

**Biological and Environmental Research Advisory Committee
(BERAC) Meeting Minutes
April 21-22, 2022
Remote Access Meeting**

BERAC Members Present

Bruce Hungate, Chair	Gerald Meehl
Caroline Ajo-Franklin	Gloria Muday
Cris Argueso	Dev Niyogi
Sarah Assman	Himadri Pakrasi
Ana Barros	Kristala Jones Prather
Bruno Basso	Patrick Reed
Julie Biteen	Gemma Reguera
Sen Chiao	Jeremy Schmutz
Leo Donner	Matthew Shupe
Matthew Fields	Huimin Zhao
Robert Fischetti	
Ann Fridlind	Guest Speakers
Ramon Gonzalez	Steve Allison
Jorge Gonzalez-Cruz	William Bialek
Randi Johnson	J. Stephen Binkley
Kerstin Kleese van Dam	Helena Fu
Sonia Kreidenweis	Nicki Hickmon
Xiaohong Liu	Michelle Newcomer
Maureen McCann	Geraldine Richmond

**BERAC and/ or
Subcommittee Working
Group Speakers**

Ann Fridlind
Maureen McCann
Kristala Jones Prather
Patrick Reed
Margaret Torn
John Weyant
Shaocheng Xie

Other Contributors
Colleen Hartman

**Designated Federal
Officer**
Tristram West

Others

Todd Anderson, Biological Systems Science Division Director, Office of Biological and Environmental Research (BER), Department of Energy Office of Science (DOE SC)
Gary Geernaert, Earth and Environmental Systems Sciences Division Director, BER, DOE SC
Sharlene Weatherwax, Associate Director, BER, DOE SC
Holly Holt, Science Writer, Oak Ridge Institute for Science and Education (ORISE)

Approximately 228 others were in attendance during the course of the meeting.
All presentations are posted to the BERAC website: <https://science.osti.gov/ber/berac/Meetings>

Thursday, April 21, 2022

Introduction and BERAC Roundtable

BERAC Chair, **Bruce Hungate**, called the meeting to order at 11:30 a.m. Eastern Time and welcomed attendees. If factors driving climate change were social media influencers, the world's top five influencers would be the sun and earth's orbit, atmosphere, planetary reflection, and plants and associated microbes.

The theme for Earth Day 2022 is invest in our planet; BER operates at the cutting edge of research in planetary stewardship, and BERAC plays an important role in guiding investment strategies. For example, BER's new \$84M Urban Integrated Field Laboratories (IFLs) initiative

evolved from a 2009 BERAC charge. Urban IFLs will fund investment in community-scale climate impacts with a focus on informing equitable climate solutions for places and people where impacts are disproportionately large.

BERAC Roundtable

Hungate invited all BERAC members to share BER-relevant thoughts. Discussion traversed new centers, capabilities, tools, and discoveries while emphasizing the urgent need to leverage interdisciplinary, interagency, and international expertise and resources in the face of the climate crisis. Research opportunities across scientific topics and impinging on social outcomes were highlighted, especially those in modeling, plant resilience, microbial studies, and methane capture. To be a true leader of positive change, BER must imbue all aspects of its scientific enterprises and solutions with diversity, equity, and inclusion (DEI) as well as transparency. Interwoven throughout remarks were the challenges and opportunities inherent in translating vital science to socially actionable and equitable outcomes.

New centers, initiatives, upgrades, and related efforts:

