Biological and Environmental Research

Overview

The mission of the Biological and Environmental Research (BER) program is to support transformative science and scientific user facilities to achieve a predictive understanding of complex biological, Earth, and environmental systems for clean energy and climate innovation. This fundamental research, conducted at universities, DOE national laboratories, and research institutions across the country, explores organisms and ecosystems that can influence the U.S. energy system and advances understanding of the relationships between energy and the environment from local to global scales, including a focus on climate change experimental research and predictive modeling. BER's support of basic research will contribute to a future of stable, reliable, and resilient energy sources and infrastructures that will contribute to evidence-based climate solutions with a focus on environmental justice. Research within BER can be categorized into biological systems and Earth and environmental systems. Biological systems research seeks to characterize and predictively understand microbial and plant systems using genomic science, computational analyses (including Artificial Intelligence [AI] and Machine Learning [ML]), experimental, and modeling approaches. Foundational knowledge of the structure and function of these systems underpins the ability to leverage natural processes for clean energy production, including the sustainable development of biofuels and other bioproducts, as well as natural carbon sequestration capabilities. Characterization of microbial communities will lead to understanding the impacts of how vulnerable environments will respond to climate change. Earth and environmental systems research seek to characterize and understand the feedbacks between Earth and energy systems, which includes studies on atmospheric physics and chemistry, ecosystem ecology and biogeochemistry, and development and validation of Earth system models extending from local to global scales. These models integrate information on the biosphere, atmosphere, terrestrial land masses, oceans, sea ice, subsurface, and human components. To promote world-class research in these areas, BER supports user facilities that enable observation and measurement of atmospheric, biological, and biogeochemical processes using the latest technologies. All BER activities are informed by the scientific community and engagement with the federally chartered BER Advisory Committee.

Over the last three decades, BER's scientific impact has been transformative. Mapping the human genome through the U.S. supported international Human Genome Project that DOE initiated in 1990 ushered in a new era of modern biotechnology and genomics-based systems biology science. Today, researchers in the BER Genomic Sciences activity and the Joint Genome Institute (JGI), as well as in the four DOE Bioenergy Research Centers (BRCs), are using the powerful genomics-based tools of plant and microbial systems biology to pursue the early-stage research that will lead to the development of transformative bio-based products and clean energy technologies to underpin a bioeconomy.

Since the 1950s, BER and its predecessor organizations have been critical contributors to the fundamental scientific understanding of climate change and the atmospheric, land, ocean, and environmental systems. BER research contributes to reducing the greatest uncertainties in model predictions, e.g., involving clouds and aerosols, and is incorporating new observations and information from initiatives such as the Urban Integrated Field Laboratories (IFLs). DOE research has made considerable advances in increasing the reliability and predictive capabilities of these models using AI/ML, access to DOE's fastest computers, and systematic comparisons with observational data to improve confidence in model predictions.

BER-supported research continues to produce the software and algorithms that enable the productive application of models that span genomics, systems biology, environmental and climate sciences. These mission-driven models that are run on DOE's fastest supercomputers, are game-changing and among the most capable in the world. For example, BER's models of biological and environmental processes are exploring the systems level complexity of genomics, protein structures, and microbial dynamics that will serve as a basis for addressing of future bioenergy and environmental challenges. BER's JGI and Environmental Molecular Sciences Laboratory (EMSL) provide the necessary information to achieve these goals. Model developments in climate and Earth system science are shifting to ultra-high resolution to better represent the processes that limit prediction uncertainty. Cloud-aerosol data provided by the Atmospheric Radiation Measurement (ARM) are necessary in developing, testing, and validating increasingly sophisticated system models.

Highlights of the FY 2024 Request

The FY 2024 Request for BER is $931.7 million. BER will enhance its research on climate science by expansion of Urban Integrated Field Laboratories (Urban IFLs) and the network of climate centers, affiliated with Historically Black Colleges and Universities (HBCUs) and Minority Serving Institutions (MSIs); continue investments in AI approaches for improving Earth and environmental system predictability; and expanded Earthshots that focus on science at the nexus of clean energy production and climate change. BER will enhance its biosystems research by: continuing the Energy Earthshot Research Centers (EERCs) and expanding Earthshot Research activities to bring together multi-disciplinary teams to more rapidly remove barriers hampering the translation of basic science into innovative technological solutions; speeding development of new innovations in biotechnology under the Accelerate and the Advanced Manufacturing initiatives to include development of sensor technologies to enable the translation of laboratory-scale results, such as in fabricated ecosystems, to broader-scale field ecosystems. BER will continue the Established Program to Stimulate Competitive Research (EPSCoR) and the Reaching a New Energy Sciences Workforce (RENEW) and Funding for Accelerated, Inclusive Research (FAIR) initiatives, BER will build stronger programs with underrepresented institutions and regions, including investing in a more diverse and inclusive workforce.

Research

- Within Genomic Sciences, the BRCs will provide new research both individually and through shared research themes, underpinning the production of clean energy and chemicals from sustainable biomass resources. The EERCs will continue efforts with a specific focus on translational research that lowers risks and speeds adoption of basic research results to industry for a broader bio-based economy. The Biopreparedness Research Virtual Environment (BRaVE) will add additional functionality to its collaborative cyber infrastructure allowing distributed networks of scientists to work on multidisciplinary research priorities and/or national emergency challenges and include low dose radiation research. Efforts to accelerate emerging technologies and advanced manufacturing techniques will be enhanced. Computational Biosciences efforts will support Advanced Computing to deploy a flexible multi-tier data and computational management architecture for microbiome system dynamics and behavior. Research in Biomolecular Characterization and Imaging Science will develop multi-modal and QIS-enabled techniques to understand biological processes.
- BER will continue FAIR to provide focused investment on enhancing biological and environmental research and capacity building involving clean energy and climate research at HBCUs and MSIs.
- Earth and Environmental Systems Sciences research will focus on improving the representation of physical, biogeochemical, and human processes to enhance the predictability of climate, Earth, and environmental systems. Environmental System Science integrates physical and hydrobiogeochemical sciences to provide scale-aware predictive understanding of above- and below-surface terrestrial ecosystems. Atmospheric System Research will investigate cloud-aerosol-precipitation interactions. Modeling research, in particular the DOE Exascale Energy Earth System Model (E3SM), will expand and continue activities to utilize advanced software and AI/ML for running on future DOE computer architectures, exascale research activities will transition from the Exascale Computing Project (ECP) to a broader focus on software for advanced computing and sustainability across current and future computing platforms. The Data Management effort will enhance data archiving and management capabilities, including use of AI research for watershed systems.
- RENEW expands targeted efforts including a RENEW graduate fellowship, to broaden participation and advance justice, equity, diversity, and inclusion in SC-sponsored research. RENEW encompasses all BER activities.

Facility Operations

- The JGI will continue providing genome sequence data and analysis techniques for a wide variety of plants and microbial communities. ARM will continue new observations to advance Earth System models. The site in Alabama will be fully operational. EMSL will provide analytical and imaging capabilities in support of BER's biological, environmental, and climate science priorities; and will embark on development of a capability for microbial molecular phenotyping.

Projects

- The BER FY 2024 Request includes $10.0 million to initiate the Microbial Molecular Phenotyping Capability (M2PC) project at the Pacific Northwest National Laboratory.
- General Plant Projects (GPP) funding provides for minor new construction, for other capital alterations and additions, and for improvements to land, buildings, and utility systems to maintain the productivity and usefulness of DOE-owned facilities and to meet requirements for safe and reliable operation.

Biological and Environmental Research
Funding

(dollars in thousands)

	FY 2022 Enacted	FY 2023 Enacted	FY 2024 Request	FY 2024 Request vs FY 2023 Enacted
Biological and Environmental Research				
Genomic Science	275,500	328,685	338,750	+10,065
Biomolecular Characterization and Imaging Science	45,000	45,000	45,750	+750
Biological Systems Facilities & Infrastructure	84,500	90,000	92,000	+2,000
Total, Biological Systems Science	**405,000**	**463,685**	**476,500**	**+12,815**
Atmospheric System Research	36,000	36,000	40,000	+4,000
Environmental System Sciences	114,000	120,800	137,000	+16,200
Earth and Environmental Systems Modeling	105,000	115,500	120,500	+5,000
Earth and Environmental Systems Sciences Facilities and Infrastructure	155,000	172,700	147,700	-25,000
Total, Earth and Environmental Systems Sciences	**410,000**	**445,000**	**445,200**	**+200**
Subtotal, Biological and Environmental Research	**815,000**	**908,685**	**921,700**	**+13,015**
Construction				
24-SC-31 Microbial Molecular Phenotyping Capability (M2PC), PNNL	–	–	10,000	+10,000
Subtotal, Construction	**–**	**–**	**10,000**	**+10,000**
Total, Biological and Environmental Research	**815,000**	**908,685**	**931,700**	**+23,015**

SBIR/STTR funding:

- FY 2022 Enacted: SBIR $25,184,000 and STTR $3,545,000
- FY 2023 Enacted: SBIR $21,327,000 and STTR $2,999,000
- FY 2024 Request: SBIR $22,278,000 and STTR $3,137,000

Biological and Environmental Research
Explanation of Major Changes

(dollars in thousands)

