Biological and Environmental Research

Overview

The mission of the Biological and Environmental Research (BER) program is to support transformative science and scientific user facilities to achieve a predictive understanding of complex biological, earth, and environmental systems for energy and infrastructure security and resilience.

The program seeks to understand the biological, biogeochemical, and physical principles needed to understand fundamentally and be able to predict the processes occurring at scales ranging from the molecular and genomics-controlled smallest scales to environmental and ecological processes at the scale of the planet Earth. Starting with the genetic information encoded in organisms' genomes, BER research seeks to discover the principles that guide the translation of the genetic code into the functional proteins and the metabolic and regulatory networks underlying the systems biology of plants and microbes as they respond to and modify their environments. This predictive understanding will enable design and reengineering of microbes and plants for improved energy resilience and sustainability, including improved biofuels and bioproducts, improved carbon storage capabilities, and controlled biological transformation of materials such as nutrients and contaminants in the environment. BER research also advances the fundamental understanding of dynamic, physical, and biogeochemical processes required to systematically develop Earth System models that integrate across the atmosphere, land masses, oceans, sea ice, and subsurface required for predictive tools and approaches needed to inform policies and plans for future energy and resource needs.

Over the last two decades, BER's scientific impact has been transformative. Mapping the human genome through the U.S.-supported international Human Genome Project that DOE initiated in 1990 ushered in a new era of modern biotechnology and genomics-based systems biology. Today, researchers in the BER Genomic Sciences activity and the Joint Genome Institute (JGI) are using the powerful tools of plant and microbial systems biology to pursue the fundamental breakthroughs needed to advance the frontiers in energy-relevant systems biology. The three DOE Bioenergy Research Centers (BRCs) presently lead the world in fundamental biofuels-relevant research.

Since the 1950s, BER and its predecessor organizations have been critical contributors to fundamental scientific understanding of the atmospheric, land, ocean, and environmental systems in which life exists. The earliest work, dating back to the 1950s, included atmospheric and ocean circulation studies initiated to understand the effects of fallout from nuclear explosions in the early period of the Cold War. These efforts were the forerunners of the modern earth system models that are in use today. Presently, BER research contributes to model development and analysis; in the last decade, DOE research has made considerable advances in increasing the reliability and predictive capabilities of these models using applied mathematics and systematic comparisons with observational data to reduce uncertainties. BER-supported research also has produced the software and algorithms that enable the productive application of these models on DOE supercomputers, which are among the most capable in the world. These leading U.S. models are used to further fundamental understanding of two of the most critical areas of uncertainty in contemporary earth system sciences—the impacts of clouds and aerosols—with data provided by the Atmospheric Radiation Measurement Research Facility (ARM), a DOE user facility serving hundreds of scientists worldwide. Also, BER research has pioneered ecological and environmental studies in terrestrial ecosystems, seeking to describe the continuum of biological, biogeochemical, and physical processes across the multiple scales that control the flux of environmentally-relevant compounds between the terrestrial surface and the atmosphere. BER's Environmental Molecular Sciences Laboratory (EMSL) provides the scientific community with a powerful suite of tools to characterize biological organisms and molecules as well as atmospheric aerosol particulates. BER-supported systematic and objective model intercomparisons provide U.S. government policy makers up-to-date insight of the relative quality and capabilities of U.S. versus foreign earth-systems models, necessary for science-based international policy discussions.

Highlights of the FY 2018 Budget Request

The FY 2018 BER Budget Request implements Administration decisions to prioritize more fundamental research, overall, and to focus research on advancing the core missions of the DOE while maintaining American leadership in the area of scientific inquiry. BER support of basic research today will contribute to a future of stable, reliable, and secure sources of American energy based on transformative science for economic prosperity. BER places a priority on the DOE high-resolution earth system model, with significantly reduced contributions to the interagency Community Earth System Model (CESM) that is co-funded by DOE and the National Science Foundation (NSF). BER activities continue to support core research and scientific user facilities in key areas of bioenergy, earth systems modeling and observations, and environmental sciences. Activities eliminated or significantly reduced in the Earth and Environmental Systems Sciences subprogram (formerly known as the "Climate and Environmental Sciences" subprogram) include integrated assessments, support of the U.S. Global Change Research Program (USGCRP), climate feedbacks, anthropogenic aerosols and black carbon, analysis of the Atmospheric Radiation Measurement Research Facility (ARM) observations, field activity in the tropics, and user support to the northern peatland field site focused on functional responses to climate variability and atmospheric stressors.

The federally chartered BER Advisory Committee (BERAC) advises BER on its future development of effective research strategies for sustained leadership in biological and environmental research. BERAC holds targeted workshops, periodic reviews and forward looking overviews of BER relevant science, and the outcomes of these activities inform BER's ongoing and future research.

Biological Systems Science

Investments in the Biological Systems Science subprogram will provide the fundamental understanding to underpin transformative science in sustainable bioenergy production and to gain a predictive understanding of carbon, nutrient, and metal transformation in support of DOE's environmental missions. The subprogram prioritizes Genomic Sciences research activities to continue with core research that will provide a scientific basis for sustainable and cost effective bioproducts and bioenergy production. This includes reduced scope of the recompeted next phase DOE BRCs, which will initiate new research to provide a broad scientific underpinning to the production of fuels and chemicals from sustainable biomass resources and speed the translation of basic research results to industry. The subprogram directs efforts towards advanced biofuels and bioproducts research as it closes out completed research targeted on cellulosic ethanol. Biosystems design research continues to develop the knowledge necessary to engineer specific beneficial traits into plants and microbes for making biofuels or bioproducts from renewable biomass. Investment in microbiome research continues to build on BER's considerable experience in fundamental genomic science of plants and microbes and extend that expertise to understand the fundamental principles governing microbiome establishment, function, and interactions in diverse environments. Gaining a predictive understanding of how microbiomes control the availability of materials such as carbon and nutrients, and respond to changes in the environment or interact with plants, is crucial to advancing DOE's biotechnology and environmental research. The subprogram supports these fundamental genomic science activities with ongoing efforts to combine molecular and genomic scale information within the DOE Systems Biology Knowledgebase and to develop integrated networks and computational models of system dynamics and behavior.

