Biological and Environmental Research

Overview

The mission of the Biological and Environmental Research (BER) program is to support fundamental research and scientific user facilities to achieve a predictive understanding of complex biological, climatic, and environmental systems for a secure and sustainable energy future.

The program seeks to understand the continuum of biological, biogeochemical, and physical processes needed to describe both simple and complex genomes, on the smallest scales, to environmental and Earth system change, on the largest scales. The program strives to describe and explain how genomic information is translated to functional capabilities, enabling more confident redesign of microbes and plants for sustainable biofuels production, improved carbon storage, and understanding the biological transformation of materials such as nutrients and contaminants in the environment. BER research also advances understanding of how the Earth's dynamic, physical, and biogeochemical systems (the atmosphere, land, oceans, sea ice, and subsurface) interact and cause future climate and environmental change, to provide information that will inform plans for future energy and resource needs.

BER research uncovers nature's secrets from the diversity of microbes and plants to understand how biological systems work, how they interact with each other, and how they can be manipulated to harness their processes and products. Starting with the genetic potential encoded by organisms' genomes, BER scientists seek to define the principles that guide the translation of the genetic code into functional proteins and the metabolic and regulatory networks underlying the systems biology of plants and microbes as they respond to and modify their environments. BER plays a unique and vital role in supporting research on atmospheric and terrestrial system processes, interactions between ecosystems and greenhouse gases (especially carbon dioxide [CO_2]), climate and earth system modeling, and analysis of impacts and interdependencies of climatic change with energy production and use. BER research addresses the three most important sources of uncertainty in our understanding of the earth's radiant energy balance—clouds, aerosols, and atmospheric greenhouse gases—through coordinated efforts in climate modeling and observation. BER also supports research to improve the understanding of terrestrial ecosystem processes and their representation in Earth system models. Finally, BER research seeks understanding of the critical role that biogeochemical processes play in controlling the cycling and mobility of energy byproducts (e.g., carbon, nutrients, radionuclides and heavy metals) in the earth's subsurface and across key surface-subsurface interfaces in the environment.

BER's scientific impact has been transformative. Efforts to map the human genome, including the U.S.-supported international Human Genome Project, which DOE formally began in 1990, initiated the era of modern biotechnology and genomics-based systems biology. Today, with its Genomic Sciences activity and the DOE Joint Genome Institute (JGI), BER researchers are using the powerful tools of plant and microbial systems biology to pursue fundamental breakthroughs needed to develop cost-effective cellulosic biofuels. The three DOE Bioenergy Research Centers lead the world in fundamental biofuels-relevant research.

Since the 1950s, BER has been a critical contributor to climate science research in the U.S., beginning with atmospheric circulation studies that were the forerunners of modern climate models. Today, BER research contributes to model development and analysis using community-based models, e.g., Community Earth System Model (CESM), the Advanced Climate Model for Energy (ACME), and the Global Change Assessment Model (GCAM). These leading U.S. models are used to address two of the most critical areas of uncertainty in contemporary climate science—the impacts of clouds and of aerosols—with data provided by the Atmospheric Radiation Measurement Climate Research Facility (ARM), a DOE user facility serving hundreds of scientists worldwide. Also, BER has been a pioneer of ecological and environmental studies in terrestrial ecosystems and seeks to describe the continuum of biological, biogeochemical, and physical processes across multiple scales that control the flux of climate and environmentally-relevant compounds between the terrestrial surface and the atmosphere. BER's Environmental Molecular Sciences Laboratory (EMSL) provides the scientific community with powerful suites of instruments and a high performance computer to characterize biological organisms and molecules.

Highlights of the FY 2016 Budget Request

Biological and Environmental Research will support core research and scientific user facilities in key areas of bioenergy, climate, and environmental sciences.

Biological Systems Science

Investments in Biological Systems Science will provide the fundamental understanding to underpin advances in sustainable bioenergy production, and to gain a predictive understanding of carbon cycling in the environment and bioremediation processes. Genomic Sciences research activities continue with core research currently underway at the DOE Bioenergy Research Centers to provide a scientific basis for sustainable and cost effective bioenergy production. These efforts are complemented by continued research on potential plant feedstocks for bioenergy purposes, new efforts to understand the sustainability of bioenergy production, and biosystems design efforts to modify plants and microbes for bioenergy purposes. Efforts to understand the impact of microbial communities on the cycling of carbon, nutrients and contaminants in understudied environments continues as well as the development of new enabling technologies to visualize the spatial and temporal relationships of key metabolic processes within and among cells. These fundamental genomic science activities are supported by ongoing integrative efforts to combine genomic information in hypothesis-testing computational formats and continued developments to sequence and interpret DNA from a wide variety of plants and microbial communities at the Joint Genome Institute (JGI). The JGI remains an essential component for DOE systems biology efforts providing high quality genome sequence data and analysis techniques to the research community. The JGI continues to implement a new strategic plan to incorporate new capabilities to not only sequence DNA but to interpret, manipulate, and synthesize DNA in support of biofuels, biodesign, and environmental research. Funding levels decrease for efforts in Structural Biology Infrastructure and are completed for Radiological Sciences as Biological Systems Science activities continue to prioritize on DOE’s bioenergy and environmental missions.

Climate and Environmental Sciences

Climate and Environmental Research activities will focus on scientific analysis of the sensitivity and uncertainty of climate predictions to physical as well as biogeochemically dominated processes, within both Arctic and Tropical environments, as part of the Next Generation Ecosystem Experiments (NGEEs) in Alaska and at tropical sites. Each major field study contains a modeling component. A new investment in Climate Model Development and Validation focuses on model architecture restructuring, exploiting new software engineering and computational upgrades, incorporating scale-aware physics in all model components and enhanced efforts to assess and validate model results. Increased investment will produce an earth system model capability that includes a human component involving vulnerability analysis and integrated assessment, tailored to DOE requirements, e.g., new research to understand the interdependencies of water, energy and climate change, for a variety of scenarios applied to spatial scales as small as 10km. The model system will have improved resolution that will include new codes for running on numerous processors, flexibility toward future computer architectures, and enhanced usability, testing, adaptability, multi-scale treatments, and provenance. The modeling efforts will be validated against new atmospheric and terrestrial observations.

ARM continues long-term measurements at fixed sites in Alaska, Oklahoma, and the Azores, selected for scientific impact on improving climate models. The ARM mobile facilities will rotate deployments to three climate-sensitive regions demanding focused and targeted measurements in the Arctic, Antarctic, and the Pacific Ocean. EMSL will focus on an aggressive research agenda, utilizing the High Resolution and Mass Accuracy Capability (HRMAC), i.e., a powerful magnet integrated with a sophisticated spectrometer that combines with major computational assets.

The Data Management effort will focus on advancing the Climate and Environmental Data Analysis and Visualization activity that will incorporate high resolution Earth system models with interdependent components involving energy and infrastructure sector models, field observations, raw data from environmental field experiments, and analytical tools for system diagnostics, validation, and uncertainty quantification.

Within the FY 2016 Budget Request, the Climate and Environmental Sciences supports the DOE Energy-Water Nexus Crosscut. Specifically, BER Climate and Earth System Modeling Integrated Assessment activities support the crosscut. These investments position DOE to contribute strongly to the Nation’s transition to more resilient energy and coupled energy-water systems.