	FY 2024 Request vs FY 2023 Enacted
Biological Systems Science	**+$12,815**
Activities will continue early-stage core research to understand the complex mechanisms controlling the interplay of microbes and plants within broader organized biological systems. The enhanced BRCs will provide new research underpinning the production of clean energy and chemicals from sustainable biomass resources through individual efforts and inter-BRC shared-theme research. BER will continue the EERCs and enhance the Earthshot Research to bring together multi-investigator, multi-disciplinary teams to remove barriers to implementation of the innovations emerging from basic science into potential solutions for technological challenges. Efforts in secure biosystems design research will decrease as projects are completed. FAIR is enhanced, including clean energy and climate research at HBCUs and MSIs. New emerging technologies will develop capabilities that scale from laboratory fabricated ecosystems to field ecosystems using integrated automated sensor networks, complementing new efforts to understand molecular processes governing soil-microbe-plant interactions with the environment that control carbon turnover. Biotechnology innovations will continue to be pursued to assist development of advanced manufacturing techniques. BRaVE is expanded to include low dose radiation research. Development of new bioimaging, measurement and characterization approaches will include expanded integrative imaging and analysis platforms, including using QIS materials. JGI will initiate plant transformation research to accelerate the understanding and design new beneficial functions into plants. EPSCoR continues to support research activities related to BER.	
Earth and Environmental Systems Sciences	**+$200**
Activities will continue to support the development of high-resolution Earth system predictive modeling, analysis, and intercomparison capabilities focused on DOE mission needs for evidence-based energy and infrastructure resilience and security. The Integrative Artificial Intelligence for Earth System Predictability (AI4ESP) effort will motivate the radical acceleration of high-resolution predictive capabilities across the DOE climate model-data-experiment enterprise, taking advantage of AI/ML techniques for climate science. The ECP activities transition to core research efforts as the ECP concludes. Environmental System Science will increase support of the Urban IFLs providing new place-based data for informing climate and Earth system models. The support for the Energy Earthshot Research activities will be enhanced. An enhanced RENEW will increase research and capacity building at under-represented institutions and HBCUs and MSIs across all BER activities, including through a RENEW graduate fellowship. The network of climate resilience centers is expanded. Using observations from the ARM facility, Atmospheric System Research will focus activities to advance knowledge and improve model representations of atmospheric gases, aerosols, and clouds on the Earth's energy balance. ARM will initiate full operations with community engagement at its Alabama observatory, and a cloud chamber research effort will be initiated to complement ARM's field observations of cloud-aerosol interactions. EMSL will focus on biological and environmental molecular science and new technologies for molecular microbial phenotyping. Data management activities will enhance applying advanced analytics to environmental field data.	
Construction	**+$10,000**
Design activities will be initiated for the Microbial Molecular Phenotyping Capability (M2PC) at the Pacific Northwest National Laboratory.	
Total, Biological and Environmental Research	**+$23,015**

Basic and Applied R&D Coordination

BER research underpins the needs of DOE's energy and environmental missions and is coordinated through the National Science and Technology Council (NSTC) and other committees of the Office of Science and Technology Policy (OSTP). This includes all biological, Earth and environmental systems investments in theoretical, experimental, and predictive modeling research, renewable energy, and field experiments involving atmospheric, ecological, and hydro-biogeochemical sciences research. Basic research on microbes and plants provides fundamental knowledge that can be used to develop new bioenergy crops and improved biofuel and bioproduct production processes that enable a more sustainable bioeconomy and enables climate risk analysis with more accurate capabilities to design, finance, and deploy clean energy solutions. Coordination with other federal agencies on priority bioeconomy science needs, occurs through the Biomass Research and Development Board, a Congressionally mandated interagency group created by the Biomass Research and Development Act of 2000, as amended by the Energy Policy Act of 2005 and the Agricultural Act of 2014. Coordination with OSTP and other federal agencies on short-term weather, seasonal, and short-term climate forecasts is conducted under the Interagency Council for Advancing Meteorological Services (ICAMS), chartered by OSTP in 2020 as part of the U.S. Weather Act of 2017. Furthermore, BER coordinates with DOE's energy technology programs through regular joint program manager meetings, by participating in their internal program reviews and in joint principal investigator meetings, as well as conducting joint technical workshops.

BER supports some interagency projects to manage databases (such as the Protein Data Bank) through interagency awards and funding for complementary community resources (such as beamlines and cryo-electron microscopy), mostly with NIH and NSF. BER is a member of the advisory committee for DoD's BioMADE project researching synthetic biology applications.

All climate systems research activities within BER are coordinated through the interagency U.S. Global Change Research Program (USGCRP) and other NSTC subcommittees. Through this engagement, the DOE E3SM has evolved to become the world's highest resolution Earth system model able to run on exascale computers, facilitating the scientific community in developing and testing system-level scientific concepts on the smallest scales. Other agencies, e.g., NOAA, NASA, the Navy, and NSF, are following developments in E3SM via both USGCRP and ICAMS. The Intelligence Community has indicated significant interest in E3SM, as a platform to incorporate their data to address national security problems. The E3SM research is tightly coordinated with BER's large scale experimental activities and has strong linkages to DOE applied programs and DOE Office of Policy.

Program Accomplishments

Biological Systems Science conducts fundamental genomic science on plants and microorganisms across a broad range of biological applications including biosystems design and environmental research. The portfolio also includes the development of enabling computational, analytical, and bioimaging capabilities for hypothesis-based experimental research.

Several improvements towards a better understanding of the capture, cycling and conversion of carbon in the environment and within industrial processes were made across the biological systems science programs. Molecular scale understanding of enzymatic CO_2 capture and fixation, using instruments at the SLAC National Accelerator Laboratory are leading to new ways to design and optimize biomolecules for CO_2 capture. Research on carbon cycling processes at the Universities of California-Berkeley and Wisconsin-Madison, for example, led to the discovery of the importance of fungal organisms in the restoration of soil microbial ecology after a fire. Another research project, funded by BER, DOE Bioenergy Technologies Office, and Lanzatech, engineered a bacterial species capable of utilizing gaseous CO_2 in an industrial waste stream and convert it to acetone and isopropanol, valuable chemical products. The work highlights an efficient approach to engineering organisms for industrial-scale purposes.

Bioenergy Research Centers are focused on research to fill basic science knowledge gaps for the commercial production of biofuels and bioproducts, including sustainable production of biomass, plant feedstock development, and biomass deconstruction and conversion.

Notable accomplishments from the Bioenergy Research Centers include:

- Improved pathway engineering in microbes to convert cellulosic sugars to biofuels. The Joint BioEnergy Institute optimized an alternate metabolic pathway in E. coli to increase production efficiency of isoprenols as biofuel substitutes.

- Improved ethanol production through modification of transcription factor expression in Poplar (trees). Researchers at the Center for Bioenergy Innovation, aided by previous studies of the Poplar genome, identified and altered the expression of a key transcription factor impacting the lignin composition within the cell wall.
- Key data informing the agronomics of perennial bioenergy crops for bioenergy and bioproduct production. Researchers at the Center for Advanced Bioenergy and Bioproducts Innovation used a meta-regression model to analyze 4,214 yield observations and found that yields peaked between 6 and 7 years, increased nitrogen resulted in small yield increases but at declining rates with crop age, and that growth of these crops on low-productivity lands can equal that on high-productivity lands.
- Recovery of valuable components from lignin. The Great Lakes Bioenergy Research Center is exploring an oxidative alkaline depolymerization process to break down lignin and separate it into components for later conversion to products of higher value.

Earth and Environmental Systems Sciences conducts research to improve the predictability of the Earth system at different scales, with particular focus on the interdependencies of the physical, biogeochemical, and human processes that govern variability, change, and the evolution of extreme climate events.

The DOE E3SM developed and incorporated a new cryosphere configuration that better simulates Antarctic iceshelf melting commensurate with present day observations. This is an important improvement that reduces uncertainties in the projections of the Antarctic response to climate change and Antarctica's contribution to global sea-level rise. Future changes in hydrology caused by shifts in the jet stream were also analyzed for the midwestern U.S. Findings indicate that the North American westerly jet stream is projected to shift northward under global warming scenarios, causing more intense late-spring rainfalls, and a higher chance of late-summer droughts. In another project led by Lawrence Berkeley National Laboratory, ground-breaking analyses focused on the interdependence of forest change, surface climate, and evapotranspiration, and the processes governing observed changes between 1980 and 2016. Observations show a slowing of the hydrologic cycle associated with Amazonian deforestation, including a reduction in evapotranspiration causing a drying of the atmosphere. Finally, a new focus on urban climate science and the representation of local scale, physical, biogeochemical, ecological, and human processes for diverse urban communities has been incorporated into Earth system models. Results show that novel building designs can measurably mitigate the impacts of urban climate change.

User Facilities house state-of-the-art tools and expertise to enable the scientific community to address and solve research questions for biological and environmental systems.

Notable accomplishments from the User Facilities include:

- The JGI developed two new streamlined approaches for studying transcription factors involved in gene expression. The two new complementary methods, called Biotin DAP-seq and MultiDAP allow for quick protein purification, reducing workflows from months to days, and comparative analyses across genomes of multiple species in a single experiment leading to new comprehensive insights into gene regulatory processes within cells.
- The EMSL studied chemical processes inside roots from three tropical rainforest plants using EMSL's metabolomic and imaging technologies to better predict how different plants react to rising temperature and drought. Each of the plant roots responded differently (e.g., building thicker roots or generating a biochemical defense), indicating that multiple strategies are needed to achieve drought resilience.
- The ARM used large eddy simulations at the Southern Great Plains (SGP) observatory in Oklahoma to make major improvements to convective parameterizations that are necessary to improve predictability of climate and Earth system models. A major advancement from this research is a more sophisticated three-dimensional mathematical characterization of updrafts in storms, leading to improved rainfall predictions.

Biological and Environmental Research
Biological Systems Science

Description
Biological Systems Science integrates discovery and hypothesis-driven science with technology development on plant and microbial systems relevant to national priorities in energy security and resilience and innovation in life sciences and biology. Systems biology is the multidisciplinary study of complex interactions specifying the function of entire biological systems from single cells to multicellular organisms rather than the study of individual isolated components. The Biological Systems Science subprogram employs systems biology approaches from a genome-based perspective to define the functional principles that drive living systems, from microbes and microbial communities to plants and other whole organisms and microbiomes. The research will pursue the fundamental science needed to understand, predict, manipulate, and design biological systems that underpin innovations for clean energy production and biotechnology and enhance our understanding of natural, DOE-relevant environmental processes needed to promote social equity and enhance response to the climate crisis.

Key questions that drive these studies include:
- What information is encoded in the genome sequence and how does this information explain the functional characteristics of cells, organisms, and whole biological systems?
- How do interactions among cells regulate the functional behavior of living systems and how can those interactions be understood dynamically and predictively?
- How do plants, microbes, and communities of organisms adapt and respond to changing environmental conditions (e.g., temperature, water, nutrient availability, and ecological interactions), and how can their behavior be manipulated toward desired outcomes?
- What organizing biological principles need to be understood to facilitate the design and engineering of new biological systems for beneficial purposes?

