Biological and Environmental Research

Funding Profile by Subprogram

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
Biological and Environmental Research		
Biological Systems Science	309,766	376,262
Climate and Environmental Sciences	278,265	341,638
Total, Biological and Environmental Research	588,031[a]	717,900

Public Law Authorizations:
Public Law 95–91, "Department of Energy Organization Act", 1977
Public Law 109–58, "Energy Policy Act of 2005"
Public Law 110–69, "America COMPETES Act of 2007"
Public Law 111–358, "America COMPETES Act of 2010"

Program Overview

Mission

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

Background

We live in a world shaped and dominated by forms of life that we cannot even see—the world of microbes. Over the millennia, microbes formed an atmosphere that supports life on Earth as we know it today and the fertile soils on which we grow our food. They are Earth's ultimate recyclers, whether contributing to the global carbon cycle, a key component of climate change, or processing toxic environmental contaminants including those from energy production and DOE's Cold War activities. Understanding the remarkable diversity and capabilities of these minute forms of life is a key element of the BER program. By unlocking the secrets held in the DNA of these remarkable creatures, creatures found in every conceivable spot on Earth from boiling deep sea vents to frozen tundra, we can devise biologically inspired solutions to many challenges facing us today—clean energy, global warming, and environmental contamination.

Plants also hold potential solutions for many of the energy and environmental challenges facing our Nation and are a central element of the BER program. Although critical sources of nutrition for all of us, plants are also significant recyclers of carbon dioxide and hold the promise as feedstocks for clean, renewable sources of energy. But just as with microbes, this potential is locked in the fundamental biology that has given rise to the diversity of plants we know today. Only by unlocking the mysteries of

[a] Total is reduced by $16,151,000, $14,421,000 of which was transferred to the Small Business Innovation Research (SBIR) program, and $1,730,000 of which was transferred to the Small Business Technology Transfer (STTR) program. Additionally, $153,000 of prior year balances was transferred as follows: $137,000 for SBIR and $16,000 for STTR.

plant biology can we develop new strategies that will revolutionize the future of renewable energy use and development.

The BER science portfolio includes research programs and scientific user facilities addressing some of today's most important and mission-critical problems in biological, climatic, and environmental research. Two areas vital to the Nation's energy security and environmental future lie at the core of the BER research agenda: developing cost-effective cellulosic biofuels and improving our ability to understand, predict, and mitigate the impacts of energy production and use on climate change. Over the decades, BER's impact on the scientific world has been transformative, and this commitment to scientific leadership continues today. In 1986, BER initiated the Human Genome Project, which eventually gave birth to the modern biotechnology revolution and virtually created the new field of genomics-based systems biology. Today, with its Genomic Sciences Program and the DOE Joint Genome Institute (JGI) now sequencing over four trillion genome base pairs per year, BER-supported researchers are using the powerful tools of contemporary systems biology to pursue the scientific breakthroughs needed for the development of cost-effective cellulosic biofuels. They are probing the role that microbes can play in environmental remediation and gaining critical insight into the terrestrial carbon cycle. Indeed, BER-sponsored researchers lead the world in the sequencing, study, and reengineering of microorganisms and plants with direct relevance to energy, climate, and environment. From the characterization of biological molecules and the probing and modeling of cellular metabolism, to the genomic redesign of microbes and plants, to the capture of powerful new enzymes through the metagenomic sequencing of microbial communities, BER-supported researchers are penetrating some of the deepest mysteries of living systems and uncovering powerful new biological tools to help meet the Nation's major challenges in energy and climate. As part of the Genomic Sciences program, our three DOE Bioenergy Research Centers lead the world in fundamental biofuels research. This research is laying the foundation for a revolution in the technologies of biofuels production and contributing to unprecedented deepening of our fundamental knowledge of microbial and plant systems.

BER has similarly had a longstanding leadership role in climate science. The first studies of atmospheric circulation—forerunners of today's climate models—were initiated by SC's predecessor agency, the Atomic Energy Commission's Division of Research, in the 1950s; it was the AEC that led the way in applying computation to the study of climate in the early decades, motivated initially by an interest in radioactive fallout. Today, building on this legacy, BER is a major supporter of the Community Climate System Model, a leading U.S. climate model. Improvement of today's climate models will depend heavily on gaining a more accurate understanding of climate processes, and BER's program addresses two of the most critical and challenging areas of uncertainty in contemporary climate science: the impact of clouds and aerosols. BER supports the world's leading facility for the study of clouds and aerosols, the Atmospheric Radiation Measurement Climate Research Facility, used by hundreds of scientists worldwide. Funds from the American Recovery and Reinvestment Act (Recovery Act) have enabled a major upgrade of ARM instrumentation, which will provide data and insights needed to model these key climate processes more accurately. At the same time, through its research program, BER is spearheading greater and more rapid integration of climate data into climate models. The Program for Climate Model Diagnosis and Intercomparison project at Lawrence Livermore National Laboratory, supported by BER, remains the gold standard in climate model evaluation and validation. In addition, BER is supporting cutting-edge research into the terrestrial carbon cycle, another major piece of the climate puzzle where there are many unknowns.

Through close partnership with the Advanced Scientific Computing Research (ASCR) program, BER is leveraging DOE's high-end computational modeling, simulation, and data capabilities. DOE's world-leading computational facilities—including a new generation of petaflop computers—are enabling BER-supported researchers to increase the complexity and resolution of models and to tackle new problems that were too computationally intense for an earlier generation of machines. Among these projects was the first-ever high-resolution modeling of abrupt climate change using the Cray Jaguar XT5 at Oak Ridge National Laboratory, one of the fastest computers in the world.

Simultaneously, BER actively encourages its community of biology researchers to begin to take greater advantage of DOE's computational resources for computational biology and bioinformatics. Seed money from the Recovery Act has enabled BER to launch an initiative for a Systems Biology Knowledgebase—an effort to harness computational resources to address one of the greatest challenges of contemporary systems biology: mining knowledge from the mountain of data that is accumulating from genomic sequencing and other high-throughput "omics" technologies.

Confronted with the Cold War legacy of subsurface toxins at DOE sites, BER pioneered the new frontier of subsurface science, with BER-supported researchers discovering novel microorganisms and understanding important geochemical and hydrological processes, including the fate of environmental contaminants. The BER-supported Environmental Molecular Science Laboratory (EMSL) at Pacific Northwest National Laboratory (PNNL) provides one of the world's most powerful suites of instruments for the characterization of biological organisms and molecules, combined with enormous computational resources, enabling researchers to attack problems from multiple angles. EMSL's instrumentation was recently upgraded with a major infusion of Recovery Act funds. With EMSL's unique capabilities, PNNL leads the world in the field of proteomics.

A common theme across BER's research portfolio is the challenge and excitement of studying complex systems. Biology, climate, and subsurface environments alike confront researchers with systems not easily understood though simple reductive methods, and which pose major challenges of scale at both ends of the continuum, from the infinitesimal to the global. A major part of the intellectual excitement shared by BER-supported researchers lies in the challenges to scientific ingenuity and creativity posed by these complex systems for those who would seek useable knowledge and practical solutions from their investigation. BER's search for mission-relevant solutions to the Nation's major challenges in energy, climate, and environment is inextricably bound up with the search for foundational and fundamental insights into nature and requires the tools, the perspective, and the intellectual curiosity and integrity that are the hallmark of basic science.

Major scientific goals for BER include:

- **Genomic Science:** conducting explorations of microbes and plants at the molecular, cellular, and community levels with the goal of gaining insight about fundamental biological processes, ultimately leading to a predictive understanding of how living systems operate. This challenge is articulated in a 2009 National Research Council report on "A New Biology for the 21st Century,"[a] which advocates the systems-level study of biological systems using the latest interdisciplinary tools and approaches.

- **Radiological Sciences:** supporting research in radiochemistry and radiotracer development with the goal of developing new methodologies for real-time, high-resolution imaging of dynamic biological systems. This goal is supported by a 2008 community-based workshop, "New Frontiers of Science in Radiochemistry and Instrumentation for Radionuclide Imaging."[b] Radiobiology provides systems level research to understand radiation-induced perturbations of physiological processes.