Mesoscale research continues to provide spatial and temporal understanding of functional genomics within living cells; new efforts to explore use of quantum materials for advanced bioimaging and characterization will contribute towards a systems-level predictive understanding of biological processes.

The DOE Joint Genome Institute (JGI) remains an essential component for DOE systems biology efforts providing high quality genome sequence data and analysis techniques for a wide variety of plants and microbial communities. The JGI continues to implement its strategic plan to incorporate new capabilities to sequence DNA and also to interpret, manipulate, and synthesize DNA in support of sustainable renewable energy and products, and environmental research. With this range of capabilities, JGI is also uniquely positioned to support and advance DOE bioenergy and environmental microbiome research.

Earth and Environmental Systems Sciences

Earth and Environmental Systems Sciences research activities will focus on scientific analysis of how physical and biogeochemical processes impact the sensitivity and uncertainty of earth system predictions, with continued field studies on the Arctic through the Next Generation Ecosystem Experiment (NGEE) in Alaska. The Subsurface Biogeochemistry Research activity continues to focus on modeling and experimentation of the flows of subsurface nutrients and materials. Investments continue to support the E3SM (Energy Exascale Earth System Model) capability, tailored to DOE requirements for a variety of scenarios applied to spatial scales as small as 10 km. The model system will have improved resolution that will include advanced software 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 will continue to provide new observations selected to represent the diversity of environmental conditions necessary to advance earth system models. ARM continues long-term measurements at fixed sites in Alaska and Oklahoma. Operations at the fixed site in the Azores will be limited. An ARM mobile observatory will be deployed for focused and targeted measurements in the Southern Ocean.

EMSL will focus on a research agenda aligned with BER program research areas and highlighting opportunities with the High Resolution and Mass Accuracy Capability (HRMAC) instrument. With greatly improved dynamic range and sensitivity, HRMAC will enable a characterization and quantification of the chemical constituents and dynamics of complex natural systems in the environment including microbial communities, and soil and rhizosphere ecosystem.

The Data Management effort will focus on field observations and data from environmental field experiments.

Biological and Environmental Research
Funding ($K)

	FY 2016 Enacted[a]	FY 2017 Annualized CR[b]	FY 2018 Request	FY 2018 vs FY 2016
Biological Systems Science				
Genomic Science				
Foundational Genomics Research	76,125	–	75,000	-1,125
Genomics Analysis and Validation	9,248	–	7,474	-1,774
Metabolic Synthesis and Conversion	16,262	–	7,250	-9,012
Computational Biosciences	16,395	–	13,116	-3,279
Bioenergy Research Centers	75,000	–	40,000	-35,000
Total, Genomic Science	**193,030**	–	**142,840**	**-50,190**
Mesoscale to Molecules	**9,623**	–	**8,701**	**-922**
Radiological Sciences				
Radiochemistry and Imaging Instrumentation	1,000	–	0	-1,000
Radiobiology	1,000	–	0	-1,000
Total, Radiological Sciences	**2,000**	–	**0**	**-2,000**
Biological Systems Facilities and Infrastructure				
Structural Biology Infrastructure	10,000	–	8,000	-2,000
Joint Genome Institute	69,500	–	57,570	-11,930
Total, Biological Systems Facilities and Infrastructure	**79,500**	–	**65,570**	**-13,930**
SBIR/STTR	10,118	–	8,194	-1,924
Total, Biological Systems Science	**294,271**	–	**225,305**	**-68,966**
Earth and Environmental Systems Sciences				
Atmospheric System Research	**26,392**	–	**12,000**	**-14,392**
Environmental System Science		–		
Terrestrial Ecosystem Science	40,035	–	10,000	-30,035
Subsurface Biogeochemical Research	23,207	–	10,000	-13,207
Total, Environmental System Science	**63,242**	–	**20,000**	**-43,242**
Earth and Environmental Systems Modeling		–		
Climate Model Development and Validation	15,448	–	0	-15,448
Regional and Global Model Analysis	30,108	–	12,610	-17,498
Earth System Modeling	35,530	–	12,595	-22,935

[a] The FY 2016 Enacted level includes SBIR and STTR and reflects updates through the end of the fiscal year.
[b] The FY 2017 Annualized CR amounts reflect the P.L. 114-254 continuing resolution level annualized to a full year. These amounts are shown only at the congressional control level and above, below that level, a dash (-) is shown.

	FY 2016 Enacted[a]	FY 2017 Annualized CR[b]	FY 2018 Request	FY 2018 vs FY 2016
Integrated Assessment	17,583	–	2,000	-15,583
Total, Earth and Environmental Systems Modeling	**98,669**	–	**27,205**	**-71,464**
Earth and Environmental Systems Sciences Facilities and Infrastructure				
Atmospheric Radiation Measurement Research Facility	65,429	–	34,000	-31,429
Environmental Molecular Sciences Laboratory	43,191	–	25,000	-18,191
Data Management	7,069	–	1,000	-6,069
Total, Earth and Environmental Systems Sciences Facilities and Infrastructure	**115,689**	–	**60,000**	**-55,689**
SBIR/STTR	10,737	–	4,440	-6,297
Total, Earth and Environmental Systems Sciences	**314,729**	–	**123,645**	**-191,084**
Total, Biological and Environmental Research	**609,000**	**607,842**	**348,950**	**-260,050**

SBIR/STTR Funding:

- FY 2016 transferred: SBIR $18,135,000; STTR $2,720,000
- FY 2018 Request: SBIR $11,076,000; STTR $1,558,000

[a] The FY 2016 Enacted level includes SBIR and STTR and reflects updates through the end of the fiscal year.