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

The subprogram supports the operation of the DOE BRCs, as well as the DOE JGI, a DOE scientific user facility.

<u>Genomic Science</u>
The Genomic Science activity supports research seeking to reveal the fundamental principles that drive biological systems relevant to DOE missions in clean energy and climate resilience. These principles guide the interpretation of the genetic code into functional proteins, biomolecular complexes, metabolic pathways, and the metabolic/regulatory networks underlying the systems biology of plants, microbes, and communities. Advancing fundamental knowledge of these systems in concert with integrative, collaborative, and open access computational platforms will accelerate biological research for solutions to clean energy production, breakthroughs in genome-based biotechnology underpinning a broader decarbonized bioeconomy, understanding the role of biological systems in the environment, including carbon capture and sequestration, and adapting biological design paradigms to physical and material systems.

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

Foundational Genomics supports fundamental research on discovery and manipulation of genome structural and regulatory elements and epigenetic controls to understand genotype to phenotype translations in microbes and plants. Systems biology research on microorganisms with potential bioenergy/bioproduct-relevant traits will yield new pathways to convert plant biomass to a range of fuels, chemicals, and bioinspired products and biomaterials. Efforts in biosystems design research build on existing genomics-based research and develops broad-based, gene-editing techniques in plants and microbes for a wide variety of advanced biotechnologies. Together these efforts will yield a broader range of platform organisms to be employed in a wide variety of clean energy and biotechnology applications underpinning a more decarbonized bioeconomy. The climate related-science supports new approaches and systems for low carbon biomanufacturing, especially with respect to genome-enabled engineering and design of biomaterials, along with developing new technologies and integrated automated sensors that scale from laboratory-fabricated ecosystems to field ecosystems. These enhanced efforts support the development of emerging technologies under the Accelerate and the Advanced Manufacturing initiatives. BER's contribution towards understanding and anticipating the convergence of advanced genome science with other fields is critical for foresight into technology development, leveraging scientific communities across biological, physical, and computational science fields with the unique ability to evaluate systems across disciplinary boundaries. The Funding for Accelerated, Inclusive Research (FAIR) initiative will provide opportunities to enhance clean energy and climate research at minority serving institutions, including attention to underserved and environmental justice communities. FAIR will expand and encompass all BER activities.

The EERC program, launched in FY 2023, will enhance multi-investigator, multi-disciplinary teams led by the DOE laboratories to perform energy-relevant research with a scope and complexity beyond what is possible in standard or small-group awards. The EERCs will continue to address key research challenges hampering the translation of basic research results to applied research and development activities. These challenges are barriers to implementation of the innovations emerging from basic science into potential solutions for technological challenges and are vital to realizing the stretch goals of the DOE Energy Earthshots. EERCs' team awards will entail collaboration involving academic, national laboratories, and industrial researchers with SC and the DOE technology offices, establishing a new era of cross-office research cooperation. The EERCs are complemented by expanded Energy Earthshot research conducted within academia and focused on cross-cutting basic research themes and interfaces among the Centers. BER funding will ensure that directed biological fundamental research and capabilities at SC user facilities address the most challenging barriers hampering the translation of basic research innovations to applied research and development activities.

BRaVE will continue to provide a single portal through which a distributed network of capabilities and scientists can work together on multidisciplinary and multiprogram priorities to tackle significant DOE mission-relevant science challenges and provide a ready resource to quickly address urgent national emergencies as needed. The overall goals of the virtual environment are to understand the function of whole biological systems, effectively integrating knowledge from distributed datasets, individual process components, and individual component models in an AI/ML-enabled, open access computational environment. The BRaVE effort will expand to include low dose radiation research.

Environmental Genomics supports research focused on understanding plants and soil microbial communities and how they impact the cycling and/or sequestration of carbon, nutrients, and contaminants in the environment. The activity includes the study of a range of natural and model microbiomes in targeted field environments relevant to BER's bioenergy and environmental research efforts. With a long history in plant and microbial genomics research coupled with substantial biotechnological and computational capabilities available within the DOE user facilities, BER is well positioned to make transformative contributions in biotechnology and understanding microbiome and phytobiome function.

Computational Biosciences supports all Genomic Science systems biology activities through the ongoing development of bioinformatics and computational biology capabilities within the DOE Systems Biology Knowledgebase (KBase) and the National Microbiome Data Collaborative (NMDC). The integrative KBase project seeks to develop the necessary hypothesis-generating analyses techniques and simulation capabilities on high performance computing platforms to accelerate collaborative and reproducible systems biology research within the Genomic Sciences. The activity supports the Advanced Computing initiative.

The DOE BRCs effort within the Genomic Science portfolio seeks to provide a fundamental understanding of the biology of plants and microbes as a basis for developing sustainable innovative processes for clean bioenergy and a range of

bioproducts from inedible cellulosic biomass supporting a more decarbonized bioeconomy. Research will accelerate genome engineering, using AI/ML techniques, in plants and microbes to expand the range of products that can be produced from sustainable plant biomass, expand understanding of plant-microbe interactions to inform better agronomic practices for clean bioenergy production, develop new plant varieties with expanded capabilities for sustainable product production and increased collaboration among the broader research community including HBCUs and MSIs, and within rural communities where new crop-based clean energy and bioproduct production could spark new industries and bioeconomic development.

This activity provides support for the DOE EPSCoR that funds research in states and territories with historically lower levels of Federal academic research funding. In FY 2024, the EPSCoR program will focus on EPSCoR State-National Laboratory Partnership awards to promote single PI and small group interactions with the unique capabilities of the DOE national laboratory system and continued support of early career awards.

Biomolecular Characterization and Imaging Science supports integrative approaches to detecting, visualizing, and measuring systems biology processes engaged in translating information encoded in an organism's genome to those traits expressed by the organism. These genotype to phenotype translations are key to gaining a holistic and predictive understanding of cellular function under a variety of environmental and bioenergy-relevant conditions. The activity will enable development of new multimodal bioimaging, measurement, and characterization technologies to visualize the structural, spatial, and temporal relationships of key metabolic processes governing phenotypic expression in plants and microbes. The activity includes efforts in QIS-enabled concepts for imaging and to advance design of sensors and detectors based on correlated materials, crucial for developing an understanding of the impact of various environmental and/or biosystems designs on whole cell or community function.

Biological Systems Facilities and Infrastructure

The DOE JGI is the only federally funded major genome sequencing center focused on genome discovery and analysis in plants and microbes for energy and environmental applications, and is widely used by researchers in academia, the national laboratories, and industry. High-throughput DNA sequencing underpins modern systems biology research, providing fundamental biological data on organisms and groups of organisms. By understanding shared features of multiple genomes, scientists can identify key genes that may link to biological function. These functions include microbial metabolic pathways and enzymes that are used to generate a range of different chemicals, affect plant biomass formation, degrade contaminants, or sequester carbon dioxide, leading to the optimization of these organisms for cost effective biofuels and bioproducts production and other DOE missions.

The DOE JGI is developing aggressive new strategies for interpreting complex genomes through new high-throughput functional assays, DNA synthesis and manipulation techniques, and genome analysis tools in association with the DOE KBase and the NMDC. Related efforts use genomic information to infer natural product production from microorganisms and plants. These advanced capabilities are part of the DOE JGI strategic plan to provide users with additional, highly efficient, capabilities supporting biosystems design efforts for biofuels and bioproducts research, and environmental process research. The DOE JGI also performs metagenome (genomes from multiple organisms) sequencing and analysis from environmental samples and single cell sequencing techniques for hard-to-culture microorganisms from understudied environments relevant to the DOE missions. In FY 2024, the JGI will explore new plant transformation capabilities to accelerate the ability to modify and/or design new beneficial functions into plants. The lack of effective techniques for plant transformation across species severely limits plant science and this new activity addresses this crucial need within the bioenergy/bioproduct research community.

Activities and Explanation of Changes

(dollars in thousands)

FY 2023 Enacted		FY 2024 Request	Explanation of Changes FY 2024 Request vs FY 2023 Enacted
Biological Systems Science	**$463,685**	**$476,500**	**+$12,815**
Genomic Science	$328,685	$338,750	+$10,065
Foundational Genomics research supports new research on microorganisms with advantageous bioenergy and bioproduct traits. Biosystems design research accelerates the ability to design plants and microorganisms with specific beneficial low carbon clean energy, bioproduct and biomaterials production traits. New efforts provide emerging technologies to develop integrated automated sensors that scale from laboratory fabricated ecosystems to field ecosystems as part of the Accelerate initiative.		Foundational Genomics research will support new research on microorganisms with advantageous bioenergy and bioproduct traits. Biosystems design research will accelerate the ability to design plants and microorganisms with specific beneficial low carbon clean energy, bioproduct and biomaterials production traits. New efforts will support emerging technologies to develop integrated automated sensors that scale from laboratory fabricated ecosystems to field ecosystems as part of the new Accelerate and Advanced Manufacturing initiatives.	Funding will support new research on microorganisms and plants with clean energy, carbon sequestration and bio-inspired bioproduct-relevant traits to broaden the range of platform organisms available for biotechnology use, for cross-cutting goals supporting a more decarbonized bioeconomy. To support the Accelerate and Advanced Manufacturing initiatives, new emerging technologies will integrate *in situ* sensors, imaging, 'omics analysis, and autonomous controls and continuous data acquisition and analysis. Completed efforts in Secure Biosystems Design will ramp down to fully fund efforts within the BRCs.
BER launches Energy Earthshot Research Centers to address key biological research challenges at the interface between currently supported basic research and applied research and development activities.		BER will expand the Energy Earthshot Research and continue Centers initiated in FY 2023 to include additional key biological research challenges at the interface between currently supported basic research and applied research and development activities to help speed translation of basic discoveries to industry.	Funding will support additional research for the DOE Earthshot activities.