- Interconnected risks and the need for resilience and sustainability have become increasingly important as has the need to address the science of equity. The MultiSector Dynamics (MSD) Community of Practice formed a steering group in 2019 and has since engaged hundreds of researchers from >30 countries to build a vision for the next generation of adaptive human earth systems science. MSD's working groups contribute 10% of the U.S. Global Change Research Program's abstracts. MSD has funded both DOE and BER work and has released a special report titled *Scientific Challenges and a Research Vision for 2030*. MSD advertises funding opportunity announcements (FOAs) and career positions with a focus on the next generation workforce. All are invited to connect and share resources.
- A year from now, a new Advanced Photon Source (APS) ring will be installed that will be 100-1000 times brighter than the current source. Ring installation will enable new science but will require a dark period of about a year. The APS structural biology community will be notified of the shutdown via email. APS will also hold a town hall meeting to discuss the new capabilities following the upgrade and to connect the user community with other U.S. beamlines. A similar session will be held at the 2022 American Crystallographic Association meeting. In January 2022, Laurent Chapon stepped in as the new APS Director.
- The Massachusetts Institute of Technology (MIT) launched five flagship projects for MIT's Climate Grand Challenges initiative. Project themes are closely linked to BER's mission and address building equity and fairness in climate solutions; decarbonizing complex industries and processes for managing and storing greenhouse gases; and using data and science to forecast climate-related risks. It is heartening to see human impact and equity featured in proposals. Senator Kerry, present for the launch, commented government cannot tackle climate change alone. BER is encouraged to consider how to leverage both its own resources and the significant capital resources in the public and private sectors to have a substantial impact.
- Founded in 2020, the Molecule Maker Lab Institute, a National Science Foundation (NSF) Artificial Intelligence (AI) Research Institute, develops new AI and chemistry to radically accelerate and democratize molecular synthesis and functional materials discovery. Research overlaps with BER interests. The Institute's outreach program engages many collaborators and develops new educational programs.

- There will be a \$100M competition to turn New York City's Governor's Island into a Climate Center promoting social equity and creating opportunities for connecting with IFLs.
- What began as a grassroots effort at Michigan State University to create a circular economy has drawn faculty across politics, engineering, economics, sociology, and microbial biology fields. DOE will need to consider major economic issues, and BER is well positioned to lead efforts in finding creative solutions, including those using microbes.
- Colorado State University is creating a new Institute for Plant Adaptation. With little time left to develop new technologies, understanding the role of plant hormones in trade-offs between biotic and abiotic stressors versus growth is important for developing adaptable plants.
- The new Extreme Wind Resilience Center at the University of Illinois at Urbana-Champaign (UIUC) is addressing how to design resilient roads and buildings. Other recent findings include the discovery that rural aerosol pollution tied to agriculture is as hazardous as urban pollution. UIUC is also participating in Illinois Automated and Connected Track (I-ACT) development focused on testing smart city technologies in a human field lab incorporating a rural to urban gradient and a 40% minority population. This presents opportunities to examine multiple issues surrounding economic and social inequities in a comprehensive manner.

Discoveries and opportunities in modeling, plants, microbes, and greenhouse gas capture:

- Studying the Coastal Atmospheric Boundary Layer Environment (CABLE) enables parameterization of models to understand interactions between coastal and built environments and weather across micro- to macroscales. Models point to cross-sector opportunities to create new technologies for a sustainable environment.
- Climate modeling is germane to understanding how to create resilient societies in the face of shocks and how to prevent hazards from becoming disasters. Going forward, determining how to integrate human decisions underlying complex systems such as cities or agriculture into geophysical climate models will be important along with developing and applying explainable artificial intelligence/ machine learning (AI/ ML) techniques like digital twins while determining how to harness the massive amounts of data now available.
- Ongoing modeling work on cloud feedback is helping to constrain predictions of climate sensitivity and narrow the uncertainty behind the physics of events like 100-year floods.
- BER's international benchmarking report highlights the European Commission's Destination Earth Program which leverages digital twin modeling to enable interactive testing of climate mitigation and infrastructure-hardening activities. The U.S. has no concrete plans for this type of advanced, integrated, and centralized capability that has been realized through inter-agency European leadership.
- The Intergovernmental Panel on Climate Change has highlighted the need to better understand the relationship among aerosols originating from natural and human activities, cloud processes, and climate change. These dynamics must be incorporated into climate models, including DOE's Energy Exascale Earth System Model (E3SM) and NSF's Community Earth System Model (CESM). Using volcanic eruptions, is it possible to predict unintended consequences of potential climate solutions like stratospheric aerosol injection on cloud formation and ozone depletion. Additionally, there is interest in how thawing arctic permafrost relates to particulate matter release. Relationships between surface change and atmosphere are also important for wildfires and the resulting smoke impact on visibility and public health. Recent studies have benefited from cross-agency cooperation, yielding better integrated field data and enabling predictions over longer time periods to protect public health.

