

Biological and Environmental Research

Funding Profile by Subprogram

(dollars in thousands)

	FY 2007 Current Appropriation	FY 2008 Original Appropriation	FY 2008 Adjustments	FY 2008 Current Appropriation	FY 2009 Request
Biological and Environmental Research					
Biological Research	350,485	411,273	-3,743 ^a	407,530	413,613
Climate Change Research	129,619	138,124	-1,257 ^a	136,867	154,927
Total, Biological and Environmental Research	480,104 ^{bcd}	549,397	-5,000 ^a	544,397	568,540

Public Law Authorizations:

Public Law 95-91, "Department of Energy Organization Act", 1977

Public Law 109-58, "Energy Policy Act of 2005"

Public Law 110-69, "America COMPETES Act of 2007"

Mission

The mission of the Biological and Environmental Research (BER) program is to advance environmental and biological knowledge that promotes national security through improved energy production, development, and use; international scientific leadership that underpins our Nation's technological advances; knowledge needed to support the President's National Energy Plan; and research that improves the quality of life for all Americans. BER supports these missions through competitive and peer-reviewed research at national laboratories, universities, and private institutions.

Strategic and GPRA Unit Program Goals

The Department of Energy's Strategic Plan identifies five Strategic Themes (one each for nuclear, energy, science, management, and environmental aspects of the mission) plus 16 Strategic Goals that tie to the Strategic Themes. The BER program supports the following goals:

Strategic Theme 3, Scientific Discovery & Innovation

Strategic Goal 3.1, Scientific Breakthroughs: Achieve the major scientific discoveries that will drive U.S. competitiveness; inspire America; and revolutionize our approaches to the Nation's energy, national security, and environmental quality challenges.

Strategic Goal 3.2, Foundations of Science: Deliver the scientific facilities, train the next generation of scientists and engineers, and provide the laboratory capabilities and infrastructure required for U.S. scientific primacy.

^a Reflects a reduction for the 0.91% rescission in P.L. 110-161, the Energy and Water Development and Related Agencies Appropriations Act, 2008.

^b Total is reduced by \$13,311,000: \$11,885,000 of which was transferred to the Small Business Innovative Research (SBIR) program and \$1,426,000 of which was transferred to the Small Business Technology Transfer (STTR) program.

^c Total includes \$9,920,000 reprogrammed from prior year balances to support the GTL Bioenergy Research Centers.

^d The Congressional control level in FY 2007 is at the Biological and Environmental Research level. Starting in FY 2008, it is at the Biological Research and Climate Change Research levels.

The BER program has one GPRA Unit Program Goal which contributes to Strategic Goals 3.1 and 3.2 in the “goal cascade”:

GPRA Unit Program Goal 03.1/2.48.00: Harness the Power of Our Living World—Provide the biological and environmental discoveries necessary to clean and protect our environment, offer new energy alternatives, and facilitate the entrainment of physical sciences advances in the biomedical field.

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

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

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

BER research leads to the development of advanced medical imaging technology, including radiopharmaceuticals for use in diagnosis and treatment of disease. BER research currently supports the development of an artificial retina that will enable the blind to see.

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

In addition, BER plans, constructs, and operates reliable, scientific facilities to serve thousands of researchers at universities, national laboratories, and private institutions from all over the world. These include structural biology research beam lines at the synchrotron light sources and neutron sources; the William R. Wiley Environmental Molecular Sciences Laboratory (EMSL) (including the Molecular Sciences Computing Facility) which provides integrated experimental and computational resources for discovery and technological innovation in the environmental molecular sciences to support the needs of DOE and the nation; the Joint Genome Institute/Production Genomics Facility (JGI/PGF) for high-throughput DNA sequencing of non-medical microbes and plant targets; and the Atmospheric Radiation Measurement (ARM) facilities for climate change research.

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

Biological Research

- **Life Sciences:** Provide the fundamental scientific understanding of plants and microbes necessary to develop new robust and transformational basic research strategies for producing biofuels, cleaning up waste, and sequestering carbon.

- **Medical Applications:** Develop intelligent biomimetic electronics that can both sense and correctly stimulate the nervous system.^a
- **Environmental Remediation:** Provide sufficient scientific understanding such that DOE sites would be able to incorporate coupled physical, chemical, and biological processes into decision making for environmental remediation and long-term stewardship.

Climate Change Research

- **Climate Change Research:** Deliver improved scientific data and models about the potential response of the Earth’s climate and terrestrial biosphere to increased greenhouse gas levels for policy makers to determine safe levels of greenhouse gases in the atmosphere.

BER Facilities

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

Funding by Strategic and GPRA Unit Program Goal

(dollars in thousands)

FY 2007	FY 2008	FY 2009
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Strategic Goal 3.1, Scientific Breakthroughs and 3.2, Foundations of Science

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

Biological and Environmental Research	480,104	544,397	568,540
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^a This indicator is not a PART measure.

Annual Performance Results and Targets

FY 2004 Results	FY 2005 Results	FY 2006 Results	FY 2007 Results	FY 2008 Targets	FY 2009 Targets
GPRA Unit Program Goal 03.1/2.47.00 (Harness the Power of Our Living World)					
Biological Research					
Life Sciences					
Increase the rate of DNA sequencing: Produce at least 20 billion base pairs of high quality DNA microbial and model organism genome sequence. [Met Goal]	Increase the rate of DNA sequencing: Number (in billions) of base pairs of high quality (less than one error in 10,000 bases) DNA microbial and model organism genome sequence produced annually. FY 2005 at least 28 billion base pairs will be sequenced. [Met Goal]	Increase the rate of DNA sequencing: Number (in billions) of base pairs of high quality (less than one error in 10,000 bases) DNA microbial and model organism genome sequence produced annually. FY 2006 at least 30 billion base pairs will be sequenced. [Met Goal]	Increase the rate and decrease the cost of DNA sequencing – Cost reductions will increase the number of high quality base pairs determined (less than one error in 10,000 bases) by 25% from the FY 2006 target of 582 base pairs per dollar to 781 base pairs per dollar. [Met Goal]	Increase the rate and decrease the cost of DNA sequencing – Increase by 10% the number (in billions) of high quality (less than one error in 10,000) bases of DNA from microbial and model organism genomes sequenced the previous year, and decrease by 10% the cost (base pair/dollar) to produce these base pairs from the previous year's actual results. FY08: 42.8 billion base pairs (bp) and 785bp/\$1 (based on FY07 actual was 38.95 Billion base pairs (bp), and JGI achieving 714bp/\$1.)	Increase the rate and decrease the cost of DNA sequencing – Increase by 10% the number (in billions) of high quality (less than one error in 10,000) bases of DNA from microbial and model organism genomes sequenced the previous year, and decrease by 10% the cost (base pair/dollar) to produce these base pairs from the previous year's (FY08) actual results.
Medical Applications ^a					
Advance blind patient sight: Complete fabrication of 60 microelectrode array for use as an artificial retina and tested in animal subject. [Met Goal]	Advance blind patient sight: Complete testing on a 60 microelectrode array artificial retina and insert prototype device into a blind patient. [Goal Not Met]	Advance blind patient sight: Begin testing of prototypes for 256 microelectrode array artificial retina. [Met Goal]	Advance blind patient sight: complete design and construction of final 256 electrode array. Begin in vitro testing and non-stimulating testing in animals. [Met Goal]	Advance blind patient sight: Complete in vitro testing of 256 electrode array and continue animal studies of final design 256 electrode array.	Advance blind patient sight: Complete in vitro and in vivo studies of final design 256 electrode device. Submit test data to FDA for approval of 256 electrode array for human studies.

^a This is not a PART measure.

FY 2004 Results	FY 2005 Results	FY 2006 Results	FY 2007 Results	FY 2008 Targets	FY 2009 Targets
Environmental Remediation					
<p>Perform combined field/laboratory/modeling to determine how to interpret data at widely differing scales: Quantify contaminant immobilization and remobilization by different factors: 1. natural microbial mechanisms; 2. chemical reactions with minerals; and 3. colloid formation. [Met Goal]</p>	<p>Determine scalability of laboratory results in field experiments—Conduct two sets of field experiments to evaluate biological reduction of chromium and uranium by microorganisms and compare the results to laboratory studies to understand the long term fate and transport of these elements in field settings. [Met Goal]</p>	<p>Develop predictive model for contaminant transport that incorporates complex biology, hydrology, and chemistry of the subsurface. Validate model through field tests. [Met Goal]</p>	<p>Implement a field-oriented, integrated experimental research program to quantify coupled processes that control reactive transport of at least one key DOE contaminant. [Met Goal]</p>	<p>Determine scalability of laboratory results in field environments—Determine the dominant processes controlling the fate and transport of contaminants in subsurface environments and develop quantitative numerical models to describe contaminant mobility at the field scale. For FY 2008: Identify the critical redox reactions and metabolic pathways involved in the transformation/ sequestration of at least one key DOE contaminant in a field environment.</p>	<p>Determine scalability of laboratory results in field environments—Determine the dominant processes controlling the fate and transport of contaminants in subsurface environments and develop quantitative numerical models to describe contaminant mobility at the field scale. For FY 2009: Test geophysical techniques that measure parameters controlling contaminant movement under field conditions in at least two distinct subsurface environments.</p>
Climate Change Research					
<p>Improve climate models: Implement a model test bed system to incorporate climate data rapidly into climate models to allow testing of the performance of sub-models (e.g., cloud resolving module) and model parameters by comparing model simulations with real world data from the ARM sites and satellites. [Met Goal]</p>	<p>Improve climate models: Implement three separate component submodels (an interactive carbon cycle submodel, a secondary sulfur aerosol submodel, and an interactive terrestrial biosphere submodel) within a climate model and conduct 3-4 year duration climate simulation using the fully coupled model. [Met Goal]</p>	<p>Improve climate models: Produce a new continuous time series of retrieved cloud properties at each ARM site and evaluate the extent of agreement between climate model simulations of water vapor concentration and cloud properties and measurements of these quantities on the timescale of 1 to 4 days. [Met Goal]</p>	<p>Provide new mixed-phase cloud parameterization for incorporation in atmospheric GCMs and evaluate extent of agreement between climate model simulations and observations for cloud properties in the arctic. [Met Goal]</p>	<p>Improve climate models— Develop a coupled climate model with fully interactive carbon and sulfur cycles, as well as dynamic vegetation to enable simulations of aerosol effects, carbon chemistry, and carbon sequestration by the land surface and oceans and the interactions between the carbon cycle and climate. FY 2008: Report results of decade-long control simulation using geodesic grid coupled climate model and produce new continuous time series of retrieved cloud, aerosol, and dust properties, based on results from the ARM Mobile Facility deployment in Niger, Africa.</p>	<p>Improve climate models— Develop a coupled climate model with fully interactive carbon and sulfur cycles, as well as dynamic vegetation to enable simulations of aerosol effects, carbon chemistry, and carbon sequestration by the land surface and oceans and the interactions between the carbon cycle and climate. FY 2009: Provide improved climate simulations on subcontinental, regional, and large watershed scales, with an emphasis on improved simulation of precipitation and produce new continuous time series of retrieved cloud, aerosol, and radiation for Arctic region.</p>

FY 2004 Results	FY 2005 Results	FY 2006 Results	FY 2007 Results	FY 2008 Targets	FY 2009 Targets
All BER Facilities					
<p><u>Maintain and operate BER facilities such that achieved operation time is on average greater than 90% of the total scheduled annual operation time. [Met Goal]</u></p>	<p><u>Maintain and operate BER facilities (Life Science—PGF and the Mouse facility; Climate Change Research—ARM and FACE; and Environmental Remediation—EMSL) such that achieved operation time is on average greater than 90% of the total scheduled annual operation time for each group of facilities. [Met Goal]</u></p>	<p><u>Maintain and operate BER facilities (Life Science—PGF and the Mouse facility; Climate Change Research—ARM and FACE; and Environmental Remediation—EMSL) such that achieved operation time is on average greater than 95% of the total scheduled annual operation time for each group of facilities. [Met Goal]</u></p>	<p><u>Maintain and operate BER facilities (Life Science—PGF and the Mouse facility; Climate Change Research—ARM and FACE; and Environmental Remediation—EMSL) such that achieved operation time is on average greater than 98% of the total scheduled annual operation time for each group of facilities. [Met Goal]</u></p>	<p><u>The achieved operation time of the scientific user facility (Life Science—PGF; Climate Change Research—ARM; and Environmental Remediation—EMSL) as a percentage of the total scheduled annual operating time is greater than 98%.</u></p>	<p><u>The achieved operation time of the scientific user facility (Life Science—PGF; Climate Change Research—ARM; and Environmental Remediation—EMSL) as a percentage of the total scheduled annual operating time is greater than 98%.</u></p>

Means and Strategies

The BER program will use various means and strategies to achieve its program goals. However, various external factors may impact the ability to achieve these goals.