(dollars in thousands)

FY 2023 Enacted	FY 2024 Request	Explanation of Changes FY 2024 Request vs FY 2023 Enacted
Environmental Genomics continues plant functional genomics research to understand genotype to phenotype translations leading to beneficial bioenergy or bioproduct traits in potential bioenergy crops.	Environmental Genomics will continue plant functional genomics research to understand genotype to phenotype translations leading to beneficial bioenergy or bioproduct traits in potential bioenergy crops.	No change
Environmental microbiome science continues efforts to understand the functions of environmentally relevant microbial communities in a variety of ecosystems.	Environmental microbiome science continues efforts to understand the functions of environmentally relevant microbial communities in a variety of ecosystems.	No change
BRaVE expands to build out a computational platform and experimental workflow through which a distributed network of data and experimental capabilities can be accessed by multidisciplinary teams of scientists working together on urgent multiprogram priorities, including low dose radiation research.	BRaVE will continue to add functionality to its expanding computational platform and experimental workflows. BRaVE continues to build a distributed network of data and experimental capabilities that can be accessed by multidisciplinary teams of scientists working together on urgent multiprogram priorities and/or emergency situations. BRaVE will expand current efforts addressing environmental biothreat scenarios to include low dose radiation research.	The BRaVE efforts will expand to include low dose radiation research.
The FAIR initiative strengthens clean energy genomic research at HBCUs and MSIs, building partnerships with the DOE national labs.	The FAIR initiative will strengthen clean energy and climate research at HBCUs and MSIs, building partnerships with the DOE national labs.	FAIR will expand and encompass all BER activities, supporting opportunities at HBCUs and MSIs.
Computational Bioscience supports research efforts within Genomic Science by providing bioinformatics, simulation and modeling capabilities through the KBase platform and within the NMDC. Both platforms continue integrative activities among each other within the Advanced Computing Initiative and with the JGI.	Computational Bioscience will support research efforts within Genomic Science by providing bioinformatics, simulation, and modeling capabilities through the KBase platform and within the NMDC. Both platforms will continue integrative activities among each other within the Advanced Computing Initiative and with the JGI.	Increased funding will support research and linkages among KBase, NMDC and JGI.

(dollars in thousands)

FY 2023 Enacted	FY 2024 Request	Explanation of Changes FY 2024 Request vs FY 2023 Enacted
The four BRCs continue with 5-year renewal to support multidisciplinary clean energy research underpinning a broader bio-based economy. The BRCs broaden their collaborative activities to accelerate plant and microbial genome engineering with AI/ML techniques to diversify the range of products that can be sustainably produced from plant biomass, expand understanding of plant-microbe interactions to create better agronomic practices for clean bioenergy production, develop new plant varieties with expanded capabilities for biofuels and bioproduct production and increase collaboration among the broader research community (including HBCUs) and within rural communities where new crop-based clean energy and bioproduct production could spark new industries and bioeconomy development.	The BRCs will broaden their collaborative activities to accelerate plant and microbial genome engineering with AI/ML techniques to diversify the range of products that can be sustainably produced from plant biomass, expand understanding of plant-microbe interactions to create better agronomic practices for clean bioenergy production, develop new plant varieties with expanded capabilities for biofuels and bioproduct production and increase collaboration among the broader research community (including HBCUs and MSIs) and within rural communities where new crop-based clean energy and bioproduct production could spark new industries and bioeconomy development.	The four BRCs will expand their efforts on theme-based collaborative activities to accelerate genome engineering for plants and microbes advance sustainability research through research on plant-microbe interactions, develop new plant varieties with an expanded range of biofuels and bioproducts, and engage a broader spectrum of the research community (including HBCUs and MSIs) and rural communities where this research could lead to new bioeconomy opportunities.
Funding supports early-stage R&D, including research that underpins DOE energy technology programs, the SC Energy Earthshots initiative, and innovations for climate science. Following the previous year's focus on State-National Laboratory Partnership awards, FY 2023 emphasizes Implementation Awards to larger multiple investigator teams that develop research capabilities in EPSCoR jurisdictions. Investment continues in early career research faculty from EPSCoR-designated jurisdictions and in co-investment with other programs for awards to eligible institutions.	Funding supports EPSCoR State-National Laboratory Partnership awards and early career awards.	Continued support for research in EPSCoR jurisdictions.

(dollars in thousands)

FY 2023 Enacted	FY 2024 Request	Explanation of Changes FY 2024 Request vs FY 2023 Enacted
Biomolecular Characterization and Imaging Science $45,000	$45,750	+$750
New multimodal bioimaging research supports new capabilities to characterize, measure, visualize and test hypotheses on plant and microbial cell function and metabolism. Quantum-enabled science concepts for imaging techniques will continue.	New multimodal bioimaging research will provide new capabilities to characterize, measure, visualize and test hypotheses on plant and microbial cell function and metabolism. Quantum-enabled science concepts for imaging techniques will continue.	Funding will support additional multimodal bioimaging research activities.
Biological Systems Facilities & Infrastructure $90,000	$92,000	+$2,000
JGI provides users with high quality genome sequences and new analysis techniques for complex plant and microbiome samples. Integrative activities with KBase and the NMDC provides new cross-platform capabilities for users. Genome-based discovery efforts for natural product production in microbial isolates continues in concert with expanded metagenomics analysis techniques. The multi-year instrument and equipment refresh continues at a reduced pace to support the integrative activities with KBase and the NMDC.	JGI will provide users with high quality genome sequences and new analysis techniques for complex plant and microbiome samples. Integrative activities with KBase and the NMDC will provide new cross-platform capabilities for users. Genome-based discovery efforts for natural product production in microbial isolates continues in concert with expanded metagenomics analysis techniques. The multi-year instrument and equipment refresh will continue at a reduced pace to support the integrative activities with KBase and the NMDC. A new plant transformation capability will be explored to provide needed techniques to transform a wider variety of plants for genome interrogation and design.	Funding will support expanded integrative efforts with KBase and the NMDC to provide new analysis capabilities for microbiome science. The continuing instrument and equipment refresh will be slowed to support the expanded integrative activities with KBase and the NMDC. Funding will also support a new plant transformation activity to provide the genomic tools to more broadly understand, modify, and design plants with beneficial traits for bioenergy and bioproducts.

Note:

- *Funding for the subprogram above, includes 3.65 percent of research and development (R&D) funding for the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) Programs, excluding facility operations.*

Biological and Environmental Research
Earth and Environmental Systems Sciences

Description

The Earth and Environmental Systems Sciences subprogram supports fundamental science and research capabilities that enable major scientific developments in climate, environmental, and Earth system research, in support of DOE's mission goals for transformative science for energy and national security. This includes research on atmospheric, terrestrial, and human components of the Earth system; modeling of oceanic and Great Lakes systems; modeling of climate system component interdependencies under a variety of natural and anthropogenic forcings; studies involving the interdependence and perturbations involving cloud, aerosol, marine, ecological, hydrological, biogeochemical, and cryospheric processes; analysis of the vulnerabilities that affect the resilience of the full suite of energy and related infrastructures as well as the vulnerabilities of other human systems to extreme events; and uncertainty quantification. This integrated portfolio of research extends from molecular-level to field-scales, spans time scales from seasonal to centennial, and emphasizes the coupling of multidisciplinary experimentation with increasingly sophisticated computer models. The goal of new science is to develop and enhance a predictive, systems-level understanding of the fundamental processes that addresses environmental and energy-related challenges associated with extreme phenomena. Investments emphasize the most difficult challenges limiting prediction uncertainty, including cloud-aerosol interactions; terrestrial systems experiencing rapid transitions; the role of human activities as they couple with the natural system; and increasing opportunities provided by machine learning (ML) and emerging technologies to push the envelope on predictive capacity. The research will pursue the fundamental scientific understanding necessary to inform the design, development, financing, and deployment pathways of climate friendly technical solutions that promote social equity and enhance urban resilience in response to the climate crisis.

The subprogram supports three primary research activities: atmospheric sciences; environmental system science; and modeling. In addition, the subprogram supports a data management activity, and two SC scientific user facilities: the ARM and EMSL facilities. ARM provides unique, multi-instrumented, high-resolution capabilities for continuous, three-dimensional, long-term observations that researchers need to improve scientific understanding of atmospheric and climate processes involving clouds, aerosols, precipitation, and the Earth's energy balance. ARM also contains a sophisticated model-simulation component that scientists use to augment field observations. EMSL provides integrated experimental and computational resources that researchers utilize to extend understanding of the physical, biogeochemical, chemical, and biological processes that underlie DOE's energy and environmental mission. The data management activity encompasses both tool development and archival capabilities that combine observed and model-generated data that are produced by field experiments and modeling activities conducted by scientists supported by DOE and other relevant organizations. This activity also serves the international community by archiving information generated by all domestic and international climate modeling centers that participate in the U.S. National Climate Assessment and/or the Intergovernmental Panel on Climate Change (IPCC).

Atmospheric System Research

Atmospheric System Research (ASR) is the primary U.S. research activity addressing the main source of uncertainty in climate and Earth system models: the interdependence of clouds, aerosols, and precipitation that in turn influences the Earth's radiation balance. ASR coordinates with ARM, using the facility's continuous long-term datasets that provide three-dimensional measurements of a variety of aerosol types that includes natural, brown, and black carbon; cloud, aerosols, and precipitation microphysics under a variety of dynamical and turbulence conditions; and targeted geographic regions that are climate-sensitive or are known to limit predictability in Earth system models. The long-term observational datasets are supplemented with shorter-duration, ground-based and airborne field campaigns as well as laboratory studies to target specific atmospheric phenomena that limit the predictability of atmospheric processes, properties, and dynamical evolution. Using integrated, scalable testbeds that incorporate process-level understanding, climate, Earth, and environmental system models ASR research seeks to assure greater confidence in system level understanding and dramatically improved predictions that span local to global scales.