The energy-water nexus crosscut is an integrated set of cross-program collaborations designed to accelerate the Nation's transition to more resilient energy and coupled energy-water systems. The crosscut supports: (1) an advanced, integrated data, modeling, and analysis platform to improve understanding and inform decision-making for a broad range of users and at multiple scales; (2) investments in targeted technology research opportunities within the system of energy-water flows that offer the greatest potential for positive impact; and (3) policy analysis and stakeholder engagement designed to build from and strengthen the two preceding areas while motivating more rapid community involvement and response.

As part of the Exascale Crossscut, BER will be responsible for determining the scope and management of the Climate Modeling programs. Climate modeling science requires resolution of atmospheric and terrestrial processes across multiple scales, to project how systems such as aerosols, clouds, precipitation, ecosystems, and Arctic tundra will shift with climate. Energy and infrastructure planning will require precise projection of temperature exceedances, water availability, sea-level rise, storm likelihood, and crop potentials. The Extreme Challenges workshop series and the Advanced Scientific Computing Advisory Committee Subcommittee report on Exascale climate science articulated the need to understand the dynamic ecological and chemical evolution of the climate system, with quantification of the uncertainties in the impacts on regional and decadal scales.

Exascale systems are needed to support areas of research that are critical to national security objectives as well as applied research advances in areas such as climate models, combustion systems, and nuclear reactor design that are not within the capacities of today's systems. Exascale systems' computational power are needed for increasing capable data-analytic and data-intense applications across the entire Federal complex. Exascale is a component of long-term collaboration between the SC's Advanced Scientific Computing Research (ASCR) program and the National Nuclear Security Administration's (NNSA) Advanced Simulation and Computing Campaign (ASC) program.

FY 2016 Crosscuts ($K)

	Energy-Water	Exascale Computing	Total
Biological and Environmental Research	11,800	18,730	30,530

Biological and Environmental Research
Funding ($K)

	FY 2014 Enacted	FY 2014 Current[1]	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Biological Systems Science					
Genomic Science					
Foundational Genomics Research	74,225	74,225	73,228	76,125	+2,897
Genomics Analysis and Validation	10,052	10,052	10,000	9,248	-752
Metabolic Synthesis and Conversion	19,562	19,562	16,262	16,262	0
Computational Biosciences	16,480	16,480	16,395	16,395	0
Bioenergy Research Centers	75,000	75,000	75,000	75,000	0
Total, Genomic Science	**195,319**	**195,319**	**190,885**	**193,030**	**+2,145**
Mesoscale to Molecules	**7,990**	**7,990**	**9,680**	**9,623**	**-57**
Radiological Sciences					
Radiochemistry and Imaging Instrumentation	11,861	11,861	2,665	1,000	-1,665
Radiobiology	3,217	3,217	2,409	1,000	-1,409
Total, Radiological Sciences	**15,078**	**15,078**	**5,074**	**2,000**	**-3,074**
Biological Systems Facilities and Infrastructure					
Structural Biology Infrastructure	14,990	14,990	14,895	10,000	-4,895
Joint Genome Institute	70,143	70,143	69,500	69,500	0
Total, Biological Systems Facilities and Infrastructure	**85,133**	**85,133**	**84,395**	**79,500**	**-4,895**
SBIR/STTR	8,251		9,858	10,118	+260
Total, Biological Systems Science	**311,771**	**303,520**	**299,892**	**294,271**	**-5,621**
Climate and Environmental Sciences					
Atmospheric System Research	**26,632**	**26,632**	**25,892**	**26,392**	**+500**
Environmental System Science					
Terrestrial Ecosystem Science	45,256	45,256	44,034	40,035	-3,999
Subsurface Biogeochemical Research	24,422	24,422	23,533	23,207	-326
Total, Environmental System Science	**69,678**	**69,678**	**67,567**	**63,242**	**-4,325**

[1] Funding reflects the transfer of SBIR/STTR to the Office of Science.

	FY 2014 Enacted	FY 2014 Current[1]	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Climate and Earth System Modeling					
Climate Model Development and Validation	0	0	0	18,730	+18,730
Regional and Global Climate Modeling	28,472	28,472	26,159	30,088	+3,929
Earth System Modeling	35,541	35,541	35,303	35,569	+266
Integrated Assessment	10,028	10,028	9,733	17,567	+7,834
Total, Climate and Earth System Modeling	**74,041**	**74,041**	**71,195**	**101,954**	**+30,759**
Climate and Environmental Facilities and Infrastructure					
Atmospheric Radiation Measurement Climate Research Facility	68,644	68,644	67,429	65,429	-2,000
Environmental Molecular Sciences Laboratory	46,942	46,942	45,501	43,191	-2,310
Data Management	3,653	3,653	5,000	7,066	+2,066
General Purpose Equipment (GPE)	250	250	0	0	0
General Plant Projects (GPP)	250	250	0	0	0
Total, Climate and Environmental Facilities and Infrastructure	**119,739**	**119,739**	**117,930**	**115,686**	**-2,244**
SBIR/STTR	7,835	0	9,524	10,855	+1,331
Total, Climate and Environmental Sciences	**297,925**	**290,090**	**292,108**	**318,129**	**+26,021**
Total, Biological and Environmental Research	**609,696**	**593,610**	**592,000**	**612,400**	**+20,400**

SBIR/STTR Funding:

- FY 2014 transferred: SBIR $13,666,000 and STTR $2,420,000 of FY 2014 dollars, plus $3,277,000 in unobligated prior year dollars for SBIR.
- FY 2015 projected: SBIR $17,034,000; STTR $2,348,000
- FY 2016 Request: SBIR $18,238,000; STTR $2,735,000

Biological and Environmental Research
Explanation of Major Changes ($K)

	FY 2016 vs. FY 2015
Biological Systems Science: Investments in Genomic Science continue integrative efforts at the Bioenergy Research Centers with complementary research on potential bioenergy feedstock plants, sustainability research for bioenergy, biosystems design, microbial community impacts on carbon and nutrient cycling, and integrative computational approaches for systems biology research. The development of enabling technology to visualize key metabolic processes within and among cells continues with application across the Genomic Science portfolio. JGI continues to provide DNA sequencing, analysis and synthesis support to researchers. Funding for Radiological Sciences is completed and funding for Structural Biology Infrastructure decreases as activities within the portfolio continue to emphasize fundamental genomic science in support of bioenergy and environmental research.	**-5,621**
Climate and Environmental Sciences: Climate and Earth System modeling increases with investments in new research to evaluate geographic regions complementary to existing efforts in the Arctic and the Tropics, that are cause for significant sources of prediction uncertainty. With this new research, science will focus on understanding the interdependencies of water, energy, and climate changes, on spatial resolutions as low as 10 km. Climate Model Development and Validation is initiated to support model architecture restructuring, exploit new software engineering and computational upgrades, and incorporate scale-aware physics in all model components. Environmental System Science decreases and will exploit opportunities for greater efficiencies by aggregating a higher fraction of its research into decadal-scale climate-ecosystem science campaigns e.g., NGEE Arctic, NGEE Tropics, a northern peatland experiment, and AmeriFlux. The Environmental Molecular Sciences Laboratory (EMSL) will address a more focused set of scientific challenges, resulting in sunsetting some capabilities and more efficient utilization of remaining instrumentation and laboratory data collected at EMSL. The Climate and Environmental Data Analysis and Visualization activity increases to provide an integrated capability that allows compatibility and interoperability involving both observed and model generated climate information. Information as part of this activity involves multiple model products in the Earth System Grid Federation (ESGF), and data from environmental field experiments, ARM facility observations, and components of the EMSL data base. ARM decreases its investments in a planned field deployment of the first ARM mobile facility (AMF1) due to delays in field campaigns schedules.	**+26,021**
Total, Biological and Environmental Research	**+20,400**