The BER program will continue its investments in core fundamental science and technologies needed to address the interfaces between scientific disciplines such as biology, physics, chemistry, engineering, and information science. Within the Biological Research subprogram, of highest priority will be the Genomics: GTL program which develops an understanding of the fundamental principles underlying the function and control of biological systems. This approach of well-integrated, technology based, interdisciplinary research teams will facilitate the study of complex biological systems to solve problems in energy production and environmental cleanup. As part of this approach to biological research, the GTL Bioenergy Research Centers were initiated in FY 2007 and will be fully operational in FY 2008.

BER priorities within the Climate Change Research subprogram are to develop the ability to predict climate on global and regional scales; to explore the impacts of excess atmospheric CO₂ on the Earth system; to develop strategies for its removal and sequestration from the atmosphere; and, provide the science to underpin the prediction of the impacts of climate change. These priorities will depend on the continued development of novel research tools and a close integration of experimental, observational, and computational research.

BER also plays a key role in constructing and operating a diverse array of biological and environmental user facilities for the Nation's researchers. These facilities include the William R. Wiley Environmental Molecular Sciences Laboratory (EMSL), the Production Genomics Facility (PGF), and the Atmospheric Radiation Measurement (ARM) facilities.

All BER-supported research projects undergo regular peer review and merit evaluation based on procedures established in 10 CFR 605 for the extramural grant program, and under a similar process for the laboratory programs and scientific user facilities. All new projects are selected through peer review and merit evaluation.

External factors that affect the programs and performance include: (1) mission needs as described by the DOE (e.g., the basic research needs of the energy technology programs within DOE) and SC mission statements and strategic plans; (2) evolving scientific opportunities that sometimes revolutionize disciplines; (3) results of external program reviews and international benchmarking activities of entire fields or subfields, such as those performed by the National Academy of Science; (4) unanticipated failures or unexpected developments, for example, in critical components of scientific user facilities that cannot be mitigated in a timely manner; and (5) strategic and programmatic decisions made by other (non-DOE) Federal agencies and by international entities.

The BER program is closely coordinated with the activities of other federal organizations (e.g., National Institutes of Health [NIH], National Science Foundation [NSF], National Aeronautics and Space Administration [NASA], Department of Commerce/National Oceanic and Atmospheric Administration [NOAA], Environmental Protection Administration [EPA], Nuclear Regulatory Commission [NRC], Department of Agriculture [USDA], the Department of State (DOS), and the Department of Defense [DOD]). BER Climate Change Research is coordinated with the U.S. Global Change Research Program, an interagency program codified by Public Law 101-606 and involving thirteen federal agencies and departments.

BER also promotes the transfer of the results of its basic research to contribute to DOE missions in areas of future energy sources, improved use of fossil fuels (carbon sequestration), reduced environmental impacts of energy production and use, and environmental cleanup and monitoring.

Validation and Verification

Progress against established plans is evaluated by periodic internal and external performance reviews. These reviews provide an opportunity to verify and validate performance. Quarterly, semiannual, and annual reviews consistent with specific program management plans are held to ensure technical progress, cost and schedule adherence, and responsiveness to program requirements.

Program Assessment Rating Tool (PART)

The Department implemented a tool to evaluate selected programs. PART was developed by OMB to provide a standardized way to assess the effectiveness of the Federal Government's portfolio of programs. The structured framework of the PART provides a means through which programs can assess their activities differently than through traditional reviews. The Biological and Environmental Research program has incorporated feedback from OMB into the FY 2009 Budget Request and will continue to take the steps necessary to improve performance.

In the FY 2003 PART review for the FY 2005 Budget, OMB gave the BER program a score of 86% overall which corresponds to a rating of "Effective". The assessment found that BER had developed a limited number of adequate performance measures which are continued for FY 2009. These measures have been incorporated into this Budget Request, BER grant solicitations, the performance plans of senior managers and are considered in routine decisions for research funding within the Program. As appropriate, they will be incorporated into the performance based contracts of M&O contractors. Roadmaps, developed in consultation with the Biological and Environmental Research Advisory Committee (BERAC), will guide triennial reviews by BERAC of progress toward achieving the long term Performance Measures. The Annual Performance Targets are tracked through the Department's Joule system and reported in the Department's Annual Performance and Accountability Report.

OMB has previously provided BER with three recommendations to further improve performance:

- Finding: Engage the National Academies in an independent assessment of the scientific basis and business case for the program's microbial science research efforts. [Action completed]

The National Research Council (NRC) reviewed the design of the Genomics: GTL program and its infrastructure plan. The NRC committee recommended that the GTL facilities should be focused not on particular technologies, but on research underpinning particular applications—bioenergy, carbon sequestration, or environmental remediation.

In response to the NRC recommendations, the Office of Science revised its original single-purpose user facilities plan to develop and support vertically-integrated GTL Research Centers to accelerate systems biology research. The vertically-integrated GTL Research Centers will not require construction of facilities. The first three research centers, selected and implemented in FY 2007, have a focus on bioenergy research; subsequent centers will focus on carbon sequestration and environmental remediation.

- Finding: Implement the recommendations of past external panel reviews of the program's research portfolio and management practices. [Actions are completed and/or on-going as appropriate]

In response, BER is using external panels (Committee of Visitors – COVs) to review the quality, relevance, and performance of its research portfolio and grant management practices. COVs findings and BER responses can be viewed at <http://www.sc.doe.gov/measures/FY06.html> and <http://www.sc.doe.gov/measures/FY07.html>

- Finding: Review operations of user facilities, and improve discrimination in identifying open user facilities versus collaborative research facilities. [Actions are completed and/or on-going as appropriate]

BER conducted reviews of the Joint Genome Institute Production Genomics Facility (JGI/PGF), EMSL facilities, and the ARM facilities.

To improve public access to PART assessments and follow up actions, OMB has created the ExpectMore.gov web site. Information concerning BER PART assessments and current follow up actions can be found by searching on “biological and environmental research” at <http://www.ExpectMore.gov>.

Basic and Applied R&D Coordination

Carbon Dioxide Capture and Storage: BER is requesting \$17,374,000 to support basic research in carbon dioxide (CO₂) capture and storage. This R&D integration focus area was the subject of four DOE workshops, including:

- Carbon Sequestration Research and Development (December, 1999—Jointly sponsored by the Office of Fossil Energy and Office of Science),
- Computational Subsurface Sciences Workshop Report (January, 2007),
- Basic Research Needs for Geosciences: Facilitating 21st Century Energy Systems (February, 2007), and
- Carbon Sequestration Technology Roadmap and Program Plan 2007 (May 2007, Office of Fossil Energy).

The workshops support the need for additional research emphasis in CO₂ capture and storage to benefit the optimization of fossil fuel power generation and the development of carbon neutral fuels. The BER research includes understanding, modeling, and predicting the processes that control the fate of carbon dioxide injected into geologic formations, subsurface carbon storage, and the role of microbes and plants in carbon sequestration in both marine and terrestrial environments. Such research could increase the likelihood for success in DOE strategic initiatives since achieving the goal of net-zero carbon emissions from fossil fuel usage requires efficient and cost-effective capture of CO₂ as well as safe and reliable storage, which poses substantial science and technology challenges.

Applied technology offices within DOE that could benefit from the carbon dioxide capture and storage research integration effort include: the Offices of Fossil Energy and Energy Efficiency and Renewable Energy (for development of biofuels).

Characterization of Radiological Waste: BER is requesting \$1,500,000 to support basic research in characterization of radiological waste. This R&D integration focus area was included as a subject area in six DOE workshops, including:

- Basic Research Needs for Advanced Nuclear Energy Systems (July 2006—NE, BES),
- Nuclear Physics and Related Computational Science R&D for Advanced Fuel Cycles Workshop (August 2006—NE, NP, ASCR),
- EM Technical Integration Workshop: Reducing Technical Uncertainty in Clean-up Operations (October 2006—EM),
- Computational Subsurface Sciences Workshop (January 2007—ASCR, EM, FE, RW),

- Basic Research Needs for Geosciences: Facilitating 21st Century Energy Systems (February 2007—BES), and
- National Academy of Sciences: Science and Technology Needs for DOE Site Cleanup, EM Roadmap (March 2007—EM).

The workshops support the need for additional research emphasis in the characterization of radiological waste to address critical unanswered scientific questions to facilitate the stabilization, long-term storage, treatment, and ultimate disposal of radioactive waste.

The BER research effort addresses processes that control the mobility of radiological waste in the environment. This research will increase the likelihood for success in DOE strategic initiatives for clean up of legacy nuclear wastes and nuclear energy applications.

Applied technology offices within DOE that will benefit from the characterization of radiological waste research integration effort include: Offices of Environmental Management, Civilian Radioactive Waste Management, Legacy Management, and Nuclear Energy.

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Carbon Dioxide Capture And Storage			
Biological Research	12,980	12,127	12,627
Climate Change Research	3,861	4,747	4,747
Total Carbon Dioxide Capture And Storage	16,841	16,874	17,374
Characterization of Radiological Waste			
Biological Research	—	—	1,500
Total Basic and Applied R&D Coordination	16,841	16,874	18,874

Overview

BER supports basic research in genomics, proteomics, radiation biology, climate change, environmental remediation, and medical sciences. BER supports leading edge research facilities used by public and private sector scientists across the range of BER disciplines. BER works with other federal agencies to coordinate research across all of its programs. BER validates its long-range goals through its advisory committee, the BERAC.

The Challenges

A new biology—Can we understand the workings of biological systems, both plants and microbes, well enough so that we can use nature’s own principles of design to solve energy and environmental challenges? Understanding nature’s array of multi-protein molecular machines and complex microbial communities and the sophistication of diverse plants, each with exquisitely precise and efficient functions and controls, will enable us to understand the functioning of complex biological systems in order to use and even redesign these molecular machines, microbes, or plants to address DOE and national needs.

A healthier Nation—At the crossroads of the physical and biological sciences is the promise of remarkable technology for tomorrow’s medicine. Developments in imaging technology, including radiochemistry, have the potential to revolutionize all of medical imaging with increases in resolution and sensitivity, ease of use, and patient comfort. Furthermore, understanding the biological effects of

low doses of radiation will lead to the development of science-based health risk policy to better protect workers and citizens.