Environmental System Sciences

Environmental System Science supports research to provide an integrated, robust, and scale-aware predictive understanding of environmental systems, including the roles of physical and hydro-biogeochemical processes and variable geomorphology, while extending from the subsurface to the top of the vegetative canopy. Short-term extreme events that act on spatial scales that span from molecular to global are of particular interest. New multi-scale data are essential to advance basic understanding and improve climate and Earth system models that can and are being used to achieve broad benefits ranging from planning and development of energy infrastructure to natural resource management, clean water, environmental stewardship and identifying equitable solutions to the Nation's most vulnerable communities. The vision for this activity is to develop a unified predictive capability that integrates scale-aware process understanding with unique characteristics of watersheds, terrestrial-aquatic interfaces that include coastal zones, and urban-rural transitions. Research spans the Arctic, midlatitude boreal zone, the Tropics, mountainous zones, and coastal regions that include the Delaware and Susquehanna watersheds, the Great Lakes, and Puget sound.

Using decadal-scale investments, such as the Next Generation Ecosystem Experiments (NGEEs), to study the variety of time scales and processes associated with ecological change, Environmental System Science research focuses on understanding, observing, and modeling the processes controlling exchange flows between the atmosphere and the terrestrial biosphere, and improving and validating the representation of environmental systems in coupled climate and Earth system models. Research supports the integration of observations with process modeling from molecular to field scales, to improve understanding of hydrological, and biogeochemical processes that affect terrestrial environments.

Research activities will continue place-based Urban Integrated Field Laboratories (IFLs) with strengthened coordination in support of climate science. The Urban IFLs are dedicated to developing the science framework for advancing observational and prediction capabilities to tackle the following interdependent challenges: constraining climate changes and its impacts on all scales across urban regions; evaluating the mitigation-potential for emerging energy technologies that can be deployed to urban and suburban regions; and addressing environmental justice by enabling neighborhood scale evaluation of climate impacts and energy needs. The Urban IFL scope targets a greater set of urban regions, integrates field data within a next generation Earth System Modeling framework, and creates a science capability to advance climate and energy research as a unified co-dependent system. The enhanced scope will provide DOE, its stakeholders, and impacted communities with the best possible science-based tools that enable the evaluation of the societal and environmental benefits of current and future energy policies.

The RENEW initiative expands across BER activities. RENEW will target efforts, including a RENEW graduate fellowship, to broaden participation and advance justice, equity, diversity, and inclusion in SC-sponsored research. The National Virtual Climate Laboratory (NVCL) will continue to provide greater access to information about DOE's climate science activities at the National Laboratories, with the intended audience to be, in particular, HBCUs, Tribal Colleges and Universities (TCUs), Hispanic Serving Institutions (HSIs), and other MSIs, as well as stakeholder communities. A network of climate resilience centers that are affiliated with HBCUs and MSIs will expand, with a focus on developing the science base to achieve climate resilience solutions that can be deployed to America's communities.

The activity also supports the management of Ameriflux, a network of 373 field sites funded by a variety of federal agencies and other research institutions to measure the air-surface exchanges of heat, moisture, and other gases. Management activities focus on data quality and organizational support to the network and directed funding for 13 of the network sites.

Earth and Environmental Systems Modeling

Earth and Environmental Systems Modeling develops the physical, biogeochemical, and dynamical underpinning of fully coupled climate and Earth System Models (ESMs), in coordination with other Federal efforts. The continuing Integrative Artificial Intelligence Framework for Earth System Predictability (AI4ESP) effort will motivate the radical acceleration of predictive capabilities across the DOE climate model-data-experiment enterprise, taking advantage of emerging AI/ML techniques, robust couplers, diagnostics, performance metrics, and advanced data analytics. AI4ESP will feature development of novel approaches for automated feature detection and unsupervised learning techniques in heterogeneous multi-scale laboratory and field data; data quality validation; edge computing; nonlinear and multiscale data assimilation methodologies; model parameter estimation; and hybrid prediction model architectures that combine physics with AI/ML across multiple aspects of climate models. Furthermore, as the ECP concludes, the exascale research activities will

transition from the ECP to a broader focus on software for advanced computing and sustainability across current and future computing platforms. Priority Earth system model components include the ocean, sea-ice, land-ice, atmosphere, terrestrial ecosystems, urban systems, and human activities, where these are treated as interdependent and able to exploit dynamic grid technologies. Support of diagnostic and intercomparison activities, combined with scientific analysis, allows BER-funded researchers to exploit the best available science within each of the world's leading climate and Earth system modeling research programs. In addition, DOE continues to support the Energy Exascale Earth System Model (E3SM), i.e., a computationally efficient model that runs on DOE's Leadership Computing Facility exascale architectures, that will be extended with greater sophistication and fidelity for high resolution simulation of extreme phenomena and complex processes in heterogeneous landscapes. Earth system modeling, simulation, and analysis tools are essential for informing energy infrastructure investment decisions that have the future potential for large-scale deployment that in turn benefit national security and environmental justice. New modeling efforts will contribute to the current and future Earthshot topics by providing supporting climate information needed to enhance future designs and deployment strategies. For example, the current activities support offshore wind energy production as well as evaluating the impacts of a future hydrogen economy on climate change predictions.

Earth and Environmental Systems Sciences Facilities and Infrastructure

The Earth and Environmental Systems Sciences Facilities and Infrastructure activity supports data management and two scientific user facilities for the Earth and environmental systems sciences communities. The scientific user facilities, ARM and EMSL, provide the broad scientific community with technical capabilities, scientific expertise, and unique information to facilitate cutting edge science in areas integral to BER's mission.

ARM is a multi-laboratory, multi-platform, multi-site, national scientific user facility, providing the world's most comprehensive, continuous, and precise observations of clouds, aerosols, radiative transfer, and related meteorological information. These observations provide new data to address the main source of uncertainty in climate and Earth system models: the interdependence of clouds, atmospheric aerosols, and precipitation that in turn influences the Earth's radiation balance. In addition to supporting interdisciplinary science challenges, extreme events represented in DOE's Earth system model are used to inform plans for designs and deployment of future energy infrastructures. ARM currently consists of three fixed, long-term measurement facility sites (in Oklahoma, Alaska, and the Azores), three mobile observatories, and an airborne research capability that operates at sites selected by the scientific community. In FY 2024, ARM will continue operations at the three fixed sites. One mobile facility will continue its deployment to San Diego for the Eastern Pacific Cloud Aerosol Precipitation Experiment (EPCAPE) with the goal to characterize the microphysics and dynamics of marine stratocumulus clouds across all four seasons at a coastal location, such as the Scripps Pier and the Scripps Mt. Soledad sites in La Jolla. An important enhancement as part of this study is the collection of simultaneous in-cloud aerosol and droplet measurements to investigate the differences in these cloud properties during regional polluted and clean marine conditions. The second mobile unit, after having completed its deployment in central Colorado, will be deployed to Tasmania, Australia, to study cloud-aerosol interactions in the Southern Ocean. The third mobile unit will continue its long-term deployment in Alabama to observe cloud-aerosol interactions in a midlatitude forested ecosystem. ARM will continue to incorporate very high-resolution Large Eddy Simulations during specific campaigns as requested by the scientific community. BER is also maintaining the exponentially increasing data archive to support enhanced analyses and model development. The data extracted from the archive are used to improve atmospheric process representations at higher resolution, greater sophistication, and robustness of ultra-high-resolution atmospheric models. Besides supporting BER atmospheric sciences and Earth system modeling research, the ARM facility freely provides key information to other agencies that are engaged in different types of atmospheric sciences research, e.g., calibration and validation of space-borne sensors, and improvements in weather models. A cloud chamber research effort will be initiated to complement ARM's field observations of cloud-aerosol interactions.

BER-supported scientists require high-quality and well-characterized in-situ aircraft observations of aerosol and cloud microphysical properties and coincident dynamical and thermodynamic properties to continue to improve fundamental understanding of the physical and chemical processes that control the formation, life cycle, and radiative impacts of cloud and aerosol particles. To meet these needs, the ARM user facility will continue to utilize its aerial capabilities, including the Arctic Shark as an uncrewed aerial system (UAS) and the crewed Bombardier Challenger aircraft, Air-ARM. Acceptance testing and evaluation on the crewed aircraft will be completed, meeting Federal Aviation Administration (FAA)

requirements, including modifications to the air frame as needed to install numerous existing and new atmospheric aerosol, cloud, turbulence, and other sensors. Research flight operations will be delayed until FY 2024.

EMSL provides integrated experimental and computational resources for discovery and technological innovation in the environmental molecular sciences. EMSL enables users to undertake molecular-scale experimental and theoretical research on biological systems, biogeochemistry, catalysts, and both interfacial and surface materials (including aerosols), that are relevant to energy and environmental challenges facing DOE and the Nation. This research informs the development of advanced biofuels and bioproducts, the design of novel methods to accelerate environmental cleanup, and contributes to an improved understanding of the biogeochemical controls on thawing permafrost that in turn affect Arctic infrastructure vulnerability. EMSL will address a more focused set of scientific topics that continue to exploit High Resolution and Mass Accuracy Capability (HRMAC), live cell imaging, and more extensive utilization of other EMSL instrumentation into process and systems models and simulations to address challenging problems in the biological and environmental sciences.

GPP funding will provide for minor new construction, for other capital alterations and additions, and for improvements to land, buildings, and utility systems to maintain the productivity and usefulness of DOE-owned facilities and to meet requirements for safe and reliable operation.

Data sets generated by ARM, EMSL, other DOE, and other federally supported experimental and modeling research activities are enormous. The trend towards more sophisticated science, derived from the integration of observations and models that can lead to increased complexity and improved predictability, requires the use of training data associated with AI/ML. While these capabilities will propel American science to the next generation, these new capabilities are also needed to more efficiently extend scientific discovery in support of evolving technological and innovation challenges, e.g., to inform the design of more robust resilient infrastructures, conduct more robust analyses of mitigation options to avert the impacts of natural disasters, enhance management choices to secure supply chains, and create novel opportunities for environmental stewardship. Accessibility and usage of these complex and interconnected data sets are fundamental for scientific discovery, technological innovation, decision-making, and national security.

The BER Data Management activity will focus efforts on archiving scientifically useful data from the Earth System Grid Federation, Ameriflux, NGEE field experiments, SPRUCE site observations, and experimental programs involving watersheds and coastal systems.

