STATEMENT OF

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Thank you Mr. Chairman, Ranking Member Inglis, and Members of the Committee. I appreciate the opportunity to appear before you today to discuss the Biological and Environmental Research (BER) Program in the Department of Energy's (DOE's) Office of Science (SC). I am the Program Director..

Overview of the Biological and Environmental Research Program

The BER program supports fundamental research and scientific user facilities designed to advance our understanding of complex biological, climate, and environmental systems. A hallmark of BER-supported research is the strong coupling of theory, observations, experiments, models, and simulations, with an emphasis on interdisciplinary research. The nature of biological, climate, and environmental research necessitates involvement of a wide range of scientific disciplines including microbiology, plant sciences, computational sciences, ecology, geochemistry, atmospheric sciences, and hydrology, to name just a few.

Using peer review to ensure scientific excellence, the BER program engages scientists from national laboratories, universities, and the private sector to generate cutting edge science. In FY 2009, BER supported more than 1,800 Ph.D. scientists and nearly 500 students. In addition, BER user facilities hosted more than 2,500 biological, climate, and environmental scientists. In FY 2009, the BER program funded research at more than 85 academic and private institutions in 39 states and at nine DOE laboratories in eight states.

The BER program is organized into two subprograms—Biological Systems Science and Climate and Environmental Sciences—that provide the fundamental knowledge for:

Exploring the frontiers of genome-enabled biology. BER Biological Systems Science subprogram supports research that uncovers nature's secrets to harness the catalytic power and biomass of microbes and plants for DOE mission priorities in bioenergy, carbon cycle, and bioremediation. Starting with an organism's DNA, BER-funded scientists seek to understand whole biological systems as they interact with their environments. BER scientists investigate a range of systems from individual proteins and other molecules, to groups of molecules that comprise molecular machines, to interconnected biological networks comprising whole cells, communities, and entire ecosystems. BER also supports the development of new tools and technologies to explore the interface of the biological and physical sciences.

Discovering the physical, chemical, and biological drivers of climate change. The BER Climate and Environmental Sciences subprogram plays a vital role in the U.S. Global Change Research Program by supporting research to improve predictive climate models by addressing key uncertainties such as clouds and aerosols and the carbon cycle. BER scientists study atmospheric processes, climate change modeling, interactions between ecosystems and greenhouse gases, and the impacts of climate change on energy production and use.

Seeking the geochemical, hydrological, and biological determinants of environmental sustainability and stewardship. The Earth's subsurface is a new frontier for discovering novel microorganisms and understanding important geochemical and hydrological processes that affect the fate and transport of environmental contaminants. The BER Climate and Environmental Sciences subprogram supports laboratory studies and field scale hypothesis-testing at BER's Integrated Field Research Centers to provide the foundational knowledge needed for cost-effective strategies for environmental stewardship and remediation.

BER supports three world-leading scientific facilities. The Biological Systems Science program supports the Joint Genome Institute (JGI) which provides state-of-the-art genome sequencing and bioinformatic analysis for microbes and plants of energy and environmental significance. The JGI has sequenced 500 microbes and microbial communities, as well as 25 plants using state-of-the-art sequencing and genomic analysis. The JGI is an innovator in genomic sequence and analysis of complex microbial communities that degrade cellulose, sequester carbon dioxide, and remediate environmental contaminants. Recent scientific accomplishments include the genome sequencing of key plants of bioenergy and agricultural importance (soybean, sorghum) and microbes of importance to the carbon cycle (single celled algae) and development of advanced data analysis tools for metagenomes.

The Climate and Environmental Sciences program supports the Atmospheric Radiation Measurement Climate Research Facility (ACRF) and the Environmental Molecular Sciences Laboratory (EMSL). ACRF consists of three stationary facilities that provide an unmatched level of observations and measurements of clouds and aerosols, as well as two mobile facilities that are strategically deployed by the scientific community. In the past year, a mobile facility was deployed to China to measure aerosols and to the Azores to collect measurements on the marine boundary layer near the Equator. In 2009, the ACRF hosted more than 800 users, resulting in over 185 publications in the scientific literature. The Environmental Molecular Sciences Laboratory (EMSL) supports scientific discovery at the frontier of molecular systems science and serves 600-700 scientists annually. EMSL develops and applies one-of-a-kind experimental and computational tools to novel molecular-level studies of complex environmental systems.