A cleaner environment—The Department of Energy faces the country’s largest set of environmental remediation challenges, many of which currently have no solutions. The Department’s environmental clean up objectives require advances in our understanding of the biological, chemical, and physical processes that control contaminant mobility in the environment. Improved understanding is needed to allow accurate predictions of future conditions and the ability to make science-based decisions regarding the need for, and nature of, remedial actions at a given site. BER provides the understanding needed to underpin novel and more effective remediation and monitoring technologies. Many remediated sites have intractable residual contamination that will require long-term stewardship, including monitoring and actions to ensure protection of human health and the environment in perpetuity.

Understanding and predicting climate—Advanced climate and Earth system models are needed to describe and predict the roles of oceans, the atmosphere, sea ice, and land masses on climate, including the interactions and feedbacks among the various components of the climate system. They are also needed to predict how climate at regional to global scales is likely to evolve in the future in response to human and natural forcing. So too, the role of clouds and aerosols in controlling solar and terrestrial radiation onto and away from the Earth needs to be better understood since their effects are still a major source of uncertainty in climate prediction. Moreover, the impacts of excess carbon dioxide in the atmosphere from human activities, including energy use, on Earth’s climate and ecosystems need to be determined and possible mitigation strategies developed and evaluated.

Significant Program Shifts

- The BER program has been restructured, as directed by Congress, into two separate sub programs— Biological Research and Climate Change Research. Biological Research includes activities in Life Sciences, Medical Applications, and Environmental Remediation Research.
- Radiopharmaceuticals and Imaging activities renamed as Radiochemistry and Instrumentation and moved from Medical Applications to Life Sciences.

Biological Research

Funding Schedule by Activity

(dollars in thousands)

	FY 2007	FY 2008	FY 2009
Biological Research			
Life Sciences	252,502	294,681	296,206
Medical Applications	6,584	8,226	8,226
Environmental Remediation	91,399	93,764	98,383
SBIR/STTR	—	10,859	10,798
Total, Biological Research	350,485	407,530	413,613

Description

The BER program will continue its investments in core fundamental science and technologies needed to address the interfaces between scientific disciplines such as biology, physics, chemistry, engineering, and information science. Within the Biological Research subprogram, of highest priority will be the Genomics: GTL program which develops an understanding of the fundamental principles underlying the function and control of biological systems. This approach of well-integrated, technology based, interdisciplinary research teams will facilitate the study of complex biological systems to solve problems in energy production and environmental cleanup. As part of this approach to biological research, the GTL Bioenergy Research Centers were initiated in FY 2007 and will be fully operational in FY 2008.

Fundamental research in Genomics: GTL, systems biology, and the health effects of low dose radiation are used to understand why some people are more sensitive to low doses of radiation and how plants and microbes can be used to produce clean energy, remediation or stabilize wastes *in situ*, or sequester excess atmospheric carbon dioxide. New radiotracers and imaging technologies and reagents are developed for the biological and environmental research communities. Research on contaminant transport, novel remediation methods and cutting edge molecular tools for investigating and monitoring environmental processes are expected to reduce the costs, risks, and schedules for the cleanup and monitoring of the DOE nuclear weapons complex and to provide knowledge for a broad range of remediation problems, including avoidance of environmental hazards for future nuclear energy options and geologic sequestration of excess atmospheric carbon. New, research-based, strategies and tools are already being deployed by the offices of Environmental Management and Legacy Management. Scientific user facilities are made available for determining high-resolution protein structures at DOE synchrotrons and neutron sources; for high-throughput genomic DNA sequencing of microbes, microbial communities, and complex organisms such as plants at the Joint Genome institute; and for the environmental molecular sciences at the Environmental Molecular Sciences Laboratory.

The Biological Research subprogram continues a substantial involvement of academic scientists along with the scientists at the national laboratories.

Periodic retrospective analysis will be employed to evaluate research directions, the accumulation of knowledge, and to validate specific outcomes. Biological Research activities have been reviewed by a BERAC Committee of Visitors (COV) and future reviews are scheduled. In FY 2005, Life Sciences activities were reviewed and the next scheduled review of Life Sciences activities will be in FY 2008. For the Medical Applications activities, a COV was originally planned for FY 2006. This review has

been delayed pending the completion of the National Academy of Science (NAS) review of U.S. nuclear medicine research and will be combined with the scheduled review of the Life Sciences activities in FY 2008. Environmental Remediation activities were reviewed by a BERAC COV in FY 2005 with another COV review planned for FY 2008. The BERAC COV reports and the BER responses are at <http://www.science.doe.gov/ober/berac.html>.

FY 2007 Accomplishments

- **Surveying New Protein Families:** The Global Ocean Survey (GOS) project performed metagenomic sampling from diverse aquatic environments—including estuaries, lakes, and open ocean sites. The analysis of the geographically diverse environmental genomic data set of 6.3 billion base pairs—twice the size of the human genome and vastly larger than the initial Sargasso Sea data set—has resulted in the development and use of a new, improved method for assembling the sequence data. The new method of assembly, allows robust genomic comparison and inference of genetic adaptation in response to specific environmental conditions; and the development of a powerful new computational algorithm to predict protein function from metagenomic sequence data. The new protein prediction tool revealed an astonishingly high number of new proteins from the GOS data, and demonstrates the significant value of metagenomic studies in gene and protein function discovery.
- **Evidence for Non-Linear Dose Responses:** New research from the Low Dose Radiation Program has demonstrated that following exposures to low doses of radiation there are unique dose-dependent changes in gene and protein expression which differ from those seen after high dose exposures. Low dose activation of such mechanisms supports the existence of non-linear dose-response relationships for low-LET (linear energy transfer) radiation. Identification of these genes is providing a scientific basis for defining metabolic pathways activated by radiation and determining mechanisms of action. The magnitude of the response for these phenomena has been shown to be dependent on the genetic background of the cells, tissues and organisms in which they are being measured.
- **Simultaneous PET/MRI Instrument Development:** The first truly simultaneous hybrid PET/MRI scanner, based on an all-solid state detector contained in the Positron Emission Tomography (PET), Magnetic Resonance Imaging (MRI) insert has been developed. This novel BER-funded PET/MRI imaging technology can provide simultaneous quantitative functional information about receptor occupancy or enzyme concentration (from PET) and high resolution structural/anatomical data (from MRI) for research purposes in animals, and eventually perhaps human subjects, *in vivo*. In this way, structural and functional information about the same cells can be obtained and correlated.
- **EMSL Magnetic Resonance Users Develop Method to Quantify Radiation Damage in Nuclear Waste Containment Material:** EMSL users have developed a method to analyze the stability of proposed waste encapsulation forms. Encapsulation of nuclear waste into various crystalline solids such as zircon is proposed as one method to immobilize wastes for long term storage. However, methods to directly assess the effects of prolonged radiation exposure on the stability of these crystalline solids have remained elusive. Using EMSL's solid state nuclear magnetic resonance (NMR) spectrometry capabilities researchers have been able to evaluate the effects of radiation on the stability of one proposed crystalline encapsulation material. The technique allows designers to assess rates of degradation of crystalline materials in order to improve the design and performance of waste encapsulation forms.
- **BER Environmental Remediation research contributes to savings for the cleanup of Rocky Flats:** Research established that a colloid-based mechanism for plutonium and americium mobility

existed in surface soils and sediments at the Rocky Flats site rather than an aqueous sorption-controlled mechanism. This result provided the scientific basis for understanding the nature of the threat posed by these contaminants. The research allowed contractors to shift focus towards implementing soil erosion control strategies rather than groundwater remediation strategies to prevent the transport of contaminants saving billions of dollars in cleanup costs at the site. The science-based approach was featured late in 2006 in the journal *Physics Today*.

Detailed Justification

(dollars in thousands)

	FY 2007	FY 2008	FY 2009
Life Sciences	252,502	294,681	296,206
▪ Structural Biology	15,722	15,300	15,300

In FY 2009, the Structural Biology program continues to develop and support access to beamlines and instrumentation at DOE's national user facilities for the Nation's structural biologists. BER coordinates, with the NIH and the NSF, the management and maintenance of 22 experimental stations at several DOE synchrotrons (Advanced Photon Source [APS], Advanced Light Source [ALS], and Stanford Synchrotron Radiation Laboratory [SSRL]). User statistics for all BER structural biology user facilities are included in the Basic Energy Sciences (BES) facility user reports. BER continually assesses the quality of the instrumentation at its experimental stations and supports upgrades to install the most effective instrumentation for taking full advantage of the facility capabilities as they are improved by DOE. Fundamental science related to protein structure and instrument development is also supported at the beamlines.

▪ Molecular and Cellular Biology	145,879	177,421	190,464
• Carbon Sequestration Research	7,480	7,127	7,127

Microbes and plants play substantial roles in the cycling of carbon through the environment. Carbon sequestration research seeks to understand the fundamental mechanisms of carbon fixation, conversion and cycling in microbes, microbial communities, and plants. The program has initiated a new focus on carbon sequestration and utilization for biofuels, with genomics-based research that will lead to the improved use of plant feedstocks for the production of carbon-neutral fuels such as ethanol or renewable chemical feedstocks. This is part of the BER contribution to the Climate Change Technology Program (see the Climate Change Research subprogram for additional information). Systems biology approaches are supported to yield fundamental knowledge of the structure, function, and organization of plant genomes leading to increased carbon fixation and biomass yield, improved feedstock characterization and sustainability. In FY 2009 fundamental research focuses on understanding carbon uptake, fixation, and storage in plants and soil and marine microbes, strongly leveraging the increasing availability of information from whole organism genomes and community metagenomes. Research will also focus on understanding the role that microbial communities or plant-microbe associations play in the transfer of carbon between the roots and the soil, to identify strategies that would lead to increased carbon storage in the root zone environment and surrounding soil. This research leverages BER's fundamental microbial systems biology research in Genomics: GTL and BER's terrestrial carbon cycle research to evaluate options for molecular-based terrestrial carbon sequestration and contributes to the President's Advanced Energy Initiative

(dollars in thousands)

FY 2007	FY 2008	FY 2009
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(AEI).

• Genomics: GTL	121,000	152,713	162,731
▶ Genomics: GTL Foundational Research	43,023	37,713	42,731

Genomics: GTL has the mission goal of developing the science, technology, and knowledge base to harness microbial and plant systems for cost-effective renewable energy production, carbon sequestration, and environmental remediation. The Foundational Research activity supports fundamental research and technology development that underpins all microbial and plant research conducted in the Genomics: GTL program overall and in the GTL Bioenergy Research Centers. GTL Foundational Research also develops the robust computational infrastructure needed to understand, predict, and ultimately use the genomic potential, cellular responses, biological regulation, and behaviors of complex biological systems of interest to the DOE mission.

In FY 2009, the program continues to support a mix of approximately eight large multidisciplinary research teams and 30 smaller individual investigator projects to:

- develop innovative high-throughput genomic and analytic strategies and research tools for improving plant biomass and for the subsequent microbial conversion of plant biomass to biofuels: fundamental research that will contribute to GTL Bioenergy Research Centers and to GTL Bioethanol research;
- develop novel technologies to characterize the internal environment, subcellular architecture and metabolism of microbes: fundamental research that will contribute to GTL Bioenergy Research Centers and to GTL Bioethanol and Biohydrogen research; and
- develop genomic, metabolic, and imaging technologies to study the structure and function of microbial communities with respect to fate and transport of environmental contaminants, bioenergy production, and the fate and flow of carbon through terrestrial and marine environments.