Activities and Explanation of Changes

(dollars in thousands)

FY 2023 Enacted	FY 2024 Request	Explanation of Changes FY 2024 Request vs FY 2023 Enacted
Earth and Environmental Systems Sciences **$445,000**	**$445,200**	**+$200**
Atmospheric System Research $36,000	$40,000	+$4,000
Funding for ASR continues research on clouds, aerosols, and thermodynamic processes, with a focus on data from the ARM fixed sites as well as recent field campaigns conducted in the Arctic during FY 2020 and data from the TRACER and SAIL campaigns. ASR continues to make use of data generated by Large Eddy Simulations at the ARM Oklahoma site.	ASR will continue research on clouds, aerosols, and thermodynamic processes, with a focus on data from the ARM fixed sites as well as data from the TRACER and SAIL campaigns. ASR will continue to make use of data generated by Large Eddy Simulations as part of ARM facility deployments. Scope will be expanded to include urban areas.	Funding will support an expanded scope to include urban areas.

(dollars in thousands)

FY 2023 Enacted	FY 2024 Request	Explanation of Changes FY 2024 Request vs FY 2023 Enacted
Environmental System Sciences $120,800	$137,000	+$16,200
Funding for ESS focuses research on permafrost and maintains investments in studies of boreal ecology and modeling hydrobiogeochemistry of watersheds and terrestrial-aquatic interfaces, with a focus on the coastal zones encompassed by the Delaware and Susquehanna watersheds and the Great Lakes, and Puget Sound. The Urban IFLs expand to support climate science. The NVCL is fully implemented and continues to provide access to the single portal to DOE lab climate capabilities. Funding initiates the network of climate centers focused on resilience. RENEW expands to provide undergraduate and graduate training opportunities for students and academic institutions not currently well represented in the U.S. S&T ecosystem.	ESS will continue research on permafrost and will maintain investments in studies of boreal ecology and modeling hydrobiogeochemistry of watersheds and terrestrial-aquatic interfaces, with a focus on the coastal zones encompassed by the Delaware and Susquehanna watersheds and the Great Lakes, and Puget Sound. Urban IFLs will be enhanced to support climate science yet with more coordination. The NVCL will continue to provide access as the single portal to DOE lab climate science capabilities with key stakeholders from underrepresented and impacted communities through training and outreach for equitable climate resilience solutions. The network of climate resilience centers focused on resilience will increase. The RENEW initiative expands targeted efforts, including a RENEW graduate fellowship, to increase participation and retention of individuals from underrepresented groups in SC research activities and encompasses all BER activities.	Funding will continue investments for coastal watershed research in the mid-Atlantic, Great Lakes, and Puget Sound with new observations, enhanced modeling, and data-model synthesis. The Urban IFLs will expand coordination and collaboration, with more integrated field data with a next generation Earth System Modeling framework, and create a science capability to advance climate and energy research as a unified co-dependent system. The increase broadens RENEW activities across BER.

(dollars in thousands)

FY 2023 Enacted	FY 2024 Request	Explanation of Changes FY 2024 Request vs FY 2023 Enacted
Earth and Environmental Systems Modeling $115,500	$120,500	+$5,000
Funding for Earth and Environmental Systems Modeling focuses investments on further refinement of the science underpinning non-hydrostatic adaptive mesh modeling and incorporating the necessary software for deployment of the model onto more advanced exascale computing architectures. The E3SM version 2 incorporates AI and unsupervised learning capabilities and enables more sophisticated research based on higher model resolution, through the Integrative AI4ESP. The new version adds advanced capabilities for exploring cryosphere-ocean dynamics' impacts of climate variability on Antarctic ice shelf melting, continental ice sheet evolution and sea level rise, and the effects of changing water cycles on watershed and coastal hydrological systems. Funding also initiates foundational modeling for the offshore wind and hydrogen Energy Earthshots.	Earth and Environmental Systems Modeling will focus investments on further refinement of the science underpinning non-hydrostatic adaptive mesh modeling and incorporating the necessary software for deployment of the model onto more advanced exascale computing architectures. The E3SM will continue AI/ML capabilities and enable more sophisticated science that demands higher model resolution and greater accuracy, through the Artificial Intelligence Framework for AI4ESP. As the ECP concludes, the exascale research activities will transition from the ECP to a broader focus on software for advanced computing and sustainability across current and future computing platforms. The new E3SM version will add advanced capabilities for exploring cryosphere-ocean dynamics' impacts of climate variability on Antarctic ice shelf melting, continental ice sheet evolution and sea level rise, the effects of changing water cycles on watershed and coastal hydrological systems, and new challenges involving urban systems. The Request will also support foundational modeling in support of Energy Earthshot topics that focus on robust projections that link details of climate change with the design and deployment of clean energy initiatives.	Funding will continue deployment of a higher resolution and more sophisticated version of E3SM and affiliate models to the scientific community in support of broad-based basic research as well as to energy sector stakeholders who require projections. The ECP research activities will transition ECP researchers, software, and technologies into core research efforts. New investments enhance support for Earthshot topics, that focus on efficient design, deployment, and effectiveness of renewable and clean energy infrastructures to combat climate change.

(dollars in thousands)

FY 2023 Enacted	FY 2024 Request	Explanation of Changes FY 2024 Request vs FY 2023 Enacted
Funding focuses on core research in model intercomparisons and diagnostics. In addition, research incorporates limited fine scale physics and dynamics that can be applied to metrics for application to coastal zones (including the Great Lakes and Puget Sound), mid-latitude-Arctic interactions, and high-resolution studies of urban and urban-rural transition regions.	The Request will focus on core research in model intercomparisons and diagnostics. In addition, research will incorporate limited fine scale physics and dynamics that can be applied to metrics for application, in particular, to coastal zones (including the Great Lakes and Puget Sound), and high-resolution studies of urban and urban-rural transition regions.	Funding will continue to support research with a shift in emphasis from large scale dynamics to examine heterogeneous and boundary regions that also include urban regions as well as coastal zones that encompass the mid-Atlantic, the Great Lakes, and Puget Sound.
Earth and Environmental Systems Sciences Facilities and Infrastructure $172,700	$147,700	-$25,000
Funding for ARM continues to provide new observations through long term measurements at fixed sites in Alaska, Oklahoma, and the Eastern North Atlantic site. An ARM mobile unit completes installation and begin operations in Alabama. The funding prioritizes all ARM activities for critical observations needed to improve the E3SM model. ARM continues and completes deployment of its second mobile facility to Colorado; and it prepares and deploys its first mobile facility to San Diego. Scientists are using the precipitation radars together with sophisticated meteorological instrumentation to learn more about cloud and aerosol interactions in a variety of geographic domains, including urbanized coastal regions and mountainous terrain. After rebaselining to meet FAA requirements, acceptance testing and evaluation are completed on the Air-ARM aircraft, including modifications to the air frame as needed to install numerous existing and new atmospheric aerosol, cloud, turbulence, and other sensors. The ARM support for the Urban IFL for climate science continues as well as continuing a multi-year instrumentation refresh.	ARM will continue to provide new observations through long term measurements at fixed sites in Alaska, Oklahoma, and the Eastern North Atlantic site. The ARM mobile unit in Alabama will be fully operational. The Request prioritizes all ARM activities for critical observations needed to improve the E3SM model. ARM will continue deployment to the EPCAPE campaign in San Diego. Scientists will use the precipitation radars together with sophisticated meteorological instrumentation to learn more about cloud and aerosol interactions in a variety of geographic domains, including urbanized coastal regions and mountainous terrain. A third ARM unit will be deployed to Tasmania to study cloud-aerosol interactions. Acceptance testing and evaluation will be completed on the Air-ARM aircraft, including modifications to the air frame as needed to install numerous existing and new atmospheric aerosol, cloud, turbulence, and other sensors. Air-ARM flight operations are anticipated in late FY 2024 pending FAA final reviews and approvals.	Funding will support ARM site operations, and mobile facilities operations. A mobile facility will continue deployment to the EPCAPE campaign, in San Diego; and another facility will be deployed to Australia. After major investments in FY 2022 to install the third ARM unit to Alabama, this capability will routinely collect data in support of community science. Air-ARM flight operations are anticipated in late FY 2024 pending FAA reviews and approvals. A cloud chamber research effort will be initiated to complement ARM's field observations of cloud-aerosol interactions. Reductions are due to the completion of the installation of the Alabama site.

(dollars in thousands)

FY 2023 Enacted	FY 2024 Request	Explanation of Changes FY 2024 Request vs FY 2023 Enacted
	The ARM support for the Urban IFL for climate science will continue as well as continue a multi-year instrumentation refresh. A cloud chamber research effort will be initiated to complement ARM's field observations of cloud-aerosol interactions.	
Funding for EMSL emphasizes new science that requires combinations of advanced technologies, such as mass spectrometry, live cell imaging, Quiet Wing, Dynamic Transmission Electron Microscopy, and high-performance computing. A multi-year instrumentation refresh continues. Other Project Cost support the microbial molecular phenotyping capability planned project.	EMSL will emphasize new science that requires combinations of advanced technologies, such as mass spectrometry, live cell imaging, Quiet Wing, Dynamic Transmission Electron Microscopy, and high-performance computing. Planning for a multi-year instrumentation refresh continues, including the initial construction of microbial molecular phenotyping capability.	Funding will promote multi-disciplinary science using various combinations of EMSL's most sophisticated instrumentation. Reallocations within EMSL rebalances operations and research.
GPP funding provides for minor new construction, for other capital alterations and additions, and for improvements to land, buildings, and utility systems to maintain the productivity and usefulness of DOE-owned facilities and to meet requirements for safe and reliable operation. In FY 2023 GPP supports improved cooling for High Performance Computing infrastructure at EMSL and remodeling EMSL laboratories to create lab spaces to co-locate capabilities that cross-cut EMSL's integrated research platforms	GPP funding will provide for minor new construction, for other capital alterations and additions, and for improvements to land, buildings, and utility systems to maintain the productivity and usefulness of DOE-owned facilities and to meet requirements for safe and reliable operation. The Request provides for EMSL laboratories remodel to unpack and relocate prioritized core capabilities. This includes refurbishing electrical, HVAC, and other safety-related systems in several core analytical and microscopy instrument labs and moving instruments to relieve overcrowding.	Funding will support the remodeling efforts at EMSL to unpack and relocate prioritized core capabilities.