Basic and Applied R&D Coordination

BER research underpins the needs of DOE's energy and environmental missions. Basic research on microbes and plants provide fundamental understanding that can be used to develop new bioenergy crops and improved biofuel production processes that enable a sustainable bioeconomy. This research is relevant to other DOE offices and agencies, including DOE's Office of Energy Efficiency and Renewable Energy (EERE) and the Advanced Research Projects Agency-Energy (ARPA-E), and the U.S. Department of Agriculture. Coordination with other federal agencies on priority science needs occurs through the Biomass Research and Development Board, a Congressionally mandated interagency group created by the Biomass Research and Development Act of 2000, as amended by the Energy Policy Act of 2005 and the Agricultural Act of 2014, and under the White House Office of Science and Technology Policy (OSTP). Additionally, memoranda of agreements (MOAs) have been signed with the National Science Foundation (NSF) and the National Institute of Allergy and Infectious Diseases (NIAID) to cooperate on computational biology and bioinformatic developments within the DOE Systems Biology Knowledgebase (KBase).

BER research to understand and predict future changes in the earth's climate system provides important tools that link climate predictions to evaluations of new energy policies and help to guide the design criteria for next generation energy infrastructures. An example is water. Water and energy bring together the Office of Science, energy technology offices, and energy policy offices of the Department. Coordination among these offices is important for understanding not only water required for all facets of energy production, from biofuels to thermoelectric cooling, but also the energy required to provide water for various uses. BER research on the transport and transformation of energy-related substances in subsurface environments provides understanding that can enable DOE's Office of Environmental Management (EM) to develop new strategies for the remediation of weapons-related and other contaminants at DOE sites. In general, BER coordinates with DOE's applied technology programs through regular joint program manager meetings, by participating in their internal program reviews and in joint principal investigator meetings, as well as conducting joint technical workshops. Coordination with other federal agencies on priority climate science needs occurs through the interagency U.S. Global Climate Change Research Program under OSTP.

Program Accomplishments

Fundamental Bioenergy Research. DOE's Bioenergy Research Centers (BRCs) continue to advance the fundamental research enabling future efficient use of plant biomass for biofuel production. Detailed studies of how plants build cell walls have yielded new clues to inform the eventual development of woody trees such as poplar as a dedicated bioenergy crop with modified cell wall structures more amendable to sugar release upon biomass deconstruction. New insights into the metabolism of microbes living in extreme environments has resulted in the consolidation of biomass deconstruction and conversion processes in a single microbe, thereby demonstrating proof of concept for direct conversion of plant biomass to ethanol without pre-treatment, which would present a significant potential cost savings for biofuel production. Additionally, incorporation of new metabolic pathways engineered or derived from other organisms in nature, combined with the latest insights into gene regulation have produced a range of advanced biofuels and/or important precursors to advanced biofuels in model platform microorganisms. These results are but a snapshot of a much larger volume of research from the BRCs that continue to provide a firm scientific foundation to cellulosic biofuels development.

Genome-Enabled Systems Biology Research. New Genomic Science research on carbon cycling that combines DNA sequencing of the full microbial community (metagenomics) and analysis of expressed proteins has led to the identification of key active members of a methane-generating microbial community present in thawing arctic bogs. This new group of methanogenic microbes is widely dispersed in similar arctic bogs around the world and could help to simplify efforts to predict microbial methane production in these environments. In related studies, detailed genome-enabled approaches applied to methane-consuming bacteria led to the discovery of microbial methane consumption via a new fermentative pathway in the absence of oxygen. Combined, these discoveries are providing detailed new knowledge on how the activity of multiple members of a microbial community impact and control the cycling of methane in key environments.

New Translations of the Genetic Blueprint. Researchers at the Joint Genome Institute (JGI) used a combination of microbial community DNA sequencing techniques (metagenomics) and single-cell recovery and genome sequencing of microorganisms from a broad range of environments demonstrated that alternative translations of the genetic code exist in nature. Analysis of genomic DNA from some species could not be interpreted using the canonical techniques; however, translating the sequence using the new alternative coding rules revealed interpretable genomes. These results challenge researchers to consider alternative interpretations of genomes recovered from nature, with profound implications for understanding the origins of the genetic code, evolutionary pressures on genome coding and manipulation of metabolic pathways for beneficial purposes.

Improving Climate Models to Better Predict Precipitation. While climate models are adept at predicting future temperature changes on regional and global scales, the quality of precipitation predictions has not kept pace. To address this need, scientists used observations from the DOE Atmospheric Radiation Measurement Climate Research Facility (ARM) to discover that precipitation forecasts are limited largely by overly simplistic formulas for Secondary Organic Aerosols (SOAs) that influence droplet initiation and cloud formation. Using laboratory and field experimental data, the research has improved the understanding of SOA chemistry, including better understanding of how SOAs serve as cloud condensation nuclei. The improved formulas were incorporated into a climate model with significantly improved predictability of clouds and precipitation.

Simulating Agricultural Irrigation in Earth System Models. World agriculture consumes about 87 percent of global fresh water withdrawal, acting as a dominant component of the global water cycle with impacts on local and regional climates. Previous studies of irrigation impacts on climate have focused on a subset of local surface processes, but no study has applied uncertainty quantification methodologies to the combination of atmospheric, terrestrial, and water cycle interdependencies. Scientists upgraded the land component (CLM4) of the Community Earth System Model (CESM), to simulate irrigation water use and climatic feedbacks. Drawing upon two widely-used data sets from the agriculture census, they found that CLM4 could be improved by applying updated calibrations and incorporating information on the spatial distribution and intensity of irrigated areas. More importantly, the team identified a way to realistically assess the impacts of irrigation on climate and strategies to improve water management practices. Their results integrate a new set of CLM4 modules into CESM that describe groundwater pumping and irrigation efficiency, stream flow routing, and water management.

Description

Biological Systems Science integrates discovery- and hypothesis-driven science with technology development on plant and microbial systems relevant to DOE bioenergy mission needs. 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 using systems biology approaches to define the functional principles that drive living systems, from microbes and microbial communities to plants and other whole organisms.

Key questions that drive these studies include:

- What information is encoded in the genome sequence?
- How is information exchanged between different subcellular constituents?
- What molecular interactions regulate the response of living systems and how can those interactions be understood dynamically and predictively?

The subprogram builds upon a successful track record in defining and tackling bold, complex scientific problems in genomics—problems that required the development of large tools and infrastructure; strong collaboration with the computational sciences community and the mobilization of multidisciplinary teams focused on plant and microbial bioenergy research. The approaches employed include genome sequencing, proteomics, metabolomics, structural biology, high-resolution imaging and characterization, and integration of information into computational models that can be iteratively tested and validated to advance a predictive understanding of biological systems from molecules to mesoscale.

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

Genomic Science

The Genomic Science activity supports research aimed at identifying the fundamental principles that drive biological systems relevant to DOE missions in energy, climate, and the environment. These principles guide the translation of the genetic code into functional proteins and the metabolic/regulatory networks underlying the systems biology of plants, microbes, and communities. Advancing fundamental knowledge of these systems will enable new solutions to national challenges in sustainable bioenergy production, understanding how microbial activity impacts the fate and transport of materials such as nutrients and contaminants in the environment, and developing new approaches to examine the role of biological systems in carbon cycling, biosequestration, and global climate.

