Biological and Environmental Research

Funding Profile by Subprogram (Non-Comparable, or as Appropriated, Structure)

(dollars in thousands)

	FY 2008 Current Appropriation	FY 2009 Current Appropriation	FY 2009 Additional Appropriation[a]	FY 2010 Request to Congress
Biological and Environmental Research				
Biological Research	397,976	423,613	100,793	—
Climate Change Research	133,087	177,927	64,860	—
Biological Systems Science	—	—	—	318,476
Climate and Environmental Sciences	—	—	—	285,706
Total, Biological and Environmental Research	531,063[bc]	601,540	165,653	604,182

Funding Profile by Subprogram (Comparable Structure to the FY 2010 Request)

(dollars in thousands)

	FY 2008 Comparable Appropriation	FY 2009 Comparable Appropriation	FY 2009 Additional Appropriation[a]	FY 2010 Request to Congress
Biological and Environmental Research				
Biological Systems Science	303,961	322,815	40,793	318,476
Climate and Environmental Sciences	227,102	278,725	124,860	285,706
Total, Biological and Environmental Research	531,063[bc]	601,540	165,653	604,182

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"

Modifications were made to the budget structure to better reflect the subprogram's activities in FY 2010. The two tables above show a non-comparable and comparable funding profile for the subprogram. The non-comparable table presents the FY 2010 funding in the new budget structure only and FY 2008 and FY 2009 funding is shown as appropriated. The comparable table shows the FY 2008 and FY 2009 funding in the new budget structure to assist in comparing year-to-year funding trends. A crosswalk of the new and old structure is provided at the end of this chapter, describing in detail the modification to the budget structure.

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[a] The Additional Appropriation column reflects the planned allocation of funding from the American Recovery and Reinvestment Act of 2009, P.L. 111–5. See the Department of Energy Recovery website at http://www.energy.gov/recovery for up -to-date information regarding Recovery Act funding.
[b] Total is reduced by $13,334,000: $12,065,000 of which was transferred to the Small Business Innovative Research (SBIR) program and $1,269,000, of which was transferred to the Small Business Technology Transfer (STTR) program.
[c] The Congressional control level in FY 2008 and FY 2009 is at the Biological Research and Climate Change Research levels.

Program Overview

Mission

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

Background

The wonders of planet 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 editorial page 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 that 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. Each of these practical challenges, questions, and arguments is driven by a base of scientific knowledge and inquiry in atmospheric chemistry and physics, ecology, genetics, and subsurface science. 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 subsurface environment? The Office of Biological and Environmental Research (BER) program supports research addressing these questions, providing understanding of nature that enables DOE to find 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. Health effects research gave us 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 understanding the most fundamental level of biology, DNA, and in turn led DOE to initiate 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, research 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 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 they 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, 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 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. 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, indeed across the Office of Science, is the challenge and excitement of studying complex systems. BER's systems have their own unique complexity covering remarkable spatial and temporal scales. In living systems, whether a microbe, a microbial community, a plant, an entire ecosystem, or a person exposed to low doses of radiation, 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 the decades or even centuries to understand the long-term ecological impacts of a changing climate or the sustained production of specific 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. Spatially 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. BER science also exploits DOE's computational resources, developing computational models that can be used to make experimentally testable predictions about climate, complex subsurface environments, or biological systems. Today, computational models are an essential tool for all BER science.

Major scientific goals for BER are outlined below:

- **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 system."

- **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 2009 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 seminal 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 should

[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

"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.

Subprograms

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

- 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 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 over124 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, as well as in Medical Applications where an artificial retina is being developed.
- 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, through its Atmospheric Radiation Measurement (ARM) activity, to help resolve the greatest uncertainties in climate change-the role of clouds and aerosols in Earth's radiation balance. The 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, a mobile facility, and an aerial vehicles program; it served over 1000 users from around the world in FY 2008. Climate and Earth System Modeling supports some of the worlds most powerful and sophisticated climate models that contribute to reports by the Intergovernmental Panel on Climate Change. 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 improved human health, advanced scientific discovery, and revolutionized the field of biology. Decades of biological research have led to the development of dosimeters to monitor exposure to radiation and radioisotopes used in tens of millions of medical diagnostic procedures annually. 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.

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 by teams of scientist in the public and private sectors from around the world, information that has provided unprecedented opportunities for discovering and understanding fundamental principles of life. BER carried this new capability to rapidly sequence an organism's complete genome to the fields of microbial and plant biology with an emphasis on organisms with energy and environmental relevance. High throughput technologies for genome sequencing have led to the discovery of novel microorganisms with unanticipated biotechnological capabilities and provided new insights into a variety of plants including trees, legumes and grasses. The ability to study an organism beginning with its DNA sequence has provided unprecedented understanding of fundamental biological processes from the production of proteins to the control of groups of genes linked in a biochemical pathway to the genetic basis for interactions of organisms in complex ecosystems.

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. 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 provides new understanding of the biological, physical, and chemical mechanisms responsible for the natural sequestration of carbon dioxide, a key greenhouse gas, in terrestrial ecosystems. This knowledge is useful in understanding the impacts of land use and land management decisions on carbon release or storage from various ecosystems. Through hypothesis-driven research in both laboratories and the field, BER research has revealed new biogeochemical processes that influence the fate and transport of contaminants from a legacy of weapons production.

Program Planning and Management

BER uses broad input from scientific workshops or 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 (NSF), National Aeronautics and Space Administration (NASA), Department of Commerce/National Oceanic and Atmospheric Administration (NOAA), Environmental Protection Agency (EPA), Nuclear Regulatory Commission (NRC), Department of Agriculture (USDA), National Institutes of Health (NIH), Department of State (DOS), and Department of Defense (DOD). 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 Climate Change Science Program.

BERAC conducts reviews of BER subprograms by COVs every three years. Results of these reviews and BER responses are posted on the BERAC 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.

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 provide 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 four mission priorities: understanding complex biological, climatic, and environmental systems across spatial and temporal scales; exploring the frontiers of genome-enabled biology; discovering the physical, chemical, and biological drivers of climate change; and seeking the molecular determinants of environmental sustainability and stewardship. The BER scientific user facilities are key to supporting these mission priorities.

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[a] Http://www.science.doe.gov/ober/berac.html and http://www.science.doe.gov/SC-2/Committee_of_Visitor.htm

- Genomic science research, including the DOE Bioenergy Research Centers, will 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 facility operation 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.
- Atmospheric System Research will improve understanding and quantification of the role of aerosols and clouds on climate change. Research will be expanded to examine clouds and aerosols in different climatic regions using data from new Atmospheric Radiation Measurement (ARM) sites and lab studies. Results will be used to evaluate and improve performance of regional and global climate models. The new ARM sites and lab 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).
- Climate and Earth System Modeling will establish a climate modeling center with Advanced Scientific Computing Research. This activity will enhance development, robustness, and resolution of climate models through integration of climate research with DOE Leadership Computing Facilities. High-resolution regional climate simulations will be developed to assess regional and national implications of climate change on human systems and infrastructure, especially energy demand, production, and supply, such as biofuel feedstock production.
- Environmental System Science will initiate an additional large-scale, manipulative experiment in a major terrestrial ecosystem 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. Research will focus 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. Integration of experimentation and computation will be encouraged by replacing the third generation high performance computing system with two or more systems having architectures appropriate to specific areas of science. 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.

Significant Program Shifts

The BER program has been restructured to combine and integrate climate and environmental science in the Climate and Environmental Sciences subprogram and to define common, integrating themes for life and medical sciences in a Biological Systems Science subprogram. This new budget structure aligns with the BER science mission and increases management efficiency and balance. The outcome will be improved management of BER investments, better integration across the BER portfolio, and improved communication of BER science within DOE, and to the Administration, Congress, the scientific community and the public.

Strategic and GPRA Unit Program Goals

The BER program has one Government Performance and Results Act (GPRA) Unit Program Goal which contributes to Strategic Goals 3.1 and 3.2 in the "goal cascade":

- GPRA Unit Program Goal 03.1/2.48.00: 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 sciences advances in the biomedical field.

Contribution to GPRA Unit Program Goal 03.1/2.48.00, Harness the Power of Our Living World

BER contributes to this goal by advancing fundamental world-class, merit-reviewed systems research in genomics, proteomics, climate change, environmental remediation, radiobiology, and imaging instrumentation. Discoveries at these scientific frontiers will bring revolutionary and unconventional solutions to some of our most pressing and expensive challenges in energy and the environment.

We intend to understand how living organisms interact with and respond to their environments to be able to use biology to produce clean energy, remove excess carbon dioxide from the atmosphere, and help clean up the environment. Our understanding of the causes and consequences of regional and global climate change and our ability to predict climate over decades to centuries at regional to global scales enables development of science-based solutions to minimize the potential adverse impacts of climate change and to better plan for our Nation's future energy needs and resource use. Understanding the biological effects of low doses of radiation can lead to the development of science-based health risk policy to better protect workers and citizens. Understanding the fate and transport of environmental contaminants can lead to improved decision making as well as the discovery of innovative approaches to remediate and monitor the environment.