BER is using FY 2009 American Recovery and Reinvestment Act (Recovery Act) funds to update, improve, and optimize the capabilities of its three user facilities and the three Bioenergy Research Centers and to initiate planning and development for a Systems Biology Knowledgebase to manage and integrate large systems biology data sets.

Biological Systems Science

BER supported biological research has a long history of major contributions to DOE mission and national needs through science, discovery, and innovation. BER's origins date to 1946, the atomic bomb, concerns for health effects from exposure to radiation, and the promise of benefits from peaceful uses of nuclear energy. Health effects research gave us breakthroughs in genetics and developments in nuclear medicine. Interest in the effects of radiation exposure led to understanding the most fundamental level of biology, DNA, and prompted DOE to initiate the Human Genome Project, spearheading today's biotechnology revolution.

Today, BER supports discovery science to understand complex biological systems. Our ultimate goal is to predict, manage, and control biological systems to support mission needs in bioenergy production, climate change, and environmental stewardship and sustainability. To this end, BER supports work to address some of the toughest grand challenge science questions facing biologists: to understand the functions and emergent properties of biological systems at multiple levels. These systems can range in complexity from single microbes to multicellular frameworks of plants, microbial communities, and plant-microbe associations; yet all are specified by underlying information encoded in the organism's genome. The subprogram supports systems biology approaches that translate the genomic blueprint into subcellular proteins, metabolites, and cellular architecture that govern biological function and the interactions between an organism and its environment. Systems biology approaches include genome sequencing, proteomics, metabolomics, structural biology, high-resolution imaging and characterization, and integration of the resulting information into predictive computational models of biological systems that can be tested and validated.

BER's foundational science in biological systems addresses critical national needs in energy production and understanding the consequences of energy use. Scientific innovation and discovery that drive new solutions is essential for meeting the challenges posed by the energy demands of a growing population and the impacts of energy use on climate and the environment. The ongoing revolution in biological sciences, driven by genomics, provides new ideas and paradigms for the synthesis of novel biofuels as well as new approaches for understanding the carbon cycle and harnessing the catalytic power of microbes for bioremediation.

Input from the Scientific Community

The BER biological sciences subprogram engages the scientific community through focused scientific workshops and program reviews and through the Biological and

Environmental Research Advisory Committee (BERAC). Hundreds of scientists provide input to BER programs every year.

For example, in May 2008, BER hosted a workshop on "Systems Biology Knowledgebase for a New Era in Biology" in coordination with the Office of Science's Office of Advanced Scientific Computing Research. A knowledgebase is comprised of a data repository and a suite of tools for data analysis, comparison, visualization, and integration. It also provides a framework for creating, testing, and improving predictive models of biological systems. The workshop participants described the need to facilitate the integration of diverse types of biological data as well as environmental data describing the organism's habitat.

Another example is a November 2008 community-based workshop, "New Frontiers of Science in Radiochemistry and Instrumentation for Radionuclide Imaging." BER supports research in radiochemistry and radiotracer development with the goal of developing new methodologies for real-time, high-resolution imaging of dynamic in plants and microbes, with the potential for broader application to areas of human health. Participants included leading scientists from DOE laboratories, universities, and federal agencies such as the National Institutes of Health (NIH). The workshop participants identified knowledge gaps and future opportunities for development of new radiochemical tracers and new imaging modalities.

Details of the Biological Systems Science Subprogram

This subprogram explores the fundamental principles that drive the function and structure of living systems of importance to energy and the environment.

Genomic sciences use the genome as a blueprint for the foundational biological understanding of microbes, microbial communities, and plants. The research addresses: What information is contained in the genome sequence of microbes and plants? How is that information translated to proteins and metabolic networks? And, how can we predict and control biological responses to environmental changes?

Three DOE *Bioenergy Research Centers* (BRCs)—led by Lawrence Berkeley National Laboratory, Oak Ridge National Laboratory, and the University of Wisconsin at Madison in partnership with Michigan State University—support multidisciplinary teams of leading scientists to accelerate transformational breakthroughs needed to convert cellulose to biofuels. A more detailed description of the BRCs is provided later in the testimony.