(dollars in thousands)

FY 2023 Enacted	FY 2024 Request	Explanation of Changes FY 2024 Request vs FY 2023 Enacted
Funding for the Earth and Environmental Sciences Data Management activity enhances support to maintain existing and new critical software and data archives in support of ongoing experimental and modeling research. Essential data archiving and storing protocols, capacity, and provenance are maintained. Advanced analytical methodologies such as Machine Learning is used to improve the predictability of extreme events more rapidly using the combination of field observations with Earth system models.	The Earth and Environmental Sciences Data Management activity will continue support to maintain existing and new critical software and data archives in support of ongoing experimental and modeling research. Essential data archiving and storing protocols, capacity, and provenance will be maintained. Advanced analytical methodologies such as Machine Learning will be used to improve the predictability of extreme events more rapidly using the combination of field observations with Earth system models.	No Change.

Note:

- *Funding for the subprogram above, includes 3.65 percent of research and development (R&D) funding for the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) Programs, excluding facility operations.*

Biological and Environmental Research
Construction

Description

This subprogram supports line-item construction for the BER program. All Total Estimated Costs (TEC) are funded in this subprogram, including engineering, design, and construction. The FY 2024 Request of $10,000,000 initiates the Microbial Molecular Phenotyping Capability project.

24-SC-31, Microbial Molecular Phenotyping Capability (M2PC), PNNL

The M2PC project will design and construct a new capability that will provide approximately 36,000 gross square feet of wet chemistry and instrumentation space conducive for highly autonomous operations. In addition, the M2PC design will include acquisition of analytical instrumentation and microbial culturing and characterization capabilities that will be modular and expandable, self-contained, and operate in an automated pod configuration. Capabilities will include a suite of 5 to 10 microbial culturing pods, 3 to 5 biological and functional assay pods, and 4 to 5 analytical phenotyping workflow pods with workstations for 10 to 15 research and support staff. This new capability will position the BER program to take a global lead in answering the most pressing challenge in biology—generating molecular phenotypic data at a pace that matches the rapid developments in high throughput genome sequencing and synthesis. Applicability of this capability to BER interests in biofuels production, lignocellulose breakdown, and carbon/nutrient/elemental cycling, will create a knowledge ecosystem that will provide data to amplify BER's genome engineering and biosystems design efforts, as well as mechanistic hydro-biogeochemistry modeling capabilities.

Activities and Explanation of Changes

(dollars in thousands)

FY 2023 Enacted	FY 2024 Request	Explanation of Changes FY 2024 Request vs FY 2023 Enacted
Construction **$ —**	**$10,000**	**+$10,000**
24-SC-31, Microbial Molecular Phenotyping Capability (M2PC), PNNL $ —	$10,000	+$10,000
No funding was requested in FY 2023.	Funding will support the new M2PC project at PNNL.	Funding will initiate the new M2PC project at PNNL.

Biological and Environmental Research
Capital Summary

(dollars in thousands)

	Total	Prior Years	FY 2022 Enacted	FY 2023 Enacted	FY 2024 Request	FY 2024 Request vs FY 2023 Enacted
Capital Operating Expenses						
Capital Equipment	N/A	N/A	25,000	34,950	25,500	-9,450
Minor Construction Activities						
General Plant Projects	N/A	N/A	–	10,000	5,000	-5,000
Total, Capital Operating Expenses	**N/A**	**N/A**	**25,000**	**44,950**	**30,500**	**-14,450**

Capital Equipment

(dollars in thousands)

	Total	Prior Years	FY 2022 Enacted	FY 2023 Enacted	FY 2024 Request	FY 2024 Request vs FY 2023 Enacted
Capital Equipment						
Major Items of Equipment						
Earth and Environmental Systems Sciences						
Atmospheric Radiation Measurement (ARM) Aerial Observation Capability (Air-ARM)	27,186	17,486	–	9,700	–	-9,700
Total, MIEs	N/A	N/A	–	9,700	–	-9,700
Total, Non-MIE Capital Equipment	N/A	N/A	25,000	25,250	25,500	+250
Total, Capital Equipment	**N/A**	**N/A**	**25,000**	**34,950**	**25,500**	**-9,450**

Note:

- *The Capital Equipment table includes MIEs located at a DOE facility with a Total Estimated Cost (TEC) > $5M and MIEs not located at a DOE facility with a TEC >$2M.*

Minor Construction Activities

(dollars in thousands)

	Total	Prior Years	FY 2022 Enacted	FY 2023 Enacted	FY 2024 Request	FY 2024 Request vs FY 2023 Enacted
General Plant Projects (GPP)						
GPPs (greater than or equal to $5M and less than $30M)						
HPC Infrastructure Upgrades (GPP HPC Upgrades [Refresh]), PNNL	5,000	–	–	5,000	–	-5,000
Project 2 - Crosscutting Capabilities (3020EMSL Remodel to Cross-Cut IRPs), PNNL	5,000	–	–	5,000	–	-5,000
Project 3 - Relocations (3020EMSL Remodel to Unpack and Relocate), PNNL	5,000	–	–	–	5,000	+5,000
Total GPPs (greater than or equal to $5M and less than $30M)	N/A	N/A	–	10,000	5,000	-5,000
Total, General Plant Projects (GPP)	**N/A**	**N/A**	**–**	**10,000**	**5,000**	**-5,000**
Total, Minor Construction Activities	**N/A**	**N/A**	**–**	**10,000**	**5,000**	**-5,000**

Biological and Environmental Research
Major Items of Equipment Description(s)

Earth and Environmental Systems Sciences Facilities and Infrastructure:

Atmospheric Radiation Measurement Research Facility (ARM) – Air-ARM

The Air-ARM project received CD-2/3 approval on November 12, 2018, with an original total project cost of $17,700,000. BER-supported scientists require high-quality and well-characterized *in situ* aircraft observations of aerosol and cloud microphysical properties and coincident dynamical and thermodynamic properties to continue to improve fundamental understanding of the physical and chemical processes that control the formation, life cycle, and radiative impacts of cloud and aerosol particles. To meet these needs, the ARM user facility has been using a dedicated large twin-turboprop Gulfstream-1 (G-1) aircraft to conduct weeks- to months-long intensive observational campaigns over a range of meteorological conditions and locations around the world. The G-1 aircraft used by ARM was built in 1961, was one of only 10 G-1's that remain in service worldwide, and is at the end of its service life. BER retired and replaced the aircraft in FY 2019. The FY 2019 Enacted Budget included funding to replace the Battelle-owned G-1 aircraft that supported airborne data collection as part of ARM field campaigns. Since FY 2020, the newly acquired aircraft has undergone testing and evaluation, including modifications to the air frame to install numerous existing and new atmospheric aerosol, cloud, turbulence, and other sensors. Also, the aircraft has undergone ground-based and airborne testing, in order to prepare it for scientific studies. In order to meet FAA requirements the total project cost has increased (+$9.7M), and planned research flight operations will be delayed until FY 2024.

Biological and Environmental Research
Minor Construction Description(s)

General Plant Projects $5 Million to less than $30 Million

Outfitting of Research and Collaborations Spaces
General Plant Project Details

Project Name:	Project 3 – Relocations (3020EMSL Remodel to Unpack and Relocate), PNNL
Location/Site:	Pacific Northwest National Laboratory
Type:	GPP
Total Estimated Cost:	$5,000,000
Construction Design:	$0
Project Description:	EMSL has been developing plans for backfill of space vacated in EMSL once the capability relocations into the Energy Sciences Center have been completed. Approximately 13,000 square feet equivalent of lab modules have been relocated and EMSL has identified four strategic priorities for backfilling the space. This project will renovate and backfill laboratory spaces in support of EMSL capabilities and strategic plan with a focus on unpacking crowded laboratories that support EMSL's prioritized core capabilities. Conceptual design is planned for completion in FY 2023 in anticipation of FY 2024 funding.

Biological and Environmental Research
Scientific User Facility Operations

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

(dollars in thousands)

	FY 2022 Enacted	FY 2022 Current	FY 2023 Enacted	FY 2024 Request	FY 2024 Request vs FY 2023 Enacted
Scientific User Facilities - Type B					
Environmental Molecular Sciences Laboratory	**56,000**	**54,231**	**64,750**	**50,250**	**-14,500**
Number of Users	850	744	750	750	–
Joint Genome Institute	**84,500**	**81,580**	**90,000**	**92,000**	**+2,000**
Number of Users	2,200	2,243	2,300	2,350	+50
Atmospheric Radiation Measurement Research Facility	**90,000**	**87,003**	**87,000**	**85,500**	**-1,500**
Number of Users	980	1,113	1,200	1,200	–
Total, Facilities	**230,500**	**222,814**	**241,750**	**227,750**	**-14,000**
Number of Users	4,030	4,100	4,250	4,300	+50

Biological and Environmental Research
Scientific Employment

	FY 2022 Enacted	FY 2023 Enacted	FY 2024 Request	FY 2024 Request vs FY 2023 Enacted
Number of Permanent Ph.Ds (FTEs)	1,600	1,750	1,805	+55
Number of Postdoctoral Associates (FTEs)	410	460	480	+20
Number of Graduate Students (FTEs)	580	640	685	+45
Number of Other Scientific Employment (FTEs)	395	430	435	+5
Total Scientific Employment (FTEs)	**2,985**	**3,280**	**3,405**	**+125**

Note:
- *Other Scientific Employment (FTEs) includes technicians, engineers, computer professionals and other support staff.*

24-SC-31, Microbial Molecular Phenotyping Capability (M2PC), PNNL
Pacific Northwest National Laboratory, PNNL
Project is for Design and Construction

1. Summary, Significant Changes, and Schedule and Cost History

Summary

The FY 2024 Request for the Microbial Molecular Phenotyping Capability is $10,000,000 of Total Estimated Cost (TEC) funding and $950,000 of Other Project Cost (OPC) funding. This is the initial Construction Project Data Sheet (CPDS) for the project. The project proposes to design and construct a new research capability for the M2PC that will be broadly available to the scientific community as part of an Office of Science User Facility. The preliminary Total Project Cost (TPC) range is $80,000,000 to $120,000,000.