BER radiochemistry and advanced instrumentation research seeks to develop new technologies for imaging and sensing applications and for high-throughput characterization and analysis in real time and at multiple spatial scales to enable progress in BER missions in bioenergy, subsurface science, and climate change research. BER research will be completed for development of an artificial retina that will enable the blind to see.

The BER research program capitalizes on the national laboratories' resources and expertise in biological, chemical, physical, and computational sciences, and on their sophisticated instrumentation (e.g., neutron and light sources, mass spectroscopy, high field magnets, lasers, and supercomputers). This research is coordinated with and complementary to other Federal programs.

In addition, BER operates reliable, scientific facilities to serve thousands of researchers at universities, national laboratories, and private institutions from all over the world. These include structural biology research beam lines at the synchrotron light sources and neutron sources; the William R. Wiley Environmental Molecular Sciences Laboratory (EMSL) (including the Molecular Sciences Computing Facility) which 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; the Joint Genome Institute (JGI) for high-throughput DNA sequencing of non-medical microbes and plant targets; and the Atmospheric Radiation Measurement (ARM) Climate Research Facility

(ACRF) for addressing the two major uncertainties in climate change research, the impact of clouds and aerosols on the radiative budget.

The following indicators establish specific long-term goals in Scientific Advancement that the BER program is committed to, and against which progress can be measured.

Biological Systems Science

- Genomic Science: Provide the fundamental scientific understanding of plants and microbes necessary to develop new robust and transformational basic research strategies for producing biofuels, cleaning up waste, and sequestering carbon.
- Medical Applications: Develop intelligent biomimetic electronics that can both sense and correctly stimulate the nervous system.

Climate and Environmental Sciences

- Climate Science: Deliver improved scientific data and models about the potential response of the Earth's climate and terrestrial biosphere to increased greenhouse gas levels for policy makers to determine safe levels of greenhouse gases in the atmosphere.
- Subsurface Biogeochemical Research: Provide sufficient scientific understanding such that DOE sites would be able to incorporate coupled physical, chemical, and biological processes into decision making for environmental remediation and long-term stewardship.

BER Facilities

- Facilities: Manage facilities operations to the highest standards of overall performance using merit evaluation with independent peer review.

Annual Performance Results and Targets

FY 2005 Results	FY 2006 Results	FY 2007 Results	FY 2008 Results	FY 2009 Targets	FY 2010 Targets
GPRA Unit Program Goal 03.1/2.47.00 (Harness the Power of Our Living World)					
Biological Systems Science					
Genomic Science					
Increase the rate of DNA sequencing: Number (in billions) of base pairs of high quality (less than one error in 10,000 bases) DNA microbial and model organism genome sequence produced annually. FY 2005 at least 28 billion base pairs will be sequenced. [Met Goal]	Increase the rate of DNA sequencing: Number (in billions) of base pairs of high quality (less than one error in 10,000 bases) DNA microbial and model organism genome sequence produced annually. FY 2006 at least 30 billion base pairs will be sequenced. [Met Goal]	Increase the rate and decrease the cost of DNA sequencing – Cost reductions will increase the number of high quality base pairs determined (less than one error in 10,000 bases) by 25% from the FY 2006 target of 582 base pairs per dollar to 781 base pairs per dollar. [Met Goal]	Increase the rate and decrease the cost of DNA sequencing—Increase by 10% the number (in billions) 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 10% the cost (base pair/dollar) to produce these base pairs from the previous year's actual results. FY 2008: 42.8 billion base pairs and 785 base pairs per dollar (based on the FY 2007 actual of 38.95 billion base pairs, and JGI achieving 714 billion base pairs per dollar.) [Met Goal]	Increase the rate and decrease the cost of DNA sequencing—Increase by 10% the number (in billions) 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 10% the cost (base pairs per dollar) to produce these base pairs from the previous year's actual results. FY 2009: 253 billion base pairs and 4600 base pairs per dollar (based on FY2008 actual of 125.5 Giga base pairs, and achieving 2350 base pairs per dollar.)	Increase the rate and decrease the cost of DNA sequencing—Increase by 10% the number (in billions) 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 10% the cost (base pairs per dollar) to produce these base pairs from the previous year's (FY 2009) actual results.
Medical Applications					
Advance blind patient sight: Complete testing on a 60 microelectrode array artificial retina and insert prototype device into a blind patient. [Goal Not Met]	Advance blind patient sight: Begin testing of prototypes for 256 microelectrode array artificial retina. [Met Goal]	Advance blind patient sight: complete design and construction of final 256 electrode array. Begin in vitro testing and non-stimulating testing in animals. [Met Goal]	Advance blind patient sight: Complete in vitro testing of 256 electrode array and continue animal studies of final design 256 electrode array. [Met Goal]	Advance blind patient sight: Complete development of entire 256 electrode implantable device.	Advance blind patient sight: Complete final in vitro and in vivo studies of entire 256 electrode implantable device.

FY 2005 Results	FY 2006 Results	FY 2007 Results	FY 2008 Results	FY 2009 Targets	FY 2010 Targets
Climate and Environmental Sciences					
Climate Science					
Improve climate models: Implement a model test bed system to incorporate climate data rapidly into climate models to allow testing of the performance of sub-models (e.g., cloud resolving module) and model parameters by comparing model simulations with real world data from the ARM sites and satellites. [Met Goal]	Improve climate models: Implement three separate component submodels (an interactive carbon cycle submodel, a secondary sulfur aerosol submodel, and an interactive terrestrial biosphere submodel) within a climate model and conduct 3-4 year duration climate simulation using the fully coupled model. [Met Goal]	Improve climate models: 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 the timescale of 1 to 4 days. [Met Goal]	Improve climate models—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 2008: 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. [Met Goal]	Improve climate models—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 2009: 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.	Improve climate models—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 2010: Provide a new parameterization for aerosol effects on cloud drizzle for incorporation into atmospheric models.
Subsurface Biogeochemical Research					
Perform combined field/laboratory/modeling to determine how to interpret data at widely differing scales: Quantify contaminant immobilization and remobilization by different factors: 1. natural microbial mechanisms; 2. chemical reactions with minerals; and 3. colloid formation. [Met Goal]	Determine scalability of laboratory results in field experiments—Conduct two sets of field experiments to evaluate biological reduction of chromium and uranium by microorganisms and compare the results to laboratory studies to understand the long term fate and transport of these elements in field settings. [Met Goal]	Develop predictive model for contaminant transport that incorporates complex biology, hydrology, and chemistry of the subsurface. Validate model through field tests. [Met Goal]	Determine scalability of laboratory results in field environments—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. For FY 2008: Identify the critical redox reactions and metabolic pathways involved in the transformation/ sequestration of at least one key DOE contaminant in a field environment. [Met Goal].	Determine scalability of laboratory results in field environments—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. For FY 2009: Test geophysical techniques that measure parameters controlling contaminant movement under field conditions in at least two distinct subsurface environments.	Determine scalability of laboratory results in field environments—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. For FY 2010: Using field experiments and reactive transport models, describe the key processes for subsurface mass transfer of contaminants to inform the development of next generation models.

FY 2005 Results	FY 2006 Results	FY 2007 Results	FY 2008 Results	FY 2009 Targets	FY 2010 Targets
All BER Facilities					
Maintain and operate BER facilities such that achieved operation time is on average greater than 90% of the total scheduled annual operation time. [Met Goal]	Maintain and operate BER facilities (Life Science—PGF and the Mouse facility; Climate Change Research—ARM and FACE; and Environmental Remediation—EMSL) such that achieved operation time is on average greater than 90% of the total scheduled annual operation time for each group of facilities. [Met Goal]	Maintain and operate BER facilities (Life Science—PGF and the Mouse facility; Climate Change Research—ARM and FACE; and Environmental Remediation—EMSL) such that achieved operation time is on average greater than 95% of the total scheduled annual operation time for each group of facilities. [Met Goal]	The achieved operation time of the scientific user facility (Genomic Science—JGI; Climate Science—ACRF; and Subsurface—EMSL) as a percentage of the total scheduled annual operating time is greater than 98%. Milestone met for ACRF and EMSL; JGI was at 94%. This reflects the December shutdown for ergonomic safety. The safety issue has been corrected. [Goal Not Met]	The achieved operation time of the scientific user facility (Genomic Science—JGI; Climate Science—ACRF; and Subsurface—EMSL) as a percentage of the total scheduled annual operating time is greater than 98%.	The achieved operation time of the scientific user facility (Genomic Science— GI; Climate Science—ACRF; and Subsurface —EMSL) as a percentage of the total scheduled annual operating time is greater than 98%.