[b] The FY 2017 Annualized CR amounts reflect the P.L. 114-254 continuing resolution level annualized to a full year. These amounts are shown only at the congressional control level and above, below that level, a dash (-) is shown.

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

	FY 2018 vs FY 2016
Biological Systems Science: Genomic Sciences research activities are prioritized to continue with core research that will provide a scientific basis for sustainable and cost effective bioproducts and bioenergy production. Genomic Science will continue to build on BER's fundamental genomic science research and will support development of a select range of platform microorganisms, plants and fungi to expand available biological systems for bioenergy and biotechnology. The recompeted BRCs will initiate the next phase of BER's bioenergy research to underpin efforts to produce cost effective biofuels and bioproducts from sustainable biomass resources. Biosystems design activities will continue research to modify plants and microorganisms with beneficial traits relevant to bioenergy and bioproduct production. Work on cellulosic ethanol under Metabolic Synthesis and Conversion is completed as efforts focus on advanced biofuels and bioproduct research. Microbiome research addresses understanding how microbes and plants interact in a range of microbiomes of relevance to DOE's biotechnology and environmental missions. Development of new bioimaging, measurement and characterization technology through the Mesoscale to Molecules activity will create new integrative imaging and analysis platforms, including using quantum materials, to understand the expression and function of genome information encoded within cells.	**-68,966**
Earth and Environmental Systems Sciences: Focused investments continue to develop an earth system model capability focused on DOE mission needs for energy and infrastructure resilience and security. Environmental System Science, Subsurface Biogeochemistry Research sub-element activity continues a focus on fate and transport of nutrients. ARM continues to advance knowledge and improving model representations of atmospheric gases, aerosols, and clouds on the Earth's energy balance. Two mobile facilities will be placed in reserve; the Azores fixed site will have limited operations. EMSL continues a more focused set of scientific topics that exploit recently installed capabilities involving HRMAC and live cell imaging; data from EMSL instrumentation will be integrated into process and systems models and simulations to address challenging problems in the biological and environmental sciences. Climate Model Development and Validation (exascale activities) is completed in FY 2017 and Integrated Assessment activities begin close-out in FY 2018.	**-191,084**
Total, Biological and Environmental Research	**-260,050**

Basic and Applied R&D Coordination
BER research underpins the needs of DOE's energy and environmental missions. Basic research on microbes and plants provides fundamental knowledge that can be used to develop new bioenergy crops and improved biofuel and bioproduct production processes that enable a more sustainable bioeconomy, as outlined in the Federal Activities Report on the Bioeconomy (FARB[a]) and highlighted in the National Academy of Sciences study on the Industrialization of Biology (NAS 2015[b]). BER fundamental bioenergy science underpins and is relevant to other DOE offices and agencies. Coordination with other federal agencies on priority bioeconomy 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. Additionally, memoranda of agreement (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 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, as informed by a recent workshop on Basic Research Needs for EM. 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 earth system science needs occurs through regular interagency dialogue and the USGCRP program.

Program Accomplishments
Fundamental Bioenergy Research. Efforts at the three DOE BRCs continue to lead the world in basic research to underpin the development of biofuels and bioproducts from sustainable biomass resources.

Lignin is a major structural component of plants, and a major focus for bioenergy research. The recalcitrance of lignin to degradation and lack of methods to convert it to useful products is a major impediment to cost-effective production of fuels and chemicals from plant biomass. Results have identified naturally occurring modified lignin structures in native tree species and key enzymes controlling lignin formation in grasses that could be enhanced or modified to develop bioenergy crops with superior cell wall deconstruction traits. Detailed structural biology studies of key enzymes involved in lignin bond cleavage are developing a burgeoning suite of enzymatic tools to create valuable chemicals and fuels from lignin. Also, combined studies pairing modified microorganisms and new biomass deconstruction methods are demonstrating novel paths to convert ionic-liquid treated biomass into jet fuel precursor compounds.

Biosystems Design Research. Biotechnology is evolving rapidly and BER's systems biology research efforts are at the forefront of this field, particularly for bioenergy related research. Results targeting fundamental principles of genome engineering will have far-reaching impacts not only on biofuel and bioproduct development but on biotechnology development as a whole. Genome recoding offers the ability to design new beneficial functions into microorganisms. Recent results show how a microorganism can be modified to convert non-standard amino acids into proteins. The research opens up the possibility to design parallel metabolic pathways within microorganisms for bioproducts production that do not interfere with normal metabolism.

The systems biology research community needs a broader range of platform organisms on which to build engineered biological systems for beneficial purposes. A genetic transformation technique for diatoms is now available that allows additional genetic engineering of this group of organisms for a host of bioenergy and biotechnology purposes. Diatoms and other photosynthetic organisms are potential biocatalysts for converting carbon dioxide and sunlight into biofuels and bioproducts. Researchers using the Joint Genome Institute user facility successfully adapted a yeast DNA recombination system to engineer the entire pathway of a soil bacterial pigment into a plant as well as to drop in an entire biodiesel

[a] https://biomassboard.gov/pdfs/farb 2_18_16.pdf
[b] http://www.nap.edu/catalog/19001/industrialization-of-biology-a-roadmap-to-accelerate-the-advanced-manufacturing

metabolic pathway. The work is a significant advance towards developing new biotechnology tools for use in a broad range of plants by radically simplifying stacking of genes from different sources and engineering them into a different organism.

Modeling the Earth System. Advanced modeling concepts, high performance computing, and new observations allow emerging earth system models to more confidently capture extreme weather events and to better understand how these events interact with the atmospheric, oceanic, and terrestrial components of the Earth system. A new DOE high-resolution earth system model will be released in December 2017 as the world's highest resolution capability to study interdependencies involving the atmosphere, oceans, and terrestrial processes. With the power of DOE's fastest supercomputers, this Energy Exascale Earth System Model (E3SM) will be able to conduct complex uncertainty analyses using spatial data resolutions down to 500m. This capability has resulted in identification and reduction of significant errors and biases in earth system models that use coarser spatial data inputs. In addition, super parameterization of clouds in the high resolution atmospheric component of E3SM can more accurately capture extreme precipitation patterns and rainfall events. Results also indicate that the amount of precipitation can vary over the course of successive El Niño Southern Oscillation (ENSO) events of different strengths, thereby producing even more confident projections of extreme precipitation in the future.