The major objectives of the Genomic Science activity are to determine the molecular mechanisms, regulatory elements, and integrated networks needed to understand genome-scale functional properties of microbes, plants, and communities; develop "-omics" experimental capabilities and enabling technologies needed to achieve a dynamic, system-level understanding of organism and community functions; and develop the knowledgebase, computational infrastructure, and modeling capabilities to advance predictive understanding, manipulation and design of biological systems.

A major effort within the portfolio seeks to provide a fundamental understanding of the biology of plants and microbes as a basis for developing cost effective processes for biofuel production from cellulosic biomass. The DOE Bioenergy Research Centers (BRCs) are central to this effort and have provided a substantial body of scientific literature and intellectual property towards this goal. Additional efforts within Genomic Sciences include fundamental research on new plant feedstocks for bioenergy, new sustainability research for bioenergy production, biosystems design to develop new plants and microbes with bioenergy-relevant traits and environmental microbiological research to understand the cycling and fate of carbon, nutrients and contaminants in the environment. These systems biology efforts are supported by the ongoing development of bioinformatics and computational biology capabilities within the DOE Systems Biology Knowledgebase (KBase). The integrative KBase projects seek to develop the necessary hypothesis-generating analysis techniques and simulation capabilities on high performance computing platforms to accelerate systems biology research within the Genomic Sciences.

Mesoscale to Molecules

BER approaches to systems biology focus on translating information encoded in an organism's genome to those traits expressed by the organism. These genotype to phenotype translations are key to gaining a predictive understanding of cellular function under a variety of environmental and bioenergy-relevant conditions. The Mesoscale to Molecules activity will continue to encourage the development of new measurement and imaging technologies to visualize the spatial and temporal relationships of key metabolic processes governing phenotypic expression in plants and microbes. This information is crucial towards developing an understanding of the impact of various environmental and/or biosystems design impacts on whole cell or community function.

Radiological Sciences

Radiological Sciences supports radionuclide tracer synthesis and imaging research for real-time visualization of dynamic biological processes in energy and environmentally relevant contexts. The activity has significantly transitioned from its historical focus on nuclear medicine research and applications for human health to focus on real-time, whole organism understanding of metabolic and signaling pathways in plants and nonmedical microbes. 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. The instrumentation research focuses on improved metabolic imaging in living systems, including plants and microbial-communities, relevant to biofuels production and environmental processes. The activity also supports fundamental research on the impacts of low dose radiation on metabolic processes and DNA repair mechanisms in model biological systems.

Biological Systems Science Facilities and Infrastructure

Biological Systems Science supports unique scientific facilities and infrastructure related to genomics and structural biology that are widely used by researchers in academia, the national laboratories, and industry. The DOE Joint Genome Institute (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. High-throughput DNA sequencing underpins modern systems biology research, providing fundamental biological data on organisms and groups of organisms. By understanding shared features of multiple genomes, scientists can identify key genes that may link to biological function. These functions include microbial metabolic pathways and enzymes that are used to generate fuel molecules, affect plant biomass formation, degrade contaminants, or capture CO_2, leading to the optimization of these organisms for biofuels production and other DOE missions.

The JGI is developing aggressive new strategies for interpreting complex genomes through new high-throughput functional assays, DNA synthesis and manipulation techniques and, genome analysis tools in association with the DOE Systems Biology KBase. These new capabilities are part of the JGI's latest strategic plan to provide users with additional capabilities supporting biosystems design efforts for biofuels and environmental process research. The JGI also performs metagenome (genomes from multiple organisms) sequencing and analysis from environmental samples and single cell sequencing techniques for hard-to-culture microorganisms from understudied environments relevant to the DOE missions.

BER also supports development and use of specialized instrumentation for biology at major DOE user facilities, such as synchrotron light sources and neutron facilities, in collaboration with the other SC program offices. These research facilities enable science aimed at understanding the structure and properties of biological molecules at resolutions and scales not accessible with instrumentation available in university, research institute, or industrial laboratories. This information is critical in contributing to our understanding of the relationship between genome, biological structure, and function. BER is also taking steps to ensure that the data will be integrated into the DOE Systems Biology KBase to help accelerate practical applications of this knowledge for energy and the environment.

Activities and Explanation of Changes

FY 2015 Enacted	FY 2016 Request	Explanation of Change FY 2016 vs. FY 2015
Biological Systems Science $299,892,000	**$294,271,000**	**-$5,621,000**
Genomic Science ($190,885,000)	**($193,030,000)**	**(+$2,145,000)**
Genomic Science research remains a priority activity. Foundational Genomics Research continues to support development of biosystems design tools and biodesign technologies for plant and microbial systems relevant to bioenergy production, and genomics enabled approaches to examine impacts of bioenergy production and climate change on carbon and nutrient cycling processes in terrestrial ecosystems. At least 5% of the funding for biodesign efforts is used to study the environmental, ethical, legal, and societal impacts. Genomics Analysis and Validation integrates experimental biology and technology development to improve functional characterization of genomic datasets. The emphasis of research in Metabolic Synthesis and Conversion shifts to advancing systems biology understanding and developing tools for the genetic modification of a broader set of plant and microbial species relevant to carbon cycling and bioenergy production. Research efforts at the Bioenergy Research Centers continue to advance biofuels development from foundational biological systems science. Computational Biosciences continues to support the operation of the DOE Systems Biology KBase, providing the research community with online tools for data integration and predictive modeling and increasing development of interoperable platforms for varying data types and scaling of data environments	Genomic Science will continue to remain a top priority. Foundational Genomics will increase to develop biosystems design techniques for plants and microbial systems relevant to bioenergy production and research on key parameters influencing the sustainability of bioenergy crops. Genome Analysis and Validation will continue research on improving the functional characterization of microorganisms and microbial communities relevant to biofuel production. Metabolic Synthesis and Conversion will continue research to broaden the range of model plant and microbial systems available for bioenergy research and, to understand the impact of microbial communities on the fate of carbon, nutrients and contaminants in the environment. At least 5% of the funding for biodesign efforts will be used to study the environmental, ethical, legal, and societal impacts. Computational Biosciences will continue to advance the bioinformatics and computational biology techniques needed within the DOE Systems Biology KBase to accelerate systems biology research. Bioenergy research at the DOE Bioenergy Research Centers will continue to provide a fundamental scientific basis for cellulosic biofuels production.	Increased efforts in Biosystems design efforts will develop additional metabolic engineering techniques for bioenergy production. Other Genomic Science research including bioenergy, computational biology and, plant and microbial research relevant to bioenergy and environmental research continue at near FY 2015 levels. Genome Analysis and Validation is reduced in order to support biosystems design efforts.