This activity includes capital equipment support for the Genomics: GTL program that will provide state-of-the-art equipment and high performance instrumentation to meet the program's advanced imaging, high-throughput, and analytic requirements.

This activity will develop a computational infrastructure for Genomics: GTL research. The necessary algorithmic and computational tools will be developed to allow modeling of critical metabolic pathways in plants, microbes, and microbial communities. Further, computational databases will be developed that have the capacity to integrate large and diverse data sets into a unified model that predicts the behavior of relevant biological systems. The research is closely coordinated with SC's Advanced Scientific Computing Research program and includes the GTL SciDAC research.

In FY 2009, increased funding to GTL SciDAC research will initiate new research to develop mathematical and computational tools needed to model, through computer programs, genomic changes to plants and microbes. This new computational capability is expected to enable the more economical design, development and improvement of desirable

(dollars in thousands)

FY 2007	FY 2008	FY 2009
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properties of specific enzymes, metabolic pathways, and whole organisms to enable more efficient conversion of sunlight to biomass and biomass to biofuels as well as to better predict the quantitative role of plants and microbes in the Earth's complex biological carbon cycle.

Over the long-term, the GTL Foundational Research will provide the scientific knowledge base and technology that can accelerate progress in all aspects of the Genomics: GTL program, as well as bridge to other DOE offices such as Energy Efficiency and Renewable Energy, Fossil Energy, and Environmental Management to develop biotechnology solutions for DOE energy and environmental needs. The program focuses on interdisciplinary scientific challenges that can be uniquely addressed by DOE and its national laboratories in partnership with scientists at universities and in the private sector.

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

DNA sequence data underpins and is the starting point for all aspects of the Genomics: GTL program. The vast majority of high-throughput DNA sequencing of plants, microbes, and microbial communities conducted at the JGI/PGF user facility is directly relevant to the Genomics: GTL program. In FY 2009, research will continue within Genomics: GTL to generate DNA sequence data of individual genes as they are expressed, whole genomes, and metagenomes in order to provide essential information needed to formulate genetic engineering strategies for microbes and plants, to understand plant and microbe molecular machines, to determine the composition of complex microbial communities, and to dissect plant-microbe associations. The DNA sequencing done in this activity is accomplished at JGI/PGF and complements the broader DNA sequencing activities conducted at the JGI/PGF and will specifically provide genetic data to projects within the Genomics: GTL activity. The DNA sequencing needs of the DOE Bioenergy Centers will be supported within this activity.

► **Genomics: GTL Biohydrogen Research** **19,334** **15,000** **15,000**

Genomics: GTL research will contribute to the President's Advanced Energy Initiative with biotechnology solutions for production of two biofuels: hydrogen and ethanol. Hydrogen is the ultimate carbon-free energy carrier that can be converted efficiently to energy in fuel cells with water as the only chemical by-product. Microbes exist that can use solar energy to convert water to hydrogen and oxygen, or to break down biomass and convert the component sugars into hydrogen.

This activity supports innovative systems biology research with a specific emphasis on biological hydrogen production, such as the discovery and development of improved or oxygen-tolerant hydrogenases, characterization of specific cellular architecture to facilitate electron transfer for optimum hydrogen production, and the redirection of metabolic pathways and metabolite flow into hydrogen production. While this activity draws upon the foundational research and technology development within the broader GTL portfolio, it is specifically directed towards scientific issues and challenges unique to biological hydrogen production. In FY 2009 research will continue on understanding key metabolic pathways in order to enhance microbial biohydrogen production.

(dollars in thousands)

FY 2007	FY 2008	FY 2009
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► **Genomics: GTL Bioethanol Research**

18,723 15,000 20,000

GTL research will contribute to the President’s Advanced Energy Initiative with biotechnology solutions for the production of two biofuels: ethanol and hydrogen. Cellulosic ethanol is a carbon-neutral fuel that can already be used within today’s energy infrastructure. Microbes or microbial processes are used to produce ethanol from residues such as corn plants left after a corn harvest or energy crops such as poplar trees that are specifically grown as biomass for energy production.

While this activity draws upon the foundational research and technology development within the broader GTL portfolio it is specifically directed towards scientific issues and challenges unique to understanding the metabolic conversion of 5- and 6-carbon sugars to ethanol. In FY 2009, research will support understanding of mechanisms that control glycolytic flux, analysis, and rational design of more robust ethanolgenic biocatalysts. The increased funding in FY 2009 will support peer-reviewed research to identify microorganisms in nature that retain glycolytic and fermentative activity in the presence of high ethanol concentrations, and engineer ethanol tolerant organisms to produce ethanol. These activities will be coordinated with the three DOE Bioenergy Centers to facilitate development of reagents of general use for the entire GTL research activity.

► **Genomics: GTL Bioenergy Research Centers**

29,920 75,000 75,000

GTL Bioenergy Research Centers will contribute to the President’s Advanced Energy Initiative. The Research Centers will conduct fundamental biological research and, with this funding, involve no construction of facilities. The three Bioenergy Research Centers, all involving academic, industrial, and national lab scientists, are designed to accomplish the GTL program objectives more effectively. The centers will serve as catalysts for innovation and change, by concentrating appropriate technologies and scientific expertise to go from the genome sequence to an integrated systems understanding of the pathways and internal structures of plants and microbes most relevant to the steps required to develop bioenergy compounds.

The first three GTL Bioenergy Research Centers were selected and initiated in late FY 2007 following the issuance of a competitive funding opportunity announcement on August 1, 2006 and site selection according to merit-based peer review criteria. The three centers are: The Joint BioEnergy Institute at Lawrence Berkeley National Laboratory; The Great Lakes Bioenergy Research Center at the University of Wisconsin at Madison; and the BioEnergy Science Center at the Oak Ridge National Laboratory. In FY 2009, the three Bioenergy Centers are fully supported at approximately \$25,000,000 each.

Research at the Centers will focus on developing the science underpinning biofuel production that will ultimately lead to technology deployable in the Nation’s energy economy. A major emphasis will be on development of cost-effective strategies to convert plant biomass to ethanol, and potentially, production of biodiesel, hydrogen, methane, and biofuels for aviation. The Centers will develop new technologies but also draw on technology and basic

(dollars in thousands)

FY 2007	FY 2008	FY 2009
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science generated in the foundational research, biohydrogen, and bioethanol Genomics: GTL activities. The research programs in the Centers will be distinguished from those activities by being broader in scientific scope and in having multiple, coordinated disciplines focusing on the specific scientific goals of the centers. The research at the Centers will:

- encompass the entire spectrum from research on enhancing biomass generation of multiple model plant species and improving/modifying biomass feedstocks to biofuel production,
- pursue more high-risk, high-return approaches to bioenergy production,
- be more flexible in being able to incorporate new knowledge and change scientific direction, and
- be more problem oriented with respect to industrial utilization and cost-effective biofuel production.

The Centers will be held to both intermediate and long term (i.e., develop innovative industrial ethanol producing methodologies) scientific deliverables to ensure that they will help meet the longer-term goals (i.e., genetically engineered model plants) of the Advanced Energy Initiative.

- **Low Dose Radiation Research** **17,399** **17,581** **20,606**

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

It remains a substantial challenge to resolve the scientific uncertainty surrounding the current use of the linear no-threshold (LNT) model for developing radiation protection standards at low doses of radiation.

In FY 2009, the program is emphasizing the use of genome-based technologies to learn how cells communicate with each other in tissues in response to radiation, what causes cells and tissue to undergo different biological responses to radiation at different times, and what causes some individuals to be more sensitive to radiation than others. Comparative genomics will afford new opportunities for identification of specific genetic markers within affected cell populations.

University scientists, competing for funds in response to requests for applications, conduct a substantial fraction of the research in this activity.

(dollars in thousands)

FY 2007	FY 2008	FY 2009
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- **Human Genome**
 - **Joint Genome Institute, Production Genomics Facilities**

69,736	72,733	70,000
53,397	60,000	55,000

The Joint Genome Institute's (JGI) high-throughput DNA sequencing factory, the Production Genomics Facility (PGF) is focused on helping to meet the demand for DNA sequencing in the broader energy and environment scientific community. Funding will be decreased in FY 2009, reflecting a transition in emphasis to research in Tools for DNA Sequencing and Sequence Analysis (see below). The JGI functions as a user facility for universities, National laboratories, and the Bioenergy Research Centers. All sequencing is on plants and microbes within the DOE science mission. The JGI's Community Sequencing Program (CSP) devotes all of its sequencing capacity to the merit-reviewed sequencing needs of the broader scientific community, while addressing the DOE mission-relevant criteria of energy production, carbon sequestration research and bioremediation research, and low dose radiation research.

In FY 2009, the CSP will sequence DNA from individual microbes, microbial communities, and small and large plants that will be selected by the CSP's merit review panel in FY 2008. A Laboratory Science Program that was initiated in FY 2007 has successfully expanded participation in genomic-based research at the DOE national laboratories and will be integrated with the CSP.

The JGI is a virtual research institute principally comprised of research programs at DOE national laboratories (LLNL, LANL, LBNL, PNNL, and ORNL). The JGI's DNA production sequencing facility is located in Walnut Creek, California.

In November 2005, BERAC conducted a comprehensive review of the science, management, and operations of the DOE JGI/PGF. The committee gave high marks to the JGI with respect to scientific vision, the implementation of the role of the JGI as a user-facility and its focus on DOE mission objectives, and to the PGF for its state of the art operations with respect to cost, quality, and quantity of sequences that it produces. The JGI/PGF Will be next reviewed in the Fall of 2008.

(estimated)

	FY 2007	FY 2008	FY 2009
Optimal hours	8,400	8,400	8,400
Scheduled hours	8,400	8,400	8,400
Operation Time	>98%	>98%	>98%
Users ^a	120	120	120

- **Tools for DNA Sequencing and Sequence Analysis**

14,339	7,733	10,000
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BER continues to develop the tools and resources needed by the scientific, medical, and

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

(dollars in thousands)

FY 2007	FY 2008	FY 2009
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industrial sector communities to fully exploit the information contained in complete DNA sequences, from energy-relevant microbes to low dose radiation effects. Use of sequence information to understand human biology and health effects will also require new strategies and tools capable of high-throughput, genome-wide experimental and analytic approaches. BER will continue efforts to develop high-throughput approaches for analyzing gene regulation and function.

In FY 2009, the increased funding will support efforts to develop high-throughput annotation methods and DNA sequencing research that addresses unique sequencing challenges primarily attributable to the complexity or difficulty of the environments from which the microbes or plants were isolated, as well as to the increasing difficulty of assembly of highly repetitive complex plant genomes.

- **Ethical, Legal, and Societal Issues (ELSI)**

2,000 5,000 5,000

BER ELSI research will continue the transition to activities applicable to Office of Science issues in bioenergy, synthetic biology, and nanotechnology, including exploration of, and communication of, the societal implications arising from these programs. The ecological and environmental impacts of nanoparticles (including nanotracers) resulting from nanotechnology applied to energy technologies will be studied. The research is coordinated across the Office of Science and with other relevant Federal agencies and offices (e.g., EPA, NSF, and OSTP).

In FY 2009, activities will continue to support peer-reviewed research on intellectual property and commercialization issues, economic impacts of sustainable agriculture-based biofuels, including land-use patterns, biorefineries, public perceptions of synthetic biology and nanotechnology applications, and support activities exploring the societal implications of research to be carried out by and at the BES Nanoscience Centers. The funding will continue to support ELSI research on the ecological and environmental impacts of nanoparticles (including nanotracers) resulting from nanotechnology applied to energy technologies.