Biological Systems Science

Funding Schedule by Activity[a]

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010
Biological Systems Science			
Genomic Science	164,085	169,858	165,626
Radiological Sciences	46,674	50,768	46,615
Ethical, Legal, and Societal Issues	5,000	5,000	5,000
Medical Applications	8,191	8,226	8,226
Biological Systems Facilities and Infrastructure	80,011	80,300	84,300
SBIR/STTR	—	8,663	8,709
Total, Biological Systems Science	303,961	322,815	318,476

Description

Systems biology is the holistic, multidisciplinary study of complex interactions that specify the function 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. These principles require understanding the genomic blueprint that underlies the potential for life processes, the translation of that blueprint into subcellular proteins, metabolites, and cellular architecture, and the organizing principles between these molecules. 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. This coupling between experimentation and modeling of how biological systems receive, process, and respond to signals—from genetic or developmental programs and external cellular or environmental cues—is the systems biology theme for the research supported by this subprogram. These signals can be exchanged between different biological systems, such as in a microbial community within the termite gut or associated with plant roots, and can enable biological systems to probe and respond to their physical environment.

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, in radiochemistry and instrumentation research, and the proof-of-concept design of an implantable, artificial sensor.

[a] This table shows the FY 2008 and FY 2009 funding in the new (comparable) budget structure to assist in comparing year-to-year funding trends. A cross-walk of the new and old structure is provided at the end of this chapter, describing in detail the modification to the budget structure.

Selected FY 2008 Accomplishments

- Systems biology approaches have enabled scientists to determine how a newly-discovered microbial species can exist by itself in complete darkness nearly two miles below the Earth's surface. Examination of its genome reveals the presence of everything needed for the organism to sustain an independent existence and reproduce, including the ability to incorporate the elements necessary for life from inorganic sources, move freely, and protect itself from viruses, harsh conditions, and nutrient-poor periods. Results of these studies have not only provided new insights into the mechanism that microbes use to survive under challenging environmental conditions, but also provide clues on how to manipulate them for bioremediation of contaminants.
- The DOE Bioenergy Research Centers have developed a variety of new methods that can overcome the resistance of plant biomass to breakdown and conversion into biofuels. These methods range from using ionic liquids to break apart linkages between biomass molecules such as cellulose, hemicellulose, and lignin, to developing an integrated high throughput characterization screen that allows the rapid identification and correlation of the chemical, structural, and genetic features of plant biomass.
- The DOE Joint Genome Institute (JGI) contributed significant achievements in genome sequencing and analysis in support of the DOE missions. Major accomplishments include: completing a draft assembly of the one billion nucleotide soybean genome—roughly one-third the size of the human genome—containing as many as 66,000 genes that hold the keys to edible protein production, biodiesel fuel, and carbon-nitrogen nutrient cycling in agricultural soils; and sequencing the genome of the photosynthetic alga, *Chlamydomonas reinhardtii*, revealing fundamental mechanisms for absorbing sunlight and coupling carbon dioxide and water to build cell structure and drive carbon metabolism.
- Scientists have developed a way to synthesize a whole new class of radiotracers, compounds that can be tracked by PET scanners to monitor the movement and interactions of a wide range of chemicals in biological and environmental systems. This new methodology uses a commercially available, inexpensive compound (trimethylamine-N-oxide) for rapid, efficient conversion of carbon-11-labeled methyl iodide to carbon-11-labeled formaldehyde, a useful reagent central to synthesis of a wide range of radiolabeled compounds to probe biological processes.

Detailed Justification

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010
Genomic Science	**164,085**	**169,858**	**165,626**
▪ **Foundational Genomics Research**	**33,422**	**38,267**	**33,216**

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

	FY 2008	FY 2009	FY 2010
	(dollars in thousands)		

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 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, to provide real-time insight into actively occurring 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 2010, research is supported to advance the understanding of how complex biological system function is specified by genome organization, expression, and regulation. This includes developing genomic and analytical technologies to study the structure, interdependence, and function of microbial communities. Capital equipment investments to support the program's advanced imaging and analytic requirements for multifactorial measurements of genome-directed cellular function are completed in FY 2009.

	FY 2008	FY 2009	FY 2010
▪ **Genomics Analysis and Validation**	**10,521**	**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 2010, research supports the experimental validation and improvement of genome-scale annotation and gene models in microbes, plants, and complex biological systems.

	FY 2008	FY 2009	FY 2010
▪ **Metabolic Synthesis and Conversion**	**41,297**	**42,127**	**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

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010

can enable strategies to increase biomass formation for conversion into advanced biofuels or to increase the sequestration of carbon in terrestrial ecosystems.

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 2010, funds will continue to support research on carbon storage in plant biomass for conversion into advanced biofuels or 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. Pilot studies to develop advanced research technologies for imaging of lignocellulose during conversion to cellulosic ethanol or for validation of metabolic pathways during microbial hydrogen production are competed in FY 2009.

▪ **Computational Biosciences**	**3,845**	**4,464**	**8,283**

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.

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 SC's Advanced Scientific Computing Research Program.

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010

In FY 2010, funding will support ongoing SciDAC research on the modeling of protein structure and function. Funding is increased to support establishment of 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 will develop and test predictive models for microbial systems of DOE relevance with respect to physiological properties, behavior and whole microbe 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. The initial primary microbial experimental datasets for integration will be drawn from research conducted at the DOE Bioenergy Research Centers, the Joint Genome Institute, and the Environmental Molecular Sciences Laboratory.

	FY 2008	FY 2009	FY 2010
▪ **Bioenergy Research Centers**	**75,000**	**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 we possess 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.

The first year progress of each center was evaluated by an on-site review of science and management activities and progress against stated milestones. The external review teams were comprised of scientists from universities and a DOE National Laboratory, with expertise in systems biology, microbial physiology and genetics, plant genomics and bioinformatics, genomic database management and informatics, and analytical chemistry. All three centers received highly favorable evaluations of progress against milestones and for the planned science programs.

The Great Lakes Bioenergy Research Center (GLBRC), led by the University of Wisconsin in partnership with Michigan State University, milestones:

- Completion of start-up activities and achievement of full operational status.
- Identification of key structural carbohydrate biosynthesis genes in model plant systems.
- Complete proof-of-concept research for oil production in plant vegetative tissues.
- Establishment of a cell wall analytical platform.

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010

- Identification of a new catalytic processes for direct conversion of lignocellulose to biofuel precursor molecules.
- Establishment of field experiments and development of methodology for data collection and analysis for sustainable biofuel production.

The Joint BioEnergy Institute (JBEI), led by Lawrence Berkeley National Laboratory, milestones:

- Completion of start-up activities and achievement of full operational status.
- Identification and selection of key candidate genes for controlling cell wall synthesis and composition.
- Development of new high-throughput assays for biomass characterization, pretreatment, and enzymatic deconstruction.
- Complete characterization of one targeted plant feedstock under ionic liquid pretreatment conditions.
- Initial metabolic profiling of microbial community samples and selection of key candidate novel cellulase enzymes.
- Identification and prioritization of candidates for metabolic engineering of advanced hydrocarbon biofuels.

The BioEnergy Science Center (BESC), led by Oak Ridge National Laboratory, milestones:

- Completion of start-up activities and achievement of full operational status.
- Establishment of preliminary models of cell wall biosynthesis pathways in poplar and switchgrass.
- Establishment of full high-throughput pipelines for plant transformation, biomass pretreatment and enzyme deconstruction analysis.
- High-throughput screening of environmental diversity poplar samples and identification of modified cell wall composition.
- Identification of over 20 new components in the cellulosome from transcriptomics and proteomic studies.
- Completion of initial round of microbial sampling from targeted diverse environments for new biocatalyst discovery.

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 2010, 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 bioengineering of new microbes and enzymes capable of degrading lignocellulose, and conversion of cellulose-derived sugars to carbon-neutral biofuels.

	FY 2008	FY 2009	FY 2010
	(dollars in thousands)		
Radiological Sciences	**46,674**	**50,768**	**46,615**
▪ **Radiochemistry and Imaging Instrumentation**	**21,789**	**22,841**	**20,688**

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 2010, 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. Multi-year activities initiated in FY 2009 in development of new radiochemistry synthetic and detection methods will continue in FY 2010. Pilot activities initiated in FY 2008 for the development and use of innovative radiotracer chemistry or instrumentation technologies will be completed in FY 2010.

▪ **Radiobiology**	**24,885**	**27,927**	**25,927**

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 development of systems genetic strategies, including the role of epigenetics in integrated gene function and response of biological systems to environmental conditions.

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.

In FY 2010, funds will support the development of models that integrate responses to low dose radiation at the tissue or whole organism level with available epidemiological 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. Funds are decreased to reflect the full transfer of mouse stocks at the Laboratory of Comparative and Functional Genomics (the Mouse House) to the University of North Carolina. Research on the low dose radiation response in individual cell types is decreased in FY 2010.