FY 2015 Enacted	FY 2016 Request	Explanation of Change FY 2016 vs. FY 2015
across multiple levels of biological organization.		
Mesoscale to Molecules ($9,680,000)	**($9,623,000)**	**(-$57,000)**
The properties of many complex systems at one observational scale cannot be extrapolated accurately from processes at another scale because the nature of the scaling relationships is unknown. Increased investments complement pilot projects initiated in FY 2014 and continue efforts to understand the spatial organization of metabolic processes in cells and the physical rules that govern metabolism in subcellular organelles in biological systems. Identifying scaling relationships allows accurate representation of functional relationships within the cell, facilitating improved predictions of multicellular interactions and biological organism behavior with respect to energy and the environment. New modeling concepts will be developed and validated with new imaging tools and resources at the national scientific user facilities and within the DOE Systems Biology KBase.	The development of new enabling technologies to visualize key metabolic processes in plants and microbes will continue. These new techniques will provide integrative information on the spatial and temporal relationships of metabolic processes occurring within and among cells. This information is crucial to integrating molecular scale understanding of metabolic processes into the context of the dynamic whole cell environment and to the development of predictive models of cell function.	No significant change.
Radiological Sciences ($5,074,000)	**($2,000,000)**	**(-$3,074,000)**
Core activities in Radiochemistry and Imaging Instrumentation continue to stress development of radiotracer techniques and instrumentation to visualize metabolic processes in plants and microbes non-invasively and in real time. Core efforts in radiobiology continue to evaluate methods to translate molecular-scale effects of low dose radiation to whole model organisms.	Funds are requested for an orderly closeout of Radiological Science activities in FY 2016.	Activities within the Radiological Sciences continue to decrease as research within the Biological Systems Science activity is prioritized on bioenergy and environmental research within the Genomic Science activity. Funding levels are reduced as these activities are proposed to be closed out in FY 2016.

FY 2015 Enacted	FY 2016 Request	Explanation of Change FY 2016 vs. FY 2015
Biological Systems Science Facilities and Infrastructure ($84,395,000)	**($79,500,000)**	**(-$4,895,000)**
The JGI maintains its efforts to provide high quality DNA sequence and also brings on new capabilities to interpret, manipulate, and write DNA in support of biofuels, biodesign, and environmental research as part of the implementation of JGIs' new strategic plan. JGI continues to maintain a close linkage with the DOE Systems Biology KBase allowing the research community to access and analyzes the latest genome sequence information produced by the JGI.	The JGI remains an essential component for genomic research within BER. The facility will continue to implement its latest strategic plan and provide scientific users with plant and microbial genome sequences of the highest quality and advanced capabilities to analyze, interpret and manipulate genes in support of bioenergy, biosystems design and environmental research. The JGI will continue to collaborate closely with the DOE Systems Biology KBase to provide not only community access to sequenced genomes but access to computational systems to experimentally interrogate those genomes.	No significant change in funding. The number of JGI users is expected to increase as new functional genomics and DNA synthesis capabilities become available.
Support continues for the instrumentation and end stations for structural biology at the DOE synchrotron light and neutron sources. Additional efforts are made to link the resulting data from these stations with the DOE Systems Biology KBase.	Access to the Structural Biology Infrastructure at the DOE synchrotron light and neutron sources will continue to provide information on the structural features of biomolecules and continue to make this information available to the larger research community through the Protein Data Base and the DOE Systems Biology KBase.	Structural Biology decreases as efforts in bioenergy and environmental research in Genomic Science are prioritized within the current budget request. End stations at the DOE synchrotron light and neutron sources will continue to support scientific users. The portfolio will be assessed to ensure that the latest capabilities are available to and being used by the scientific community.

Biological and Environmental Research
Climate and Environmental Sciences

Description

The Climate and Environmental Sciences subprogram supports fundamental science and research capabilities that enable major scientific developments in climate-relevant atmospheric and ecosystem process and modeling research, in support of DOE's mission goals for basic science, energy, and national security. This includes research on clouds, aerosols, and the terrestrial carbon cycle; large-scale climate change and Earth system modeling; the interdependence of climate change and ecosystems; and integrated analysis of climate change impacts on energy and related infrastructure. It also supports subsurface biogeochemical research that advances fundamental understanding of coupled physical, chemical, and biological processes controlling both the terrestrial component of the carbon cycle and the environmental fate and transport of energy byproducts, including greenhouse gases. This integrated portfolio of research from molecular-level to field-scales emphasizes the coupling of multidisciplinary experimentation and advanced computer models and is aimed at developing predictive, systems-level understanding of the fundamental science associated with climate change and other energy-related environmental challenges. The Department will continue to advance the science necessary to further develop predictive climate and Earth system models targeting resolution at the regional spatial scale and interannual to centennial time scales and to focus on areas of critical uncertainty including Arctic ecology and permafrost thaw, tropical ecological change, and carbon release, in close coordination with the U.S. Global Change Research Program (USGCRP) and the international science community. In addition, environmental research activities will support fundamental research to explore advances in environmental cleanup and reductions in life cycle costs.

The subprogram supports three primary research activities, two national scientific user facilities, and a major data activity. The two national scientific user facilities are the Atmospheric Radiation Measurements Climate Research Facility (ARM) and the Environmental Molecular Sciences Laboratory (EMSL). ARM provides unique, multi-instrumented capabilities for continuous, long-term observations needed to develop and test understanding of the central role of clouds and aerosols on the earth's climate. EMSL provides integrated experimental and computational resources needed to understand the physical, chemical, and biological processes that underlie DOE's energy and environmental mission. The data activity encompasses observations collected by dedicated field experiments, routine and long term observations accumulated by user facilities, and model generated information derived from climate modeling platforms.

Atmospheric System Research

Atmospheric System Research (ASR) is the primary U.S. activity addressing two major areas of uncertainty in climate change model projections: the role of clouds and the effects of aerosols on precipitation, and the atmospheric radiation balance. ASR coordinates with ARM, using the facility's continuous long-term datasets that provide three-dimensional measurements of radiation, aerosols, clouds, precipitation, dynamics, and thermodynamics over a range of environmental conditions at diverse climate-sensitive locations. The long-term observational datasets are supplemented with laboratory studies and shorter-duration ground-based and airborne field campaigns to target specific atmospheric processes under a diversity of locations and atmospheric conditions. ASR research results are incorporated into Earth system models developed by Climate and Earth System Modeling to both understand the processes that govern atmospheric components and to advance Earth system model capabilities with greater certainty of predictions. ASR seeks to develop integrated, scalable test-beds that incorporate process-level understanding of the life cycles of aerosols, clouds, and precipitation into dynamic models.

Environmental System Science

Environmental System Science supports research to provide a robust, predictive understanding of terrestrial surface and subsurface ecosystems, including the effects of climate change, from the subsurface to the top of the vegetated canopy and from molecular to global scales. This includes understanding the role of ecosystems in climate with an emphasis on carbon cycling and the role of subsurface biogeochemical processes in the fate and transport of carbon, nutrients, radionuclides, and heavy metals.

A significant fraction of the carbon dioxide (CO_2) released to the atmosphere during fossil fuel combustion is taken up by terrestrial ecosystems, but the impacts of climatic change, particularly warming, on the uptake of CO_2 by the terrestrial biosphere remain poorly understood. The significant sensitivity of climate models to terrestrial carbon cycle feedback and the uncertain signs of that feedback make resolving the role of the terrestrial biosphere on the carbon balance a high priority. Using decadal-scale investments such as the Next Generation Ecosystem Experiments (NGEEs) to study the variety of time scales and processes associated with ecological change, the research focuses on understanding, observing, and modeling the processes controlling exchange rates of greenhouse gases, in particular CO_2 and methane (CH_4), between atmosphere and terrestrial biosphere, evaluating terrestrial source-sink mechanisms for CO_2 and CH_4, and improving and validating the representation of terrestrial ecosystems in coupled Earth system models. This research supports the USGCRP interagency priority to understand the impacts of global change on the Arctic Region and resulting effects on global climate.

Subsurface biogeochemical research supports integrated experimental and modeling research, ranging from molecular to field scales, to understand and predict the role that biogeochemical processes play in controlling the cycling and mobility of energy-relevant materials in the subsurface and across key surface-subsurface interfaces in the environment, including environmental contamination from past nuclear weapons production.