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[a] http://www.nap.edu/openbook.php?record_id=12764
[b] http://www.sc.doe.gov/ober/radiochem_2008workshop_report.pdf

- **Climate Research:** supporting research in atmospheric and environmental systems, and predictive climate and Earth system models. This research is guided by a 2008 report by the BER Advisory Committee entitled, "Identifying Outstanding Grand Challenges in Climate Change Research: Guiding DOE's Strategic Planning."[a] The report recommended that BER research seek to understand Earth's climate system by characterizing current climate and its evolution over the last century to its present state, predicting regional climate change for the next several decades, and simulating Earth System changes and their consequences over centuries. Additional scientific insights were determined from a May 2010 community based workshop, "Climate Research Roadmap Workshop." Topics discussed included improving model simulations and quantifying uncertainty, enhancing the representation of biogeochemical process in models, and a focus on understanding and quantifying the mechanisms responsible for cloud feedbacks and aerosol effects on clouds and climate in order to improve the reliability of predictions of climate change in the future with particular attention to the impact on the radiative balance and precipitation.
- **Subsurface Biogeochemistry:** seeking to understand the role that subsurface biogeochemical processes play in determining the fate and transport of contaminants including heavy metals and radionuclides. Computational models of coupled biological, geochemical, and hydrological processes are needed to predict the rates and kinetics of transformation and sequestration of these critical DOE contaminants. This research is guided by the March 2010 community-based workshop report, "Complex Systems Science for Subsurface Fate and Transport."[b]

Subprograms

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

- The *Biological Systems Science* subprogram explores the fundamental principles that drive the function and structure of living systems. The target systems range from microbes and microbial communities to plants and other whole organisms. Using the genome as a blueprint, Genomic Science 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 and clean energy. The BRCs have accelerated progress in using systems biology tools to reengineer organisms and adapt them to address energy solutions. The potential for systems biology to address our energy challenges is enormous and only realized through standardization and centralization of knowledge and tools. A mature synthetic systems biology approach would have well-characterized, standardized functional biological components along with well-articulated design principles. In time, the goal would be to achieve computer-aided design of new biological systems for clean energy solutions and a range of other applications. As part of the President's commitment to clean energy R&D, BER is supporting foundational research toward this end. New Genomic Science research will identify and articulate general biological design principles, enabling functional characterizations of biological systems and synthetic redesign, paving the way for new clean energy sources. The impact of such an effort—not only on the search for energy solutions, but on U.S. competitiveness in a global bio-based economy—could be comparable to the sweeping impact of the genomics revolution, launched when

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[a] http://www.sc.doe.gov/ober/berac/Grand_Challenges_Report.pdf
[b] http://www.sc.doe.gov/ober/subsurfacecomplexity_03-05-10.pdf

DOE initiated the Human Genome Project in 1986. The DOE Joint Genome Institute (JGI), a high-throughput DNA sequencing user facility, provides the basis for systems biology and unmatched capabilities to understand and predict the function of environmental and energy-related microbes and plants. Current sequencing capacity at the JGI is over 4 trillion base pairs per year (compared to about 3 billion base pairs for the entire human genome) and growing rapidly. To understand the proteins encoded by DNA, the Structural Biology activity supports access to DOE's world-class synchrotron and neutron sources. The interface between biology and the physical sciences is explored in the Radiological Sciences with new methods for real-time high resolution imaging of dynamic biological processes and with molecular and genomic biology to underpin radiation risk policy.

- The *Climate and Environmental Sciences* subprogram advances science to understand, predict, and mitigate the impacts of energy production and use on the Earth system. Atmospheric System Research supports research to help resolve two the greatest uncertainties in climate change—the role of clouds and aerosols in Earth's radiation balance. The Atmospheric Radiation Measurement Climate Research Facility provides key observational data to the climate research community on clouds and properties of the atmosphere, especially their impact on the radiative balance. The facility includes highly instrumented ground stations, two mobile facilities, and an aerial vehicles program; it served 1,200 users from around the world in FY 2010. Climate and Earth System Modeling develops and evaluates powerful and sophisticated climate models that contribute to reports by the Intergovernmental Panel on Climate Change. 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) houses a supercomputer and over 60 major instruments, providing integrated experimental and computational resources for discovery and technological innovation in the environmental molecular sciences, and in systems biology by providing leading edge capabilities in proteomics. EMSL serves over 700 users annually.

Benefits

BER science continues to have broad benefits for society and for science. BER's long history of biological discovery has advanced scientific discovery, improved human health, and revolutionized the field of biology. Today, some of the most daunting scientific challenges for DOE require understanding and ultimately predicting the behaviors of plant and microbial systems.

BER research on a range of biological challenges has led to the development of a number of biology-based solutions: microbes that chemically alter environmental contaminants; fungi and bacteria that degrade plant cell walls or produce next-generation biofuels; and trees, grasses, algae, and microbes that cycle carbon or serve as sources for biofuels production.

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

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

BER researchers have pushed the technological frontiers by not only demanding but also achieving increasingly sophisticated characterization of the chemical and biological constituents of living systems. Their expanding toolkit includes the high-throughput sequencing capabilities underpinning all modern genomics; mass spectrometry to predict and identify proteins, metabolites, and lipids; and a wide-ranging array of imaging and spectroscopic techniques (many located at the DOE light sources) to enable the functional determinants of protein structures. The advances resulting from such multi-disciplinary approaches provide an unprecedented opportunity to achieve a deeper understanding of the natural world at all levels.

Program Planning and Management

BER uses broad input from scientific workshops and external reviews, including those performed by the National Academies, to identify current and future scientific and technical needs and challenges in current national and international research efforts. The resulting National Academies' reports e.g., "Research at the Intersection of the Physical and Life Sciences"[a] and BER scientific workshop reports are available online.[b] 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.

In FY 2010, BERAC was charged to develop an overall strategy for drafting a long-term vision for BER. A key focus of this visioning activity was 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 pursue to achieve its future mission challenges; and the future scientific and technical advances needed to underpin BER's complex systems science. BERAC's report, "Grand Challenges for Biological and Environmental Research: A Long-Term Vision identified grand challenges in complex systems and synthetic biology, climate modeling and climate-related ecosystem science, energy sustainability, computing, and education and workforce development".[c]

BERAC conducts reviews of BER subprograms by COVs every three years. Results of these reviews and BER responses are posted online.[d] A COV was assembled in 2010 to review the Climate and Environmental Sciences Division of the BER program, and one is planned for 2011 to review the Biological Systems Science Division. 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.

The BER program is coordinated with activities of other federal organizations supporting or conducting complementary research, e.g., the National Science Foundation, National Aeronautics and Space

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[a] http://www.nap.edu/catalog.php?record_id=12809
[b] http://www.sc.doe.gov/ober/BER_workshops.html
[c] http://www.science.doe.gov/ober/berac/BER_LTVreport.pdf
[d] http://www.science.doe.gov/SC-2/Committee_of_Visitors.htm

Administration, Department of Commerce/National Oceanic and Atmospheric Administration, Environmental Protection Agency, Nuclear Regulatory Commission, Department of Agriculture (USDA), National Institutes of Health, Department of State, and Department of Defense. BER Climate Change Research is coordinated with the U.S. Global Change Research Program, an interagency program codified by Public Law 101–606 and involving thirteen federal agencies and departments, and the U.S. Climate Change Technology Program. BER supports research at universities, research institutes, private companies, and DOE national laboratories. All BER-supported research undergoes regular peer review and merit evaluation based on procedures established in 10 CFR 605 for the external grant program and using a similar process for research at the national laboratories.

Basic and Applied R&D Coordination

BER research underpins the needs of DOE's energy and environmental missions. Fundamental research on microbes and plants to understand their biochemical pathways and the genetic mechanisms that control their interactions and behavior provides knowledge needed by DOE's Office of Energy Efficiency and Renewable Energy (EERE) and the USDA about new bioenergy crops and bioenergy production facilities that are cost effective and sustainable. For EERE, much of the research being carried out at the three BER-funded Bioenergy Research Centers is providing foundational knowledge for application by EERE to development of systems for conversion of biomass to biofuels that can be commercialized. BER's "Plant Feedstock Genomics for Bioenergy" program is jointly managed with and funded by USDA's National Institute of Food and Agriculture to provide fundamental knowledge about potential biomass crops.

BER research on the behavior and interactions of contaminants in the subsurface environment provides knowledge needed by DOE's Office of Environmental Management (EM) to develop new strategies for the remediation of weapons-related contaminants at DOE sites and by DOE's Office of Legacy Management (LM) to develop tools for monitoring the long-term status of contaminants at cleanup sites. BER continues to build on breakthrough advances in microbial genome science to measure expressed genes for a variety of metabolic processes in the environment and couple these results with advanced *in silico* computational approaches to develop a more predictive understanding of microbial impacts on metal and radionuclide mobility in the environment. In FY 2010, EM initiated a new modeling initiative called Advanced Simulation Capability for Environmental Management, which heavily leverages BER science investments and advances. Knowledge of the subsurface environment as a complete system will also be useful to the DOE Office of Fossil Energy (FE) in their efforts to predict the long-term behavior of carbon dioxide injected underground for long-term storage. The current focus on the understanding of processes impacting the mobility of contaminant metals and radionuclides found in the subsurface at DOE legacy waste sites is directly applicable to LM.

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 (PI) as it develops strategies for our Nation's future energy needs and control of greenhouse gas emissions. The BER Integrated Assessment model continues to be an important tool for PI in evaluating the impact of new energy policy on greenhouse gas emissions. In general, BER coordinates with DOE's applied technology programs through regular joint program manager meetings, participating in their internal program reviews, participating in joint contractor meetings, and conducting joint technical workshops.

Budget Overview

BER's budget strategy is based on three science drivers: exploring the frontiers of genome-enabled biology; discovering the physical, chemical, and biological drivers and environmental impacts of climate change; and seeking the geochemical, hydrological, and biological determinants of environmental sustainability and stewardship. The targeted research investments in FY 2012 and the BER scientific user facilities are key to supporting these mission priorities. In FY 2012, the BER budget request will support approximately 2,400 researchers and graduate students at over 200 U.S. academic, federal, and private sector institutions.