	FY 2008	FY 2009	FY 2010
	(dollars in thousands)		
Ethical, Legal, and Societal Issues	**5,000**	**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 EPA, NSF and OSTP.

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 2010, 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.

Medical Applications	**8,191**	**8,226**	**8,226**

Research continues to utilize resources of the national laboratories in material sciences, engineering, microfabrication, and microengineering to develop unique neuroprostheses and to continue development of 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.

In FY 2010, BER will support final testing of a completely fabricated 240+ electrode retinal device as a basis for fabrication of the 1,000+ electrode device. The DOE-funded phase of this effort will be completed in FY 2010.

Biological Systems Facilities and Infrastructure	**80,011**	**80,300**	**84,300**
▪ **Structural Biology Infrastructure**	**15,446**	**15,300**	**15,300**

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 as they are improved by DOE.

The Structural Biology infrastructure enables a broad user community to conduct the high-

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010

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 2010 funds will continue to support biological community access to structural biology beamlines and instrumentation at DOE national user facilities.

▪ **Joint Genome Institute**	**64,565**	**65,000**	**69,000**

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 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 2010, funding will continue to support user community access and DOE Bioenergy Research Center to integrative large-scale genome data acquisition and analysis of biological systems at the JGI. Funding is increased to focus on metagenome expression and sequencing of environmental microbial communities or the plant-microbe rhizosphere, as well as improved genome annotation and functional analysis and verification of genome-scale models.

	FY 2008	FY 2009	FY 2010
(dollars in thousands)			

	FY 2008	FY 2009	FY 2010
	(estimated)		
Achieved Operating Hours	7,704	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	92%	100%	100%
Unscheduled Downtime	696	N/A	N/A
Number of Users[a]	679	780	940

	FY 2008	FY 2009	FY 2010
SBIR/STTR	**—**	**8,663**	**8,709**

In FY 2008, $6,947,000 and $786,000 were transferred to the SBIR and STTR programs, respectively. FY 2009 and FY 2010 amounts shown are the estimated requirements for continuation of the congressionally mandated SBIR and STTR programs.

	FY 2008	FY 2009	FY 2010
Total, Biological Systems Science	**303,961**	**322,815**	**318,476**

Explanation of Funding Changes

	FY 2010 vs. FY 2009 ($000)
Genomic Science	
▪ **Foundational Genomics Research**	
Investments in capital equipment for the program's advanced imaging and analytic requirements for multifactorial measurements of genome-directed cellular function are completed in FY 2009.	-5,051
▪ **Metabolic Synthesis and Conversion**	
Pilot studies to develop advanced research technologies for imaging of lignocellulose during conversion to cellulosic ethanol or for validation of metabolic pathways during microbial hydrogen production are completed in FY 2009.	-3,000
▪ **Computational Biosciences**	
Funding is increased to support establishment of a systems biology computational framework to provide multi-scale data analysis tools for biological networks and metabolic pathways. Research will initially focus on integrated genome-scale	+3,819

[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.

	FY 2010 vs. FY 2009 ($000)
reconstruction of metabolic and transcriptional regulatory networks in microbial systems of DOE relevance. Initial targets will include experimental datasets from the DOE Bioenergy Research Centers, the Joint Genome Institute, and the Environmental Molecular Sciences Laboratory, leading to predictive modeling of physiological properties, behavior and whole microbe responses.	
Total, Genomic Science	**-4,232**
Radiological Sciences	
▪ **Radiochemistry and Imaging Instrumentation**	
Multi-year activities in the development of new radiochemistry synthetic and detection methods will continue in FY 2010. Pilot activities initiated in FY 2008 for the development and use of innovative radiotracer chemistry or instrumentation technologies will be completed in FY 2010.	-2,153
▪ **Radiobiology**	
The decrease discontinues research support at the Mouse House with the complete transfer of genetically-defined mouse strains from Oak Ridge National Laboratory to the University of North Carolina.	-2,000
Total, Radiological Sciences	**-4,153**
Biological Systems Facilities and Infrastructure	
▪ **Joint Genome Institute**	
Funding is increased for metagenome expression and sequencing of environmental microbial communities or the plant-microbe rhizosphere, as well as improved genome annotation and functional analysis and verification of genome-scale models.	+4,000
SBIR/STTR	
▪ SBIR/STTR is increased as research support is enhanced.	+46
Total Funding Change, Biological Systems Science	**-4,339**

Climate and Environmental Sciences

Funding Schedule by Activity[a]

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010
Climate and Environmental Sciences			
Atmospheric System Research	25,201	25,316	26,452
Environmental System Science	77,816	79,631	82,558
Climate and Earth System Modeling	35,141	72,029	69,775
Climate and Environmental Facilities and Infrastructure	88,944	94,450	99,479
SBIR/STTR	—	7,299	7,442
Total, Climate and Environmental Sciences	227,102	278,725	285,706

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. 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. 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. 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.

Climate change research involves advances in the comprehensive understanding of the basic chemical, physical, and biological processes of the Earth's atmosphere, land, and oceans and how these processes may be affected by energy production and use, primarily the emission of carbon dioxide from fossil fuel combustion. The fundamental research is designed to provide the scientific data and understanding that will enable an objective assessment of the potential for, and consequences of, global warming. The research elements are: understanding the quantitative role of atmospheric processes, particularly clouds and aerosols, on the radiation balance of Earth's atmosphere; advancing state-of-the-science models of climate change from regional to global scales for climate change projections; and quantifying effects of

[a] This table shows the FY 2008 and FY 2009 funding in the new (comparable) budget structure to assist in comparing year-to-year funding trends. A cross-walk of the new and old structure is provided at the end of this chapter, describing in detail the modification to the budget structure.

climate change on the terrestrial biosphere and the dynamic role of the terrestrial biosphere in the global carbon cycle. Environmental system science seeks a basic understanding of subsurface biogeochemical processes to predict terrestrial carbon dynamics and storage, and contaminant fate and transport processes. The subsurface biogeochemical fate and transport research advances the fundamental science needed to understand, predict, and mitigate the impacts of environmental contamination from past nuclear weapons production and provides a scientific basis for the long-term stewardship of nuclear waste disposal. Research focuses on understanding the biogeochemical processes that influence and control the environmental mobility of DOE-relevant contaminants in the subsurface and developing the tools and technologies needed to advance subsurface science.

Selected FY 2008 Accomplishments

- ACRF data have been used to significantly improve representations of mixed-phase (liquid and ice) clouds in climate models, an ARM science priority, resulting in better climate simulations. These clouds dominate low-level Arctic atmosphere and have a significant impact on the surface energy budget in this climatically important region.
- Scientists have documented climate-related shifts of plant distribution in the mountains of California**.** This study is consistent with the hypothesis that ongoing global warming is expected to shift the geographic distribution of plants as species expand into newly favorable areas and decline in increasingly hostile locations.
- Scientists stimulated the activity of a specific group of microorganisms to successfully reduce the concentration of chromium in groundwater at Hanford. Using the latest genomic science-enabled techniques, researchers were able to correlate shifts in microbial community composition and specific functional genes with decreasing chromium concentrations. These results provide new insights into subsurface microbial ecology and activity that will aid *in situ* bioremediation.

Detailed Justification

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010
Atmospheric System Research	**25,201**	**25,316**	**26,452**

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 the 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. The 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 2010, 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. Research will focus on furthering our understanding of the life cycle of marine boundary layer clouds and their impacts on radiation. Priority aerosol studies include transformations and properties of carbonaceous aerosols,

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010

especially secondary organic aerosols, which are poorly predicted by current atmospheric models. The research will also focus on aerosol processes controlling new particle formation and growth, as well as the properties that affect their activation as droplet and crystal nuclei. Research will use atmospheric measurements from laboratory, ACRF, and other sources in this effort. Research will also be coordinated with Earth System Modeling to quickly and effectively incorporate results into climate models. The additional funds will support development and evaluation of new representations of cloud and aerosol processes for the next generation Earth System Model.

	FY 2008	FY 2009	FY 2010
Environmental System Science	**77,816**	**79,631**	**82,558**
▪ **Terrestrial Ecosystem Science**	**26,005**	**25,913**	**27,913**

The Terrestrial Ecosystem Science activity develops the scientific understanding of 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, evaluating terrestrial source-sink mechanisms for atmospheric carbon dioxide, and improving reliability of global carbon cycle models for predicting future atmospheric concentrations of carbon dioxide.

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 therefore needed to establish cause-and-effect relationships between climate changes and effects on ecosystems. A significant fraction of the CO_2 released to the atmosphere during fossil fuel combustion is taken up by terrestrial ecosystems. However, the 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 on the carbon balance a high priority.