Climate and Earth System Modeling

Climate and Earth System Modeling develops physical, chemical, and biological model components, as well as fully coupled Earth system models that combine with sophisticated representations of human activities. This research includes the interactions of human and natural Earth systems needed to simulate climate variability and change from years to decades to centuries at regional and global scales. The research specifically focuses on quantifying and reducing the uncertainties in Earth system models based on more advanced model development, diagnostics, and climate system analysis. Priority model components include the ocean, sea-ice, land-ice, aerosols, atmospheric chemistry, terrestrial carbon cycling, multi-scale dynamical and physical interdependencies, and dynamical cores. This research supports the USGCRP interagency priority in intraseasonal to centennial predictability, predictions and projections, including focus on extreme events.

In FY 2016, BER will initiate an investment in Climate Model Development and Validation. The focus of the investment involves model architecture restructuring, exploiting new software engineering and computational upgrades, and incorporating scale-aware physics in all model components, as part of the DOE-wide Exascale crosscut. DOE modeling activities will continue development of modularized components that can act either alone or as a system able to run on current and next generation supercomputers, thus allowing greater certainty of predictions in a flexible structure. Because model development requires systematic validation at each step, investment in model assessment and validation will continue. Examples include the use of ARM data combined with scale-aware Large Eddy Simulation products. High resolution ARM and model ensemble data bases will be integrated into the advanced data management infrastructure effort, the Climate and Environmental Data Analysis and Visualization activity, for use by the scientific research community. Other validation platforms include the sensitivity and uncertainty of climate predictions to explore climate sensitive geographies or processes as well as the representation of extreme events in these next generation models.

The Regional and Global Climate modeling activity will increase investments in scientific analyses using DOE's investments in climate and Earth system model development combined with new efforts to advance and apply modeling and analysis tools as part of the DOE-wide Energy-Water Nexus Tobjectives, with particular focus on developing regional simulations based on interdependencies of climate change with dynamical representation of components of energy flow Sankey diagrams. The Regional and Global Climate modeling activity will additionally conduct scientific analyses to study the predictability of statistical distributions of future weather extremes; causes and distributions of droughts; biogeochemical controls on abrupt climate change; the role of the highly resolved patterns of carbon budgets on regional and global climate change; energy-water interdependencies; and the roles of cryospheric phenomena (sea ice, glaciers, ice sheets, and permafrost thaw) on Arctic climate, sea level rise, and large scale modes of variability. Also, research will explore model derived analogs that combine historical and projected climate changes, with an objective to validate and improve the uncertainty characterization of future climate projections based on the prediction successes using existing data testbeds. To rapidly and efficiently advance model capabilities, BER supports a unique and powerful intercomparison resource, the Program for Climate Model Diagnosis and Intercomparison (PCMDI), for global climate model development, validation, diagnostics, and outputs, using over 40 world-leading climate models. This set of diagnostic and intercomparison activities combined with scientific analysis, ensures that BER funded researchers can exploit the best available science and practice within each of the world's leading climate research programs.

The Earth System Modeling activity in BER will continue to coordinate with the National Science Foundation (NSF) to provide support for greater sophistication of Earth system models, in particular the Community Earth System Model system (CESM) that is co-funded by DOE and NSF. CESM is designed by the research community with open access and broad use by climate researchers worldwide. In addition, DOE will continue to advance a new version of CESM, i.e., the Advanced Climate Model for Energy (ACME), as a computationally efficient model adaptable to emerging computer architectures and with greater sophistication and fidelity for high resolution simulation. This system of models provides a critical capacity for regional climate projections, including information on how the frequency of occurrence and intensity of storms, droughts, heat waves, and regional sea-level will change as climate evolves. The scientific priorities for improvement of the community models are based on efforts to quantify uncertainties relative to specific scientific questions; and the outputs of the intercomparison and validation resource allow one to determine best features of all global models that can be considered for incorporation into DOE's ACME modeling platform. DOE also has provided computational capability and expertise to the climate research community through a partnership between BER and the Office of Science's Advanced Scientific Computing Research (ASCR) program, which is investing in innovative code and algorithm designs for optimal model computation on its petascale computers. Climate modeling, simulation, and analysis tools are essential for informing investment decision-making processes for infrastructure associated with future large-scale deployment of energy supply and transmission.

The Integrated Assessment activities in BER develop integrated assessment (IA) models and impacts analyses, and will add in FY 2016 a new effort to integrate adaptation and vulnerability (IAV) capabilities into the modeling and predictive capabilities. These new efforts will specifically support the Energy-Water Nexus objectives, with focus on development and demonstration of a novel high resolution community IA-IAV hybrid model system, improving not only the resolution but the detailed process representations for autonomous elements as well as for coupled energy-water-land system interdependencies. New efforts will also include development of a generalized regional connected infrastructure model, with software compatibility to IA, IAV, and climate system models. The Integrated Assessment activity will also address uncertainty characterization of both the individual physical, biogeophysical, and sectoral (including energy infrastructure as well as emerging clean energy technology deployment) drivers, extending from macroscale (greater than 50 km resolution) to the much finer scales of Earth system prediction (order of 10 km).

Climate and Environmental Facilities and Infrastructure

Climate and Environmental Facilities and Infrastructure include two scientific user facilities, and climate data management for the climate science community. The 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 BER's mission.

ARM is a multi-platform multi-site national scientific user facility, providing the world's most comprehensive continuous field measurements of climate data to advance atmospheric process understanding and climate models through precise observations of atmospheric phenomena. ARM currently consists of three fixed long-term measurement facility sites (in Oklahoma, Alaska, and the Azores), three mobile facilities, and an airborne research capability that operates at sites selected by the scientific community. The ARM fixed sites and mobile measurement campaigns are distributed around the world in locations where the scientific community most critically needs enhanced understanding and data to incorporate into climate models, thereby improving model performance and predictive capabilities. Each of the ARM sites includes scanning radars, lidar systems, and in situ meteorological observing capabilities; the sites are additionally used to demonstrate technologies as they are developed by the community. ARM experiments to study the impact of evolving clouds, aerosols, and precipitation on the Earth's radiative balance and rate of climate change address the two most significant scientific uncertainties in climate research. ARM will incorporate very high resolution Large Eddy Simulations (LES) at the permanent Oklahoma site, during specific campaigns requested by the scientific community. Also, BER is also maintaining the exponentially increasing data archive to support enhanced analyses and model development. The data extracted from the archive are used to improve climate projections at higher resolution, greater sophistication, and lower uncertainty.

EMSL provides integrated experimental and computational resources for discovery and technological innovation in the environmental molecular sciences. EMSL enables users to undertake molecular-scale experimental and theoretical research on biological systems, biogeochemistry, aerosol chemistry, and interfacial and surface science relevant to climate, energy, and environmental challenges facing DOE and the Nation. This includes science supporting alternative energy sources, improved catalysts and materials for industrial applications, insights into factors influencing climate change and carbon sequestration processes, and subsurface biogeochemical drivers.

Data sets generated by ARM, other DOE and Federal Earth observing activities, and Earth system modeling activities, are enormous. The information in Earth observations data can be used to achieve broad benefits ranging from planning and development of energy infrastructure to natural disaster impact mitigation to commercial supply chain management to natural resource management. Access to and uses of these data are fundamental to supporting decision-making, scientific discovery, and technological innovation. DOE's data management activities will be coordinated with the Big Data Research and Development Initiative,[a] and internally collaborative with the Advanced Scientific Computing Research program.