Observations from the BER Atmospheric Radiation Measurement Research Facility (ARM), a scientific user facility, were used to develop and evaluate new formulations of low cloud processes for global models. Low clouds, which are highly reflective of incoming sunlight, are a source of significant uncertainty in earth system models. An analysis of cloud condensation nuclei from ARM observations collected at five different sites around the world led to improved model representation of the variability of cloud water content in different geographic regions.

Understanding Global Ecosystem Dynamics. Arctic and tropic field experiments are delivering new insights on ecosystem-climate interactions, including methane release in the Arctic and vegetation response to drought in the tropics, to advance Earth system understanding and models.

Arctic permafrost soils have the potential to release vast amounts of carbon dioxide and methane into the atmosphere; however, understanding and predicting this release is challenging due to environmental differences across the landscape. Ongoing experiments conducted in northern Alaska have utilized stable carbon isotopes to estimate the portioning and transformation of carbon dioxide and methane within the coupled soil-plant portion of permafrost ecosystems. Results indicate that the majority of subsurface natural methane can easily be transported upward to the atmosphere by soils and plants, without being converted to carbon dioxide. Because the partition between naturally occurring carbon dioxide and methane emissions in permafrost landscapes influences the rate of permafrost thaw, this finding suggests that permafrost thaw may lead to a more rapid transformation of Arctic landscapes that in turn influences Alaskan infrastructure.

Previous observations suggested that evergreen tropical forests may increase photosynthesis during the dry season, but the causes have been unknown. To address this scientific mystery, DOE scientists combined measurements of atmosphere-plant gas fluxes with an innovative visual monitoring technology able to observe leaf changes throughout the canopy. They discovered that old leaves die back during the dry season and are replaced by more efficient new leaves. Using these results, ecosystem models within high-resolution earth system models such as E3SM can now be adjusted to represent more dynamic canopy greenness, feedbacks with wet and dry seasons, and more accurate global feedbacks between tropical ecosystems and the Earth system.

Biological and Environmental Research
Biological Systems Science

Description

Biological Systems Science integrates discovery- and hypothesis-driven science with technology development on plant and microbial systems relevant to national priorities energy security and resilience and innovation in life sciences and biology. 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 isolated components. The Biological Systems Science subprogram employs 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 require 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 subprogram employs approaches such as 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 the operation of a scientific user facility, the DOE JGI, and the use of structural biology facilities through the development of instrumentation at DOE's national scientific user facilities. It also provides support for research at the interface of the biological and physical sciences, and instrumentation to develop new methods for real-time, high-resolution imaging of dynamic biological processes.

<u>Genomic Science</u>

The Genomic Science activity supports research seeking to reveal the fundamental principles that drive biological systems relevant to DOE missions in energy security and resilience. These principles guide the interpretation of the genetic code into functional proteins, biomolecular complexes, metabolic pathways, 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 long-term national challenges in sustainable energy production, breakthroughs in genome-based biotechnology, and understanding the role of biological systems in the environment.

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; to develop "-omics" experimental capabilities and enabling technologies needed to achieve a dynamic, system-level understanding of organism and community functions; and to 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 bioenergy production from cellulosic biomass. The DOE BRCs are central to this effort and have provided a substantial body of scientific literature and intellectual property towards this goal. Initiation of recompeted BRC research focuses efforts to develop a range of advanced biofuels and bioproducts from sustainable biomass resources and transition the research results to industry. Through extensive community engagement, scientific workshops, and external studies and reports from the National Academies, BER developed scientific priorities for the recompeted BRC activity. The Genomic Science activity will develop an increased range of microorganisms and plants as platform organisms to expand and complement available biological systems for bioenergy and biotechnology research. The activity also supports fundamental research on identification and introduction of desired traits for new bioenergy crops and microbes, as well as understanding soil microbial communities and how they impact the cycling and fate of carbon, nutrients and contaminants in the environment. Efforts in biosystems design and microbiome research continue to build on and complement existing genomics-based research, through development of new genomic design techniques for microbes and plants, and the study of a range of natural and model microbiomes in targeted field environments relevant to BER's research efforts. With a long history in microbial genomics research coupled with substantial biotechnological and computational capabilities available within the DOE user facilities, BER is well positioned to make transformative contributions in biotechnology and understanding microbiome function.

Finally, the ongoing development of bioinformatics and computational biology capabilities within the DOE Systems Biology Knowledgebase (KBase) support these systems biology efforts. The integrative KBase project seeks to develop the necessary hypothesis-generating analysis techniques and simulation capabilities on high performance computing platforms to accelerate collaborative and reproducible 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 enable development of new bioimaging, measurement and characterization technologies to visualize the spatial and temporal relationships of key metabolic processes governing phenotypic expression in plants and microbes. The activity will include new efforts to use quantum materials for high-resolution imaging. This information is crucial for developing an understanding of the impact of various environmental and/or biosystems designs on whole cell or community function.

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 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 cost effective biofuels and bioproducts 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 advanced capabilities are part of the JGI's latest strategic plan to provide users with additional, highly efficient, 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. These new metagenomics capabilities will be crucial to supporting efforts in microbiome research.

BER also supports development and use of specialized instrumentation for biology at major DOE user facilities, such as synchrotron light sources and neutron facilities. 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 universities, research institutes, 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 KBase to help accelerate practical applications of this knowledge for energy and the environment.