In FY 2010, the activity will continue ongoing research and initiate new research to understand important potential effects of climate change, and increasing atmospheric carbon dioxide concentration, on terrestrial ecosystems and the terrestrial carbon cycle. Continuing research will support AmeriFlux, the network of CO_2 flux, for directly estimating net ecosystem production and carbon sequestration 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[a], development of the next-generation of ecosystem-climate change experiment, with a focus on ecosystems that: are of significant importance at the regional or global scales; are expected to be sensitive to climate change; and have been poorly studied to date. The increased funding will support the development of the experimental framework and the target ecosystem will be identified in 2009–2010 based on analysis of the most recent climate model projections. In FY 2010, based on input from the scientific community, an experimental site will be located, the ecological characterization of the

[a] See the report of the BERAC Subcommittee "Reviewing the FACE and OTC Elevated CO_2 Projects in DOE and Ecosystem Experiments: Understanding Climate Change Impacts on Ecosystems and Feedbacks to the Physical Climate."

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010

site will begin, and the engineering methods for environmental manipulations will be prototyped in a field setting.

▪ **Terrestrial Carbon Sequestration Research**	**4,896**	**5,233**	**4,747**

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 2010, ongoing research will seek to determine if "double dividends" can be achieved from switchgrass systems that provide above-ground cellulose for ethanol production and simultaneously enhance belowground carbon sequestration. The overall goal is to understand and quantify physical, chemical, and biological controls over soil carbon sequestration using switchgrass as the test bed. The research will be carried out through field experiments with switchgrass, which will produce results on below-ground carbon transformations that involve plant roots, the rhizosphere, and soil microbial communities. The role of microaggregates and other soil properties in stabilizing and protecting carbon complexed with soil minerals will also be investigated. Data from the field experiments will be utilized for mechanistic and prognostic modeling of soil carbon sequestration. A focused experiment on climate mitigation initiated in 2009 to study the role of subsurface process in sequestration will achieve its goals and be completed in 2010.

▪ **Subsurface Biogeochemical Research**	**46,915**	**48,485**	**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 and gene expression, mineral transformation, and solution composition in the environment. The current focus of the activity is to predict the impact of biogeochemical processes on the fate and transport in the subsurface. This activity supports 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.

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010

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 will also assist the Department's research on using deep geological formations to store carbon dioxide taken from the atmosphere.

In FY 2010, integrated multi-scale, multi-disciplinary research will continue, emphasizing the integrated field research challenge sites. The increased research effort addresses processes that control the mobility of radionuclides in the environment. This research will help address DOE strategic initiatives for clean up of legacy nuclear wastes and nuclear energy applications. Increased funding will support fundamental research on reactive transport of transuranic contaminants in the subsurface.

	FY 2008	FY 2009	FY 2010
Climate and Earth System Modeling	**35,141**	**72,029**	**69,775**
▪ **Regional and Global Climate Modeling**	**21,795**	**36,801**	**27,856**

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 regions to the globe. The activity supports research in the following core areas: 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 Nino Southern Oscillation, Pacific Decadal Oscillation, and Northern Annular Mode) changes as atmospheric greenhouse gas concentrations continue to increase.

In FY 2010, analyses will be conducted on a suite of global climate modeling experiments that are currently being planned under the auspices of the Working Group of Coupled Modeling (WGCM) of the World Climate Research Program. These simulations will be conducted by approximately 20 modeling groups world-wide, one of which will be supported by BER. It is anticipated this activity will be coordinated with other federal agencies, e.g., NASA, NOAA, and NSF. The analysis of these climate change projections will comprise the Climate Model Intercomparison Project (CMEP5). Research will also continue to support and coordinate model-data intercomparisons, the development and improvement of metrics and diagnostic tools for evaluating model performance, and the maintenance of test beds for evaluating model parameterizations. The effort will move beyond the traditional testing of atmospheric models to include testing and evaluation of high resolution ocean models, e.g., eddy permitting and eddy-resolving simulations. A peer-reviewed, multiyear-funded activity on regional modeling was begun in FY 2009 and will be completed in FY 2010. Additionally, a Congressionally-directed, collaborative activity with NNSA on scaling models from global to regional was begun in FY 2009 and will be completed in FY 2010.

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010
▪ **Earth System Modeling**	**8,536**	**25,596**	**30,596**

Earth System Modeling develops the components and the coupling mechanisms needed to develop the coupled 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 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. 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 understanding, detection, 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 simulate regional climate variability and change with greater fidelity.

In FY 2010, BER will focus on improvement and evaluation of earth system models incorporating advanced representations of cloud-aerosol and carbon-cycle-climate interactions; global cloud resolving modeling; incorporation of land-ice in the coupled climate model; and predictability on decadal time scales using ocean initialization. For example, the spread in climate change projections resulting from the use of different climate models has been identified as largely due to the different way cloud feedbacks are represented in different general circulation models, and it has been noted that atmospheric aerosols are one of the largest sources of uncertainty in quantifying radiative forcing. To advance the field, systematic development and thorough testing of various cloud and aerosol representations developed by improved process understanding is needed. The climate modeling program will continue to investigate physical mechanisms that have the potential to lead to abrupt climate change. Research will continue to improve the understanding of thresholds and nonlinearities in the climate system with a focus on mechanisms of abrupt climate change, incorporating these mechanisms into Earth System Models, and testing the models vis-à-vis records of past abrupt climate change.

In FY 2010, a focused activity will be undertaken to evaluate how earth system models simulate major modes of low frequency climate variability and how these are likely to change under enhanced greenhouse forcing. A new activity in FY 2010 for model visualization will develop new onsite and remote-access tools for model development and evaluation, real-time planning for field campaigns, and for expediting model intercomparisons. This visualization activity will provide access to several data sources, including the ARM facility data, needed to meet the goals of the activity. The visualization activity will enable users to render the data in a form that displays the evolution of the climate state variable and will provide powerful tools for testing hypotheses.

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010

Congressionally-directed, collaborative activities with NNSA on climate modeling and linking ground and space observations were begun in FY 2009 and will be completed in FY 2010.

▪ **Integrated Assessment**	**4,810**	**9,632**	**11,323**

Integrated Assessment research provides scientific insights into options for mitigation and 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.

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; development of 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 2010, BER will enhance research to enable new efforts and progress on several key research challenges identified in the recent Integrated Assessment Research Workshop held in November of 2008. And importantly, it responds to the challenge of "Science for Science Policy."[a] In particular, Integrated Assessment provides 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 enhanced research also responds to expressed congressional interest in developing improved science-based decision support tools on the human dimensions of climate change. Specifically, the increased funding would: pursue new and improved methodologies for representing the role of science, innovation, and potential transformational technological improvements within current modeling and analysis frameworks; support the incorporation of explicit representation of impacts adaptations within integrated assessment models with an initial emphasis on energy and infrastructure vulnerabilities and natural systems that significantly influence the overall carbon cycle; initiate development of regional modeling methods and capabilities to respond to critical needs for regional information; improve representations of energy-water-land interactions and interdependencies at relevant spatial and temporal scales; and support expansion beyond economics to reveal risk and uncertainty in perspectives of integrated assessment modeling. A Congressionally-directed, collaborative activity with NNSA to develop decision tools was initiated in FY 2009 and will be completed in FY 2010.

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[a] http://www.ostp.gov/galleries/NSTC%20Reports/39924_PDF%20Proof.pdf

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010
Climate and Environmental Facilities and Infrastructure	**88,944**	**94,450**	**99,479**
▪ **Atmospheric Radiation Measurement Climate Research Facility**	**37,644**	**40,353**	**41,809**

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.

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 2010, ACRF will continue its long-term observations from the fixed sites and will conduct four field experiments to study various cloud types—cirrus, marine, and mixed-phase (ice and water)—to improve computer models that simulate climate change. In 2010, new aerosol measurements from the Darwin site will be available to users; these data will support research on the impacts of biomass burning in the region. A campaign at the Southern Great Plains site will address outstanding questions regarding mid-latitude cirrus properties and processes. The first mobile facility will be deployed to study low marine clouds and aerosols in the Azores. The second mobile facility will study liquid and mixed-phase clouds in Colorado. These measurements support research efforts designed to address the largest uncertainties in the climate models. The increased funding will support a field experiment at the North Slope of Alaska site that will be the first to capture a full atmospheric profile of in situ cloud microphysics, aerosols, and radiative measurements during the arctic transition season.

Additional funds will also cover increased contractor defined-benefit pension liabilities costs at Pacific Northwest National Laboratory.