In FY 2016, the BER Data Management activity includes efforts to harmonize and integrate metadata from the Earth System Grid Federation, ARM and NGEE field experiments, and relevant components of data. Analytical tools will be integrated into the program, including capabilities for diagnostics, validation, and uncertainty quantification.

[a] (http://www.whitehouse.gov/sites/default/files/microsites/ostp/big_data_press_release_final_2.pdf)

Activities and Explanation of Changes

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Climate and Environmental Sciences $292,108,000	**$318,129,000**	**+$26,021,000**
Atmospheric System Research (ASR) ($25,892,000)	**($26,392,000)**	**(+$500)**
ASR continues to focus on highest priority areas of uncertainty in climate projections—the behavior and function of clouds and aerosols and their role in controlling the atmospheric radiation balance.	ASR will continue to focus on atmospheric cloud and aerosol issues that limit climate modeling capabilities, with a particular emphasis on Arctic mixed phase clouds and tropical systems with large variations of aerosol characterization. ASR will also exploit Large Eddy Simulation (LES) as a tool to understand scale-aware physics governing aerosol transformations, cloud nuclei formation and growth, and cloud evolution. ASR will utilize a combination of observations and LES modeling to explore strongly heterogeneous environments, as observed in the Arctic and the Tropics, to advance the range of conditions applicable to nonhydrostatic parameterizations (models with less than 10 km resolution).	Initiation of a new effort will demonstrate use of Large Eddy Simulations to improve understanding of mid-latitude cloud physics.

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Environmental System Science (ESS) ($67,567,000)	**($63,242,000)**	**(-$4,325,000)**
Research continues to understand and predict the roles of terrestrial ecosystems in the larger earth system. NGEE Arctic will begin the transition to Phase II of the project, building from three years of field sampling and process modeling at the Barrow, Alaska site for Phase I and extending to seven additional years of multiple site sampling, multiple site process modeling, and dynamic model integration. NGEE Tropics continues with investments to carefully connect field and modeling activities. AmeriFlux emphasizes efforts to encourage common practices and protocols across the network. Subsurface biogeochemistry continues to focus on fundamental processes that control the fate and transport of energy byproducts, including greenhouse gasses in the subsurface and across key surface-subsurface interfaces in the environment.	Research will continue with NGEE Arctic Phase II, with multiple sites in northern Alaska involved in observation and modeling. NGEE Tropics will begin early observations to test new modeling architectures, appropriate for tropical terrestrial systems. The subsurface biogeochemistry investments will involve a combination of advanced modeling architectures and field research, with existing data used to test predictive modeling concepts. AmeriFlux will support efforts to improve terrestrial land modeling component, to test new concepts and build testbeds for high resolution land model validation.	Environmental System Sciences decreases but will exploit opportunities for greater efficiencies by aggregating a higher fraction of its research into decadal-scale climate-ecosystem science campaigns e.g., NGEE Arctic, NGEE Tropics, a northern peat land experiment, and AmeriFlux. This peat land site in northern Minnesota will be fully accessible for research in FY 2016, with numerous laboratory and academic research projects coordinated under a strategy to advance system predictability.

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Climate and Earth System Modeling ($71,195,000)	**($101,954,000)**	**(+$30,759,000)**
Research to provide advanced software and improved algorithms for DOE Climate Modeling leads to improved Earth system model code that is designed to run optimally on next-generation supercomputers with numerous processors. Research on climate model development and analysis focuses on the science underpinning high-resolution predictability. Emphasis continues on land and atmosphere modeling investments that parallel and connect with investments in the process research aspects of the subprogram.	Research will continue to extend capabilities for the Advanced Climate Model for Energy (ACME) to include nonhydrostatic atmospheric modeling (less than 10 km resolution), more sophisticated ice sheet physics, and a new approach for terrestrial modeling that uses plant functional traits instead of plant "types" for more physical representation of biology. Investments will begin to advance software and physics describing the interface between ice-sheets and other components (ocean, land and atmosphere). New methods for capturing the statistics of climate change will be initiated. Regional climate analysis will address interdependencies involving the water and energy sectors, using details on existing and projected infrastructures. In addition, new multi-ensemble statistical methods for vulnerability analysis applied to the energy-water-land nexus will be developed, with special focus on regional coastal inundation and storm-surge, changes in water availability for a coupled climate-human system, and energy implications of extreme events. Interdependencies of the energy-water nexus will be explored within a full climate system analysis, as well as developing vulnerability analysis techniques to treat the energy-water nexus with existing and projected infrastructure. Climate Model Development and Validation will focus on model architecture restructuring, exploiting new software engineering and computational upgrades, incorporating scale-aware physics in all model components and enhanced efforts to assess and validate model results.	Climate and Earth System Modeling will increase investment to understand the interdependencies of the energy-water-land nexus, using a combination of integrated assessment and impacts, analysis, and vulnerability (IAV) that couple with Earth system models. New multi-ensemble statistical methods will be incorporated into the analysis, and software interfaces will be improved to accommodate IAV coupling with IA and Earth system models. Funding also increase for the new investment in Climate Model Development and Validation that will employ new software and improved scale-aware physics to allow fully integrated climate models to achieve much higher spatial resolution.

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Core research in Regional and Global Climate Modeling, Earth System Modeling and Integrated Assessment continues to underpin high-resolution predictability using adaptive grids and uncertainty characterization. These investments provide scientific analyses based on DOE's climate and Earth system model capabilities including the predictability of statistical distributions of extreme events, carbon budgets the impacts of changes in cryospheric phenomena, and large scale modes of variability. Continued development of a system of models provides a critical capacity for regional climate projections, including information on how the frequency of extreme events will change as climate evolves. Support also is provided for the development of integrated assessment model components with a focus on assessing the interdependencies of energy, water, and land sector activities that are coupled to the physical and biogeochemical drivers of climate and earth system change.	Core research in Regional and Global Climate Modeling, Earth System Modeling and Integrated Assessment will continue to underpin high-resolution predictability using adaptive grids and uncertainty characterization, and more sophisticated data management.	Funding is increased for unified metadata and analytical methods from the modeling and observational components of the program, with a goal increase scientific output using multi-disciplinary and multi-media capabilities.

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Climate and Environmental Facilities and Infrastructure ($117,930,000)	**($115,686,000)**	**(-$2,244,000)**
ARM continues to support its long-term measurements at fixed sites, and the mobile facilities are deployed to three climate-sensitive regions demanding targeted measurements. The first mobile facility remains in the Amazon Basin; the second is deployed on the NOAA ship Ron Brown for a campaign in the Pacific Ocean; the third continues the experiment in Oliktok, Alaska. These observations are key to reducing the earth system model uncertainties attributed to clouds and aerosols.	ARM will continue to support its long-term measurements at fixed sites, and the mobile facilities will be deployed to three climate-sensitive regions demanding targeted measurements. The first mobile facility will remain in the Amazon Basin for the first quarter, thereafter undergo maintenance; the second will be deployed to Antarctica; the third will continue the experiment in Oliktok, Alaska. These observations, combined with dedicated modeling and simulation, are key to reducing the earth system model uncertainties attributed to clouds and aerosols. The ARM second mobile facility deployment to Antarctica will represent the first major ARM campaign in the southern hemisphere. Incorporation of modeling and simulation as part of ARM data acquisition will be initiated	ARM decreases its investments in a planned field deployment of the first ARM mobile facility, AMF1, due to delays in field campaigns schedules.
EMSL continues to support users and their research in biological systems, biogeochemistry, aerosol chemistry, and interfacial and surface science relevant to climate, energy, and environmental challenges facing DOE and the Nation. Emphasis is placed on utilization of new capabilities in the Radiological Annex and Quiet wing. In FY 2015 the integrated HRMAC system will be tested to meet specifications, and procedures will be developed for user operations. EMSL will develop a plan for targeting and attracting users for the new capability.	EMSL continues to support users and their research in biological systems, biogeochemistry, aerosol chemistry, and interfacial and surface science relevant to climate, energy, and environmental challenges facing DOE and the Nation. Emphasis will be placed on utilization of new capabilities in the Radiological Annex and Quiet wing. In FY 2016 the integrated HRMAC system will be available for new research. The installation and availability of the HRMAC, with its 21Tesla magnet, will provide unique enhancements to EMSL's capabilities available to the research community.	EMSL funding decreases and EMSL will address a more focused set of scientific challenges, resulting in sunsetting some capabilities and more efficient utilization of remaining instrumentation.