- Earth system models and AI/ ML are needed to predict climate variability and extremes on seasonal to decadal timescales to enable adaptation. The Marshall Fire in Boulder, Colorado was driven by drought and a Chinook wind of >100 miles per hour. Wildfires are typically a threat in western pine forests but are increasingly an issue in prairies under dry conditions. Analysis of Chinook wind data indicates speeds are declining and the main wind axis is shifting north of Boulder. Despite this trend, drought and winds mean fires are a new normal.
- Until about 2010, climate models mostly coupled atmospheric and oceanic processes. The incorporation of biological processes, especially land vegetation and ocean biogeochemistry, has shortened estimates of the committed warming timescale from ~20-40 years to only three to five years. This result is not new but has not received widespread public attention and highlights the importance of including biology in system models.
- Integration across spatial scales and economics is important. A new study used an ensemble of crop simulation models to show planting bioenergy crops on marginal croplands could aid in climate change mitigation while leading to greater agricultural energy independence.
- Combining genetic and field studies, scientists have discovered a tradeoff between switchgrass with four (4x) versus eight (8x) chromosomal copies. While 4x switchgrass is an important bioenergy cellulosic feedstock, 8x varieties have evolved multiple times and are better at colonizing and adapting to new areas. New tools are enabling scientists to study novel alleles and understand how polyploidy affects plant fitness.
- New deep learning tools are enabling translation of knowledge gained in plant models like *Arabidopsis* to crops like tomatoes. Tools supporting such transitions will be important for developing food and biofuel crops.
- There are exciting opportunities for BER to make further progress in using plants and microbes to create materials. New synthetic biological approaches have culminated in the ability to program micron-sized bacteria to self-assemble into centimeter-scale materials with genetically tunable mechanical properties.
- Studying diverse, naturally occurring cyanobacteria has led to the discovery of more efficient photosynthetic strains. Light-harvesting antennal structures on these bacteria let in optimal amounts of light. This genetic architecture has been ported to production strains yielding a 40% increase in biomass productivity.
- Though DOE and BER have invested in this area, there is a need and huge opportunity to do more work in bioconversion of carbon dioxide (CO₂) and methane. Methane has a global warming potential ~80 times that of CO₂ over the next 20 years and presents a great short-term target for intervention. Additionally, bioconversion technologies can be deployed at small scale, something other chemical technologies cannot achieve, and thus present an affordable way to democratize deployment and social impact.

Call for an interdisciplinary, interagency, and international approach to socially translatable research that is diverse, equitable, and inclusive in practice and solutions:

- Energy affects all aspects of natural and human-made environments and underpins food production and clean water. DOE must lead truly transdisciplinary and transagency efforts in an inclusive and equitable manner to generate energy alternatives that are sustainable, affordable, and acceptable to all. Likewise, BER must leverage interdisciplinary research and a diverse and inclusive scientific enterprise to capture humanity's full creative potential and create a workforce pipeline. While solving these problems is vital, it is also important to share one's enthusiasm for science with younger mentees and the public.

- BER supports multicenter collaborations through funding mechanisms. For example, several Bioenergy Research Centers (BRCs) have collaborated on a Reaching a New Energy Sciences Workforce (RENEW) proposal.
- Transitioning climate science to people is a challenge; it is difficult to change people's actions without an understanding of sociology. The United States Department of Agriculture (USDA) Climate Hubs, work to connect science and practice through outreach.
- All BERAC members are invited to visit Howard University, a Historically Black College and University (HBCU). Washington D.C. is on the frontline of climate extremes disproportionately affecting historically underserved communities. Urban and suburban modeling combined with interdisciplinary economics and social science perspectives are important for identifying social and behavioral solutions and addressing disparities.
- A BERAC member shared a story illustrating how transdisciplinary partnerships spanning funding agencies are vital to producing work with impact; a collaboration traversing structural biology, chemistry, and microscopy was able to resolve mechanisms behind bacterial porins at cellular, molecular, and atomic scales.
- The internationally funded Multidisciplinary driving Observatory for the Study of Arctic Climate (MOSAIC) expedition is an excellent example of how international and interdisciplinary work can be successful. Sea level rise is soon going to have a large impact. There is already lots of ongoing national and international work to address this issue, but research activities are still siloed. An organizational structure, such as a national office of sea level rise, is needed to synthesize disparate work to maximize beneficial outcomes.
- The pandemic brought facilities and scientists spanning multiple disciplines together, and advanced computing methods were used to develop new AI tools for finding target molecular systems. The same methods can be translated to other areas of BER interest.
- While an international cooperative lens is important, the growing challenge of retaining research scientists at universities also deserves attention.
- The BER international benchmarking report highlights the challenge of addressing research questions ranging from grand challenges science to market impact. Finding a funding modality bridging fundamental science to technology deployment is difficult. This issue is not unique to BER, and other SC offices and the NSF have received similar recommendations. Thus, it is exciting to hear of SC's internal reorganization and fiscal year 2023 (FY23) President's Budget Request (PBR) plans to fund center-scale research.