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010

	(estimated)		
	FY 2008	FY 2009	FY 2010
Achieved Operating Hours	8,320	N/A	N/A
Planned Operating Hours	7,905	7,884	7,884
Optimal hours	7,905	7,884	7,884
Percent of Optimal Hours	105%	100%	100%
Unscheduled Downtime	N/A	N/A	N/A
Number of Users[a]	1,092	1,000	1,000

- **Environmental Molecular Sciences Laboratory** **42,568** **48,448** **52,021**

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

EMSL encourages the use of multiple systems to provide fundamental understanding of the physical, chemical, and biological processes that underlie DOE's energy and environmental missions, 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 (NMR) 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 2010, EMSL operations funding is held near level, maintaining user facility operations and service to users. The FY 2009 budget request proposed a multiyear instrument refreshment activity and that effort will continue in FY 2010. 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. The new instrument requirements were derived from user workshops that brought together hundreds of scientists to discuss new capabilities needed for addressing the EMSL science themes. Additional programmatic general plant project funding is provided to complete construction of an addition to EMSL for radiochemistry that was initiated in FY 2009. This will provide the scientific community with advanced experimental resources for interfacial molecular

[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.

	FY 2008	FY 2009	FY 2010

(dollars in thousands)

science studies of radionuclides in environmental applications.

In FY 2010, funding will be provided for the following Major Items of Equipment: an Advanced Oxygen Plasma Assisted Molecular Beam Epitaxy (OPA-MBE) with a Total Estimated Cost of $3,200,000; a Secondary Ion Mass Spectrometer (SIMS) with a Total Estimated Cost of $4,500,000; and a Next Generation, High Magnetic Field Mass Spectrometer (HFMS) with a Total Estimated Cost of $3,000,000. These instruments will enable synthesis and characterization of oxide films and surfaces; provide extremely high resolution images and quantitative data of organic and inorganic samples; and 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.

(estimated)

	FY 2008	FY 2009	FY 2010
Achieved Operating Hours	4,340	N/A	N/A
Planned Operating Hours	4,365	4,365	4,365
Optimal hours	4,365	4,365	4,365
Percent of Optimal Hours	99.4%	100%	100%
Unscheduled Downtime	25	N/A	N/A
Number of Users[a]	643	750	750

- **Data Management and Education** **4,200** **4,199** **4,199**

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.

The Global Change Education Program (GCEP) supports undergraduate and graduate students conducting research on climate change using mentors from the DOE national laboratories and other institutions. GCEP supports both undergraduate and graduate studies through the DOE Summer Undergraduate Research Experience (SURE) and the DOE Graduate Research Environmental Fellowships (GREF). Their research is conducted under a mentor of their choice at either a university or a DOE laboratory. Funding for GREF and SURE only supports the students, not the mentor under whom they each choose to work. The SURE continues to be a magnet for highly qualified undergraduates, most of whom attend graduate school to study in fields directly related to their projects under SURE. Similarly, students in the GREF program have received graduate degrees and many have stayed in the field and initiated their own research.

In FY 2010, the data management activity will continue to support data users with tools for

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

	FY 2008	FY 2009	FY 2010
	(dollars in thousands)		

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. BER's Global Change Education Program will continue to support approximately 45 students to conduct research that is relevant to DOE's climate change research.

	FY 2008	FY 2009	FY 2010
▪ **General Purpose Equipment (GPE)**	**402**	**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 supports multi-purpose research.

	FY 2008	FY 2009	FY 2010
▪ **General Plant Projects (GPP)**	**4,130**	**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 funding for ORISE. The total estimated cost of each GPP project will not exceed $10,000,000.

	FY 2008	FY 2009	FY 2010
SBIR/STTR	**—**	**7,299**	**7,442**

In FY 2008, $5,118,000 and $483,000 were transferred to the SBIR and STTR programs, respectively. FY 2009 and FY 2010 amounts shown are the estimated requirements for continuation of the congressionally mandated SBIR and STTR programs.

	FY 2008	FY 2009	FY 2010
Total, Climate and Environmental Sciences	**227,102**	**278,725**	**285,706**

Explanation of Funding Changes

	FY 2010 vs. FY 2009 ($000)
Atmospheric System Research	
The increase will support additional development and testing of atmospheric model formulations for cloud and aerosol processes for the next generation Earth System Model.	+1,136
Environmental System Science	
▪ **Terrestrial Ecosystem Science**	
The increased funding will initiate 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.	+2,000

	FY 2010 vs. FY 2009 ($000)
▪ **Terrestrial Carbon Sequestration Research**	
Funding is decreased as a focused experiment on climate mitigation initiated in 2009 to study the role of subsurface process in sequestration will achieve its goals and be completed in 2010.	-486
▪ **Subsurface Biogeochemical Research**	
Increased funding will support fundamental research on reactive transport of transuranic contaminants in the subsurface, increasing the likelihood for success in DOE strategic initiatives for clean up of legacy nuclear wastes and nuclear energy applications.	+1,413
Total, Environmental System Science	**+2,927**
Climate and Earth System Modeling	
▪ **Regional and Global Climate Modeling**	
Funding is decreased as multiyear activities are completed in FY 2010. A peer-reviewed, multiyear-funded activity on regional modeling was begun in FY 2009 and will be completed in FY 2010. Additionally, a focused, multiyear-funded, collaborative activity with NNSA on scaling models from global to regional was begun in FY 2009 and will be completed in FY 2010.	-8,945
▪ **Earth System Modeling**	
The increase will develop a visualization activity for model development and evaluation, real-time field campaign planning, and model intercomparisons. The increase will also support a focused activity to evaluate how earth system models simulate major modes of low-frequency climate variability (El Nino Southern Oscillation, Pacific Decadal Oscillation, and Northern Annular Mode) and how these are likely to change under greenhouse forcing. Funding for multiyear, focused, collaborative activities with NNSA on climate modeling and linking ground and space observations are completed in FY2010.	+5,000
▪ **Integrated Assessment**	
Funding is increased to enable new efforts and progress on key research challenges including: 1) the incorporation of explicit representation of impacts and adaptations within integrated assessment models; 2) the development of regional modeling methods and capabilities; 3) improved representations of energy-water-land interactions and interdependencies at relevant spatial and temporal scales; and 4) expansion beyond economics to reveal risk and uncertainty for perspectives of integrated assessment modeling.	+1,691
Total, Climate and Earth System Modeling	**-2,254**

	FY 2010 vs. FY 2009 ($000)
Climate and Environmental Facilities and Infrastructure	
▪ **ARM Climate Research Facility**	
The increase will support a field experiment at the North Slope of Alaska site that will be the first to capture a full atmospheric profile of in situ cloud microphysics, aerosols and radiative measurements during the arctic transition season.	+1,456
▪ **EMSL Operations and Infrastructure**	
The increase in EMSL capital equipment funding is provided to continue refresh of capital equipment for EMSL that was initiated in FY 2009. Additional programmatic GPP funding is provided to complete construction of an addition to EMSL for radiochemistry that was initiated in FY 2009.	+3,573
Total, Climate and Environmental Facilities and Infrastructure	**+5,029**
SBIR/STTR	
SBIR/STTR is increased as research support is enhanced.	+143
Total Funding Change, Climate and Environmental Sciences	**+6,981**

Supporting Information

Operating Expenses, Capital Equipment and Construction Summary

(dollars in thousands)

	FY 2008	FY 2009	FY 2010
Operating Expenses	507,554	554,101	560,666
Capital Equipment	19,379	28,777	24,164
General Plant Projects (GPP)	4,130	2,700	3,200
Other	—	15,962	16,152
Total BER	531,063	601,540	604,182

Funding Summary

(dollars in thousands)

	FY 2008	FY 2009	FY 2010
Research			
National Laboratories	229,414	265,000	265,991
University Research	126,439	128,888	120,921
Other Research[a]	5,955	19,139	5,838
Total Research	361,808	413,027	392,750
Scientific User Facilities Operations and Research	160,223	169,101	178,130
Major Items of Equipment	4,500	—	10,700
Facility related GPP	—	2,000	2,500
Other[b]	4,532	17,412	20,102
Total BER	531,063	601,540	604,182

Scientific User Facilities Operations and Research

(dollars in thousands)

	FY 2008	FY 2009	FY 2010
Biological Systems Science			
Structural Biology Infrastructure	15,446	15,300	15,300
Joint Genomics Institute	64,565	65,000	69,000
Total, Biological Systems Science	80,011	80,300	84,300

[a] Includes funding for other Federal Agencies and Industrial Firms.
[b] Includes General Purpose Equipment, GPP, SBIR and STTR.

