**5,104**	**0**	**0**
BER's carbon sequestration research, part of BER's support to the Climate Change Technology Program, continued to focus only on terrestrial carbon sequestration. Research continues on studies to enhance long-term sequestration processes and the stability of stored carbon in terrestrial vegetation and soils.			
In FY 2010 and 2011, funding is shown in Terrestrial Carbon Sequestration Research within the Climate and Environmental Sciences subprogram.			
Total, Climate Change Research	**173,023**	**0**	**0**

Supporting Information

Operating Expenses, Capital Equipment and Construction Summary

(dollars in thousands)

	FY 2009	FY 2010	FY 2011
Operating Expenses	561,792	576,818	601,786
Capital Equipment	13,943	24,164	24,414
General Plant Projects (GPP)	9,441	3,200	700
Total BER	585,176	604,182	626,900

Funding Summary

(dollars in thousands)

	FY 2009	FY 2010	FY 2011
Research	406,031	395,251	419,290
Scientific User Facilities Operations and Research	169,592	178,130	182,060
Major Items of Equipment	0	10,700	7,250
Facility related GPP	8,743	2,500	0
Other[a]	810	17,601	18,300
Total BER	585,176	604,182	626,900

Scientific User Facilities Operations and Research

(dollars in thousands)

	FY 2009	FY 2010	FY 2011
Biological Systems Science			
Structural Biology Infrastructure	15,300	15,300	15,683
Joint Genomics Institute	65,000	69,000	69,267
Total, Biological Systems Science	80,300	84,300	84,950
Climate and Environmental Sciences			
Atmospheric Radiation Measurement Climate Research Facility	40,339	41,809	45,770
Environmental Molecular Sciences Laboratory	48,953	52,021	51,340
Total, Climate and Environmental Science	89,292	93,830	97,110
Total Science User Facilities Operations and Research	169,592	178,130	182,060

[a] Includes SBIR, STTR, GPE, and non-Facility related GPP.

Facilities Users and Hours

	FY 2009	FY 2010	FY 2011
Joint Genome Institute			
Achieved Operating Hours	8,400	N/A	N/A
Planned Operating Hours	8,400	8,400	8,400
Optimal hours	8,400	8,400	8,400
Percent of Optimal Hours	100%	100%	100%
Unscheduled Downtime	0	N/A	N/A
Number of Users[a]	780	940	940
Atmospheric Radiation Measurement (ARM) Climate Research Facility (ACRF)			
Achieved Operating Hours	8,219	N/A	N/A
Planned Operating Hours	7,884	7,884	7,884
Optimal hours	7,884	7,884	7,884
Percent of Optimal Hours	104%	100%	100%
Unscheduled Downtime	0	N/A	N/A
Number of Users[b]	1,186	1,000	1,000
Environmental Molecular Sciences Laboratory			
Achieved Operating Hours	4,376	N/A	N/A
Planned Operating Hours	4,365	4,352	4,365
Optimal hours	4,365	4,365	4,365
Percent of Optimal Hours	100%	100%	100%
Unscheduled Downtime	0	N/A	N/A
Number of Users[c]	750	750	750

[a] All JGI users are remote. Primary users are individuals associated with approved projects being conducted at the JGI in a reporting period. Each user is counted once per year regardless of how many proposals their name may be associated with. Additionally, different users reflect vastly differing levels of JGI resources

[b] ARM users are both onsite and remote. A user is an individual who accesses ARM databases or uses equipment at an ARM site. Individuals are only counted once per reporting period at an individual site but may be counted at different ARM sites if they are a user at more than one site.

[c] EMSL users are both onsite and remote. Individual users are counted once per year.

	FY 2009	FY 2010	FY 2011
Total Facilities			
Achieved Operating Hours	20,995	N/A	N/A
Planned Operating Hours	20,649	20,636	20,649
Optimal hours	20,649	20,649	20,649
Percent of Optimal Hours	104%	100%	100%
Unscheduled Downtime	0	N/A	N/A
Number of Users	2,716	2,690	2,690

Structural Biology Infrastructure activities are at Basic Energy Sciences user facilities and the user statistics are included in the BES user statistics.