Activities and Explanation of Changes

FY 2016 Enacted	FY 2018 Request	Explanation of Change FY 2018 vs FY 2016
Biological Systems Science $294,271,000	**$225,305,000**	**-$68,966,000**
Genomic Science $193,030,000	**$142,840,000**	**-$50,190,000**
Genomic Science continued to remain a top priority. Foundational Genomics increased research 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 continued research on improving the functional characterization of microorganisms and microbial communities relevant to biofuel production. Metabolic Synthesis and Conversion continued 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 provided for studies on the environmental, ethical, legal, and societal impacts. Computational Biosciences continued 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 continued to provide a fundamental scientific basis for cellulosic biofuels production.	The funding for Foundational Genomics will enable BER to lead the anticipated growth in synthetic biology and biosystems design efforts for biofuels and bioproducts. This includes establishing selected sets of well-defined model microbes, plants and fungi as platforms for synthetic biology, with a robust set of tools tailored to industrially-relevant conditions and a range of environmental variables. Microbiome research will focus on improved bioinformatic tools for microbiome gene annotation, high-throughput approaches to cultivate organisms of interest, characterize their physiological properties, and develop genetic tool kits for their experimental manipulation across a range of different plant hosts and soil types. Computational Biosciences continues and integrates new datasets for protein structure, genome-based biomaterials and biosystems design toolkits and software. BER will begin the next funding period of the BRCs selected from recompetition in FY 2017, but at a reduced funding level.	. Investment in Genomic Science will build on BER's fundamental genomic science research to develop a broader range of platform organisms supporting bioenergy and biotechnology research. The subprogram shifts research focus toward more advanced biofuels and bioproducts research as it closes out successfully completed research on cellulosic ethanol under Metabolic Synthesis and Conversion. It will also initiate new efforts on microbiome gene annotation and genetic toolkit development, along with an expansion of Biosystems design research to improve model microbes, plants, and fungal systems. The recompeted Bioenergy Research Centers activity will begin its first year with a reduced scope.
Mesoscale to Molecules $9,623,000	**$8,701,000**	**-$922,000**
The program continued to develop new enabling technologies to visualize key metabolic processes in plants and microbes. These new techniques provided integrative information on the spatial and temporal relationships of metabolic processes occurring within and among cells. This information is crucial to	Bioimaging funding will continue to augment advanced imaging capabilities for biological systems through strategic investments in endstations and beamlines for the BES-supported light sources and neutron sources. BER will continue to need new capabilities beyond x-ray crystallography, such as cryo-	The decrease requires the subprogram to reduce the development of new bioimaging technology through the Mesoscale to Molecules activity, with efforts to create new integrative imaging, measurement, and characterization platforms, including the use of quantum materials, to understand the expression and

FY 2016 Enacted	FY 2018 Request	Explanation of Change FY 2018 vs FY 2016
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.	EM and other bioimaging techniques, including the use of quantum materials, to support BER's systems-level approach to understanding biological processes. Advanced multi-functional imaging techniques provide spatial and temporal understanding of functional genomics within living cells; this information can be integrated to gain a systems-level predictive understanding of biological processes.	function of genome information encoded within cells. The subprogram will support new cryo-EM bioimaging technology.
Radiological Sciences $2,000,000	**$0**	**-$2,000,000**
Funding supported the orderly closeout of Radiological Science activities in FY 2016.		
Biological Systems Science Facilities and Infrastructure $79,500,000	**$65,570,000**	**-$13,930,000**
The JGI remains an essential component for genomic research within BER. The facility continued 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 continued to collaborate closely with the DOE KBase to provide not only community access to sequenced genomes but access to computational systems to experimentally interrogate those genomes.	JGI continues to focus on sequencing very large and complex plant genomes and metagenomics samples, especially from complex field environments. It will continue to advance its capabilities to interpret genomes and provide the research community with a broad variety of new and cutting functional genomics techniques that increase efficiency. Funding will also allow for incorporation of JGI bioinformatics techniques.	JGI will reduce DNA sequencing, analysis and synthesis support to the BRCs; funding supports slower incorporation of new technologies to help validate genome sequence/ functional characterization. Reduced funding also results in reduced user access to the Community Science Program, with less frequent calls for small scale sequencing and synthesis proposals.
Access to the Structural Biology Infrastructure at the DOE synchrotron light and neutron sources continued 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 KBase.	Access to the Structural Biology Infrastructure at the DOE Synchrotron light and Neutron sources continues for high-resolution structural characterization of biomolecules. Efforts begin to link data resources (i.e., PDB) with the DOE KBase.	The decrease in funding will reduce the level of effort devoted to cooperative and integrative access/activities with other DOE User Facilities. The subprogram will terminate user support at the Structural Molecular Biology Resource at SSRL while partnering with the Mesoscale to Molecules activity to initiate new investments, such as high-resolution cryo-EM imaging instrumentation.
SBIR/STTR $10,118,000	**$8,194,000**	**-$1,924,000**

FY 2016 Enacted	FY 2018 Request	Explanation of Change FY 2018 vs FY 2016
In FY 2016, SBIR/STTR funding is set at 3.45% of non-capital funding.	In FY 2018, SBIR/STTR funding is set at 3.65% of non-capital funding.	

Biological and Environmental Research
Earth and Environmental Systems Sciences

Description

The Earth and Environmental Systems Sciences subprogram supports fundamental science and research capabilities that enable major scientific developments in earth system-relevant atmospheric and ecosystem process and modeling research in support of DOE's mission goals for transformative science for energy and national security. This includes research on components such as clouds, aerosols, and the terrestrial ecology; modeling of component interdependencies under a variety of forcing conditions; interdependence of climate and ecosystem variabilities; vulnerability, and resilience of the full suite of energy and related infrastructures to extreme events, and uncertainty quantification. It also supports subsurface biogeochemical research that advances fundamental understanding of coupled physical, chemical, and biological processes controlling energy byproducts in the environment. 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 environmental and energy-related challenges associated with e.g. extreme phenomena. The Department will continue to advance the science necessary to further develop an understanding of earth system models of variable sophistication, targeting resolution at the regional spatial scale and interannual to multi-decadal time scales and to focus on areas of critical uncertainty including Arctic ecology and permafrost thaw. All research is performed in close coordination with the 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 data activity. The two national scientific user facilities are the Atmospheric Radiation Measurement Research Facility (ARM) and the Environmental Molecular Sciences Laboratory (EMSL). ARM provides unique, multi-instrumented capabilities for continuous, long-term observations and model–simulated high resolution information that researchers need to develop and test understanding of the central role of clouds and aerosols on a variety of spatial scales, extending from local to global. EMSL provides integrated experimental and computational resources researchers need to understand the physical, biogeochemical, 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 earth models of variable complexity and sophistication.