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
The Climate and Environmental Data Analysis and Visualization activity combines high resolution earth system models with interdependent components involving energy and infrastructure sector models, field observations, raw data from environmental field experiments, and analytical tools for system diagnostics, validation, and uncertainty quantification. Existing data management activities are combined with new capabilities to create this Climate and Environmental Data Analysis and Visualization activity which will integrate and add value to the subprogram's high resolution modeling needs and output, expanding observational data sets and extensive data from field and laboratory experiments and observations.	The Climate and Environmental Data Analysis and Visualization activity will continue to advance high resolution earth system models and data management capabilities, with a greater focus on nonhydrostatic dynamical cores, extreme events, and the assimilation of Large Eddy Simulation ensembles to provide statistics of sub-grid parameterizations for a wider range of conditions involving extreme events. Model-data fusion will be explored with new visualization technologies.	Funding is increased for the Climate and Environmental Data Analysis and Visualization activity so that the existing metadata from the components of BER climate and environmental facilities (ARM, EMSL), NGEEs, and modeling can achieve compatibility. They will be unified under a common architecture with new visualization technologies.
Participation in the Big Earth Data Initiative continues.	Participation in the Big Earth Data Initiative continues.	No change.
In FY 2015, ORISE GPP/GPE is transferred to the Science Laboratories Infrastructure program.	In FY 2015, ORISE GPP/GPE was transferred to the Science Laboratories Infrastructure program.	No change.

Biological and Environmental Research
Performance Measures

In accordance with the GPRA Modernization Act of 2010, the Department sets targets for, and tracks progress toward, achieving performance goals for each program. The following table shows the targets for FY 2014 through 2016.

	FY 2014	FY 2015	FY 2016
Performance Goal (Measure)	**BER Climate Model—Develop a coupled climate model with fully interactive carbon and sulfur cycles, as well as dynamic vegetation to enable simulations of aerosol effects, carbon chemistry, and carbon sequestration by the land surface and oceans and the interactions between the carbon cycle and climate**		
Target	Use global models to estimate most sensitive elements of terrestrial carbon to climate change for tropics, mid-latitudes, and polar regions	Develop capabilities to extend temporal resolution to sub-decadal for earth system models.	Develop and apply a fully coupled ice-sheet model to estimate near-term changes to the West Antarctic ice sheet.
Result	Met	TBD	TBD
Endpoint Target	BER supports the Community Earth System Model, a leading U.S. climate model, and addresses two of the most critical areas of uncertainty in contemporary climate science—the impacts of clouds and aerosols. Delivery of improved scientific data and models (with quantified uncertainties) about the potential response of the earth atmosphere system to more accurately predict the earth's future climate is essential to plan for future energy needs, water resources, and land use. DOE will continue to advance the science necessary to further develop predictive climate and earth system models at the regional spatial scale and decadal to centennial time scales, involving close coordination with the U.S. Global Change Research Program and through the international science community.		
Performance Goal (Measure)	**BER Predictive Understanding of Biological Systems—Advance an iterative systems biology approach to the understanding and manipulation of plant and microbial genomes as a basis for biofuels development and predictive knowledge of carbon and nutrient cycling in the environment.**		
Target	Not Applicable	Develop 1 new computationally enabled approach to analyze complex genomic datasets.	Develop an improved metabolic engineering method for modifying microorganisms for biofuel production from cellulosic sugars.
Result	Not Applicable	TBD	TBD
Endpoint Target	BER will advance understanding of the operating principles and functional properties of plants, microbes, and complex biological communities relevant to DOE missions in energy and the environment. Deciphering the genomic blueprint of organisms and determining how this information is translated to integrated biological systems permits predictive modeling of bioprocesses and enables targeted redesign of plants and microbes. BER research will address fundamental knowledge gaps and provide foundational systems biology information necessary to advance development of sustainable bioenergy systems and predict impacts of changing environmental conditions on carbon cycling and other biogeochemical processes.		

Biological and Environmental Research
Capital Summary ($K)

	Total	Prior Years	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Capital Operating Expenses Summary							
Capital equipment projects under $2 million TEC	n/a	n/a	6,751	6,751	4,667	4,500	-167
General plant projects (GPP) under $5 million TEC	n/a	n/a	250	250	0	0	0
Total, Capital Operating Expenses	**n/a**	**n/a**	**7,001**	**7,001**	**4,667**	**4,500**	**-167**

Funding Summary ($K)

	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Research	392,391	392,391	375,293	403,307	+28,014
Scientific user facilities operations and research	200,719	200,719	197,325	188,120	-9,205
Major items of equipment	0	0	0	0	0
Other[a]	16,586	500	19,382	20,973	+1,591
Total, Biological and Environmental Research	**609,696**	**593,610**	**592,000**	**612,400**	**+20,400**

Facility Operations ($K)

The treatment of user facilities is distinguished between two types: TYPE A facilities that offer users resources dependent on a single, large-scale machine; TYPE B facilities that offer users a suite of resources that is not dependent on a single, large-scale machine.

	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
TYPE B FACILITIES					
Atmospheric Radiation Measurement Climate Research Facility (ARM)	**$68,644**	**$68,644**	**$67,429**	**$65,429**	**-$2,000**
Number of users	1,000	1,000	900	900	N/A
Joint Genome Institute	**$70,143**	**$70,143**	**$69,500**	**$69,500**	**0**
Number of users	1,000	1,000	1,000	1,100	+100

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

	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Environmental Molecular Sciences Laboratory	**$46,942**	**$46,942**	**$45,501**	**$43,191**	**-$2,310**
Number of users	750	750	750	750	N/A
Structural Biology Infrastructure[a]	**$14,990**	**$14,990**	**$14,895**	**$10,000**	**-$4,895**
Total Facilities	**$200,719**	**$200,719**	**$197,325**	**$188,120**	**$-9,205**
Number of users	2,750	2,750	2,650	2,750	+100

Scientific Employment

	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Estimate	FY 2016 vs. FY 2015
Number of permanent Ph.D.'s	1,290	1,290	1295	1,350	+55
Number of postdoctoral associates	315	315	320	330	+10
Number of graduate students	400	400	440	450	+10
Other[b]	315	315	320	330	+10

[a] Structural Biology Infrastructure activities are at Basic Energy Sciences user facilities and the user statistics are included in the BES user statistics.
[b] Includes technicians, engineers, computer professionals and other support staff.