Major Items of Equipment

(dollars in thousands)

	Prior Years	FY 2009	FY 2009 Recovery Act	FY 2010	FY 2011	Outyears	Total
Atmospheric Radiation Measurement (ARM) Climate Research Facility (ACRF)							
Dual-Frequency Scanning Cloud Radar for Southern Great Plains ARM Site							
Total Estimated Costs (TEC)/ Total Project Costs (TPC)	0	0	3,070	0	0	0	3,070
Dual-Frequency Scanning Cloud Radar for North Slope of Alaska ARM Site							
TEC/TPC	0	0	3,070	0	0	0	3,070
Dual-Frequency Scanning Cloud Radar for Tropical Western Pacific (Manus) ARM Site							
TEC/TPC	0	0	3,070	0	0	0	3,070
Dual-Frequency Scanning Cloud Radar for ARM Mobile Facility #1							
TEC/TPC	0	0	3,070	0	0	0	3,070
Dual-Frequency Scanning Cloud Radar for ARM Mobile Facility #2							
TEC/TPC	0	0	3,070	0	0	0	3,070
Dual-Frequency Scanning Cloud Radar for Tropical Western Pacific (Darwin) ARM Site							
TEC/TPC	0	0	3,070	0	0	0	3,070

(dollars in thousands)

	Prior Years	FY 2009	FY 2009 Recovery Act	FY 2010	FY 2011	Outyears	Total
Total ACRF TEC/TPC	0	0	18,420	0	0	0	18,420
Environmental Molecular Sciences Laboratory (EMSL)							
Field Emission-Transmission Electron Microscope (FE-TEM)							
TEC/TPC	4,500	0	0	0	0	0	4,500
Standard Transmission Electron Microscope (TEM)							
TEC/TPC	0	0	2,940	0	0	0	2,940
X-ray Phototelectron Spectrometer (XPS)							
TEC/TPC	0	0	2,027	0	0	0	2,027
3-D Atom Probe							
TEC/TPC	0	0	2,280	0	0	0	2,280
Electron Microprobe							
TEC/TPC	0	0	2,250	0	0	0	2,250
700 Megahertz Wide Bore Nuclear Magnetic Resonance (NMR) Spectrometer							
TEC/TPC	0	0	2,640	0	0	0	2,640
15 Tesla Fourier Transform-Ion Cyclotron Resonance (FT-ICR) Mass Spectrometer (MS)							
TEC/TPC	0	0	2,840	0	0	0	2,840
Ultra-High Vacuum (UHV) Scanning Tunneling Microscope/Atomic Force Microscope (STM/AFM)							
TEC/TPC	0	0	2,200	0	0	0	2,200
850 Megahertz Wide Bore Nuclear Magnetic Resonance (NMR) Spectrometer							
TEC/TPC	0	0	4,830	0	0	0	4,830
3-D Microscope System							
TEC/TPC	0	0	2,250	0	0	0	2,250

(dollars in thousands)

	Prior Years	FY 2009	FY 2009 Recovery Act	FY 2010	FY 2011	Outyears	Total
Advanced Mass Spectrometry System							
TEC/TPC	0	0	2,900	0	0	0	2,900
Advanced Oxygen Plasma Assisted Molecular Beam Epitaxy system							
TEC/TPC	0	0	0	3,200	0	0	3,200
Secondary Ion Mass Spectrometer							
TEC/TPC	0	0	0	4,500	0	0	4,500
Next Generation, High Magnetic Field Mass Spectrometer							
TEC/TPC	0	0	0	3,000	7,250	7,250	17,500
Total EMSL TEC/TPC	4,500	0	27,157	10,700	7,250	7,250	56,857
Total BER TEC/TPC	4,500	0	45,577	10,700	7,250	7,250	75,277

Atmospheric Radiation Measurement (ARM) Climate Research Facility (ACRF)

Dual-frequency scanning cloud radar for the Southern Great Plains ARM Site. This instrument will provide the capability to measure cloud properties in a volume and will provide three-dimensional cloud properties at the Southern Great Plains ARM Site. These data are essential for developing high-resolution climate models.

Dual-frequency scanning cloud radar for the North Slope of Alaska ARM Site. This instrument will provide the capability to measure cloud properties in a volume and will provide three-dimensional cloud properties at the North Slope of Alaska ARM Site. These data are essential for developing high-resolution climate models.

Dual-frequency scanning cloud radar for the Tropical Western Pacific (Manus) ARM Site. This instrument will provide the capability to measure cloud properties in a volume and will provide three-dimensional cloud properties at the Tropical Western Pacific (Manus) ARM Site. These data are essential for developing high-resolution climate models.

Dual-frequency scanning cloud radar for the ARM Mobile Facility #1. This instrument will provide the capability to measure cloud properties in a volume and will provide three-dimensional cloud properties for the ARM Mobile Facility #1. These data are essential for developing high-resolution climate models.

Dual-frequency scanning cloud radar for the ARM Mobile Facility #2. This instrument will provide the capability to measure cloud properties in a volume and will provide three-dimensional cloud properties for the ARM Mobile Facility #2. These data are essential for developing high-resolution climate models.

Dual-frequency scanning cloud radar for the Tropical Western Pacific (Darwin) ARM Site. This instrument will provide the capability to measure cloud properties in a volume and will provide three-dimensional cloud properties at Tropical Western Pacific (Darwin) ARM Site. These data are essential for developing high-resolution climate models.