- **Health Effects**

7,378 7,321 7,321

Health effects research in functional genomics provides a link between human genomic sequencing and the development of information that is useful in understanding normal human development and disease processes including susceptibility to low doses of ionizing radiation. The mouse continues to be a vital experimental tool for this understanding. The Center for Comparative and Functional Genomics (“Mouse House”) at Oak Ridge National Laboratory serves as a national focal point for high-throughput genetic studies using mice. The Mouse House creates and genetically characterizes new mutant strains of mice that serve as important models of human genetic diseases and for understanding gene function. It also develops high-throughput tools and strategies to characterize these mice.

(dollars in thousands)

FY 2007	FY 2008	FY 2009
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In FY 2009, research will continue at the Laboratory for Comparative and Functional Genomics related to low dose radiation. However, beginning in FY 2008, BER no longer funds the Mouse House as a user facility. BER's programmatic need for this facility as a resource for understanding the human genome ended with the completion of human genome related research and the growth of the GTL program. However, there is still a broad need for mouse genetic resources in the scientific community, especially at the National Institutes of Health.

The research activities are principally carried out at national laboratories and selected through merit-review processes

▪ Radiochemistry and Instrumentation	13,787	21,906	13,121
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In FY 2009, BER continues to support basic research that builds on unique DOE capabilities in physics, chemistry, engineering, and computational science. It supports fundamental imaging research, maintains core infrastructure for imaging research and development, including innovative imaging technology with respect to new radiochemistry and radiotracer methodologies for precise and dynamic metabolic imaging of biological organisms. This research will provide the capability to visualize plant and microbial metabolic networks and regulatory systems underlying cellular differentiation, specialization, and interactions with the environment.

The FY 2009 funding will support the development of peer-reviewed, multidisciplinary programs in radiochemistry at national laboratories and universities. These activities will provide for continuance and enhancement of core capabilities in radiochemistry while providing an extended framework for use of these capabilities to understand DOE mission areas in biological and environmental research. The decreased funding in FY2009 reflects the completion of awake animal imaging studies and pilot radiochemistry instrumentation projects initiated in FY2008.

Medical Applications

▪ Artificial Retina	6,584	8,226	8,226
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In FY 2009, BER continues to utilize the resources of the national laboratories in material sciences, engineering, microfabrication, and microengineering to develop unique neuroprostheses and continue development of an artificial retina to restore sight to the blind. DOE's goal for the artificial retina project is to develop the technology and fabricate a 1,000+ electrode intraocular device that will allow a blind person to read large print, recognize faces, and move around without difficulty. In FY 2009 BER will support continued testing of a completely fabricated 240+ electrode retinal device. The DOE-sponsored phase of this effort will be completed in FY 2010.

Environmental Remediation	91,399	93,764	98,383
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▪ Environmental Remediation Sciences Research	43,496	46,665	48,485
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Environmental Remediation Sciences research activities address questions of fundamental environmental remediation science at the interfaces of biology, chemistry, geology, and physics. The research will help to provide the scientific foundation for the solution of key environmental challenges within DOE's cleanup mission at scales ranging from molecular to the field, including issues of fate and transport of contaminants in the environment; novel strategies for *in situ* remediation; and long-term monitoring of remediation strategies.

(dollars in thousands)

FY 2007	FY 2008	FY 2009
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Remediation of subsurface contamination is a particularly challenging environmental problem for many DOE sites. In many cases the depth, area extent, and unique chemical characteristics of the contaminants is such that there are few remediation options available. In order to make sound, science-based decisions for dealing with subsurface contamination at DOE sites the Environmental Remediation Sciences activity funds research to: 1) understand the chemical nature of DOE-relevant contaminants; 2) understand the physical, chemical and biological processes that affect contaminant mobility in the subsurface; 3) detect the extent of contamination in the environment; 4) model and predict the mobility of contaminants in the subsurface, and; 5) devise remediation methods to remove or immobilize contaminants in the subsurface. This suite of research spans many scientific disciplines including chemistry, biology, geology, engineering and physics, and relies on integrative approaches to problem solving.

The goal of this integrative research effort is to develop accurate predictions of contaminant mobility in the subsurface under a variety of conditions, including remediation conditions, to allow DOE to make science-based decisions for environmental remediation or long term stewardship. In order to achieve this goal, research within the Environmental Remediation Sciences activity must link laboratory-derived results with processes observed in the environment. In addition to numerous laboratory-based projects at both academic institutions and national laboratories, FY 2009 funding supports three field research sites at Oak Ridge, Tennessee; Hanford, Washington; and Rifle, Colorado (a uranium mill tailings site). These field sites span a range of hydrogeochemical conditions and provide researchers opportunities to obtain sediment samples from DOE sites for further evaluation in the laboratory and to test laboratory-derived hypotheses regarding contaminant transport or remediation in the field under real world conditions. These field sites also are important for iterative testing and evaluation of computer models that will lead to more accurate descriptions of contaminant mobility in the environment.

Environmental Remediation Sciences research will continue to foster interdisciplinary research and be responsive to new knowledge and to advanced computational and analytical tools that emerge from research at the EMSL, the SciDAC program, the synchrotron light sources, the newly-commissioned Spallation Neutron Source, and from within the GTL program in support of DOE's clean-up mission.

FY 2009 support for SciDAC research is intended to provide advanced models to better understand the movement of subsurface contamination. This will benefit environmental cleanup efforts at DOE facilities, as well as improve the monitoring of contaminants in groundwater around existing and future radionuclide waste disposal and storage sites. These efforts also will assist the Department's research on using deep geological formations to store carbon dioxide taken from the atmosphere.

▪ **General Purpose Equipment (GPE)** **503** **402** **750**

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

▪ **General Plant Projects (GPP)** **6,040** **4,129** **700**

GPP funding is continued for minor new construction, other capital alterations and additions, and for buildings and utility systems, such as replacing infrastructure in 30- to 40-year old buildings.

(dollars in thousands)

FY 2007	FY 2008	FY 2009
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Funding of this type is essential for maintaining the productivity and usefulness of Department-owned facilities and meeting the requirements for safe and reliable facilities operation. This activity includes stewardship GPP funding for ORISE. The total estimated cost of each GPP project will not exceed \$5,000,000. In FY 2009, funding is reduced as GPP for PNNL will now be funded as part of the laboratory's overhead and the funds previously allocated for PNNL GPP are transferred to the Science Laboratories Infrastructure program.

▪ Facility Operations	41,360	42,568	48,448
• EMSL Operating Expenses	35,532	36,122	36,335

The William R. Wiley Environmental Molecular Sciences Laboratory (EMSL), a national scientific user facility located at the Pacific Northwest National Laboratory, provides integrated experimental and computational resources for discovery and technological innovation in the environmental molecular sciences to support the needs of DOE and the nation. Operating funds are used for: staff support for users; maintenance of instruments and buildings; utilities; environmental safety and health compliance activities; and communications. With over 55 leading-edge instruments and a supercomputer system, EMSL annually supports approximately 700 users. The core EMSL science team networks with the broader academic community as well as with DOE national laboratories and other agencies. EMSL users have access to unique expertise and instrumentation for environmental research, including a high performance computer; a 900 MHz nuclear magnetic resonance (NMR) spectrometer that highlights a suite of NMRs in EMSL; a collection of mass spectrometers, including an 11.5 Tesla high performance mass spectrometer; laser desorption and ablation instrumentation; ultra-high vacuum scanning, tunneling and atomic force microscopes; and controlled atmosphere environmental chambers.

In June 2006, BER conducted a follow-on review of the William R. Wiley Environmental Molecular Sciences Laboratory (EMSL) to validate the corrective actions taken in response to the management and operations findings of the BERAC and Office of Science/Office of Project Assessment reviews in May, 2005. These reviews validated the status of EMSL as a National Scientific User Facility. The June 2006 review committee found that actions taken in response to the May 2005 reviews were “timely, comprehensive, and on target” and that implementation of those actions was “effective, widely accepted, and appears to be on its way to completion”.

In FY 2009, EMSL operations funding is held near level, supporting user facility operations and services to users.

(dollars in thousands)

FY 2007	FY 2008	FY 2009
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(estimated)

FY 2007	FY 2008	FY 2009
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Optimal hours	4,365	4,365	4,365
Scheduled hours	4,365	4,365	4,365
Operation Time	>98%	>98%	>98%
Users ^a	1,700	700	750

• **Capital Equipment** **5,828** **6,446** **10,113**

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

In FY 2009, a multi-year equipment refresh is initiated. Capital equipment funds will be used to enhance capabilities in electron paramagnetic resonance (EPR) spectroscopy (e.g., EPR for protein complex characterization), microbial dynamics and visualization capabilities (e.g., a 3D laser confocal microscope), surface dynamics (e.g., a spectroscopy and microscopy laser detection system, and a aerosol growth chamber interfaced with a Fourier Transform Infrared spectrometer), multiscale structure synthesis and characterization (e.g., a nano Secondary Ion Mass Spectrometer), and archive and data storage enhancements, as well as maintain existing user capabilities.

The Field Emission Transmission Electron Microscope (TEM) is funded in FY 2008 with a Total Estimated Cost of \$4,500,000. This Major Item of Equipment will be delivered in FY 2009 and will enable EMSL users to image conversion reactions, including catalytic reactions, under actual reaction conditions at the atomic scale, and to thereby identify the specific reaction sites.

• **EMSL GPP** — — **2,000**

In FY 2009, GPP is provided to initiate development and construction of an addition to EMSL. Approximately 4,000 square feet of specialized space will be added to house instrumentation for users to characterize and analyze radioactive materials and samples.

SBIR/STTR — **10,859** **10,798**

In FY 2007, \$8,574,000 and \$1,029,000 were transferred to the SBIR and STTR programs, respectively. FY 2008 and FY 2009 amounts shown are the estimated requirements for continuation of the SBIR and STTR programs.

Total, Biological Research **350,485** **407,530** **413,613**

^a EMSL users are both onsite and remote. Beginning in FY 2008, BER will revise the definition of “User” for the EMSL. This change in definition is reflected in the revised target for FY 2008. Under the revised definition, individual users are counted once per year.

Explanation of Funding Changes

FY 2009 vs. FY 2008 (\$000)

Life Sciences

- **Molecular and Cellular Biology**

- **Genomics: GTL**

- ▶ **Genomics: GTL Foundational Research**

Genomics: GTL Foundational Research increases to support technology development in imaging and in DNA sequence annotation in support of the bioenergy and carbon sequestration programs. SciDAC will also increase to support dynamic computational modeling of enzymes critical in bioenergy production.

+5,018

- ▶ **Genomics: GTL Bioethanol Research**

GTL Bioethanol research increases to accelerate the identification of natural microbes and genetically engineered model microbes that demonstrate enhanced capability for commercial ethanol production.

+5,000

- ▶ **Low Dose Radiation Research**

Low Dose Radiation Research increases to support comparative genomic studies to determine susceptibility of vulnerable populations to the effects of low dose radiation.

+3,025

Total, Molecular and Cellular Biology

+13,043

- **Human Genome**

- **Tools for DNA Sequencing and Sequence Analysis**

Production Genomics Facility funding is decreased to reallocate funding to Tools for DNA Sequencing and Sequence Analysis and to support other research priorities in BER.