<u>Atmospheric System Research</u>

Atmospheric System Research (ASR) is the primary U.S. activity addressing two major areas of uncertainty in earth system models: 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 geographic 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 diverse locations and atmospheric conditions. Earth system models incorporate ASR research results to both understand the processes that govern atmospheric components and to advance Earth system model capabilities with greater certainty. ASR seeks to develop integrated, scalable test-beds that incorporate process-level understanding of the life cycles of aerosols, clouds, and precipitation, that can be incorporated into dynamic models.

<u>Environmental System Science</u>

Environmental System Science supports research to provide a robust, predictive understanding of terrestrial surface and subsurface ecosystems, including the effects of interannual variability and change, from the subsurface to the top of the vegetated canopy and from molecular to global scales.

Using decadal-scale investments such as the Next Generation Ecosystem Experiment (NGEE) to study the variety of time scales and processes associated with ecological change, Environmental System Science research focuses on understanding, observing, and modeling the processes controlling exchange flows between the atmosphere and the terrestrial biosphere, and improving and validating the representation of terrestrial ecosystems in coupled Earth system models. 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.

Earth and Environmental Systems Modeling

Earth and Environmental Systems Modeling develops physical, chemical, and biological model components, as well as fully coupled Earth system models. The research specifically focuses on quantifying and reducing the uncertainties in Earth system models based on more advanced model development, diagnostics, and 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.

Climate Model Development and Validation activities are completed in 2017. The activity focused on model architecture restructuring, exploiting new software engineering and computational upgrades, and incorporating scale-aware high resolution physics with uncertainty quantification in all model components, as part of the DOE-wide Exascale Computing Initiative (ECI). BER core earth system 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 confidence in earth system analysis for a variety of scenarios and in a flexible structure.

To rapidly and efficiently advance model capabilities, BER supports the Program for Climate Model Diagnosis and Intercomparison (PCMDI), a unique and powerful intercomparison resource for earth system model development, validation, diagnostics, and outputs, using over 50 world-leading earth system 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 earth system research programs.

The Earth System Modeling (ESM) activity in BER will continue to coordinate with the National Science Foundation (NSF) to provide limited support for the ESM that is co-funded by DOE and NSF. ESM is designed by the research community with open access and broad use by researchers worldwide. In addition, DOE will continue to advance a branch of, the Energy Exascale Earth System Model (E3SM), as a computationally efficient model adaptable to emerging computer architectures and with greater sophistication and fidelity for high resolution simulation of extreme phenomena and complex processes. Earth system 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 and national security.

The Integrated Assessment activities in BER will focus on completion of fundamental research developing multi-scale models for earth systems, including components on land use relevant to bioenergy crops.

Earth and Environmental Systems Sciences Facilities and Infrastructure

The Earth and Environmental Systems Sciences Facilities and Infrastructure support two scientific user facilities and data management for the earth and environmental systems sciences communities. The scientific user facilities, ARM and 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-laboratory, multi-platform, multi-site, national scientific user facility, providing the world's most comprehensive continuous precise observations of clouds and aerosols. ARM currently consists of three fixed, long-term measurement facility sites (in Oklahoma, Alaska, and the Azores), three mobile observatories, and an airborne research capability that operates at sites selected by the scientific community. In FY 2018, ARM will reduce operations to only the two fixed sites in Alaska and Oklahoma and one mobile observatory, which will be deployed for targeted observations and measurements in the Southern Ocean. This will reduce the number of on-site users and reduce opportunities for intensive observation deployments and studies. Researchers use observations from all ARM observatories to improve earth system models as well as to help calibrate other agency satellites. The ARM fixed sites and mobile measurement campaigns are often distributed around the world in locations where the scientific community most critically needs data to incorporate into earth system models, thereby improving model performance, enhanced understanding, and analysis capabilities. Each of the ARM sites includes scanning radars, lidar systems, and *in situ* meteorological observing capabilities; the sites are also used to demonstrate technologies as they are developed by the community. ARM experiments study the impact of evolving clouds, aerosols, and precipitation on the Earth's radiative balance and rate of earth system change, addressing the most significant scientific uncertainties in predictability research. ARM will incorporate very high resolution Large Eddy

Simulations (LES) at the permanent Oklahoma site during specific campaigns requested by the scientific community. 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 atmospheric process representations 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 energy and environmental challenges facing DOE and the nation. This includes science supporting improved catalysts and materials for industrial applications and subsurface biogeochemical drivers. In FY 2018, EMSL will address a more focused set of scientific topics that capitalize on recently installed capabilities involving HRMAC, live cell imaging, and more extensive utilization of other EMSL instrumentation into process and systems models and simulations to address challenging problems in the biological, environmental, and Earth system sciences.

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, technological innovation, and National security.

The BER Data Management activity will focus efforts to store data from the Earth System Grid Federation, ARM and NGEE field experiments.