Genomic science research supported in FY 2012, including the DOE Bioenergy Research Centers (BRCs), will continue to advance our understanding of how plant and microbial system functions are specified by genome organization, expression, and regulation. This includes developing genomic, analytical, and computational approaches to study the structure, interdependence, and function of microbial communities and the identification of plant traits for improved bioenergy production or carbon sequestration. Research is expanded to study microbial environmental interactions, with respect to chemical and metabolic signal perception and integration. In an effort to take fuller advantage of the powerful capabilities of systems biology to produce bio-based solutions to our energy challenges, a new undertaking will be initiated to identify and articulate general biological design principles that will enable functional characterizations of biological systems and synthetic biology redesign. The goal is to achieve greater standardization and centralization of knowledge and tools, using well-characterized, standardized functional biological components and design principles, with the ultimate aim of developing computer-aided design of biological solutions. This effort leverages other activities in computational biosciences to predict, design, construct, and test new, multi-scale natural and hybrid biological systems that will lead to new clean energy solutions. The JGI will continue to support sequencing needs of the Genomic Science program, especially the BRCs. JGI activities will reflect the rapid increase in production DNA sequencing as well as the resulting need for high-throughput, complex genome annotation and analysis. New efforts in FY 2012 will include JGI grand challenge activities that encompass large scale genome comparisons across different soil environments or plant-microbe associations.

Climate sciences research supported in FY 2012 will continue to improve understanding and quantification of the role of aerosols and clouds on climate change. The ARM fixed sites and mobile facility deployments 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). The arctic is a globally important and climatically sensitive region. Recent changes in cloud cover, warming, and ice sheet melting have been faster than predicted by current climate models. Since the upper three meters of tundra contain more carbon than Earth's atmosphere today, there is a potential for dramatic feedback, where the vast amounts of stored carbon, primarily methane, released from thawing tundra. Additionally, the changes in land and sea ice may have dramatic impact on cloud properties and extent in the region. In FY 2012, BER will enhance our Arctic Climate activity that develops new observations for cloud, aerosols, and the terrestrial carbon cycle designed to support existing BER process studies and modeling activities for improving climate simulations for this rapidly changing climatic regime. As part of this activity, a new ARM mobile facility will be deployed at Oliktok Point on the North Slope of Alaska to provide cloud and aerosol properties over land, sea, and ice sheets. Regular deployments of small unmanned aerial vehicles (UAVs) for in situ measurements will complement and extend the observational coverage to the North Pole. A new ARM fixed site will be developed in the Azores to provide critical long-term observations for marine clouds and aerosols. These measurements in the arctic and Azores are needed to improve understanding of cloud and aerosol lifecycles in these regions and their impact on the planet. The data will be used to evaluate and improve Earth System Model simulations both globally and for these climate sensitive regions.

In FY 2012, research will be expanded to improve understanding of the role of terrestrial ecosystems as sources and sinks of greenhouse gases focusing on the role of natural processes that control terrestrial carbon sequestration and how those processes might be managed to enhance carbon sequestration in terrestrial ecosystems. As part of the Arctic Climate activities, a new effort will focus on developing experimental infrastructure needed for the initiation of the next-generation ecosystem-climate change experiment, with a focus on arctic tundra—an ecosystem that is experiencing rapid climate changes and that contains vast amounts of frozen carbon susceptible to release into the atmosphere as either CO_2 or methane. In FY 2012, BER will support research on carbon cycle multi-scale dynamics in order to describe the nature of the presently observed system noise. This research will underpin measurement, reporting, and verification (MRV) of atmospheric greenhouse gases. The carbon cycle data will directly support ongoing projects for improving representation of processes into Earth System Models. BER Climate Modeling will continue research towards increasing model resolution and accuracy to better simulate climate on a regional scale.

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

Significant Program Shifts

In FY 2012, in an effort to take fuller advantage of the powerful capabilities of systems biology and synthetic biology, BER will initiate an effort to identify and articulate general biological design principles, enabling functional characterizations of biological systems and synthetic redesign. This new effort combines development of new molecular toolkits for understanding natural systems with testbeds for the design and construction of improved biological components or new biohybrid systems and processes. Computer-aided design and testing of directed and self-assembled natural and hybrid biological systems will provide key insights to the reorganization and remodeling of cellular processes and accelerate exploiting these insights for *in vivo* adaptation and optimization. This effort will leverage activities in computational biosciences to predict, design, construct, and test new, multi-scale natural and hybrid biological systems and will accelerate engineering plant and microbial community performance for a changing environment.

In FY 2012, BER will increase transformational science efforts towards improved understanding and predictive capabilities for the Arctic, an ecosystem that is experiencing rapid climate changes with the potential to release significant amounts of carbon into the atmosphere. Such dramatic changes in the Arctic may have powerful long-term effects on a global scale. The new research scope ranges from microbes to terrestrial ecosystems and water droplets to sea ice and cloud fields. The goal is to understand the individual components of biological carbon cycling and physical systems, and integrate them into a comprehensive Arctic environmental system model. This activity will leverage other significant investments in the program related to Arctic research, including Earth System modeling and cloud and aerosol process study research, and build upon pilot genomic activities to interrogate the microbial communities within the Arctic permafrost. A new ARM fixed site will also be developed in the Azores to provide new observations for marine clouds and aerosols.

In FY 2012, no funding is provided for Ethical, Legal and Societal Issues (ELSI), reflecting the completion of the DOE research. The societal benefits and implications of DOE mission areas are best addressed within specific programmatic activities; thus the standalone ELSI activity at DOE is complete.

BER research on the development of the components of an artificial retina was completed in FY 2010. By FY 2012, research will enable the final testing and refinement of the assembled 240+ electrode device for clinical trial readiness. No FY 2012 funding for the artificial retina is requested.

Annual Performance Targets and Results

The Department is in the process of updating its strategic plan, and has been actively engaging stakeholders including Congress. The draft strategic plan is being released for public comment concurrent with this budget submission, with the expectation of official publication this spring. The draft plan and FY 2012 budget are consistent and aligned. Updated measures will be released at a later date and available at the following link http://www.mbe.doe.gov/budget/12budget.

Biological Systems Science

Funding Schedule by Activity

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
Biological Systems Science		
Genomic Science	165,565	241,509
Radiological Sciences	46,675	34,322
Ethical, Legal, and Societal Issues	5,000	0
Medical Applications	8,226	0
Biological Systems Facilities and Infrastructure	84,300	90,173
SBIR/STTR	0	10,258
Total, Biological Systems Science	309,766	376,262

Description

Systems biology is the multidisciplinary study of complex interactions specifying the function of entire biological systems—from single cells to multicellular organisms—rather than the study of individual components. The Biological Systems Science subprogram focuses on understanding the functional principles that drive living systems, from microbes and microbial communities to plants and other whole organisms. Questions include: What information is in the genome sequence? How is information coordinated between different subcellular constituents? What molecular interactions regulate the response of living systems and how can those interactions be understood dynamically and predictively? The approaches employed include genome sequencing, proteomics, metabolomics, structural biology, high-resolution imaging and characterization, and integration of information into predictive computational models of biological systems that can be tested and validated.

The subprogram supports operation of a scientific user facility, the DOE Joint Genome Institute (JGI), and access to structural biology facilities. Support is also provided for research at the interface of the biological and physical sciences and in radiochemistry and instrumentation to develop new methods for real-time, high-resolution imaging of dynamic biological processes.

Selected FY 2010 Accomplishments

- The DOE Bioenergy Research Centers (BRCs) developed high-risk, high-return biological solutions to critical biofuel bottlenecks using basic research. The Great Lakes Bioenergy Research Center (GLBRC) discovered controls in plants to protect energy-rich lipids in leaves and is working to develop plants with higher energy content from overproduction of leaf oils. Information from field trials on the sustainability impacts of energy crops and cultivation options is linked to results from microbial populations in the soil at small scales to national-scale economic and greenhouse gas flux models at larger scales.
- The BioEnergy Science Center (BESC) identified changes in a microbial biomass hydrolysis machine, the cellulosome, during growth on different constituents of plant biomass that may lead to new bioengineering approaches to construct enzyme complexes with “plug in” components for specific biomass feedstock. A BESC industrial partner developed a yeast strain that produces

degradation enzymes and ferments most sugars, a necessary step towards consolidated bioprocessing.

- The Joint BioEnergy Institute (JBEI) discovered novel degradation genes in microbes grown on compost and adapted to growth on switchgrass and then used synthetic biology to tailor a higher-efficiency cellulase enzyme. JBEI researchers and a biotech firm used synthetic biology to modify an industrial bacterium to produce biodiesel and other important chemicals.
- Primary productivity on Earth depends on plants and microbes converting atmospheric CO_2 and N_2 into biologically useful forms. New research showed how oxidation and reduction processes are balanced during growth of the metabolically versatile microbe *Rhodopseudomonas palustris* using a combination of photosynthesis and consumption of organic acids produced by other microbes. This advanced understanding of central metabolic processes in microbes that are relevant to bioenergy applications and play a critical role in the global carbon cycle.
- JGI significantly expanded its role in large-scale genome sequencing and analysis in support of DOE missions. New sequencing technologies were used to sequence 4 trillion base pairs of DNA annually, more than 130 times the capacity of 5 years ago. This new capacity enabled the deduction of increasingly complex genomes, including soybean (important for biodiesel production, soil sustainability and nutrition) and a fungus that provides the source of industrial cellulase enzymes to break down biomass. JGI also completed the first installment of the Genomic Encyclopedia of Bacteria and Archaea to explore Earth's microbial "dark matter" by sequencing little-studied microbes that will give insights into other microbes and microbial communities facilitating searches for novel functions and our understanding of the biosphere.