-5,000

- **Tools for DNA Sequencing and Sequence Analysis**

An increase to Tools for DNA Sequencing and Sequence Analysis will support the additional annotation and genome analysis requirements of the GTL Bioenergy Research Centers.

+2,267

Total, Human Genome

-2,733

- **Radiochemistry and Instrumentation**

The decreased funding in FY2009 reflects the completion of awake animal imaging studies and pilot radiochemistry instrumentation projects initiated in FY2008.

-8,785

Total, Life Sciences

+1,525

Environmental Remediation

▪ **Environmental Remediation Sciences Research**

Increased funding will enhance basic research on biogeochemical processes that control radionuclide and heavy metal transport in the subsurface environment. +1,820

▪ **General Purpose Equipment (GPE)**

General Purpose Equipment (GPE) increases to update network systems and associated instrumentation in support of multi-purpose research. +348

▪ **General Plant Projects (GPP)**

General Plant Projects (GPP) funding is reduced as GPP for PNNL will now be funded as part of the laboratory's overhead and the funds previously allocated for PNNL GPP are transferred to the Science Laboratories Infrastructure program. -3,429

Total, Environmental Remediation Sciences Research -1,261

▪ **Facility Operations**

• **EMSL Operating Expenses**

EMSL operations funding is held near level, maintaining operations at full capacity. +213

• **Capital Equipment**

EMSL capital equipment funding is provided to initiate a capital equipment refresh for EMSL that will provide users with leading-edge capabilities for atmospheric/aerosol chemistry research, biogeochemistry and subsurface science research, and interfacial science research. +3,667

• **EMSL GPP**

EMSL GPP is provided to initiate development and construction of an addition to EMSL. Approximately 4,000 square feet of specialized space will be added to house instrumentation for users to characterize and analyze radioactive materials and samples. +2,000

Total, Facility Operations +5,880

Total, Environmental Remediation +4,619

SBIR/STTR

▪ SBIR/STTR increases with increases in research funding. -61

Total Funding Change, Biological Research +6,083

Climate Change Research

Funding Schedule by Activity

(dollars in thousands)

	FY 2007	FY 2008	FY 2009
Climate Change Research			
Climate Forcing	76,148	77,961	81,173
Climate Change Modeling	25,375	31,017	45,387
Climate Change Response	24,235	19,380	19,380
Climate Change Mitigation	3,861	4,747	4,747
SBIR/STTR	—	3,762	4,240
Total, Climate Change Research	129,619	136,867	154,927

Description

BER priorities within the Climate Change Research subprogram are to develop the ability to predict climate on global and regional scales; to explore the impacts of excess atmospheric CO₂ on the Earth system; to develop strategies for its removal and sequestration from the atmosphere; and, provide the science to underpin the prediction of the impacts of climate change. These priorities will depend on the continued development of novel research tools and a close integration of experimental, observational, and computational research.

This subprogram's research is expected to reduce and resolve key uncertainties and provide the scientific foundation needed to predict, assess, and help mitigate greenhouse gas forcing of climate resulting from energy production and use. Climate forcing research leads to understanding and quantification of natural and human-induced forcing of the climate system and the processes that affect such forcing, including the role of clouds, aerosols, and carbon cycling. Climate change modeling research leads to the development, testing, and application of fully coupled climate and Earth system models needed to project the likely response of the climate system to natural and human-induced climate forcing. Climate change response research leads to the understanding and ability to predict the response of ecological and human systems to ongoing and projected future changes in climate and atmospheric composition associated with energy production. Climate change mitigation research leads to the development of strategies or technologies for modifying or managing terrestrial systems to enhance their sequestration capacity.

Periodic retrospective analysis is employed to evaluate program management processes, priorities, and outcomes. A second BERAC Committee of Visitors (COV) for the Climate Change Research subprogram was conducted in FY 2007 to provide outside expert validation of the program's merit-based review and funding decision processes that impact scientific quality, programmatic relevance, and performance. The full report and the BER response are at <http://www.science.doe.gov/ober/berac.html>. The next COV for the Climate Change Research subprogram will be in FY 2010. The BERAC is also tasked to conduct reviews of specific programs. The most recent was a review of the ARM Infrastructure in FY 2007. BERAC also reviewed the Integrated Assessment Research Program in early FY 2007.

FY 2007 Accomplishments

- **Data from Saharan Dust Storm Reveal Model Deficiencies:** The first scientific results from the deployment of the ARM Mobile Facility in Niamey, Niger, Africa show that in a dusty atmosphere,

atmospheric radiation models generally underestimate the observed absorption of solar radiation. The mobile facility was deployed in Niamey, Niger to measure radiation, and cloud and aerosol properties during the monsoon and dry seasons. The first of several publications based on data obtained from the deployment focused on the impact on radiation of a large Saharan dust storm which raged across the North African desert in March 2006, the largest storm for the previous two years. Dust from Africa's Sahara desert—the largest source of dust on the planet—reaches halfway around the globe. Unfortunately, Africa is one of the least sampled climate regimes in the world, leaving scientists to wonder about its contribution to global climate. Saharan dust efficiently absorbs solar energy and transfers this heat to the atmosphere, which potentially alters the thermal properties of the atmosphere and affects the Earth's radiant energy budget.

- **Double Whammy to Arctic Climate:** The analysis of eight years data obtained from the Atmospheric Radiation Measurement program advanced instrumentation show that enhanced aerosol concentrations increase the amount of thermal energy emitted by many Arctic clouds to the surface, causing increased Arctic warming in addition to the greenhouse gas warming. The analysis also found that the magnitude of this increased warming is comparable to that of the surface warming effect by greenhouse gases, suggesting that aerosol indirect effect is significant to the Arctic energy balance. This study documents, for the first time, how the Arctic region's periodic influxes of anthropogenic aerosols is impacted by the industrial emissions from lower latitudes.
- **Importance of Anthropogenic Secondary Organic Aerosol:** About 90% of secondary organic aerosol (SOA) is currently believed to be due to biogenic volatile organic carbon compounds (VOCs). Anthropogenic VOCs have therefore not been included in most modeling studies that assess the relevance of SOA to climate forcing. However, a recent BER-funded study examining aerosol production in Mexico City indicates the presence of production pathways not accounted for in current atmospheric chemistry models, and that amounts of secondary organic aerosol produced from anthropogenic volatile organic carbon are as much as eight-fold greater than predicted by these models. Also contrary to current understanding, much of the excess secondary organic aerosol is formed from first-generation oxidation products. These findings demonstrate the importance of SOA as a major component of atmospheric aerosol whose influences on climate must be accurately represented in models.
- **Warming May Threaten Dryland Ecosystems:** A study of the response of grasses to an experimentally controlled year-round increase in ambient temperature of 2 degrees C (which climate models indicate might occur within 50 years), shows a 20% reduction in abundance of the dominant grass species relative to the controls exposed to ambient temperatures. More than one third of the United States is dryland, particularly in the West. Many dryland plants and animals live "on the edge," and warming has the potential to stress life in these already harsh environments. Unfortunately, little experimental data exist to determine how much of a threat warming is in dryland ecosystems. To obtain such data, DOE is sponsoring an experimental manipulation of temperature in a dryland ecosystem in eastern Utah. The decline in the abundance of the dominant grass species may have secondary ecological effects. This dominant grass species and other plants in dryland ecosystems protect soil from erosion, and they are a main food source for mice, rabbits, and other animals. Therefore, if future warming is detrimental to dryland plants, as indicated by these experiments, it could have undesirable secondary effects on the physical stability of dryland ecosystems as well as the health and success of animal species dependent on dryland plants for food and habitat.

Detailed Justification

(dollars in thousands)

	FY 2007	FY 2008	FY 2009
Climate Forcing	76,148	77,961	81,173
▪ Atmospheric Radiation Measurement (ARM) Research	14,794	14,765	14,765

A major emphasis in the Climate Forcing area of the Climate Change Research subprogram is on understanding the radiation balance from the surface of the Earth to the top of the atmosphere and how this balance is affected by clouds, aerosols, and increases in the concentration of greenhouse gases in the atmosphere. There are two major emphases in the ARM Research. The first is to understand and relate observed solar radiative fluxes and radiances in the atmosphere to the temperature and composition of the atmosphere, specifically including water vapor and clouds, aerosols, and to surface properties, using a variety of ARM observations that span a wide range of climatologically relevant conditions. The second emphasis is to promote development and testing of cloud-aerosol-radiation parameterizations that can be used in General Circulation Models (GCMs) to accurately predict the radiative properties and radiative interactions involving water vapor and clouds within the atmosphere. An additional emphasis includes research to understand the processes in the terrestrial biosphere that affect the exchange of carbon dioxide between the terrestrial biosphere and atmosphere and to quantify their net effect on atmospheric concentrations of carbon dioxide so as to better understand how they might affect atmospheric concentrations and climate forcing in the future.

In FY 2009, ARM research will continue to focus on resolving the greatest scientific uncertainty in climate change prediction—the role of clouds and aerosols and their interactions with solar radiation. An important element of this research is on developing and improving parameterization schemes of processes that affect climate forcing so they can be included and tested in climate models. The principal goal of the ARM research will continue to be the development of an improved understanding of the radiative transfer processes in the atmosphere and to formulate better parameterization schemes of these processes in climate prediction models, GCMs. A major portion of this funding will specifically support research using new types of ARM data from, for example, field campaigns to develop and test parameterization schemes for processes that are tightly coupled as observed from the field campaigns (e.g., land and ocean surface processes and their interaction with overlying boundary layer and clouds) and incorporate them in GCMs to test and compare their performance in improving climate simulations.

ARM research supports individual investigators at universities and research teams at DOE laboratories involved in studies of cloud physics and dynamics, and the interactions of solar and infrared radiation with water vapor, clouds, and aerosols (including black soot). University scientists form the core of the ARM science team that networks with the broader academic community. Focus groups of scientists from many of the DOE laboratories will contribute to comprehensive and cohesive research efforts as opposed to individual research during the past years. Networking also occurs with the federal scientists at NASA, NOAA, and DOD. To facilitate the knowledge transfer from the ARM program to the premier modeling centers and academic institutes, the ARM science program also supports ARM site scientists and scientific “Fellows” at the National Center for Atmospheric Research, Geophysical Fluid Dynamics Laboratory, and the European Center for

(dollars in thousands)

FY 2007	FY 2008	FY 2009
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Medium-Range Weather Forecasting. In addition, the model parameterization test bed implemented at Lawrence Livermore National Laboratory will be continued to enable the developing and testing of better parameterization schemes and submodels by rapidly incorporating ARM measurements into the GCMs.

▪ **Atmospheric Radiation Measurement (ARM)**

Infrastructure	34,783	35,251	37,853
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In February 2007, BER conducted a review of the ARM Climate Research Facility (ACRF) to determine the scientific and cost effectiveness of the facility operation. The review found that the ACRF provides uniquely valuable resources for the global climate research community. The review panel found that the ACRF has effectively implemented numerous cost reduction measures while simultaneously increasing the number of products delivered to the user community.

In FY 2009, the ARM infrastructure activity will continue to support and upgrade the operation of the ARM Climate Research Facility (ACRF). The ACRF consists of three stationary facilities, an ARM Mobile Facility (AMF), and the ARM Aerial Vehicles Program (AAVP). The stationary sites provide scientific testbeds in three different climatic regions (mid-latitude, polar, and tropical); the operating paradigm of continuous measurement of atmospheric and surface properties at long-term sites is well suited to climate studies. The AMF provides a capability to address high priority scientific questions in regions other than the stationary sites. The AAVP provides a capability to obtain *in situ* cloud and radiation measurements that complement the ground-based measurements.