Activities and Explanation of Changes

FY 2016 Enacted	FY 2018 Request	Explanation of Changes FY 2018 vs FY 2016
Earth and Environmental Systems Sciences $314,729,000	**$123,645,000**	**-$191,084,000**
Atmospheric System Research (ASR) $26,392,000	**$12,000,000**	**-$14,392,000**
ASR continued to focus on atmospheric cloud and aerosol issues that limit earth system modeling capabilities with a particular emphasis on Arctic mixed phase clouds and tropical systems with large variations of aerosol characterization. ASR utilized 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).	ASR will conduct research on cloud, aerosol, and thermodynamic processes using data collected during observations conducted in FY 2018 by Unmanned Aerial Systems, and the full suite of data from campaigns conducted in Alaska, Oklahoma, Antarctica, the Southern Ocean, and Azores, will be utilized.	Research activities will focus on early research studies on the physics governing cloud-aerosol-precipitation interactions in Antarctica and the Southern Oceans, i.e., two regions that are high priority earth system modeling challenges yet have lacked field data until now. There is no funding included for analysis of anthropogenic aerosols and black carbon.
Environmental System Science (ESS) $63,242,000	**$20,000,000**	**-$43,242,000**
Research continued with NGEE Arctic Phase II, with multiple sites in northern Alaska involved in observation and modeling. NGEE Tropics begins early observations to test new modeling architectures, appropriate for tropical terrestrial systems. The subsurface biogeochemistry investments involve a combination of advanced modeling architectures and field research, with existing data used to test predictive modeling concepts. AmeriFlux supported efforts to improve terrestrial land modeling component, to test new concepts and build testbeds for high resolution land model validation.	Within Environmental System Science, NGEE will continue to provide new observations for model development and validation. The Subsurface Biogeochemistry Research subprogram will focus on fate and transport of subsurface elements and hydrological cycling, uptake, and acquisition by plants and microbes, which will allow for improved integration with the Terrestrial Ecosystem Science subprogram and facilitate multi-scale, very high resolution process modeling from the bedrock to the canopy.	Terrestrial Ecosystem Science research activity will focus efforts on long-term Arctic field experiments to study Alaskan permafrost, maintenance operations only for AmeriFlux national tower network, reduced scope of terrestrial ecosystem studies to prioritize focus on synthesis of ecosystem data from watershed studies and mechanistic modeling of wetland systems including vegetation, nutrient dynamics and flux. There is no funding included for field activities at the SPRUCE (Minnesota) field site focused on functional responses to climate variability and atmospheric stressors for research activities related to climate feedbacks and carbon, or for field studies in the tropics. Subsurface research activities focus reduced efforts on experimental and modeling efforts, prioritizing on

FY 2016 Enacted	FY 2018 Request	Explanation of Changes FY 2018 vs FY 2016
		core areas of understanding dynamics of subsurface biogeochemistry and watershed modeling.
Earth and Environmental Systems Modeling $98,669,000	**$27,205,000**	**-$71,464,000**
Research continued to extend capabilities for the high-resolution E3SM project 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. The program initiated investments to advance software and physics describing the interface between ice-sheets and other components (ocean, land and atmosphere) and new methods for capturing the statistics of earth system change. Regional modeling analysis addressed interdependencies involving the water and energy sectors, using details on existing and projected infrastructures. In addition, funding for this program supported the development of new multi-ensemble statistical methods for vulnerability analysis applied to the energy-water-land nexus 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 are explored within a full earth system analysis, as well as developing vulnerability analysis techniques to treat the energy-water nexus with existing and projected infrastructure.	Earth and Environmental Systems Modeling — Earth System Modeling will continue investment in the high-resolution E3SM project, with research to introduce a non-hydrostatic dynamical core, dynamic coupling of ocean and ice, and basin and sub-basin treatments for the land models. Activities will align with anticipated exascale developments in high-performance computing platforms and algorithms. The E3SM version 1 (v1) will be released during FY 2018, with both existing and new users conducting basic research using results derived from the newest DOE computer architectures.	Research is continued at a reduced level and a new and novel non-hydrostatic dynamical core will be incorporated into the E3SM model.
Climate Model Development and Validation focused 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 Model Development and Validation is completed.	Climate Model Development and Validation is completed in FY 2017.

FY 2016 Enacted	FY 2018 Request	Explanation of Changes FY 2018 vs FY 2016
Core research in Regional and Global Model Analysis and Integrated Assessment continued to underpin high-resolution predictability using adaptive grids and uncertainty characterization, and more sophisticated data management.	Core research in model intercomparison and diagnostics will continue. Research will continue to explore how modes of variability affect spatial and temporal patterns of weather and extreme events, including the roles of atmospheric rivers and droughts. The incorporation of uncertainty and performance benchmarks will increasingly become part of research efforts.	Higher resolution models, including the new E3SM v1 model to be released in FY 2018, will allow a new level of scientific study involving high resolution process interactions and interdependencies. Models focus on new science on sea ice variability and biogeochemistry coupling with atmospheric and dynamical forcing. Research is eliminated for integrated modeling of impacts, adaptation, and vulnerability as well as for coupled climate-human system interdependencies of the energy-water nexus.
Earth and Environmental Systems Sciences Facilities and Infrastructure $115,689,000	**$60,000,000**	**-$55,689,000**
ARM continued to support its long-term measurements at fixed sites and the mobile observatories are deployed to three climate-sensitive regions that demanded targeted measurements. The first mobile facility remained in the Amazon Basin for the first quarter, and thereafter underwent maintenance; the second was deployed to Antarctica; and the third continued 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 represents the first major ARM campaign in the southern hemisphere. ARM initiated the incorporation of modeling and simulation as part of data acquisition.	ARM will continue to provide new observations, through long-term measurements at fixed sites in Alaska and Oklahoma and limited operations at the Eastern North Atlantic fixed site in the Azores. ARM will deploy a mobile observatory for targeted measurements, while holding two mobile units in reserve. ARM will also maintain an aerial capability and explore the science driven need for equipment refresh for archive upgrades, aerial capabilities, and the mobile and fixed observatories. All ARM activities will be prioritized for critical observations necessary to advance earth system models.	ARM will hold two mobile units in reserve, closing the operations in Oliktok, Alaska. An ARM mobile observatory will be deployed for targeted measurements in the Southern Ocean. Operations will be limited at the fixed site in the Azores.
EMSL continued 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. The subprogram placed emphasis on utilization of new capabilities in the	EMSL focuses on scientific topics that exploit recently installed capabilities involving HRMAC, live cell imaging, and more extensive use of integrating data from other EMSL instrumentation into process and systems models and simulations to address	EMSL will eliminate user access for research related to climate feedbacks and carbon.