	(dollars in thousands)		
	FY 2008	FY 2009	FY 2010
Climate and Environmental Sciences			
Atmospheric Radiation Measurement Climate Research Facility	37,644	40,353	41,809
Environmental Molecular Sciences Laboratory	42,568	48,448	52,021
Total, Climate and Environmental Science	80,212	88,801	93,830
Total Science User Facilities Operations and Research	160,223	169,101	178,130

Facilities Users and Hours

	FY 2008	FY 2009	FY 2010
Joint Genome Institute			
Achieved Operating Hours	7,704	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	92%	100%	100%
Unscheduled Downtime	696	N/A	N/A
Number of Users[a]	679	780	940
Atmospheric Radiation Measurement (ARM)Climate Research Facility (ACRF)			
Achieved Operating Hours	8,320	N/A	N/A
Planned Operating Hours	7,905	7,884	7,884
Optimal hours	7,905	7,884	7,884
Percent of Optimal Hours	105%	100%	100%
Unscheduled Downtime	N/A	N/A	N/A
Number of Users[b]	1,092	1,000	1,000

[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.

	FY 2008	FY 2009	FY 2010
Environmental Molecular Sciences Laboratory			
Achieved Operating Hours	4,340	N/A	N/A
Planned Operating Hours	4,365	4,365	4,365
Optimal hours	4,365	4,365	4,365
Percent of Optimal Hours	99.4%	100%	100%
Unscheduled Downtime	25	N/A	N/A
Number of Users[a]	643	750	750
Total Facilities			
Achieved Operating Hours	20,365	N/A	N/A
Planned Operating Hours	20,670	20,649	20,649
Optimal hours	20,670	20,649	20,649
Percent of Optimal Hours	98.5%	100%	100%
Unscheduled Downtime	721	N/A	N/A
Number of Users	1,670	1,770	1,775

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

Major Items of Equipment

(dollars in thousands)

	Prior Years	FY 2008	FY 2009	FY 2009 Additional Approp.	FY 2010	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)	—	—	—	3,000	—	—	3,000
Dual-Frequency Scanning Cloud Radar for North Slope of Alaska ARM Site							
TEC/TPC	—	—	—	3,000	—	—	3,000
Dual-Frequency Scanning Cloud Radar for Tropical Western Pacific (Manus) ARM Site							
TEC/TPC	—	—	—	3,000	—	—	3,000

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

	(dollars in thousands)						
	Prior Years	FY 2008	FY 2009	FY 2009 Additional Approp.	FY 2010	Outyears	Total
Dual-Frequency Scanning Cloud Radar for ARM Mobile Facility #1							
TEC/TPC	—	—	—	3,000	—	—	3,000
Dual-Frequency Scanning Cloud Radar for ARM Mobile Facility #2							
TEC/TPC	—	—	—	3,000	—	—	3,000
Dual-Frequency Scanning Cloud Radar for Tropical Western Pacific (Darwin) ARM Site							
TEC/TPC	—	—	—	3,000	—	—	3,000
Raman Lidar							
TEC/TPC	—	—	—	2,100	—	—	2,100
Total ACRF TEC/TPC	—	—	—	20,100	—	—	
Environmental Molecular Sciences Laboratory (EMSL)							
Field Emission-Transmission Electron Microscope (FE-TEM)							
TEC/TPC	—	4,500	—	—	—	—	4,500
Standard Transmission Electron Microscope (TEM)							
TEC/TPC	—	—	—	2,865	—	—	2,865
X-ray Phtotelectron Spectrometer (XPS)							
TEC/TPC	—	—	—	2,060	—	—	2,060
3-D Atom Probe							
TEC/TPC	—	—	—	2,335	—	—	2,335
Electron Microprobe							
TEC/TPC	—	—	—	2,335	—	—	2,335
700 Mega-Hertz Wide Bore Nuclear Magnetic Resonance (NMR) Spectrometer							
TEC/TPC	—	—	—	2,600	—	—	2,600
15 Tesla Fourier Transform-Ion Cyclotron Resonance (FT-ICR) Mass Spectrometer (MS)							
TEC/TPC	—	—	—	2,850	—	—	2,850

(dollars in thousands)

	Prior Years	FY 2008	FY 2009	FY 2009 Additional Approp.	FY 2010	Outyears	Total
Ultra-High Vacuum (UHV) Scanning Tunneling Microscope/Atomic Force Microscope (STM/AFM)							
TEC/TPC	—	—	—	2,200	—	—	2,200
850 MegaHertz Wide Bore Nuclear Magnetic Resonance (NMR) Spectrometer							
TEC/TPC	—	—	—	4,425	—	—	4,425
3-D Microscope System (e.g., Helium Ion Microscope)							
TEC/TPC	—	—	—	2,025	—	—	2,025
Integrated Optical Spectroscopy System							
TEC/TPC	—	—	—	2,075	—	—	2,075
Advanced Mass Spectrometry System							
TEC/TPC	—	—	—	2,680	—	—	2,680
Advanced Oxygen Plasma Assisted Molecular Beam Epitaxy (OPA-MBE) system							
TEC/TPC	—	—	—	—	3,200	—	3,200
Secondary Ion Mass Spectrometer (SIMS)							
TEC/TPC	—	—	—	—	4,500	—	4,500
Next Generation, High Magnetic Field Mass Spectrometer (HFMS)							
TEC/TPC	—	—	—	—	3,000	14,500	17,500
Total EMSL TEC/TPC		4,500	—	28,450	10,700		
Total BER TEC/TPC		4,500	—	48,550	10,700		

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.

Raman Lidar. This instrument will provide the capability to measure vertical profiles of water vapor, aerosols, and cloud properties. 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 replace EMSL’s workhorse TEM. Enables nano-meter structural and chemical characterization of complex synthesized and natural materials relevant to catalysis, fuels 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. Relevant to mineral/contaminant interactions, aging and degradation of solar cells and solid state lighting and catalytic surfaces.

Atom Probe for three dimensional atomic scale imaging of complex materials including solid-solid “buried” interfaces. To be used for material surface studies relevant to subsurface remediation, photovoltaics and catalysis.

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

700 Megahertz Wide Bore Nuclear Magnetic Resonance (NMR) Spectrometer system 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. Application to intact proteins and protein modification studies to 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. To 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 would be relevant to energy-relevant materials (including catalysts) and minerals and contaminants.

Three Dimensional Microscope System (e.g., Helium Ion Microscope) 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.

Integrated Optical Spectroscopy System combines three approaches for the study of surfaces and interfaces and will be useful in advancing alternative energy sources, processing science and geochemistry.

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 (OPA-MBE) system is designed for the growth of a wide variety of oxide materials and will be funded at $3,200,000 total estimated cost (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 (SIMS) 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 (HFMS) 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. 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 2008	FY 2009	FY 2010
		(estimated)	
# University Grants	447	480	475
Average Size per year	$320,000	$320,000	$320,000
# Laboratory Projects	355	375	370
# Permanent Ph.D.s[a]	1,320	1,480	1,460
# Postdoctoral Associates[b]	304	340	335
# Graduate Students[c]	429	485	480
# Ph.D.s awarded[c]	105	105	110

Budget Structure Funding Crosswalk

Biological and Environmental Research Comparability Matrix from FY 2009 to FY 2010 Budget Structure—FY 2008 Funding

(dollars in thousands)

	FY 2009 Budget Structure					
	Biological Research					
	Life Sciences	Medical Applica-tions	Environ-mental Remedi-ation	Total, Biological Research	Climate Change Research	Total, BER
FY 2010 Budget Structure						
Biological Systems Science						
Genomic Science	164,085	—	—	164,085	—	164,085
Radiological Sciences	46,674	—	—	46,674	—	46,674
Ethical, Legal, and Societal Issues	5,000	—	—	5,000	—	5,000
Medical Applications	—	8,191	—	8,191	—	8,191
Biological Systems Facilities and Infrastructure	80,011	—	—	80,011	—	80,011
Total, Biological Systems Science	295,770	8,191	—	303,961	—	303,961
Climate and Environmental Sciences						
Atmospheric System Research	—	—	—	—	25,201	25,201
Environmental System Science	—	—	46,915	46,915	30,901	77,816

[a] 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.
[b] Estimated for national laboratory projects.
[c] 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.