In conclusion, BERAC members expressed joy at being able to again interact in person. The in-person, International Congress on Photosynthesis Research will be held in New Zealand this summer. The hybrid Frontiers in Hydrology Meeting on the Future of Water will meet in Puerto Rico and online in June 2022. Penn State University's next in-person plant biology symposium is scheduled for May 2022 and will focus on RNA biology.

News from DOE Office of Science (SC) – Dr. J. Stephen Binkley, Acting Director

The SC's FY22 Appropriation, passed in March 2022, has a topline budget of ~\$7.5B which is a 6% increase over that of FY21. The ~\$7.8B SC FY23 PBR was recently submitted to Congress. SC is currently working on the FY24 budget. Once formulated, the budget will be submitted to Dr. Geraldine Richmond, the DOE Undersecretary for Science and Innovation, and then the Secretary. In normal cycles, the Office of Budget Management (OMB) receives the budget in September.

Under the Biden Administration, the DOE Applied Energy Programs were returned to the purview of the Under Secretary as during the second term of the Obama Administration. This reorganization offers a better venue for close work between the basic and applied energy programs. Dr. Richmond has been instrumental in fostering cross-program relationships.

Discussion

Responding to a question about the FY24 budget, **Binkley** explained the process has not fully started. At present, there are ongoing discussions among SC leadership.

An individual observed DOE is transitioning from operating primarily in foundational sciences to working in the more social realms of environmental justice and applied sciences. Are there ongoing discussions about transitioning from traditional metrics of success like publication numbers to other measures of impact? Some impacts take longer to manifest than the length of three-year projects. What metrics ought the community to consider in evaluating progress? **Binkley** said the SC is still determining how best to track impact. This administration has placed a greater emphasis on engagement of Minority Serving Institutions (MSIs) and diverse populations, including through the Established Program to Stimulate Competitive Research (EPSCoR). SC leadership supports this direction, and SC is using program policy factors to promote these activities. To realize change, there must be committed, long-term efforts.

With reference to the value of multidisciplinary scientific teams during the pandemic (COVID-19), an inquiry was made about cross-office funding programs. **Binkley** commented DOE funding is still relatively stove-piped at the Associate Director (AD) level. Starting in 2016, however, it became clear that all topline SC programs had equities in quantum information science and AI/ ML, leading to greater cross-office funding efforts. The AD is working closely with the SC Deputy Director for Science Programs to more broadly exploit this approach. This larger science funding trend is echoed in NSF and National Institutes of Health (NIH) activities.

DOE Introductory Remarks, Dr. Geraldine Richmond, Under Secretary for Science and Innovation

BER supports transformative science and user facilities to achieve a predictive understanding of complex biological, earth, and environmental systems for energy. This mission is critical to addressing the climate crisis and achieving the President's target of net-zero CO₂ emissions by 2050. These goals cannot be realized without building cross-disciplinary collaborations across institutions and geographic regions and engaging a greater diversity in endeavors.

BER is funding partnership pilots to build new connections with universities that have been underrepresented in the agency's climate, urban, and environmental science investments. BER's National Virtual Climate Laboratory (NVCL), now in planning, will act as an accessible one-stop portal for climate science while answering needs for outreach and workforce training. BER's Urban IFLs will empower collaborations among scientists and local communities to understand contributing factors to urban climate change and develop equitable solutions.