The *Joint Genome Institute* (JGI) is a high-throughput DNA sequencing facility providing the basis for the systems biology of environmental and energy-related microbes and plants. Current sequencing capacity at the JGI is over 124 billion base pairs per year and is growing rapidly. JGI provides the scientific community with the latest technologies for genomic sequencing, genetic analysis, and genomic comparison.

Structural biology supports access to DOE's world-class synchrotron and neutron sources for scientists to understand the proteins encoded by DNA. *Radiochemistry and imaging* *instrumentation* focuses on development of new methods for real-time, high-resolution imaging of energy- and environmentally-relevant biological systems. This fundamental research and tool development may have broader applications to nuclear medicine. *Radiobiology* supports research on the biological effects of exposure to low dose radiation.

DOE Bioenergy Research Centers
In September 2007, three DOE Bioenergy Research Centers (BRCs) were launched to provide transformational science to overcome the most difficult scientific and technological barriers to the production of biofuels from microbes and plants. The Centers are marshalling the full arsenal of modern genomics-based methods to overcome plant cell wall recalcitrance. Scientists are using systems biology to model, predict, and engineer optimized enzymes, microbes, and plants for the discovery and development of new, innovative approaches to efficient cellulosic biofuels production. Expertise at the BRCs spans the physical and biological sciences, including genomics, microbial and plant biology, analytical chemistry, computational biology and bioinformatics, and engineering. The BRCs engage DOE National Laboratories, universities, and the private sector in interdisciplinary partnerships to ensure the best possible science and rapid transition to application. The BRCs serve to galvanize the top researchers in the field to accelerate the scientific breakthroughs needed by the emerging biofuel industry.

Although the Bioenergy Research Centers have only been fully operational for two years, some early successes include:

1. **New High-Throughput Pipeline to Identify Improved Bioenergy Feedstocks**
   The BioEnergy Science Center (BESC) developed a screen to rapidly identify the chemical, structural, and genetic features of biomass that provide better access to the sugars within plant biomass. This pipeline can screen more than 10,000 samples per week which is over 100-fold more biomass samples per day than conventional methods. BESC researchers tested 1,100 poplar trees from the Pacific Northwest. Digestibility or sugar release ranged from 0.2 to 0.7 grams of sugar per gram of biomass – the highest numbers will bring us close to desired commercial biofuels production levels. This screening is accelerating the discovery and optimization of plants most easily converted into biofuels.

2. **Innovations in Biomass Pretreatment and Deconstruction**
   Researchers at the Joint BioEnergy Institute (JBEI) have developed an advanced biomass pretreatment process using room temperature ionic liquids that completely remove virtually all the lignin from the plant cell walls of switchgrass, corn stover, and eucalyptus. This approach has reduced by a factor of five the time required for enzymatic breakdown of biomass. Researchers have also developed a new cellulase enzyme that is more stable and active in ionic liquid solutions at elevated temperatures and low pH. Patents have been filed on both these innovations.

3. **Improved Screening for the Discovery of Biomass-degrading Enzymes**
   Microorganisms in natural environments have evolved enzymes for degrading

biomass; however, conventional methods for identifying these enzymes are inefficient and time consuming. Scientists at the Great Lakes Bioenergy Research Center (GLBRC) are coupling a novel genetic expression approach with a newly developed enzymatic screening process to dramatically improve the discovery of new cellulose-degrading enzymes. They found that the rate and efficiency of enzyme discovery was ~100 times higher with the new expression and screening tools than conventional methods. The novel cellulose-degrading microbes or enzymes that are being discovered are providing hundreds of candidate hydrolytic enzymes for use in biomass-degradation studies.

R&D Coordination in the Biological Sciences

BER is deeply committed to coordinating with DOE's technology offices to better integrate the basic and applied research supported by the Department. We have developed and maintained good working relationships with DOE technology offices and other key stakeholders. BER works closely with DOE's Office of the Biomass Program (OBP) in the Office of Energy Efficiency and Renewable Energy (EERE). Strong partnerships have been forged and maintained to facilitate the transition of scientific knowledge to applications that address DOE mission needs.