Significant Changes

This project is a new start in FY 2024. The most recent DOE O 413.3B approved Critical Decision (CD) is CD-0, which was approved on April 28, 2021, with a preliminary TPC cost range of $80,000,000 to $120,000,000 and CD-4 range of FY 2026 to FY 2029. Through the development of the draft CD-1 materials, the project scope and schedule have been conceptually defined and are reflected in the tables below. The project is pursuing a tailoring strategy to combine CD-2 and CD-3A.

In FY 2024, the TEC funding of $10,000,000 will be used to obtain designs for both the facility as well as for the instrumentation, and the $950,000 in OPC will be used to prepare for CD-2/3A.

A Federal Project Director has been assigned to the project. The Federal Project Director is level I certified with a level II certification pending approval.

Critical Milestone History

Fiscal Year	CD-0	Conceptual Design Complete	CD-1	CD-2	Final Design Complete	CD-3	CD-4
FY 2024	4/28/21	3Q FY 2023	4Q FY 2023	1Q FY 2025	4Q FY 2024	4Q FY 2025	4Q FY 2029

CD-0 – Approve Mission Need for a construction project with a conceptual scope and cost range; **Conceptual Design Complete** – Actual date the conceptual design was completed (if applicable); **CD-1** – Approve Alternative Selection and Cost Range; **CD-2** – Approve Performance Baseline; **Final Design Complete** – Estimated/Actual date the project design will be/was complete(d); **CD-3** – Approve Start of Construction; **D&D Complete** – Completion of D&D work; **CD-4** – Approve Start of Operations or Project Closeout.

Fiscal Year	CD-3A
FY 2024	1Q FY 2025

CD-3A – Approve Long-Lead Procurements and instrument configurations, including design and assembly of custom automation carts/enclosures and associated robotics, and procurement of an 800 MHz NMR (nuclear magnetic resonance) spectrometer and a cryo-EM (electron microscope) system.

Project Cost History

(dollars in thousands)

Fiscal Year	TEC, Design	TEC, Construction	TEC, Total	OPC, Except D&D	OPC, Total	TPC
FY 2024	11,000	104,000	115,000	5,000	5,000	120,000

2. Project Scope and Justification

Scope

The M2PC project will design and construct a new capability that will provide approximately 36,000 gross square feet of wet chemistry and instrumentation space conducive for highly autonomous operations. In addition, the M2PC design will include acquisition of analytical instrumentation and microbial culturing and characterization capabilities that will be modular and expandable, self-contained, and operate in an automated pod configuration. Capabilities will include a suite of 5 to 10 microbial culturing pods, 3 to 5 biological and functional assay pods, and 4 to 5 analytical phenotyping workflow pods with workstations for 10 to 15 research and support staff.

Justification

Within the Biological and Environmental Research (BER) program, basic research to gain a predictive understanding of biological systems provides the foundation for harnessing and integrating the latest biosystems design techniques with data science and multi-scale modeling approaches. This effort will advance a burgeoning bioeconomy, as well as enable prediction of the future state of the Earth system. Toward systems-level understanding, BER-supported research has increasingly embraced the integration of multi-omics analyses together with phenotypic characterization of microbial isolates and communities to determine the function of expressed genes and pathways.

While the number of microbial isolates and chassis microbes interrogated is expanding rapidly along with advances in next generation genome sequencing and synthesis, incomplete and constrained genome annotation limits the ability to understand and model the range of activities and functions of individual microbes, engineered microbial consortia with bio-industrial potential or ecological relevance, and microbial communities from natural soil environments. Specifically, there is a significant gap in the ability of the scientific community to identify proteins and biochemical pathways of unknown function in microbes at the single-cell to microbial-community scales, in part because the phenotypes of microbes change rapidly due to environmental factors and perturbations. To address this gap, BER proposes a research capability for a Microbial Molecular Phenotyping Capability that would be broadly available to the scientific community as part of a DOE Office of Science User Facility.

An emphasis on coupled high-throughput autonomous experimental and multimodal analytical capabilities would be the primary components of the instrumentation part of the M2PC. These capabilities would be integrated with, and amplify, existing BER data platforms within the DOE JGI, the NMDC, and the KBase to speed the discovery of new protein functions and metabolic pathways in microbial systems, including fungi, algae, bacteria, protists, archaea, and viruses.

This new capability will position BER to take a global lead in answering the most pressing challenge in biology—generating molecular phenotypic data at a pace that matches the rapid developments in high throughput genome sequencing and synthesis. Applicability of this capability to BER interests in biofuels production, lignocellulose breakdown, and carbon/nutrient/elemental cycling, would create a knowledge ecosystem that would provide data to amplify BER's genome engineering and biosystems design efforts, as well as mechanistic hydro-biogeochemistry modeling capabilities.

While the Office of Science is exempt from DOE O 413.3B, Program and Project Management for the Acquisition of Capital Assets, the M2PC project intends to deploy a certifiable earned value management system and be conducted in accordance with the project management principles of DOE O 413.3B[a].

Key Performance Parameters (KPPs)

The KPPs are preliminary and may change as the project continues towards CD-2. At CD-2 approval, the KPPs will be baselined. The Threshold KPPs, represent the minimum acceptable performance that the project must achieve. Achievement of the Threshold KPPs will be a prerequisite for approval of CD-4, Project Completion. The Objective KPPs represent the desired project performance.

[a] Memorandum For Office of Science Associate Directors, From W.F. Brinkman, Director, Office of Science, "Office of Science is Exempt from DOE Order 413.3B, Program and Project Management for the Acquisition of Capital Assets," dated February 2, 2011.

Performance Measure	Threshold	Objective
Demonstrate high-throughput (HTP) Strain Culturing	Capacity to operate with 500 Design, Build, Test, Learn (DBTL) Strain Starts/Week	Capacity to operate with 2,000 DBTL Strain Starts/Week
Demonstrate HTP Microbiome Culturing	Capacity to operate with 100 Microbiome Starts/Week	Capacity to operate with 500 Microbiome Starts/Week
Demonstrate HTP Assaying and Phenotyping	Capacity to obtain 1,000,000 Data Points/Month	Capacity to obtain 3,000,000 Data Points/Month
Remote Capability to Access Operations	Demonstrate that remote users can run pre-defined EMSL protocols to be executed autonomously within M2PC across culturing, assaying, and analyses	Demonstrate remote users can perform dynamic experimental intervention with help from EMSL staff

3. Financial Schedule

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs
Total Estimated Cost (TEC)			
Design (TEC)			
FY 2024	10,000	10,000	10,000
Outyears	1,000	1,000	1,000
Total, Design (TEC)	**11,000**	**11,000**	**11,000**
Construction (TEC)			
Outyears	104,000	104,000	104,000
Total, Construction (TEC)	**104,000**	**104,000**	**104,000**
Total Estimated Cost (TEC)			
FY 2024	10,000	10,000	10,000
Outyears	105,000	105,000	105,000
Total, TEC	**115,000**	**115,000**	**115,000**

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs
Other Project Cost (OPC)			
FY 2023	250	250	250
FY 2024	950	950	950
Outyears	3,800	3,800	3,800
Total, OPC	**5,000**	**5,000**	**5,000**

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs
Total Project Cost (TPC)			
FY 2023	250	250	250
FY 2024	10,950	10,950	10,950
Outyears	108,800	108,800	108,800
Total, TPC	**120,000**	**120,000**	**120,000**

4. Details of Project Cost Estimate

(dollars in thousands)

	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
Total Estimated Cost (TEC)			
Design	7,700	N/A	**N/A**
Design - Contingency	3,300	N/A	**N/A**
Total, Design (TEC)	**11,000**	**N/A**	**N/A**
Construction	72,700	N/A	**N/A**
Construction - Contingency	31,300	N/A	**N/A**
Total, Construction (TEC)	**104,000**	**N/A**	**N/A**
Total, TEC	**115,000**	**N/A**	**N/A**
Contingency, TEC	*34,600*	***N/A***	***N/A***
Other Project Cost (OPC)			
OPC, Except D&D	4,000	N/A	**N/A**
Conceptual Design	1,000	N/A	**N/A**
Total, Except D&D (OPC)	**5,000**	**N/A**	**N/A**
Total, OPC	**5,000**	**N/A**	**N/A**
Contingency, OPC	***N/A***	*N/A*	***N/A***
Total, TPC	**120,000**	**N/A**	**N/A**
Total, Contingency (TEC+OPC)	***34,600***	***N/A***	***N/A***

5. Schedule of Appropriations Requests

(dollars in thousands)

Fiscal Year	Type	Prior Years	FY 2022	FY 2023	FY 2024	Outyears	Total
FY 2024	TEC	—	—	—	10,000	105,000	115,000
	OPC	—	—	250	950	3,800	5,000
	TPC	—	—	250	10,950	108,800	120,000

6. Related Operations and Maintenance Funding Requirements

Start of Operation or Beneficial Occupancy	4Q FY 2029
Expected Useful Life	50 years
Expected Future Start of D&D of this capital asset	4Q FY 2079

Related Funding Requirements
(dollars in thousands)

	Annual Costs		Life Cycle Costs	
	Previous Total Estimate	Current Total Estimate	Previous Total Estimate	Current Total Estimate
Operations	N/A	TBD	N/A	TBD
Utilities	N/A	TBD	N/A	TBD
Maintenance and Repair	N/A	TBD	N/A	TBD
Total, Operations and Maintenance	N/A	TBD	N/A	TBD

7. D&D Information

The new area being constructed in this project is not replacing existing facilities.

	Square Feet
New area being constructed by this project at PNNL	36,000
Area of D&D in this project at PNNL	—
Area at PNNL to be transferred, sold, and/or D&D outside the project, including area previously "banked"	—
Area of D&D in this project at other sites	—
Area at other sites to be transferred, sold, and/or D&D outside the project, including area previously "banked"	36,000
Total area eliminated	—

8. Acquisition Approach

The Acquisition Strategy for the M2PC project is under development and will be reviewed as part of the CD-1 process.