The ACRF provides the infrastructure needed for studies investigating atmospheric processes and for climate model development and evaluation. As a scientific user facility, ACRF supports hundreds of scientists from universities and government laboratories. Support for the science community includes access to data from the ARM archive and infrastructure needed to conduct experiments at the facilities, both ground and aerial. Selection of proposed experiments for implementation is based on a solicitation for proposals and a competitive merit review. Ranging from two weeks to a year, the campaigns bring together teams of national and international scientists to coordinate measurements with airborne and satellite observations to measure particular processes and their effects on radiation around one of the facilities. Both NASA and DOD, for example, use the ACRF facilities to “ground truth” measurements made with some of their satellite-based instruments. The CCRI ARM Infrastructure activity will continue to deploy an ARM mobile facility in selected locations that are either data poor or represent locations of opportunity for measuring effects of atmospheric conditions on the radiation balance that are currently poorly understood (e.g., direct and indirect effects of aerosols and their interactions with clouds). The budget increase will be used to begin developing a second ARM mobile facility for deployment in FY 2010. The primary criterion for deployment of the mobile facilities is to provide needed measurements to address specific modeling needs that cannot be provided by measurements from the stationary ARM facilities. The deployment location for the ARM mobile facilities and the scientific focus and location of ACRF campaigns in FY 2009 have not yet been determined, but a decision is expected following the review of proposals that were solicited from the research community. In FY 2009 ACRF will continue to add new instrumentation for characterizing the 3D structure of clouds.

(dollars in thousands)

FY 2007	FY 2008	FY 2009
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(estimated)

	FY 2007	FY 2008	FY 2009
Optimal hours	7,884	7,884	7,884
Scheduled hours	7,884	7,884	7,884
Operation Time	>98%	>98%	>98%
Users ^a	850	900	900

▪ **Atmospheric Science** **12,241** **12,633** **13,051**

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

In FY 2009, ASP will continue its mission to characterize aerosol physical, chemical, and optical properties and their effects on the Earth's energy balance. These studies include laboratory and field research on key processes individually and as encountered in "real world" environments. Acquired data are used to develop and test predictive parameterization schemes or models for aerosol properties and their effect on radiative transfer in the atmosphere. Field and laboratory observations are also used to interpret and extend the results of process model simulations. Current priority atmospheric processes under study include transformations and properties of carbonaceous aerosols, especially secondary organic aerosols, which are poorly predicted by current atmospheric models. Also important are processes controlling new particle formation and growth, as well as the properties that affect their activation as droplet and crystal nuclei.

In early FY 2009 the ASP will participate in a major collaborative interagency field campaign aimed at measuring interactions of aerosols with clouds over the Southern Pacific Ocean near Chile, a region that is impacted both by pristine and polluted air masses. One specific objective of ASP activity is to test new process models of drizzle formation that show promise for inclusion into global climate models.

▪ **Terrestrial Carbon Processes** **12,326** **13,439** **13,631**

In FY 2009, BER will continue support of AmeriFlux, a network of research sites where the net exchange of carbon dioxide, energy, and water between the atmosphere and major terrestrial ecosystems in North America is continuously measured. Approximately 20 of the sites are funded by BER at an average of \$200,000 each, along with quality assurance of the measurements and data, and data archiving to make it available to the broader scientific community. There are approximately 70 additional sites in the AmeriFlux network that are funded by other agencies (NASA, NOAA, United States Geological Service (USGS), Forest Service, and Agriculture Research Service). The AmeriFlux measurements are linked to field measurement campaigns across major regions of North

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

(dollars in thousands)

FY 2007	FY 2008	FY 2009
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America that are designed to test how well point measurements of fluxes represent fluxes observed over larger areas within the same region and allow the estimate of carbon sources and sinks on a regional and eventually a national or continental basis.

In FY 2009, the AmeriFlux Network research sites will provide extensive measurements of terrestrial carbon sink properties, including biological and soil carbon processes. This research is important for evaluating what happens to carbon dioxide emissions from combustion of fossil fuels, and provides scientific information needed for prognostic modeling of the rate of atmospheric carbon dioxide increase, which is a key forcing factor of climate. Improved understanding of the terrestrial carbon cycle is also an integral component of the North American Carbon Program (NACP), which is employing two independent analytical methods to build confidence in estimates of the North American terrestrial carbon sink. Using common protocols across the Network, a comprehensive and coherent suite of measurements will be produced that will include radiation and micrometeorology properties, carbon dioxide and water flux, and physiological/biological/soil carbon processes that affect the net exchange of carbon dioxide between terrestrial ecosystems and the atmosphere. A key measurement will be the direct observation of net ecosystem exchange (NEE) of carbon dioxide that represents the quantity of carbon that is gained or lost from an ecosystem. Linking these comprehensive observations with forest and crop inventory data (from USDA/Forest Service) and with remote sensing observations (from NASA), the suite of observations is integrated using terrestrial ecosystem and landscape models to produce a “bottom-up” calculation of distributed carbon sinks across North America. This “bottom-up” estimate will be compared with a “top-down” calculation of the carbon sink that is based on atmospheric carbon dioxide measurements at continental boundaries and inverse modeling methods. While the “top-down” analysis will be performed by other Agencies of the NACP (i.e., NOAA, NASA, and NSF), the AmeriFlux Network will provide high precision atmospheric carbon dioxide measurements that are essential for constraining the “top-down” calculations. The pivotal AmeriFlux observations of carbon dioxide fluxes and factors that control them and the carbon cycle modeling will contribute significantly to the highly coordinated inter-agency NACP research on the magnitude and longevity of North American carbon sinks, which is a top priority of the U.S. Climate Change Science Program. The AmeriFlux research together with related observations and modeling approaches of other Agencies will provide the Nation with the needed quantification of North American terrestrial carbon sinks, with unique diagnostic tools and prognostic models for predicting future atmospheric carbon dioxide increase that will be on par with analytical capabilities of other areas of the globe (e.g., the European Union).

▪ Ocean Sciences	136	—	—
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Ocean sciences research was concluded in FY 2007.

▪ Information and Integration	1,868	1,873	1,873
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The Information and Integration element of Climate Forcing research will continue to store, evaluate, quality assure, and disseminate a broad range of climate change related data, especially data on atmospheric concentrations and industrial emissions of greenhouse gases, greenhouse gas fluxes from terrestrial systems, ocean CO₂ data, and air quality data. This is accomplished by supporting the Carbon Dioxide Information and Analysis Center (CDIAC). CDIAC's data holdings include records of the concentrations of carbon dioxide and other radiatively active gases in the

(dollars in thousands)

FY 2007	FY 2008	FY 2009
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atmosphere; the role of the terrestrial biosphere and the oceans in the biogeochemical cycles of greenhouse gases; emissions of carbon dioxide to the atmosphere; long-term climate trends; the effects of elevated carbon dioxide on vegetation; and the vulnerability of coastal areas to rising sea level. These data are used by the climate change research community for assessing changes in climate forcing due to increasing concentrations and emissions of greenhouse gases. These data are evaluated and quality assured before being disseminated. CDIAC will continue to archive, manage, and disseminate ocean carbon data. CDIAC is recognized by the World Meteorological Organization as a World Data Center for accessing information on greenhouse gas emissions and concentrations. The Center serves a diverse set of users, including academic and laboratory scientists and policy makers globally. CDIAC serves as the Quality Systems Science Center for the tri-lateral (U.S., Mexico, and Canada) NARSTO (formerly known as the North American Strategy for Tropospheric Ozone), public partnership for atmospheric research in support of both air quality management and research on the effects of air quality on climate forcing and climate change. This Center also serves a diverse set of users, especially across North America, including both scientists and policy makers. In FY 2009 CDIAC will release a database of fossil-fuel emissions data developed for use in coupled climate-carbon cycle models and Earth system models. In FY 2009, CDIAC will also produce the 2008 global fossil-fuel CO₂ emission estimates.

Climate Change Modeling	25,375	31,017	45,387
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During the past decade, considerable advances have been made in the understanding, detection and attribution of past climate change, and in projecting future changes in climate using state-of-the-art climate models. However, uncertainties due to climate forcings and feedbacks have not yet been resolved, e.g., current state-of-the-science coupled atmosphere-ocean-land-sea ice models that simulate climate variability and change over decadal to centennial time scales still have systematic precipitation biases. Improvements are needed before models can simulate regional climate variability and change with greater fidelity.

In FY 2009 BER is requesting enhanced funding to directly address these uncertainties. This effort will be closely coordinated with BER's SciDAC for Climate Change Research activities and will enhance BER's partnerships with the Advanced Scientific Computing Research program. The focus will be on incorporation and testing of various aerosol schemes, convection schemes, ice sheets, and land surface schemes in the coupled models, and evaluation using innovative metrics that span a variety of climate time scales. Specifically:

- Testing of newly developed convection schemes, cloud parameterization schemes, global cloud resolving models against observations. The emphasis of this research will be on testing cloud-aerosol-radiation parameterization schemes in Global Circulation Models (GCM).
- Characterizing aerosol-climate interactions. The greatest uncertainty in climate forcing continues to be the role of clouds and aerosols. An important element of this work will be on testing and improving aerosol parameterization schemes in atmospheric GCMs. New types of ARM data, e.g. from field campaigns that aim at understanding atmospheric properties and processes, will be brought to bear to support this research.
- Exploring Decadal Predictability of the Climate System. Currently climate models are run under emission scenarios without initializing using observations. The new effort will aim at understanding

(dollars in thousands)

FY 2007	FY 2008	FY 2009
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climate change prediction using improved initialization of the ocean and other components.

- Understanding Cryospheric Processes and their role in the Climate System. Arctic sea ice declined rapidly to unprecedented low extents in the summer of 2007 raising concern that the Arctic may be on the verge of a fundamental transition toward a seasonal ice cover. Models significantly under represent the observed trend. The reasons for this under representation remain to be fully resolved; understanding cryospheric processes requires a concerted enhanced research. Similarly the role of land-ice in the climate system will be explored.
- Understanding Climate Extremes in a Changing Climate: Climate extremes have large impacts on society. The statistics of climate extremes (temperature, precipitation) will change as climate changes. Understanding and attributing climate extremes will be a new area of study.
- Research to develop Metrics for evaluation of climate models. BER has lead the community in model diagnoses and intercomparison. It is becoming increasingly apparent that there is no single set of universal metrics for climate model evaluation and diagnostics, rather it depends on the scientific question being addressed. For each of the themes being studied (decadal prediction, cryospheric processes, climate extremes) there will be a need to understand why various climate models are giving differing answers. This would lead to a set of metrics relevant to addressing the specific issue. BER will take a proactive role in developing these metrics and diagnostic tools.
- BER will develop new metrics for ocean model evaluation and diagnostics. The new studies of decadal predictability, cryosphere, and climate extremes will also require associated metrics for model evaluation. BER will develop and apply these for the two themes mentioned above.
- Research to develop and employ Enabling Technologies for climate model simulation dissemination: Climate change information is being increasingly sought for impact studies, national and international assessments. The activity is at the interface of process research and the global climate modeling, and is expected to accelerate process representation in coupled earth system models for climate change projections. As part of this new thrust, an effort will also be initiated to strengthen the connections between the integrated assessment and the climate modeling research communities with the objective to bring to bear improved understanding of the human-earth systems dynamics for comprehensive, realistic projections of timing, scale, and geographic distribution of emissions trajectories and other critical parameters of interest. The DOE leadership class computational facilities now provides computing resources for models to be run at resolutions at which complex issues of data archival, management, dissemination need to be addressed. BER will develop such tools and capability.