Detailed Justification

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
Genomic Science	**165,565**	**241,509**
▪ **Foundational Genomics Research**	**33,671**	**102,914**

Foundational Genomics Research supports fundamental research on microbes and plants to understand biological systems across multiple scales from subcellular molecular interactions to microbial community structures. Research focuses on the spatial organization of cellular components and microbial and plant regulatory and metabolic networks. It investigates how cells balance dynamic needs for synthesis, assembly, and turnover of cellular machinery in response to changing environmental signals. Research will increasingly focus on understanding how different organisms interact within a biological or environmental system to provide unique functions through mechanisms such as nutrient exchange or horizontal gene transfer. These systems-level capabilities enable a diversity of functions, from microbial respiration and speciation of soil minerals to rhizosphere nutrient uptake and cell-cell communication, as well as a testable framework for developing genome-based models for systems biology. New approaches will be developed including methods to measure metabolites, proteins, and expressed genes for microbial communities. Novel technologies will be developed enabling multi-modal chemical and biological measurements across broad spatial and temporal ranges, providing insight into environmental processes. Research employing advanced molecular and computational biology approaches enabled by genome

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request

sequencing is emphasized, with priority to multidisciplinary efforts across microbiology, plant biology, chemistry, biophysics, bioinformatics, metabolic engineering, and other fields.

In FY 2012, new research will be initiated to provide the scientific foundation for a bio-economy in which carbon-neutral and renewable processes can be safely designed and optimized. This new research will identify and articulate general biological design principles, enabling functional characterizations of biological systems and synthetic redesign. This includes the development of new synthetic molecular toolkits for understanding natural systems and computer-aided design testbeds for the design and construction of improved biological components or new, multi-scale natural and hybrid biological processes and systems. These toolkits will include the development of new genetic transformation approaches for natural and re-engineered plant and microbial systems, as well as technology to facilitate design engineering of multi-component biological functional modules and to manipulate genetic control systems. The testbeds will allow for prototyping and functional validation of natural and engineered biological modules, especially to understand cross-talk and spatial and topological constraints within cellular systems. Computer-aided design and testing of directed and self-assembled natural and hybrid biological systems will provide key insights to the reorganization and remodeling of cellular processes and accelerate exploiting these insights for *in vivo* adaptation and optimization.

This effort will leverage knowledgebase activities in computational biosciences and capabilities at the Joint Genome Institute in genome sequencing and analysis. Multi-scale measurement and characterization technologies will be developed that validate biological function, facilitate interoperability of biological modules and processes, and standardize engineering plant and microbial community performance for changing environmental conditions. The new knowledge and tools developed from this research will advance applications of biotechnology for bio-based solutions to current and emerging energy and environmental challenges.

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

▪ **Genomics Analysis and Validation**	**10,000**	**12,000**

Genomics Analysis and Validation develops tools and resources to fully exploit information in complete DNA sequences from microbes and plants for bioenergy, carbon sequestration, and bioremediation applications. This activity supports development of new high-throughput approaches for analyzing gene regulation and function, automated tools for predicting genes and protein function from DNA sequence, and tools for identifying dynamic genome interactions within a biological or environmental system to uncover 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 2012, research supports innovative new approaches to validate and improve genome-scale annotation and gene models in microbes and plants. Increased funding will also support genome-scale validation of annotation in metagenomic datasets, a challenge due to the vast and fragmentary information contained within these datasets.

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
▪ **Metabolic Synthesis and Conversion**	**38,637**	**37,200**

This activity focuses on understanding the composition and regulation of biological pathways for converting carbon into advanced biomolecules. Research focuses on understanding carbon uptake, fixation, and storage in plants and soil microbes, leveraging new information from whole organism and community genomes. Research will focus on the role of microbial communities or plant-microbe associations in the transfer of carbon between roots and the soil to identify strategies that would lead to increased carbon storage in the rhizosphere and surrounding soil. Genomic knowledge of metabolic functions and regulatory networks in microbes, plants, and plant-microbe associations can enable strategies to increase biomass formation for conversion into advanced biofuels or to increase the sequestration of carbon in terrestrial ecosystems.

This activity draws on Foundational Genomics Research and technology development to address challenges unique to biofuels through understanding the conversion of simple sugars to ethanol and hydrogen. This will improve understanding of 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 enable understanding of how plant genomes can specify increased carbon fixation and biomass yield, improve feedstock characteristics, and increase sustainability.

In FY 2012, funds will continue to support research on carbon storage in plant biomass for conversion into advanced biofuels or for carbon sequestration. Funds will support research to characterize the 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. FY 2012 funds will support new integrated, interdisciplinary research in biological carbon cycling by plants and microbes in the Arctic to accelerate progress in climate change research and modeling. Funding decreases with the completion of projects on fermentative microbial biohydrogen production.

▪ **Computational Biosciences**	**8,257**	**14,395**

Computational models and algorithmic and computational tools that describe the biochemical capabilities of microbial communities or plants are essential to the success of the Genomic Science activity. New models are needed to integrate diverse data types and data sets into single models that accurately describe and predict the behavior of metabolic pathways and genetic regulatory networks. A systems biology knowledgebase is an integrated modeling and experimental framework to access, compare, analyze, and test 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, and organisms and communities. The systems biology knowledgebase dimensions and requirements were recently outlined in a community workshop.[a]

[a] http://genomicscience.energy.gov/compbio/

	(dollars in thousands)	
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This activity includes support for ongoing Scientific Discovery through Advanced Computing (SciDAC) research that develops multi-scale and multi-component mathematical and computational tools for modeling and analysis of complex data sets, such as mass spectrometry or metabolomics, and to develop predictive metagenomic models of complex microbial communities. SciDAC research is closely coordinated with the Advanced Scientific Computing Research program.

In FY 2012, funding will support ongoing SciDAC research to model whole cell processes that incorporate genomic information with protein production and subcellular localization, metabolic and regulatory processes, cellular signaling, and microbial sensing. Increased funding includes support to extend the systems biology knowledgebase to include research in simulating biological and ecological processes that affect microbial community physiology and the integration of three-dimensional imaging data. The developing knowledgebase will enable broad, distributed access to a virtual computational environment, enabling integrated genome-scale modeling and reconstruction using diverse microbial experimental datasets from genome sequencing, biological networks metabolic pathways, and transcriptional regulation and phenotypic data. The knowledgebase will enable interoperability among datasets and databases and new methods in data information analysis and curation. The primary experimental datasets for integration will be drawn from research conducted at the BRCs, the JGI, and from within the Genomic Science activity.

▪ **Bioenergy Research Centers**	**75,000**	**75,000**

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

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

Each center is evaluated annually by an on-site review of science and management, progress against stated milestones and planned science programs. The external review teams include scientists from universities, DOE national laboratories, and industry, with broad scientific expertise.

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.

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request

In FY 2012, funds will support the continued fundamental research to improve breakdown of plant biomass, discover and bioengineer new microbes and enzymes capable of degrading lignocellulose, and convert cellulose-derived sugars to carbon-neutral biofuels.

Radiological Sciences	**46,675**	**34,322**
▪ **Radiochemistry and Imaging Instrumentation**	**20,772**	**20,000**

This activity supports fundamental research in radiochemistry and radiotracer development including development of new methodologies for real-time, high-resolution imaging of dynamic energy- and environment-relevant biological processes. Radionuclide imaging continues to be a singular tool for studying living organisms in a manner that is quantitative, three dimensional, temporally dynamic, and non-perturbative of the natural biochemical processes.

Radiotracer imaging methods provide new opportunities for quantitative measurement of in situ chemical reactions in living systems. The activity primarily benefits DOE mission needs, while also providing fundamental research and tool development that may translate to nuclear medicine diagnostic and therapeutic research.

In FY 2012, funds will support the development and use of innovative radiotracer chemistry and complementary radionuclide imaging instrumentation technologies for quantitative in vivo measurement of radiotracer concentration and site-specific chemical reactions. Funding will continue to support integrative training opportunities in radiochemistry to build and maintain the radiochemistry scientific workforce. Funding is decreased for the development of methodologies for high activity level synthesis of immunoPET radiotracers.

▪ **Radiobiology**	**25,903**	**14,322**

The Radiobiology activity supports research to 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 includes critical biological phenomena induced by low dose exposure and support to understand the role of genetic susceptibility and epigenetics in integrated gene function and response of biological systems to environmental conditions.

Radiobiology research 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 2012, funds will support systems genetic studies of integrated gene function and response to the environment, drawing on prior studies of specific gene targets and individual cellular response and focusing at the tissue or whole organism level. These studies will contribute towards development of models that are reconciled with available epidemiological data. Funding is reduced for studies on bystander effects and adaptive immune function and is completed for research on genome instability and DNA damage in single cells.

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
Ethical, Legal, and Societal Issues	**5,000**	**0**

In FY 2012, no funding is provided for ELSI, reflecting the completion of the DOE involvement with the Human Genome Project and the alignment of the BER program with DOE mission priorities in energy and the environment. With the evolution of ELSI to address broader mission-relevant science topics, such as bioenergy, synthetic genomics, and nanoscience, the societal benefits and implications of DOE mission areas will be addressed within relevant programmatic activities.