BER's research scales from laboratories to the field, and activities enable unique user facilities like the Joint Genome Institute (JGI), Environmental Molecular Sciences Laboratory (EMSL), and Atmospheric Radiation Measurement (ARM) user facility. These BER-supported capabilities empower the community to advance critical research.

Richmond is committed to supporting collaborations between basic and applied areas and recognizes the important progress BER has made in connecting scientists, facilities, and modeling efforts with those at the Office of Energy Efficiency and Renewable Energy and the Office of

Electricity. More collaboration means faster innovation. Now is the time for all to consider how to better integrate capabilities across a more inclusive and diverse scientific workforce. Towards this goal, DOE and 90 other federal agencies released their first equity plan. DOE will invest ≤\$102M in MSIs, including HBCUs, which have been historically underrepresented in research. Likewise, the FY22 budget supports new programs to build MSI research capacity. Through RE-NEW, BER will expand training opportunities for undergraduate and graduate students from underserved groups and invest in outreach to underrepresented institutions. One of Richmond's top priorities is to make sure the next generation of scientists and engineers is inclusive and representative of the nation. Richmond appreciates BER's dedication, and looks forward to supporting BER's mission which has never been more important.

Discussion

A BERAC member revisited funding multidisciplinary work. **Richmond** said SC leadership and the national laboratories are working to remove the ropes from traditional funding swim lanes to support collaborative research across SC areas. Additional effort is needed to tie transformative fundamental research to the applied areas; ongoing work to forge relationships has already eliminated some research duplication and is leading to deployment pathways. Richmond is here to foster these efforts. It is a new DOE.

Richmond was asked how SC is prioritizing science that can anticipate tipping points. **Richmond** is working within SC and the applied areas to prioritize urgent climate change issues. The FY23 budget will support the SC Energy Earthshots initiative to solve long-standing energy issues within the next decade. This SC effort will bridge to applied areas and deployment.

Questions were posed about the permanence of DOE's transition to addressing urgent issues through multidisciplinary science. Should students be prepared for this new work and research trajectory? **Richmond** commented this is a hard question because administrations change. However, the DOE, National Science Board, and other entities recognize that a broader talent pool and set of skills are needed, including those supplied by community colleges. This DOE is shooting for the 2050 net-zero emissions goal and looking to involve young people in 1,000 Clean Energy Corps jobs. Engagement of younger generations is critical, and the SC hears their voices calling for change. Training efforts are a long-term endeavor. We must hope the country, Congress, and future administrations are willing to continue this work towards solutions.

Dialogue segued to the need for technology transition education for the public and other audiences since society must rapidly move from a linear to circular economy. **Richmond** acknowledged new technology adoption as a difficult issue and one that is part of ongoing DOE discussions. An interagency approach will be important; DOE is not yet active in the behavioral and social sciences that can identify factors behind technology adoption, but NSF is.

News from the Office of Biological and Environmental Research (BER) – Dr. Sharlene Weatherwax, Associate Director
[Presentation posted]

Discussion

Questions about Energy and Environmental Research Centers (EERCs) arose. **Weatherwax** clarified EERCs will be larger team awards, and Centers will have physical locations. BES has stood up Energy Frontier Research Centers (EFRCs) which bring together multiple disciplines from one or many institutions.

An individual asked about plans to support collaborations between MSIs and non-MSI institutions. **Weatherwax** stated BER would like such relationships to develop. There are many ways to engage MSIs in the DOE sphere, including through user facilities. The SC already has training programs for students at the undergraduate and graduate levels, and BER plans to be more intentional in building the future workforce. PhDs are not for everyone, and MSIs can help provide a workforce to sustain the many BER science areas. Funding vehicles include training grants, the NVCL, user facility opportunities, and some of the larger FOAs.

Conversation accentuated opportunities to leverage other agency funds. Has interagency cooperation been considered for the Earthshots? For example, the USDA and the United States Geological Survey are already studying soil carbon. **Weatherwax** explained DOE will reach out to other agencies once DOE has organized its own Earthshot activities.

Referring to BER publication metrics for FY21, a BERAC member asked if BER is tracking senior author gender. FY21 publication data may serve as a baseline for tracking disproportionate COVID-19 impacts on women. Meeting DEI goals includes ensuring retention of women. **Weatherwax** resonated with this comment. BER has not examined author gender yet, but is working on developing tracking mechanisms for financial grant assistance.