FY 2016 Enacted	FY 2018 Request	Explanation of Changes FY 2018 vs FY 2016
Radiological Annex and Quiet wing. In FY 2016, the integrated HRMAC system became available for new research. The installation and availability of the HRMAC, with its 21Tesla magnet, provided unique enhancements to EMSL's capabilities available to the research community.	challenging problems in the biological and environmental sciences.	
The Earth and Environmental Systems Sciences Data Analysis and Visualization activity continued 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 LES ensembles to provide statistics of sub-grid parameterizations for a wider range of conditions involving extreme events. Research explored model-data fusion with new visualization technologies.	The Earth and Environmental Systems Sciences Data Management activity will emphasize the first phase of metadata compatibility and consolidation via common protocols and standards, involving environmental observations and the Earth System Grid Federation. Essential data archiving and storing protocols, capacity, and provenance will be achieved, as part of an effort to simplify scientific community access to observed and model generated data produced by DOE.	The subprogram will prioritize data archiving and storage for ARM, AmeriFlux, Earth System Grid Federation, and Next Generation Ecosystem Experiments. No funding is provided for data curation, integration, and analysis.
SBIR/STTR $10,737,000	**$4,440,000**	**-$6,297,000**
In FY 2016, SBIR/STTR funding is set at 3.45% of non-capital funding.	In FY 2018, SBIR/STTR funding is set at 3.65% of non-capital funding.	

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.

	FY 2016	FY 2017	FY 2018
Performance Goal (Measure)	**BER Earth System Model - Develop a coupled earth system model with fully interactive water, carbon and sulfur cycles, as well as dynamic vegetation to enable simulations of earth system responses to change.**		
Target	Develop and apply a fully coupled ice-sheet model to estimate near-term changes to the West Antarctic ice sheet.	Extend the capabilities of the DOE's high-resolution Earth System Model to simulate and evaluate human-natural interdependencies for the carbon and water cycles.	Demonstrate improved ocean model simulations with the new high-resolution MPAS-Ocean.
Result	Met	TBD	TBD
Endpoint Target	BER supports the leading U.S. high-resolution earth system model, and addresses two of the most critical areas of uncertainty in contemporary earth system science—the impacts of clouds and aerosols that combine with biogeochemical and cryospheric processes. Delivery of improved scientific data and models (with quantified uncertainties) about the earth's atmospheric, oceanic, cryospheric, and terrestrial system to more accurately predict the earth system responses to change. The information is essential to plan for future national security, energy and infrastructure needs, water resources, and land use. DOE will continue to advance the science necessary to further develop predictive earth system models at the regional spatial scale and multiple time scales, involving close coordination with the U.S. and international science community.		
Performance Goal (Measure)	**BER Predictive Understanding - 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	Develop an improved metabolic engineering method for modifying microorganisms for biofuel production from cellulosic sugars.	Develop improved open access platforms for computational analysis of large genomic datasets.	Using genomics-based techniques, develop an approach to explore the functioning of plant-microbe interactions.
Result	Met	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 biotechnology 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 2016 Enacted	FY 2017 Annualized CR*	FY 2018 Request	FY 2018 vs FY 2016
Capital Operating Expenses Summary						
Total Non-MIE Capital equipment (projects under $5 million TEC)	n/a	n/a	2,543	–	2,800	+257

Funding Summary ($K)

	FY 2016 Enacted	FY 2017 Annualized CR*	FY 2018 Request	FY 2018 vs FY 2016
Research	400,025	–	211,746	-188,279
Scientific user facilities operations and research	188,120	–	124,570	-63,550
Other[a]	20,855	–	12,634	-8,221
Total, Biological and Environmental Research	**609,000**	**607,842**	**348,950**	**-260,050**

Scientific User 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 2016 Enacted	FY 2017 Annualized CR*	FY 2018 Request	FY 2018 vs FY 2016
TYPE B FACILITIES				
Atmospheric Radiation Measurement Research Facility (ARM)	**$65,429**	–	**$34,000**	**-$31,429**
Number of users	1,061	–	700	-361
		–		
Joint Genome Institute	**$69,500**	–	**$57,570**	**-$11,930**
Number of users	1,391	–	1,000	-391
		–		
Environmental Molecular Sciences Laboratory	**$43,191**	–	**$25,000**	**-$18,191**
Number of users	644	–	450	-194

[a] Includes SBIR and STTR.

*The FY 2017 Annualized CR amounts reflect the P.L. 114-254 continuing resolution level annualized to a full year. These amounts are shown only at the congressional control level and above, below that level, a dash (-) is shown.

	FY 2016 Enacted	FY 2017 Annualized CR*	FY 2018 Request	FY 2018 vs FY 2016
Structural Biology Infrastructure[a]	**$10,000**	–	**$8,000**	**-$2,000**
Total Facilities	**$188,120**	–	**$124,570**	**-$63,550**
Number of users	3,096	–	2,150	-946

Scientific Employment

	FY 2016 Enacted	FY 2017 Annualized CR*	FY 2018 Estimate	FY 2018 vs FY 2016
Number of permanent Ph.D.'s	1,350	–	1,000	-350
Number of postdoctoral associates	330	–	234	-96
Number of graduate students	450	–	350	-100
Other[b]	330	–	230	-100

[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.
*The FY 2017 Annualized CR amounts reflect the P.L. 114-254 continuing resolution level annualized to a full year. These amounts are shown only at the congressional control level and above, below that level, a dash (-) is shown.