Medical Applications	**8,226**	**0**

Research is completed by FY 2012 on the 240+ electrode artificial retina device integration and preparation for pre-clinical testing. The activity is ready to transition out of DOE for development and application.

Biological Systems Facilities and Infrastructure	**84,300**	**90,173**
▪ **Structural Biology Infrastructure**	**15,300**	**19,417**

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 DOE synchrotrons (Advanced Photon Source, Advanced Light Source, National Synchrotron Light Source, and Stanford Synchrotron Radiation Light source) and neutron sources (High Flux Isotope Reactor and Los Alamos Neutron Science Center). User statistics for BER structural biology user stations are included in the Basic Energy Sciences facility user reports. BER continually assesses the quality of the instrumentation at its experimental stations, supports development of new state-of-the-art stations, and upgrades existing stations to install the most effective instrumentation for taking full advantage of the facility capabilities.

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

In FY 2012, funds will enable initial development of life science experimental stations at the National Synchrotron Light Source II (early beam availability currently scheduled for February 2014) and at the Linac Coherent Light Source and the Spallation Neutron Source, two facilities that have commenced operations and demonstrated pilot activities with considerable potential benefits for the structural biology user community. The increased funding includes support for new end stations and access to proposed new x-ray fluorescence and absorption nanotomography undulator beamlines, optimized for lower energies (2–15 keV) and spatial resolution (less than 50nm) to allow multi-modal imaging of biological cellular substructures with co-localization of trace elements. These capabilities will allow visualization of in situ processes critical to DOE mission needs, ranging from carbon cycling in microbial communities to nutrient exchange at microbe-plant interfaces during bioenergy crop growth.

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
▪ **Joint Genome Institute**	**69,000**	**70,756**

The JGI is the only federally-funded major genome sequencing center focused on genome discovery and analysis in plants and microbes for energy and environmental applications. JGI contributes 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 genomics platforms, 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, JGI has pioneered approaches for sequencing uncultured environmental microbial isolates and microbial communities. These metagenomic capabilities will eventually enable elucidation of the functional potential of all the biological organisms that comprise a specific environmental system.

JGI provides DOE mission-relevant genome sequencing, genome data acquisition, and genome analysis to the broad scientific user community, DOE national laboratories, and the DOE Bioenergy Research Centers. JGI's 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 2012, JGI funding will continue to support access by the scientific user community and the DOE Bioenergy Research Centers to large-scale genome data acquisition and analysis. Funding will also support a greater emphasis on metagenome expression and sequencing of environmental microbial communities or the plant-microbe rhizosphere, improved genome annotation, and functional analysis and verification of genome-scale models. Funding is increased to support JGI grand challenge activities that encompass large scale genome comparisons across different soil environments or plant-microbe associations. These activities will require development of significant new capabilities for acquisition, analysis, and integration of huge genome datasets.

	FY 2010	FY 2012
Achieved Operating Hours	8,400	N/A
Planned Operating Hours	8,400	8,400
Optimal hours	8,400	8,400
Percent of Optimal Hours	100%	100%
Unscheduled Downtime	0	N/A
Number of Users[a]	940	940

[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.

	(dollars in thousands) FY 2010 Current Appropriation	FY 2012 Request
SBIR/STTR	**0**	**10,258**

In FY 2010, $7,777,000 and $933,000 were transferred to the SBIR and STTR programs, respectively. Additionally, $15,000 of prior year balances was transferred as follows: $14,000 for SBIR and $1,000 for STTR.

FY 2012 amount shown for the SBIR and STTR programs is the estimated requirement for continuation of these congressionally mandated programs.

Total, Biological Systems Science	**309,766**	**376,262**

Explanation of Funding Changes

	FY 2012 vs. FY 2010 Current Approp. ($000)
Genomic Science	
▪ **Foundational Genomics Research**	
Funding is increased to support foundational science aimed at advancing applications of biotechnology for bio-based solutions to current and emerging energy and environmental challenges. Funding will support the development of new synthetic molecular toolkits for understanding natural systems combined with computer-aided design testbeds for the design and construction of improved biological components or new, multi-scale natural and hybrid biological processes and systems. These toolkits will include the development of new genetic transformation approaches for natural and re-engineered plant and microbial systems, as well as technology to facilitate design engineering of multi-component biological functional modules and to manipulate genetic control systems. The testbeds will allow for prototyping and functional validation of natural and engineered biological modules, especially to understand cross-talk and spatial and topological constraints within cellular systems. Funding is also increased to support the development of genomic and analytical technologies for multi-modal, dynamic measurements in actively-occurring environmental processes and during cellular communication.	+69,243
▪ **Genomics Analysis and Validation**	
Funding is increased to support genome-scale validation of annotation in metagenomic datasets.	+2,000
▪ **Metabolic Synthesis and Conversion**	
Funding is decreased with the completion of projects focused on fermentative microbial biohydrogen production.	-1,437

	FY 2012 vs. FY 2010 Current Approp. ($000)
▪ **Computational Bioscience**	
Funding is increased to further develop a systems biology knowledgebase to integrate microbial community genomic, proteomic, and transcriptomic experimental data sets from research conducted at the DOE Bioenergy Research Centers, the Joint Genome Institute, and the Genomic Science supported activities. The increase will also support development of new methods for simulation of microbial metabolism and cellular regulation.	+6,138
Total, Genomic Science	**+75,944**
Radiological Sciences	
▪ **Radiochemistry and Imaging Instrumentation**	
Funding is decreased for the development of methodologies for high activity level synthesis of immunoPET radiotracers.	-772
▪ **Radiobiology**	
Funding is reduced for studies on bystander effects and adaptive immune function, and completed for research on genome instability and DNA damage in single cells in response to low dose radiation exposure.	-11,581
Total, Radiological Sciences	**-12,353**
Ethic, Legal, and Societal Issues	
ELSI research is completed in FY 2012. The societal benefits and implications of DOE mission areas will be addressed within relevant programmatic activities, completing the standalone ELSI activity in BER.	-5,000
Medical Applications	
BER funding for the Artificial Retina effort is completed with integration and pre-clinical testing of a 240 electrode retinal device as a basis for fabrication of a 1,000 electrode device. The activity is ready to transition out of DOE for development and application.	-8,226
Biological Systems Facilities and Infrastructure	
▪ **Structural Biology Infrastructure**	
Increased funding will enable initial development of life science experimental stations and instrumentation at major new DOE national user facilities such as SNS and LCLS, providing access to proposed new x-ray fluorescence and absorption nanotomography undulator beamlines. Their optimization for lower energies (2–15 keV) and spatial resolution (less than 50nm) will allow multi-modal imaging of biological cellular substructures with co-localization of trace elements.	+4,117

	FY 2012 vs. FY 2010 Current Approp. ($000)
▪ **Joint Genome Institute**	
Increased funding will support JGI grand challenge activities that encompass large scale genome comparisons across different soil environments or plant-microbe associations.	+1,756
Total, Biological Systems Facilities and Infrastructure	**+5,873**
SBIR/STTR	
Amount shown is the estimated requirement for FY 2012; FY 2010 amounts were previously transferred to the SBIR and STTR programs.	+10,258
Total Funding Change, Biological Systems Science	**+66,496**

Climate and Environmental Sciences

Funding Schedule by Activity

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
Climate and Environmental Sciences		
Atmospheric System Research	26,385	26,392
Environmental System Science	83,048	101,177
Climate and Earth System Modeling	69,081	77,294
Climate and Environmental Facilities and Infrastructure	99,751	128,171
SBIR/STTR	0	8,604
Total, Climate and Environmental Sciences	278,265	341,638

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 supporting the DOE mission. The subprogram supports an integrated portfolio of research from molecular-level to field-scale studies with emphasis on multidisciplinary experimentation and use of advanced computer models. The science and research capabilities enable DOE leadership in climate-relevant atmospheric-process research and modeling, including clouds, aerosols, and the terrestrial carbon cycle; large-scale climate change modeling; experimental research on the effects of climate change on ecosystems; integrated analysis of climate change impacts; and advancing fundamental understanding of coupled physical, chemical, and biological processes controlling contaminant mobility in the environment.

The subprogram supports three primary research activities and two national scientific user facilities.

- Atmospheric System Research seeks to resolve the two major areas of uncertainty in climate change model projections: the role of clouds and the effects of aerosols on the atmospheric radiation balance.
- Environmental System Science supports research that 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.
- Climate and Earth System Modeling focuses on development, evaluation, and use of large scale climate change models to determine the impacts of climate change and mitigation options.
- Two scientific user facilities—the Atmospheric Radiation Measurement Climate Research Facility (ARM) 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 integral to the BER mission and of importance to DOE.