DOE perspectives on stratospheric aerosol injection and funding geoengineering modeling studies were sought. **Weatherwax** remarked stratospheric aerosol injection is out of BER's experimental scope. The National Academy of Sciences (NAS) released a report discussing climate intervention technologies, how technology success might be determined, and governance. DOE engagement in this area would likely be through interagency contributions following the suggested interagency governance structure. For example, E3SM modeling activities might aid in evaluating success of various interventions. BER does manipulate small-scale testbeds and feed results into climate models. The Atmosphere Systems Research program is considering research that can be conducted in cloud chambers. This type of climate intervention work will likely continue as a BER hallmark.

Given the short timeline for Earthshot goals, an individual advised consideration of biological capture of methane from the atmosphere. There are also opportunities to connect with the new NSF directorate and other agencies. **Weatherwax** anticipates a strong NSF partnership.

Inquiries were made about opportunities for the community to provide feedback on Earthshot initiative priorities before FOA release. **Weatherwax** relayed DOE is looking to the community to propose ideas that can be scaled within a decade. The Earthshots are run from the Secretary's office which hosts community events. Dialogue with the community and other agencies will hopefully accelerate progress.

Hungate dismissed the meeting for a break at 2:34 p.m. and reconvened at 2:45 p.m.

Biological Systems Science Division (BSSD) Update – Dr. Todd Anderson, Division Director
[Presentation posted]

Discussion

Questions held for the final discussion period of the day.

Update on Earth and Environmental Systems Science Division (EESSD) – Dr. Gary Geernaert, Division Director
[Presentation posted]

Discussion

Questions held for the final discussion period of the day.

Physics of Life: Decadal Study – Dr. William Bialek, Princeton University
[Presentation posted]

Discussion

A BERAC member asserted there has always been a division between physicists and biologists. To make progress as colleagues, all must be treated equally. **Bialek** stated report conclusions were limited by the committee's lack of social scientists. However, perception of the integral relationship between physics and biology has grown. The old narrative of applying physics tools to biology problems belies the reality that biology problems required new physics.

Early divergence in biology and physics education was emphasized as a problematic. General physics courses are not relevant to biologists, and thus biologists have no foundation for the physics problems they encounter. Physicists can more easily approach biological problems because they do not need to understand all of biology to focus on physical principles. This polarization results in missed opportunities. Chemists are better prepared to bridge between physics and biology. **Bialek** drew attention to the report's chapter on education, which echoes many of the points raised. The community was most concerned about physics education. In general, the current way physics is taught is disconnected from where the field of physics, let alone biology, has now advanced to. There are many examples from the living world that are just as good as or better than those from the nonliving world for illustrating basic physics principles.

An inquiry was made about whether a macroscale view has emerged from modular interacting systems, such as those found in cities, that is relevant to the next generation of climate models. **Bialek** commented collective behaviors in systems ranging from bacteria to humans have captured the interests of the physics community, giving rise to models. With the higher quality data available today, macroscopic collective behaviors have been observed, but these were not predicted by the original simplistic models. Thus, there is new physics to be found, and the physics community is somewhat unique in studying whether generalities extend across different systems. The biological physics community has also been instrumental in demonstrating the importance of biological diversity to ecosystem stability. However, activities are still siloed; for example, NIH and DOE fund studies of intestinal or soil-dwelling microbial communities, respectively. There is also a drive for new kinds of observational tools.

Additional information was requested about the recommendation to connect DOE, NSF, and NIH through user facilities. Would a multiagency decadal survey addressing user facilities and drawing on community-guided communications be useful in integrating capabilities? **Bialek** said it was difficult for the committee to determine how much money the DOE spends on biological physics, especially in the context of user facilities. DOE facilities default to biology or physics users, and it is concerning that the nation's largest funder of physical sciences research does not acknowledge the physics of life by construction. Happily, this has not prevented DOE from providing important support. Collaboration with other agencies will be important to DOE's continued stewardship of large projects and user facilities which address a wider range of scientific problems than the DOE's nominal energy mission. Given the breadth of the biological physics field, work in this area is likely to expand. The committee's advisory role to the government precluded the ability to recommend new studies. **Hartman** encouraged communication to discuss potential spin-off studies based on decadal survey suggestions.