BER has a long history of coordination with OBP that began over a decade ago, when we worked with OBP and the scientific community to identify key microbes of importance for the breakdown of cellulosic biomass. Those microbes were subsequently sequenced by the JGI, and bioenergy researchers worldwide have greatly benefited from that new knowledge. From the earliest stages of planning BER bioenergy research, we have worked closely with OBP—beginning with the jointly funded 2006 workshop "Breaking the Biological Barriers to Cellulosic Ethanol: A Joint Research Agenda." The workshop report provided a roadmap for addressing the toughest research questions to support biofuel production. BER-supported research on the biochemical pathways and genetic mechanisms of microbes and plants provides knowledge needed by OBP (and the U.S. Department of Agriculture) to make decisions about the development and deployment of new bioenergy crops and cost effective and sustainable approaches to bioenergy production.

BER takes advantage of numerous mechanisms to encourage knowledge transfer from BER science discoveries to applied programs within the Department of Energy, including: 1) Regularly-scheduled program briefings between SC-BER and EERE-OBP program staff; 2) briefings by BRC directors to OBP program managers; 3) participation and attendance at program reviews and investigator meetings for SC-BER and EERE-OBP; and 4) joint participation in interagency working groups by SC-BER and EERE-OBP program staff, such as the Biomass Research and Development Board and the Metabolic Engineering Working Group. Moreover, EERE is planning to use Recovery Act funds to build a pilot biorefinery that can be used as a testbed for products from the three BRCs. Such an approach will help to facilitate a smooth transition of knowledge from the BRCs to applications by EERE.

Coordination and Partnering with other Federal Agencies in Biological Sciences

A hallmark of the BER program is the coordination of research across federal agencies and scientific disciplines. BER values partnering and cooperation with many research agencies, including the National Science Foundation (NSF), the U.S. Department of Agriculture USDA, the NIH, the National Aeronautics and Space Administration (NASA), and others. Several examples of interagency activities in the biological sciences include the following:

- BER and the USDA have partnered on a competitive grants program entitled Plant Feedstock Genomics for Bioenergy. Now in its fourth year, the program develops and applies the latest approaches in plant genomics to marker-assisted plant breeding and crop production for potential bioenergy crops. including fast growing trees, shrubs, and grasses.

- BER coordinates with seven other agencies in the Metabolic Engineering Interagency Program. The program, now in its 11th year, supports innovative research in the fields of targeted metabolic pathway design and construction.

- BER supports the Protein Data Bank with NIH and NSF. This community resource provides an archive of experimentally determined, 3-dimensional structures of biological macromolecules.

- BER is an active participant and partner with NSF and USDA in the National Plant Genome Initiative. Current focus of this initiative is the sequencing and analysis of the maize (corn) genome.

- BER actively coordinates with NIH on areas of common interest such as tools and technologies for data management, genome annotation, structural biology, proteomics, and radiochemistry. For example, BER and the Office of Science's Office of Nuclear Physics co-chair a working group with NIH.on radioisotope production and use.

In addition, BER actively participates in numerous working groups to enhance dialogue and coordination. Interagency activities such as these ensure that the BER portfolio is well-coordinated with other agencies and that opportunities for interagency partnering are vigorously pursued.

Climate and Environmental Sciences Subprogram

The Climate and Environmental Sciences subprogram addresses national needs and DOE priorities in energy, environment, and security. Although this hearing is focused on BER's biology programs, I would like to share a few highlights from our climate and environmental programs which represent almost half (47%) of BER's budget. The subprogram supports an integrated portfolio of research ranging from molecular to field scale studies with emphasis on the use of advanced computer models, interdisciplinary experimentation, and observations. BER supports fundamental research activities as well as two national scientific user facilities for climate and environmental science.

DOE plays a vital role in advancing fundamental climate and environmental research as part of the U.S. Global Climate Change Research Program. BER supports a unique set of resources and capabilities to address the major questions of global climate change with a goal of providing more accurate simulations of the Earth's climate. Climate simulations provide the foundations for future climate projections and guide potential mitigation or adaptation strategies, thereby informing the Nation's energy policies, and contribute to assessments by the Intergovernmental Panel on Climate Change. BER climate research addresses the areas of greatest uncertainty in climate change: clouds and aerosols and carbon cycling. BER also develops world-class coupled climate models that take advantage of DOE's leadership computing capabilities. Reducing uncertainty in climate prediction will help us to identify potential vulnerabilities and to develop new approaches for mitigation and adaptation to climate change. The BER Atmospheric Radiation Measurement Climate Research Facility (ACRF) provides key observational data to the climate research community on the radiative properties of the atmosphere, especially clouds. The facility includes highly instrumented ground stations (including radars, lidars, and a range of meteorological instrumentation), a mobile facility, and an aerial vehicles program.