BER will continue projects initiated in FY 2008 on the topic of abrupt climate change will be at a level of approximately \$2,600,000. BER research will undertake the following: understanding the thresholds and nonlinearities in the climate system with a focus on mechanisms of abrupt climate change, incorporating mechanisms into coupled climate models, and testing the models vis-à-vis records of past abrupt climate change. DOE's focus on Abrupt Climate Change Modeling is attribution of past abrupt climate change, and potential future abrupt climate change based on climate projections using a model that includes different mechanisms that have been hypothesized as causes of abrupt climatic change.

BER will also continue to support and coordinate model-data intercomparisons, the development and improvement of metrics and diagnostic tools for evaluating model performance, and the maintenance of

(dollars in thousands)

FY 2007	FY 2008	FY 2009
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test beds for evaluating model parameterizations. The effort will move beyond the traditional testing of atmospheric models to include testing and evaluation of high-resolution ocean models, e.g., eddy-permitting and eddy-resolving simulations.

BER's SciDAC for Climate Change Research (\$7,776,000) will continue partnerships with the Advanced Scientific Computing Research program. This will include work towards the creation of a first-generation Earth System model based on the Community Climate System Model that treats the coupling between the physical, chemical, and biogeochemical processes in the climate system. The model will include comprehensive treatments of the processes governing well-mixed greenhouse gases, natural and anthropogenic aerosols, the aerosol indirect effect and tropospheric ozone for climate change studies. Research will develop and test a global cloud resolving model using a geodesic grid, with grid-cell spacing of approximately 3 km, capable of simulating the circulation associated with large convective clouds.

The SciDAC university grants initiated in FY 2007 will continue to work on emerging topics on climate change science, e.g., tropical cyclone activity in future climate regimes, evaluation of the upward branch of the deep conveyor belt in ocean models, climate change in the Arctic, annual-cycle El Niño/Southern Oscillations interactions, carbon data assimilation data sets using improved techniques, investigation of regional climate variability and change in the Atlantic Sector, and climate change projections in the Asian monsoon region. The program will continue work on development of an atmospheric model with self-adapting grid and physics, global cloud resolving modeling, new grid and discretization technologies for ocean and ice simulations, a subgrid scaling framework to improve land simulation, and subgrid scale mixing in atmospheric models.

Climate Change Response	24,235	19,380	19,380
▪ Ecosystem Function and Response	12,887	13,182	13,182

The goal of the Ecosystem Function and Response research activity is to understand the potential effects of climatic change anticipated during the coming 50-100 years on the health of important terrestrial ecosystems in the United States. While ecosystem models can provide hypothetical projections of ecological responses to climatic change, present models are seriously limited by lack of relevant experimental data. To address this problem, BER sponsors experimental studies of the potential effects of warming, and changes in precipitation, on multiple terrestrial ecosystems. The new scientific data and understanding obtained by this research will facilitate informed decision making about the means of producing the energy needed by society. It will do this by defining relationships between climatic changes that might be caused by energy production and the potential effects of those changes on the health of terrestrial ecosystems, and the organisms that they contain.

The primary focus in FY 2009 will be experimental studies of the potential effects of warming on the abundance and geographic distribution of plant and animal species in several ecosystem types. The experiments will be conducted to fill specific critical knowledge gaps. In particular, experiments will determine linkages between warming and the possibility of species migrations, the expansion of species into areas that are presently too cool for their success, and the decline of species or ecosystems presently at the warm edge of their ranges. Field experiments will be conducted in high-elevation forests and meadows associated with the alpine tree line, the transition zone (ecotone) between temperate and boreal forests, and western shrubland. Field experiments in other ecosystems

(dollars in thousands)

FY 2007	FY 2008	FY 2009
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will be initiated in FY 2009 based on results of a competition planned for in FY 2008. In addition to field experiments, laboratory experiments will determine relationships between warming and the success of plants and animals in model ecosystems. Laboratory studies will focus on key testable hypotheses about ecological effects of warming.

The secondary focus in FY 2009 will be experimental studies of the potential ecological effects of changes in the annual amount, or seasonal timing, of precipitation. Climate models project reductions in precipitation in the southwestern United States, which has the potential to affect many southwestern ecosystems. Unique field experiments will document effects of experimentally altered rainfall on southwestern woodlands (including the geographically extensive pinyon-juniper ecosystem), forests, grasslands, and shrublands.

In FY 2009, the activity will continue to provide the core support for the operation of the world's largest long-term field study of the potential effects of changes in atmospheric composition caused by energy production on a terrestrial ecosystem (approximately \$1,500,000). That experiment (in central Wisconsin) is enriching the atmosphere within forest communities with carbon dioxide and ozone concentrations that are anticipated to occur within 50 years. The experiment is documenting direct and indirect effects of elevated carbon dioxide and/or ozone on three tree species, soil microorganisms, and pests that feed on trees. The experiment is used by multiple research groups from universities and federal agencies in the United States and from other nations.

▪ **Free Air Carbon Dioxide Enrichment (FACE) Facility**

4,977 — —

In FY 2008, support for the conduct of FACE experiments was discontinued as user facility activity. Instead, research experiments at the existing FACE sites in Wisconsin, Nevada, North Carolina, and Tennessee continue. Support for one of the FACE sites is provided by the Ecosystem Function and Response activity and three are supported by the Terrestrial Carbon Processes activity. Rather than as a user facility, the FACE activity is best characterized as field experiments in which multiple investigators jointly participate as collaborators to understand the direct effect of elevated carbon dioxide and other trace gases on terrestrial ecosystems.

▪ **Integrated Assessment**

4,950 **4,772** **4,772**

BER's Integrated Assessment Research (IA) supports underlying research and development of the basic methods and models for estimating costs and benefits of global climate change and possible actions to mitigate such change. Understanding the underlying and complex human-earth systems dynamics are a priority for IA research. Similarly, understanding the role of present and possible future energy technologies remains a central focus of the research, leading to improved understanding of potential emissions trajectories and the environmental costs and benefits of stabilization options.

In 2009, the program will continue to advance research on the integrated drivers of climate change. However, and consistent with recommendations by the Biological and Environmental Research Advisory Committee, the independent advisory group for BER, the activity will undergo a transformation and will shift considerable attention to the challenge of representing climate change impacts and adaptations within IA models. This shift represents a significant new direction for IA. It is, however, a necessary change if BER is to provide balanced scientific perspectives and capabilities

(dollars in thousands)

FY 2007	FY 2008	FY 2009
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that address both drivers and responses, or more specifically, costs and benefits, within integrated assessment frameworks. Development of non-monetary valuation and visualization methods and tools will be an important dimension of this new work. Additionally, BER will explore the application of more advanced computational platforms reflecting the need for tighter coupling between what are presently reduced-form IA models and the rich detail and reduced uncertainty of underlying biogeophysical models. The latter typically run on supercomputers. BER also recognizes that even reduced-form and meso-scale models of the combined human-earth systems interactions are pressing the limits of computer workstations. The program will strengthen its role in scenario analysis through supporting the climate science community with feedback on the scale, timing, and geographic distribution of parameters of interest for the development and calibration of Earth Systems Models.

▪ **Education** **1,421** **1,426** **1,426**

BER's Global Change Education Program will continue to support both undergraduate and graduate studies in FY 2009 through the DOE Summer Undergraduate Research Experience (SURE) and the DOE Graduate Research Environmental Fellowships (GREF). The GREF and the SURE provide a total of 45 students with support to conduct research that is of interest to them and relevant to DOE's climate change research. Their research is conducted under a mentor of their choice at either a university or a DOE laboratory. Funding for GREF and SURE only supports the students, not the mentor under which they each choose to work. The SURE continues to be a magnet for highly qualified undergraduates, most of who go to graduate school to study in fields directly related to what they did under SURE. Similarly students in the GREF program have received graduate degrees and many have stayed in the field and initiated their own research related to climate change.

Climate Change Mitigation **3,861** **4,747** **4,747**

In FY 2009, BER's carbon sequestration research, part of BER's support to the Climate Change Technology Program, will continue to focus only on terrestrial carbon sequestration. Research will continue on studies to enhance long-term sequestration processes and the stability of stored carbon in terrestrial vegetation and soils. In FY 2009, the research will be organized around switchgrass (*Panicum virgatum*) that will be employed in DOE's "ethanol from cellulose" research. Preliminary studies with switchgrass, a native, warm-season perennial grass with C-4 carbon metabolism, suggest that switchgrass develops an extensive rooting system that could possibly be managed for enhanced soil carbon sequestration. The research will determine if "double dividends" can be achieved from switchgrass systems that provide cellulose for ethanol production and simultaneously enhance soil carbon sequestration. The overall goal is to understand and quantify physical, chemical, and biological controls over soil carbon sequestration using switchgrass as the test bed. The research will be carried out through field experiments with switchgrass at Milan, Tennessee, and the Fermi laboratory site at Batavia, Illinois, which will produce results on below-ground carbon transformations that involve biological guilds of roots, rhizosphere and microbial communities. The role of microaggregates and other soil properties in stabilizing and protecting carbon complexed with soil minerals will also be investigated. Data from the field experiments will be provided for mechanistic and prognostic modeling soil carbon sequestration of the switchgrass system.

SBIR/STTR **—** **3,762** **4,240**

(dollars in thousands)

FY 2007	FY 2008	FY 2009
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In FY 2007, \$3,311,000 and \$397,000 were transferred to the SBIR and STTR programs, respectively. FY 2008 and FY 2009 amounts shown are the estimated requirements for continuation of the SBIR and STTR programs.

Total, Climate Change Research	129,619	136,867	154,927
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Explanation of Funding Changes

FY 2009 vs. FY 2008 (\$000)

Climate Forcing

- **Atmospheric Radiation Measurement (ARM) Infrastructure**

The ARM infrastructure increases to begin development of a second mobile ARM Climate Research Facility.

+2,602

- **Atmospheric Science**

Atmospheric Science research increases to support additional research on aerosol properties and processes, including their transport and transformations that affect their radiative properties in the atmosphere.

+418

- **Terrestrial Carbon Processes**

Terrestrial Carbon Processes is held near the FY 2008 level.

+192

Total, Climate Forcing

+3,212

Climate Change Modeling

Climate Modeling increases to exploit the Department's leadership class computing facilities to determine the effect of both resolution and improved model physics, including ice sheets, in a fully coupled climate model for use in both on simulating historic climate at decade and longer time scales and regional to global spatial scales and projecting future potential climate change at regional to global scales in response to different plausible scenarios of natural and/or human-induced forcing.

+14,370

SBIR/STTR

SBIR/STTR increases due to research program increases.

+478

Total Funding Change, Climate Change Research

+18,060

Capital Operating Expenses and Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2007	FY 2008	FY 2009
General Plant Projects	6,040	4,129	2,700
Capital Equipment	12,483	14,998	28,777
Total, Capital Operating Expenses	18,523	19,127	31,477

Major Items of Equipment *(TEC \$2 million or greater)*

(dollars in thousands)

	Total Project Cost (TPC)	Other Project Costs (OPC)	Total Estimated Cost (TEC)	Prior Year Appropriations	FY 2007	FY 2008	FY 2009	Completion Date
EMSL Field Emission Transmission Electron Microscope, PNNL	4,500	—	4,500	—	—	4,500	—	FY 2008