Selected FY 2010 Accomplishments

- ARM researchers completed peer reviewed experiments using fixed, mobile, and aerial ARM facilities in several climatically important regions including the mid-continental U.S., Tropical Western Pacific, the North Slope of Alaska, the Azores, and a mountainous region in Colorado to address critical science questions regarding marine clouds, cirrus clouds, and climatic effects of aerosols. Two ARM aerial facility experiments included a five-month campaign to determine the impact of cirrus cloud microphysical properties on radiative effects in the atmosphere and a field campaign to increase scientific knowledge about evolution of black carbon and secondary organic aerosols from both urban/manmade and biogenic sources. Strong collaborations with other agencies and countries were developed to conduct these experiments. In FY 2010, the ARM facility hosted approximately 1,200 users, resulting in over 185 publications in the scientific literature.
- Through a novel combination of field site comparisons and laboratory experiments, scientists showed that photodegradation plays a significant role in the carbon release through direct breakdown of organic matter by solar irradiance in some ecosystems. The study showed that photodegradation may account for 20-90% of carbon releases from ecosystems in which organic matter is exposed to solar irradiation. This result identifies a previously unquantified source of terrestrial ecosystem carbon flux that is not accounted for in major land models.
- Researchers characterized the genomes of the dominant microbial populations and the proteins they expressed during in situ tests of uranium bioremediation. Changes in microbial metabolism, energy generation and microbial strain composition over time reflected the changing geochemical conditions stimulated during the field test. The results yielded important insights into the functioning of subsurface microbial communities, providing mechanistic information that can be used to inform models of uranium bioremediation. This approach enables scientists to study the mechanistic basis for the growth and functioning of active microbes in the environment and is applicable not only to bioremediation but carbon sequestration, nutrient cycling, and other DOE mission areas.
- The Community Climate System Model (CCSM), the leading U.S. open-source, community-driven climate model, is supported predominantly by DOE and NSF. The most recent release, version 5 (CCSM5), included several climate system components exclusively developed by DOE supported scientists. BER provided a new sea ice sub-model, a new land ice sheet sub-model, physical formulation improvements to the global ocean sub-model, and a new option to make the CCSM5 ready for petascale computing platforms. BER provided a new radiation package, a new aerosol sub-model, and two new cloud schemes: more accurate representations of near-surface cloud formations leading to precipitation and a description of the lifecycle of cirrus clouds.

Detailed Justification

(dollars in thousands)

	FY 2010 Current Appropriation	FY 2012 Request
Atmospheric System Research	**26,385**	**26,392**

The emphasis for Atmospheric System Research is to understand and model 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 increased concentrations of greenhouse gases in the atmosphere. In the presence of clouds

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and aerosols, current transfer models are 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 we are unsure of the magnitude (or even sign) of its forcing on the climate. BER research seeks to increase the fidelity of process representations and interactions that are needed to develop the next-generation of climate models, both in the U.S. and internationally.

In FY 2012, research will continue to focus on improving understanding of the relationship of clouds and radiative transfer processes in the atmosphere, characterization of aerosol physical, chemical, and optical properties and their effects on the Earth's energy balance, and incorporation of this understanding into improved physical process representations. Specific focus areas include the life cycle of marine boundary layer clouds and their impacts on radiation, aerosol-cloud-precipitation interactions, arctic clouds and their interactions with aerosols, high altitude (cirrus) clouds and their life cycles and impacts on radiation budget, and processes and atmospheric transformations involving biogenic aerosols. Analyses will continue on data from recent ARM campaigns in the continental U.S., India, the Azores, and China. Research will be coordinated with BER's Earth System Modeling activity to quickly and effectively incorporate process representations into climate models. Research on clear sky conditions has been completed.

Environmental System Science	**83,048**	**101,177**
▪ **Terrestrial Ecosystem Science**	**28,693**	**49,994**

The Terrestrial Ecosystem Science activity advances fundamental science on the effects of climate change on terrestrial ecosystems and the role of terrestrial ecosystems in global carbon cycling. Research focuses on determining the effects of climate change on the structure and functioning of terrestrial ecosystems, including the processes that control exchanges of carbon dioxide and energy between the atmosphere and the terrestrial biosphere. Results are used to improve the reliability of global carbon cycle models for predicting future atmospheric concentrations of carbon dioxide (CO_2) and to quantify ecological effects of climate change.

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

In FY 2012, research will focus on potential effects of warming, changes in rainfall, and elevated atmospheric CO_2 on terrestrial ecosystems and the terrestrial carbon cycle. Continuing research will

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request

support AmeriFlux, the network of ecosystem CO_2 and energy flux measurement sites, for directly estimating net ecosystem production and carbon storage by terrestrial ecosystems. Ecosystem model development and testing will support the activity goals.

In FY 2012, new activities will include prototyping of experimental infrastructure needed to initiate the next-generation ecosystem-climate change experiment, with a focus on arctic tundra. The urgency of understanding the Arctic ecosystem and its fundamental responses to climate change is based on the fact that the upper three meters of tundra contain more carbon, primarily methane, than Earth's atmosphere. Release of this carbon from thawing permafrost could dramatically amplify the warming of the planet. In FY 2012, increased funding will support critical model development needs, initial data collection, prototype-scale observational efforts, and field experiments. Model development will include length scales from watershed to global, focus on extending existing models from one to three dimensions, and address spatial heterogeneities that will likely be important in understanding not only compartment interdependencies but also the impact of landscape change on carbon cycling. The research will refine the experimental approach, technology development, and field site requirements for subsequent, long-term field-intensive studies.

In FY 2012 enhanced carbon cycle research will describe and predict the emissions and dynamics governing total atmospheric greenhouse content and trace changes in atmospheric carbon content back to specific natural and anthropogenic emitters and/or natural carbon exchanges. This activity (+$9,720,000), to underpin measurement, reporting, and verification (MRV), will focus on the science and technical capability required to understand the carbon cycle and multi-scale dynamics involved in natural and anthropogenic emissions in order to describe the stochastic nature of the presently observed system noise in geographically dispersed ecosystems. While emissions rely in large part on technologies to measure or infer surface fluxes, the greatest challenge is to adequately describe and model the exchange of carbon involving and within geographically dispersed ecosystems and to reliably utilize inverse modeling to distinguish between natural and anthropogenic emissions. This activity also provides fundamental knowledge and capabilities important to future applications including, for example, the upscaling of carbon cycle dynamic modeling associated with next generation ecological experimental sites to regional scales as well as MRV related to possible future climate treaties.

▪ **Terrestrial Carbon Sequestration Research**	**4,603**	**1,000**

Terrestrial Carbon Sequestration research supports efforts to identify, understand, and predict the fundamental physical, chemical, biological, and genetic mechanisms controlling carbon sequestration in terrestrial ecosystems including soils. The activity develops models of these systems to predict future scenarios and to inform larger-scale coupled earth systems models and seeks 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 biofuels research. Results indicate that the switchgrass rooting system could be managed for enhanced soil carbon sequestration.

In FY 2012, the program will focus on completing the current field research and on the synthesis of data and knowledge collected over the history of the program. Funding is reduced with the completion of research on the cycling of carbon associated with agriculture and forestry.

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
▪ **Subsurface Biogeochemical Research**	**49,752**	**50,183**

The Subsurface Biogeochemical Research activity addresses fundamental science questions at the intersection of biology, geochemistry, and physics that, together with computational modeling, advances a predictive understanding of processes controlling the mobility of radionuclides in the environment. This activity supports research at many scales and includes field research sites at Oak Ridge, Tennessee; Hanford, Washington; and Rifle, Colorado (a uranium mill tailings site). Field sites provide researchers opportunities to obtain samples of environmental media for laboratory analysis and to test laboratory-derived hypotheses at the field scale. Field sites are also used to test and evaluate computer models describing contaminant mobility in the environment. Strong ties have been developed between the Environmental Molecular Sciences Laboratory and subsurface biogeochemical researchers. This activity includes SciDAC support for research on advanced models to predict the mobility of subsurface contaminants.

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

In FY 2012, the activity will incorporate a complex, integrated, multi-disciplinary, multi-scale systems approach that builds on the findings of the 2009 workshop, *Complex Systems Science for Subsurface Fate and Transport*, and frames the current scope of environmental research across scales as a continuum of complex interdependent processes.

Climate and Earth System Modeling	**69,081**	**77,294**

Climate and Earth System Modeling seeks to develop and test an application-focused comprehensive Earth system modeling capability and analysis environment that includes natural and human Earth systems, information on climate change at decade-to-century time scales and global-to-local spatial scales, and descriptions and quantifications of uncertainties.

▪ **Regional and Global Climate Modeling**	**27,470**	**29,061**

Regional and Global Climate Modeling focuses on the development, evaluation, and use of regional and global climate models to project future climate with quantified uncertainty over decades to centuries. Core research includes development of general circulation models and associated components; development of regional models; regional and global model diagnosis through the use of appropriate metrics; analysis of multi-model climate change simulations and projections; and the development and use of new techniques for uncertainty quantification. The activity also provides support for national and international climate modeling research and assessments. Currently there is also a pressing need to evaluate the best methods to obtain regional and local scale information for climate adaptation.

In FY 2012, the focus will be on improving and evaluating the reliability of climate predictions at higher resolution. The results of the coordinated experiments from about 20 modeling groups world-wide, available as part of the Climate Model Intercomparison Project (CMIP5) archive, will

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request

continue to facilitate the development and improvement of the diagnostic tools and metrics used to evaluate the reliability of climate change projections and the multiscale natural modes of variability. Studies on understanding climate extremes; reducing the uncertainty in model predictions, detection and attribution; and using the newly developed models will continue, as well as efforts to understand feedback processes, such as high latitude ocean-ice interaction and carbon cycle feedbacks that are important for understanding climate change. Current models have an unacceptably large range of uncertainty, due to differences in the simulation of feedbacks and insufficient information to properly constrain model parameters. Research will continue to reduce these uncertainties using leadership computing resources and integrated observational data sets.