(dollars in thousands)

	FY 2009 Budget Structure					
	Biological Research					
Climate and Earth System Modeling	—	—	—	—	35,141	35,141
Climate and Environmental Facilities and Infrastructure	—	—	47,100	47,100	41,844	88,944
Total Climate and Environmental Sciences	—	—	94,015	94,015	133,087	227,102
Total, BER	295,770	8,191	94,015	397,976	133,087	531,063

Life Sciences Comparability Matrix from FY 2009 to FY 2010 Budget Structure—FY 2008 Funding

(dollars in thousands)

	FY 2009 Budget Structure					
	Structural Biology	Molecular & Cellular Biology	Human Genome	Health Effects	Radio-chemistry & Instru-mentation	Total, Life Sciences
FY 2010 Budget Structure						
Biological Systems Science						
Genomic Science						
Foundational Genomics Research	—	33,422	—	—	—	33,422
Genomics Analysis and Validation	—	—	10,521	—	—	10,521
Metabolic Synthesis and Conversion	—	41,297	—	—	—	41,297
Computational Biosciences	—	3,845	—	—	—	3,845
Bioenergy Research Centers	—	75,000	—	—	—	75,000
Total, Genomic Science	—	153,564	10,521	—	—	164,085
Radiological Sciences						
Radiochemistry and Imaging Instrumentation	—	—	—	—	21,789	21,789
Radiobiology	—	17,983	—	6,902	—	24,885
Total, Radiological Sciences	—	17,983	—	6,902	21,789	46,674
Ethical, Legal, and Societal Issues	—	—	5,000	—	—	5,000
Biological Systems Facilities and Infrastructure						
Structural Biology Infrastructure	15,446	—	—	—	—	15,446
Joint Genome Institute	—	10,000	54,565	—	—	64,565
Total, Biological Systems Facilities and Infrastructure	15,446	10,000	54,565	—	—	80,011
Total, Biological Systems Science	15,446	181,547	70,086	6,902	21,789	295,770

Environmental Remediation Comparability Matrix from FY 2009 to FY 2010 Budget Structure—FY 2008 Funding

(dollars in thousands)

	FY 2009 Budget Structure		
	Environmental Remediation Research	Facility Operations (EMSL)	Total Environmental Remediation
FY 2010 Budget Structure			
Climate and Environmental Sciences			
Environmental System Science			
Subsurface Biogeochemical Research	46,915	—	46,915
Climate and Environmental Facilities and Infrastructure			
EMSL Operations	—	42,568	42,568
General Purpose Equipment	4,532	—	4,532
Total, Climate and Environmental Facilities and Infrastructure	4,532	42,568	47,100
Total Climate and Environmental Sciences	51,447	42,568	94,015

Climate Change Research Comparability Matrix from FY 2009 to FY 2010 Budget Structure—FY 2008 Funding

(dollars in thousands)

	FY 2009 Budget Structure				
	Climate Forcing	Climate Change Modeling	Climate Change Response	Climate Change Mitigation	Total, Climate Change Research
FY 2010 Budget Structure					
Climate and Environmental Sciences					
Atmospheric System Research	25,201	—	—	—	25,201
Environmental System Science					
Terrestrial Ecosystem Science	11,849	—	14,156	—	26,005
Terrestrial Carbon Sequestration Research	—	—	—	4,896	4,896
Total, Environmental System Science	11,849	—	14,156	4,896	30,901
Climate and Earth System Modeling					
Regional and Global Climate Modeling	—	21,795	—	—	21,795
Earth System Modeling	—	8,536	—	—	8,536
Integrated Assessment	—	—	4,810	—	4,810
Total, Climate and Earth System Modeling	—	30,331	4,810	—	35,141

(dollars in thousands)

	FY 2009 Budget Structure				
	Climate Forcing	Climate Change Modeling	Climate Change Response	Climate Change Mitigation	Total, Climate Change Research
Climate and Environmental Facilities and Infrastructure					
ARM Operations and Infrastructure	37,644	—	—	—	37,644
Data Management and Education	2,778	—	1,422	—	4,200
Total, Climate and Environmental Facilities and Infrastructure	40,422	—	1,422	—	41,844
Total Climate and Environmental Sciences	77,472	30,331	20,388	4,896	133,087

Biological and Environmental Research Comparability Matrix from FY 2009 to FY 2010 Budget Structure—FY 2009 Funding

(dollars in thousands)

	FY 2009 Budget Structure					
	Biological Research					
	Life Sciences	Medical Applica-tions	Environ-mental Remedi-ation	Total, Biological Research	Climate Change Research	Total, BER
FY 2010 Budget Structure						
Biological Systems Science						
Genomic Science	169,858	—	—	169,858	—	169,858
Radiological Sciences	50,768	—	—	50,768	—	50,768
Ethical, Legal, and Societal Issues	5,000	—	—	5,000	—	5,000
Medical Applications	—	8,226	—	8,226	—	8,226
Biological Systems Facilities and Infrastructure	80,300	—	—	80,300	—	80,300
SBIR/STTR	8,663	—	—	8,663	—	8,663
Total, Biological Systems Science	314,589	8,226	—	322,815	—	322,815
Climate and Environmental Sciences						
Atmospheric System Research	—	—	—	—	25,316	25,316
Environmental System Science	—	—	48,485	48,485	31,146	79,631
Climate and Earth System Modeling	—	—	—	—	72,029	72,029
Climate and Environmental Facilities and Infrastructure	—	—	49,898	49,898	44,552	94,450
SBIR/STTR	—	—	2,415	2,415	4,884	7,299
Total Climate and Environmental Sciences	—	—	100,798	100,798	177,927	278,725
Total, BER	314,589	8,226	100,798	423,613	177,927	601,540

Life Sciences Comparability Matrix from FY 2009 to FY 2010 Budget Structure—FY 2009 Funding

(dollars in thousands)

	FY 2009 Budget Structure						
	Structural Biology	Molecular & Cellular Biology	Human Genome	Health Effects	Radio-chemistry & Instru-mentation	SBIR/ STTR	Total, Life Sciences
FY 2010 Budget Structure							
Biological Systems Science							
Genomic Science							
Foundational Genomics Research	—	38,267	—	—	—	—	38,267
Genomics Analysis and Validation	—	—	10,000	—	—	—	10,000
Metabolic Synthesis and Conversion	—	42,127	—	—	—	—	42,127
Computational Biosciences	—	4,464	—	—	—	—	4,464
Bioenergy Research Centers	—	75,000	—	—	—	—	75,000
Total, Genomic Science	—	159,858	10,000	—	—	—	169,858
Radiological Sciences							
Radiochemistry and Imaging Instrumentation	—	—	—	—	22,841	—	22,841
Radiobiology	—	20,606	—	7,321	—	—	27,927
Total, Radiological Sciences	—	20,606	—	7,321	22,841	—	50,768
Ethical, Legal, and Societal Issues	—	—	5,000	—	—	—	5,000
Biological Systems Facilities and Infrastructure							
Structural Biology Infrastructure	15,300	—	—	—	—	—	15,300
Joint Genome Institute	—	10,000	55,000	—	—	—	65,000
Total, Biological Systems Facilities and Infrastructure	15,300	10,000	55,000	—	—	—	80,300
SBIR/STTR	—	—	—	—	—	8,663	8,663
Total, Biological Systems Science	15,300	190,464	70,000	7,321	22,841	8,663	314,589

Environmental Remediation Comparability Matrix from FY 2009 to FY 2010 Budget Structure—FY 2009 Funding

(dollars in thousands)

	FY 2009 Budget Structure			
	Environmental Remediation Research	Facility Operations (EMSL)	SBIR/STTR	Total Environmental Remediation
FY 2010 Budget Structure				
Climate and Environmental Sciences				
Environmental System Science				
Subsurface Biogeochemical Research	48,485	—	—	48,485
Climate and Environmental Facilities and Infrastructure				
EMSL Operations	—	48,448	—	48,448
General Purpose Equipment	1,450	—	—	1,450
Total, Climate and Environmental Facilities and Infrastructure	1,450	48,448	—	49,898
SBIR/STTR	—	—	2,415	2,415
Total Climate and Environmental Sciences	49,935	48,448	2,415	100,798

Climate Change Research Comparability Matrix from FY 2009 to FY 2010 Budget Structure—FY 2009 Funding

(dollars in thousands)

	FY 2009 Budget Structure					
	Climate Forcing	Climate Change Modeling	Climate Change Response	Climate Change Mitigation	SBIR/ STTR	Total, Climate Change Research
FY 2010 Budget Structure						
Climate and Environmental Sciences						
Atmospheric System Research	25,316	—	—	—	—	25,316
Environmental System Science						
Terrestrial Ecosystem Science	12,731	—	13,182	—	—	25,913
Terrestrial Carbon Sequestration Research	—	—	—	5,233	—	5,233
Total, Environmental System Science	12,731	—	13,182	5,233	—	31,146

(dollars in thousands)

	FY 2009 Budget Structure					
	Climate Forcing	Climate Change Modeling	Climate Change Response	Climate Change Mitigation	SBIR/ STTR	Total, Climate Change Research
Climate and Earth System Modeling						
Regional and Global Climate Modeling	—	36,801	—	—	—	36,801
Earth System Modeling	—	25,596	—	—	—	25,596
Integrated Assessment	—	—	9,632	—	—	9,632
Total, Climate and Earth System Modeling	—	62,397	9,632	—	—	72,029
Climate and Environmental Facilities and Infrastructure						
ARM Operations and Infrastructure	40,353	—	—	—	—	40,353
Data Management and Education	2,773	—	1,426	—	—	4,199
Total, Climate and Environmental Facilities and Infrastructure	43,126	—	1,426	—	—	44,552
SBIR/STTR	—	—	—	—	4,884	4,884
Total Climate and Environmental Sciences	81,173	62,397	24,240	5,233	4,884	177,927