BER's subsurface biogeochemistry program is the only one of its kind in the federal government that focuses on basic research in the fate and transport of radionuclides and metals in subsurface environments. BER seeks to understand the role that subsurface biogeochemical processes play in determining the fate and transport of contaminants at DOE sites. Laboratory studies are coupled with field scale hypothesis testing that is carried out through three Integrated Field Research Challenges located at sites at Hanford in Washington, Oak Ridge in Tennessee, and Rifle, Colorado. Improved understanding and predictive modeling of subsurface environments will lead to novel approaches and strategies for remediation and stewardship of DOE sites that are needed to address the staggering costs of cleanup of contaminants. BER coordinates its environmental research with other federal agencies through working groups under the aegis of the White House National Science and Technology Council. BER also plays an active role in the Strategic Environmental Research and Development Program (SERDP) in partnership with DOD and EPA. BER supports the Environmental Molecular Sciences Laboratory (EMSL) to accelerate scientific discovery at the frontier of environmental systems science. EMSL houses an unparalleled suite of state-of-the-art capabilities, including a supercomputer and over 60 major instruments. EMSL instrumentation, with capabilities in nuclear magnetic resonance, mass spectroscopy, and a range of imaging modalities, supports major science themes of biogeochemistry, biological interactions and dynamics, and catalysis.

R&D Coordination in Climate and Environmental Sciences

The knowledge and tools developed by BER research to understand Earth's climate system and to predict future climate and climate change is used by DOE's Office of Policy and International Affairs as it develops strategies for our Nation's future energy needs and control of greenhouse gas emissions. BER also works with the U.S. Global Change Research Program in numerous stakeholder engagement activities.

BER research on the behavior and interactions of contaminants in the subsurface environment provides knowledge needed by DOE's Office of Environmental Management (EM) to develop new strategies for stewardship and remediation of weapons-related contaminants at DOE sites and by DOE's Office of Legacy Management to develop tools to monitor the long-term status of contaminants at cleanup sites. Mechanisms to foster R&D integration with EM include joint participation by BER and EM in planning activities, site visits and reviews, and involvement of EM site managers in BER Integrated Field Research Challenge projects. Knowledge of the subsurface environment as a complete system will also be useful to DOE's Office of Fossil Energy in their efforts to predict the long-term behavior of carbon dioxide injected underground for long-term storage. As a direct result of BER supported basic research in modeling the fate and transport of contaminants, EM will initiate an effort in FY 2010 to develop the next generation simulation software needed to address the prediction, risk reduction, and decision support challenges faced by DOE sites.

Looking to the Future

BER continues to leverage its scientific strengths and novel community resources for understanding complex biological, climate, and environmental systems as it looks to the future. Biology has entered a systems-science era with the goal to establish a predictive understanding of the mechanisms of cellular function and the interactions of biological systems with their environment and with each other. Vast amounts of data on the composition, physiology, and function of complex biological systems and their natural environments are emerging from new analytical technologies. Effectively exploiting these data requires developing a new generation of capabilities for analyzing, mining, and managing the information.

To manage and effectively use this rapidly growing volume and diversity of data, BER is developing a systems biology knowledgebase that will facilitate a new level of scientific inquiry by serving as a central component for the integration of modeling, simulation, experimentation, and bioinformatic approaches. A systems biology knowledgebase will be a primary resource for data sharing and information exchange among scientists. It will not only enable scientists to expand, compute, and integrate data and information program wide, but it also will drive two classes of work: experimental design and modeling and simulation. Integrating data derived from computational predictions and modeling will increase data completeness, fidelity, and accuracy. These advancements in turn will greatly improve modeling and simulation, leading to new experimentation, analyses, and mechanistic insight.

BER will continue to leverage its unique combination of user facilities and DOE computational resources to improve our ability to predict future climate with greater accuracy. BER will develop high resolution regional climate simulations for use in assessing regional and national implications of climate change on human systems and infrastructure, especially energy demand, production, and supply, such as biofuel feedstock production. This effort will also support interagency activities of the U.S. Global Change Research Program.

Concluding Remarks
Thank you, Mr. Chairman, for providing this opportunity to discuss the Biological and Environmental Research program. This concludes my testimony, and I would be pleased to answer any questions to you may have.