Environmental Molecular Sciences Laboratory

Field Emission-Transmission Electron Microscope (FE-TEM) will allow imaging of reactions at the atomic scale under high temperature and pressure conditions. This understanding will be key to assess the reactivity of novel materials for use in hydrogen fuel cells and for examining the conversion of organic matter into alternative fuels.

Standard Transmission Electron Microscope (TEM) to enable nano-meter structural and chemical characterization of complex synthesized and natural materials relevant to catalysis, fuel cells, energy storage and sensing.

X-ray Photoelectron Spectrometer (XPS) will enable three dimensional chemical maps of the outer 50 nanometers of natural materials as well as designed or degraded functionalized materials. The XPS will be used to study mineral/contaminant interactions, aging and degradation of solar cells and solid state lighting and catalytic surfaces.

3-D Atom Probe for three dimensional atomic scale imaging of complex materials including solid-solid "buried" interfaces. This system will be used for material surface studies relevant to subsurface remediation, photovoltaics and catalysis.

Electron Microprobe provides elemental composition and structural imaging of materials/minerals. This capability has relevance to radiological applications such as waste storage and processing.

700 Megahertz Wide Bore Nuclear Magnetic Resonance (NMR) Spectrometer system is used to perform solid-state and liquids NMR measurements of radiological-containing and radiologically-exposed materials.

15 Tesla Fourier Transform Ion Cyclotron Resonance (FT-ICR) Mass Spectrometer to replace EMSL's original 11.5 Tesla system. This capability will enable the study of intact and modified proteins, and will fundamentally advance biological science insights for microbial and plant systems.

Ultra-High Vacuum (UHV) Scanning Tunneling Microscope/Atomic Force Microscope (STM/AFM) will enable site-specific chemical measurements with unique abilities to control the arrival of molecules at the site. This system will be used for research on catalysts for fuel cell operation, contaminant destruction and energy production.

850 Megahertz Wide Bore Nuclear Magnetic Resonance (NMR) Spectrometer will be optimized for solid-state investigation of materials and metallic systems and will be used to study energy-relevant materials (including catalysts) and minerals and contaminants.

3-D Microscope System will provide Transmission Electron Microscope-like resolution of bulk samples and will provide new 3D information on aerosol particles, microbial/mineral interfaces, catalytic surfaces and other materials.

Advanced Mass Spectrometry System with liquid chromatography capability for the identification and quantification of peptides and proteins to aid in studies of microbial communities and plant systems.

Advanced Oxygen Plasma Assisted Molecular Beam Epitaxy system is designed for the growth of a wide variety of oxide materials and will be funded at $3,200,000 TEC in FY 2010 and delivered in FY 2011.

This instrument will enable synthesis and characterization of oxide films and surfaces important for catalysis, electronic and spintronic materials, and geochemistry.

Secondary Ion Mass Spectrometer will be used for high spatial resolution as well as trace element and isotopic analysis of ultra-fine features and will be funded at $4,500,000 TEC in FY 2010 and delivered in FY 2011. This instrument will provide extremely high resolution of organic and inorganic samples applicable to geochemistry, aerosol particles and materials.

Next Generation, High Magnetic Field Mass Spectrometer system will be a world-leading system to measure and characterize complex mixtures of intact proteins and other biomolecules, aerosol particles, petroleum, and constituents from other types of fluids. Initially funded at $3,000,000 in FY 2010 with delivery in FY 2014, the TEC will be $17,500,000. The system will enable world-leading proteomics, metabolomics and lipidomics with application to bioenergy, as well as provide insights relevant to climate science, fossil fuel processing, and catalysis.

Scientific Employment

	FY 2009 Estimate	FY 2010 Estimate	FY 2011 Estimate
# University Grants	489	475	490
Average Size per year	$320,000	$320,000	$320,000
# Laboratory Projects	377	234[a]	195
# Permanent Ph.D.s[b]	1,480	1,460	1500
# Postdoctoral Associates[c]	340	335	345
# Graduate Students[c]	485	480	495
# Ph.D.s awarded[d]	105	110	110

[a] In FY 2010, BER consolidated funding for laboratories resulting in fewer individual projects.
[b] Estimated. Information is not readily available on the total number of permanent Ph.D. scientists associated with each research project. In addition to the principal investigator for each research project funded by BER, individual projects typically have between 1 and 20 additional Ph.D.-level scientists who are funded collaborators. Information on scientific collaborators is not routinely tracked.
[c] Estimated for national laboratory projects.
[d] Estimated. Information is not available on the number of Ph.D.s awarded as a result of BER funded research at universities or national laboratories.