▪ **Earth System Modeling**	**30,353**	**36,569**

Earth System Modeling develops and integrates components of climatic processes into Earth System Models (ESMs) using high computational throughput to provide simulations of climate variability and change over decades to centuries. Research includes incorporation of improved physical representations, e.g., atmospheric, biogeochemical, terrestrial, land-surface-ice, aerosol, and cloud, in the specific modules of the coupled model; development of algorithms and computational methods for coupling of ESM components; coupling and testing of ESM components; abrupt climate change; and visualization and analysis.

The high computational throughput effort is closely coordinated with BER's SciDAC Climate Change Research activities in partnership with the Advanced Scientific Computing Research program. This partnership specifically addresses scaling and other computational issues, so that needed high throughput is achieved.

Improvement of the representation of the physical, chemical, and biogeochemical processes crucial for climate change prediction, such as cloud-aerosol and carbon cycle-climate, are an important part of this activity. Development and testing of these processes and their incorporation into high resolution models will continue. The activity also continues development of software tools that enhance the ability to analyze high resolution model output and observational data in a single framework. This modeling program will also continue support of data visualization initiated in FY 2010.

In FY 2012, funding will expand research that focuses on converting observational datasets into specialized, multi-variable datasets for model testing and improvement; establishment of model development testbeds in which model components can be rapidly prototyped and evaluated using integrated observational datasets; and development of numerical methods to enable climate models to effectively use future computer architectures. The goal of these activities is to develop the next generation comprehensive coupled, high resolution earth system model.

▪ **Integrated Assessment**	**11,258**	**11,664**

Integrated Assessment research provides scientific insights into options for mitigation of 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. Research focuses on improving the fundamental knowledge and methodologies for analysis of climate change

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request

impacts and adaptations; innovative general approaches to modeling impacts and adaptation; developing different measures of impacts; and developing approaches to address probabilities and uncertainties. Integrated Assessment develops advanced quantitative tools for exploring the implications of science and technology decisions and innovations on our energy, environmental, and economic futures leading to improved understanding of potential emissions trajectories and the environmental costs and benefits of stabilization options.

In FY 2012, BER will continue research on several key research challenges identified in the November 2008 *Integrated Assessment Research* Workshop. In particular, Integrated Assessment research will continue to provide the scientifically rigorous, quantitative basis from which policy makers and researchers may assess the impacts of the Nation’s scientific and engineering enterprise, improve their understanding of its dynamics, and assess likely outcomes for decision-making on our climate, energy, economic futures. The Integrated Assessment activity will continue to support open source, community-based approaches to modeling; improve capacity to conduct inter-model comparisons and multi-model studies; improve capacity to enhance convergence of models and collaborations across the Integrated Assessment, Earth System Modeling, and Impacts, Adaptation, and Vulnerability research communities, especially for regional-scale and multi-scale questions; and enhance transparency and accessibility for both data and models by the Integrated Assessment research community, their collaborators, and other user communities.

Climate and Environmental Facilities and Infrastructure	**99,751**	**128,171**
▪ **Atmospheric Radiation Measurement Climate Research Facility**	**42,208**	**67,977**

The Atmospheric Radiation Measurement Climate Research Facility (ARM) is a multi-platform national scientific user facility, with stationary and mobile platforms and instruments around the globe. ARM provides continuous field measurements of climate data to promote the advancement of atmospheric process understanding and climate models through precise observations of atmospheric phenomena. Stationary sites provide scientific testbeds in three different climate regions (mid-latitude, arctic, 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 ARM aerial capability provides in situ cloud and radiation measurements that complement the ground-based measurements. ARM provides 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 two largest uncertainties in climate change research.

In FY 2012, ARM will continue its long-term observations from the fixed sites and will provide data from new instruments acquired with Recovery Act funding. These new instruments provide data on 3-D cloud evolution and properties, a broader geographic coverage of aerosol measurements, and enhanced surface characterization measurements. ARM will conduct field experiments to study questions on aerosols and various cloud types—cirrus, marine, and mixed-phase (ice and water)—to improve process understanding as well improving regional and Earth System Models that simulate climate change. A mobile facility and accompanying aerial measurements will support an

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request

experiment in India to examine the impact of aerosols on the Indian monsoon. The experiment using the other mobile facility will continue to examine liquid and mixed-phase clouds in Colorado. Experiments proposed for use of the mobile facilities after completion of these two deployments are currently under peer review.

Increased funding in FY 2012 will support the development of a new mobile facility to be initially located at Oliktok Point, Alaska for three dimensional measurements of cloud and aerosol properties over land, sea, and ice, as part of the program's expanded arctic research efforts. Regular flights of small UAVs will provide in situ measurements that complement the mobile facility measurements as well as extend the observational coverage from Oliktok to the North Pole. This includes full funding for a major item of equipment, the Dual-Frequency Scanning Cloud Radar at Oliktok, with a total estimated cost of $3,070,000.

Additionally, in FY 2012, a new ARM fixed site will be developed in the Azores to provide new long-term observations for marine clouds and aerosols. This includes full funding for the major item of equipment, the Dual-Frequency Scanning Cloud Radar at the Azores site, with a total estimated cost of $3,070,000.

	FY 2010	FY 2012
Achieved Operating Hours	8,185	N/A
Planned Operating Hours	7,884	7,884
Optimal hours	7,884	7,884
Percent of Optimal Hours	104%	100%
Unscheduled Downtime	0	N/A
Number of Users[a]	1,185	1,200

- **Environmental Molecular Sciences Laboratory** **52,510** **55,721**

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 experimental systems to provide fundamental understanding of the physical, chemical, and biological processes that underlie DOE's energy and environmental mission areas, including alternative energy sources, improved catalysts and materials for industrial applications, insights into the factors influencing climate change and carbon sequestration processes, and an understanding of subsurface biogeochemistry at contaminated sites. For example, EMSL's nuclear magnetic resonance spectrometers; high resolution mass spectrometers; ultra-high vacuum

[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.

scanning, tunneling, cryogenic and atomic force microscopy capabilities; and 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 2012, EMSL operations funding is increased to provide users with enhanced access to new EMSL capabilities obtained with Recovery Act funding. Capital equipment support for EMSL enables instrument upgrades and modifications as well as the development and procurement of unique state-of-the-art capabilities. A multi-year effort to acquire a High Magnetic Field Mass Spectrometer, a major item of equipment with a total estimated cost of $17,500,000, was initiated in FY 2010 and will continue in FY 2012. This transformational instrument will enable users to undertake world-leading proteomics, metabolomics and lipidomics of plant, animal and microbial cells, communities, and other complex systems with application to biofuels, systems biology, bioremediation, aerosol particle characterization, catalysis, and fossil fuel analysis. A suite of integrated imaging capabilities (advanced data processing, image correlation, and remote operational capabilities) will be developed to better understand biological transformations and energy and materials transport in complex environments and to support systems biology research, particularly proteomics.

	FY 2010	FY 2012
Achieved Operating Hours	4,329	N/A
Planned Operating Hours	4,352	4,365
Optimal hours	4,365	4,365
Percent of Optimal Hours	99.7%	100%
Unscheduled Downtime	<1%	N/A
Number of Users[a]	732	750

- **Data Management and Education** **4,258** **2,773**

The role of climate data management is to facilitate full and open access to quality-assured carbon cycle data for climate change research. Data holdings include records of the concentrations of atmospheric CO_2 and other greenhouse gases; the role of the terrestrial biosphere and the oceans in biogeochemical cycles of greenhouse gases; emissions of CO_2 into the atmosphere; long-term climate trends; the effects of elevated CO_2 on vegetation; and the vulnerability of coastal areas to rising sea levels. 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.

In FY 2012, the data management activity will continue to support data users with tools for identifying and accessing those data needed to address important climate change research questions. The activity will also implement information technology advances to meet evolving data sharing

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

(dollars in thousands)

	FY 2010 Current Appropriation	FY 2012 Request

needs of researchers. These include user interfaces, visualization capabilities, and customized data extractions from large, complex, data files. Education activities were completed in FY 2010.

▪ **General Purpose Equipment (GPE)**	**75**	**1,000**

GPE funding provides equipment for the Oak Ridge Institute for Science and Education (ORISE), such as information system computers and networks and instrumentation that support multi-purpose research. In FY 2012 GPE funding is increased to enable ORISE to replace and upgrade obsolete networking and data storage systems with more efficient and less energy intensive systems in support of programmatic activities.

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

GPP funding supports minor construction, capital alterations, and additions, such as replacing utility systems in 30 to 40 year old buildings. Funding of this type is essential for maintaining the productivity and usefulness of Department-owned facilities and meeting the requirements for safe and reliable facilities operation. This activity includes stewardship GPP funding for ORISE. The total estimated cost of each GPP project will not exceed $10,000,000 in FY 2012.

SBIR/STTR	**0**	**8,604**

In FY 2010, $6,644,000 and $797,000 were transferred to the SBIR and STTR programs, respectively. Additionally, $138,000 of prior year balances were transferred as follows: $123,000 for SBIR and $15,000 for STTR.

FY 2012 amount shown for the SBIR and STTR programs is the estimated requirement for continuation of these congressionally mandated programs.

Total, Climate and Environmental Sciences	**278,265**	**341,638**

Explanation of Funding Changes

	FY 2012 vs. FY 2010 Current Appropriation ($000)
Atmospheric System Research	
Atmospheric System Research is held at the FY 2010 appropriated level.	+7
Environmental System Science	
▪ **Terrestrial Ecosystem Science**	
The increased funding will support prototyping of experimental infrastructure needed for the initiation of the next-generation ecosystem-climate change experiment, with a focus on arctic tundra. Additionally, BER will support research on carbon cycle multi-scale dynamics in order to describe the nature of	

	FY 2012 vs. FY 2010 Current Appropriation ($000)
the presently observed system noise. This research will underpin MRV of atmospheric greenhouse gases.	+21,301
▪ **Terrestrial Carbon Sequestration Research**	
Funding is reduced with the completion of a series of research projects focused on the cycling of carbon sequestration associated with long-studied field sites.	-3,603
▪ **Subsurface Biogeochemical Research**	
Funding is held near the FY 2010 appropriated level.	+431
Total, Environmental System Science	**+18,129**
Climate and Earth System Modeling	
▪ **Regional and Global Climate Modeling**	
Funding is increased to continue efforts to improve the accuracy of climate predictions at higher resolution.	+1,591
▪ **Earth System Modeling**	
The increased funding will support enhanced research on the development of numerical methods and model testing and validation for a comprehensive coupled, high resolution earth system model.	+6,216
▪ **Integrated Assessment**	
In FY 2012, Integrated Assessment is held near the FY 2010 appropriated level.	+406
Total, Climate and Earth System Modeling	**+8,213**
Climate and Environmental Facilities and Infrastructure	
▪ **Atmospheric Radiation Measurement Climate Research Facility (ARM)**	
The increase will support new remote sensing and in situ measurements of clouds and aerosols over arctic land, ice, and ocean surfaces; a new fixed site in the Azores for remotely sensed measurements of marine clouds and aerosols; and continuing operations of the current ARM infrastructure.	+25,769
▪ **Environmental Molecular Sciences Laboratory**	
Funding is increased to support acquisition of new facility instrumentation.	+3,211
▪ **Data Management and Education**	
Funding is reduced to reflect the completion of the education program.	-1,485

	FY 2012 vs. FY 2010 Current Appropriation ($000)
▪ **General Purpose Equipment**	
GPE Funding is increased to enable ORISE to replace and upgrade obsolete networking and data storage systems with more efficient and less energy intensive systems in support of programmatic activities.	+925
Total, Climate and Environmental Facilities and Infrastructure	**+28,420**
SBIR/STTR	
Amount shown is the estimated requirement for FY 2012; FY 2010 amounts were previously transferred to the SBIR and STTR programs.	+8,604
Total Funding Change, Climate and Environmental Sciences	**+63,373**

Supporting Information

Operating Expenses, Capital Equipment and Construction Summary

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
Operating Expenses	564,523	673,636
Capital Equipment	19,640	43,564
General Plant Projects (GPP)	3,868	700
Total, Biological and Environmental Research	588,031	717,900

Funding Summary

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
Research	394,370	470,077
Scientific User Facilities Operations and Research	179,018	213,871
Major Items of Equipment	10,700	13,390
Facility related GPP	3,168	0
Other[a]	775	20,562
Total, Biological and Environmental Research	588,031	717,900

Scientific User Facilities Operations and Research

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
Biological Systems Science		
Structural Biology Infrastructure	15,300	19,417
Joint Genomics Institute	69,000	70,756
Total, Biological Systems Science	84,300	90,173
Climate and Environmental Sciences		
Atmospheric Radiation Measurement Climate Research Facility	42,208	67,977
Environmental Molecular Sciences Laboratory	52,510	55,721
Total, Climate and Environmental Science	94,718	123,698
Total Science User Facilities Operations and Research	179,018	213,871

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

Facilities Users and Hours

	FY 2010 Current Appropriation	FY 2012 Request
Joint Genome Institute		
Achieved Operating Hours	8,400	N/A
Planned Operating Hours	8,400	8,400
Optimal hours	8,400	8,400
Percent of Optimal Hours	100%	100%
Unscheduled Downtime	0	N/A
Number of Users[a]	940	940
Atmospheric Radiation Measurement Climate Research Facility (ARM)		
Achieved Operating Hours	8,185	N/A
Planned Operating Hours	7,884	7,884
Optimal hours	7,884	7,884
Percent of Optimal Hours	104%	100%
Unscheduled Downtime	0	N/A
Number of Users[b]	1,185	1,200
Environmental Molecular Sciences Laboratory		
Achieved Operating Hours	4,329	N/A
Planned Operating Hours	4,352	4,365
Optimal hours	4,365	4,365
Percent of Optimal Hours	99.7%	100%
Unscheduled Downtime	<1%	N/A
Number of Users[c]	750	750

[a] All JGI users are remote. Primary users are individuals associated with approved projects being conducted at the JGI in a reporting period. Each user is counted once per year regardless of how many proposals their name may be associated with. Additionally, different users reflect vastly differing levels of JGI resources.
[b] ARM users are both onsite and remote. A user is an individual who accesses ARM databases or uses equipment at an ARM site. Individuals are only counted once per reporting period at an individual site but may be counted at different ARM sites if they are a user at more than one site.
[c] EMSL users are both onsite and remote. Individual users are counted once per year.

	FY 2010 Current Appropriation	FY 2012 Request
Total Facilities		
Achieved Operating Hours	20,914	N/A
Planned Operating Hours	20,636	20,649
Optimal hours	20,649	20,649
Percent of Optimal Hours	101.3%	100%
Unscheduled Downtime	<1%	N/A
Number of Users	2,875	2,890

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

Major Items of Equipment

(dollars in thousands)

	Prior Years	FY 2010 Current Appropriation	FY 2011 CR	FY 2012 Request	Total
Atmospheric Radiation Measurement Climate Research Facility (ARM)					
Dual-Frequency Scanning Cloud Radar for Oliktok, Alaska ARM Site					
TEC/TPC	0	0	0	3,070	3,070
Dual-Frequency Scanning Cloud Radar for ARM Azores Climate Activity					
TEC/TPC	0	0	0	3,070	3,070
Total ARM TEC/TPC	0	0	0	6,140	6,140
Environmental Molecular Sciences Laboratory (EMSL)					
Advanced Oxygen Plasma Assisted Molecular Beam Epitaxy system					
TEC/TPC	0	3,200	0	0	3,200
Secondary Ion Mass Spectrometer					
TEC/TPC	0	4,500	0	0	4,500
Next Generation, High Magnetic Field Mass Spectrometer					
TEC/TPC	0	3,000	7,250	7,250	17,500
Total EMSL TEC/TPC	0	10,700	7,250	7,250	25,200
Total BER TEC/TPC	0	10,700	7,250	13,390	31,340

Atmospheric Radiation Measurement Climate Research Facility

Dual-frequency scanning cloud radar for the ARM Arctic Climate activity. This instrument will provide the capability to measure cloud properties in a volume and will provide three-dimensional cloud properties at Oliktok, Alaska: essential data for developing high-resolution climate models.

Dual-frequency scanning cloud radar for the ARM Azores Climate activity. This instrument will provide the capability to measure cloud properties in a volume and will provide three-dimensional cloud properties in the Azores, essential data for developing high-resolution climate models.

Environmental Molecular Sciences Laboratory

Advanced Oxygen Plasma Assisted Molecular Beam Epitaxy system is designed for the growth of a wide variety of oxide materials and is funded at $3,200,000 in FY 2010. This instrument will enable synthesis and characterization of oxide films and surfaces important for catalysis, electronic and spintronic materials, and geochemistry.

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

Next Generation, High Magnetic Field Mass Spectrometer system will be a world-leading system to measure and characterize complex mixtures of intact proteins and other biomolecules, aerosol particles, petroleum, and constituents from other types of fluids and is funded at $3,000,000 in FY 2010 and $7,250,000 in FY 2012. Mission Need (CD-0) was approved on October 14, 2009; the Alternative Selection and Cost was reviewed and approved September 28, 2010, with an estimated cost range of $16,000,000 to $17,500,000. CD-2, Approved Performance Baseline is planned for spring 2011. The system will enable world-leading proteomics, metabolomics, and lipidomics with application to bioenergy, as well as provide insights relevant to climate science, fossil fuel processing, and catalysis.

Scientific Employment

	FY 2010 Estimate	FY 2012 Estimate
# University Grants	492	530
Average Size per year	$352,000	$350,000
# Laboratory Projects	234[a]	190
# Permanent Ph.D.s[b]	1,460	1,600
# Postdoctoral Associates[c]	335	375
# Graduate Students[c]	480	535
# Ph.D.s awarded[d]	110	110

[a] In FY 2010, BER began consolidating funding for laboratories resulting in fewer individual projects in the outyears.

[b] The number of permanent Ph.D.s is estimated. Information is not readily available on the total number of permanent Ph.D. scientists associated with each research project. In addition to the principal investigator for each research project funded by BER, individual projects typically have between 1 and 20 additional Ph.D.-level scientists who are funded collaborators. Information on scientific collaborators is not routinely tracked.

[c] The number of Postdoctoral Associates and graduate students is estimated for national laboratory projects.

[d] The number of Ph.D.s awarded is 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.