Bialek was asked about entry barriers for physicists to getting involved in biology. **Bialek** identified lack of educational awareness as the biggest barrier. Physics education has not kept pace with the set of problems the physics community is considering. Students are not exposed to biological systems and consequently face a communication handicap.

Pivoting to the report finding that international students previously were welcomed as a means of diplomacy, an inquiry was made about the potential role of the NAS in reversing current, more hostile attitudes to evoke positive change. **Bialek** commented the committee articulated the need for scientific exchange and ideas immigration but did not dictate implementation. It was unclear to the committee whether it was within the purview of NAS or agencies to change fellowship eligibility rules. Reestablishing U.S. scientific openness will require policy and law changes. Implementation is complicated.

BERAC Discussion

A BERAC member suggested DOE play a more active role in delineating tipping points. Another individual observed cities may offer a lens for extrapolating from localized to global tipping points; while every city is unique, there are underlying similarities. **Geernaert** agreed DOE and other agencies need to be more engaged in studying tipping points. There are ongoing conversations between the U.S. and the United Kingdom. The global tipping point is ill defined. Consequently, regional tipping points are studied in an isolated manner.

Dialogue shifted to how the resolution of Large Eddy Simulations (LES) can affect results. How is this likely to affect modeling over the next three to five years? Also, DOE has taken a leadership role in instrumentally probing convection and updraft properties. Using these data, there are opportunities to evaluate LES's ability to represent convection in models of varying resolutions and to establish limits. **Geernaert** concurred. The ARM facility is uniquely positioned to do some of this work. LES ARM Symbiotic Simulation and Observation (LASSO) has been used to successfully model the boundary layer in the Southern Great Plains. However, challenges have been encountered when attempting to model LES for the full troposphere at a 50- to 100-meter resolution in other studies. The field will likely move towards higher resolution. However, prediction uncertainties may not be reduced because systems become more complex at higher resolutions. Hybrid models combining ML with physics-based approaches may aid in constraining uncertainties. An additional question is how high of a resolution will be sufficient. DOE is conducting a workshop next week on LES, and these topics will likely arise.

Referencing JGI microbial DNA affinity purification sequencing (DAP-Seq) results, a BERAC committee member advocated for development of similar capabilities in plants beyond *Arabidopsis*. This will enable cross-species comparisons.

Hungate dismissed the meeting for the day at 5:04 p.m.

Friday, April 22, 2022

Hungate convened the meeting at 11:30 a.m.

BERAC Subcommittee on International Competitiveness – Drs. Maureen McCann (National Renewable Energy Laboratory, NREL) and Pat Reed (Cornell University)

[Presentation posted]

Discussion

Per the International Benchmarking Subcommittee's overall recommendations, a BERAC member recognized "failure to inspire" and "failure of imagination" as risks. The NIH Director's Office supports transformative grants, and the funded science is truly inspiring. Does DOE offer an analogous award? **McCann** maintained BER does conduct transformative research at an incredible scale. Work is enabled by modalities like the BRCs. However, to fully engage the workforce at national laboratories and universities and become an attractor of global talent, BER can provide more blue sky opportunities for early- to mid-career researchers.

Emphasizing the importance of the recommendation to support scientists' careers, a question was asked about metrics of success given new research modalities like the Earthshots. How will progress towards solving problems be measured? Publications metrics may encourage researchers to continue working in the same area. Also, the DOE's practice of only offering grant opportunities every three years for most programs limits engagement of young researchers. **McCann** agreed DOE grant practices restrict support for and engagement of younger scientists. Bibliometric data was one of several types of metrics the Subcommittee discussed. Others include leading roles at conferences or community engagement. A report appendix will detail a full list of the discussed metrics and how they were used.

The Subcommittee's perspectives were sought on concerns about foreign nationals and intellectual property (IP) theft on the one hand and the fact that China is one of BER's largest collaborators, presenting recruiting opportunities, on the other. **McCann** explained the report's section on partnerships offers a strong sense of a global collective commons of science that must be weighed when considering IP and national security.

A BERAC member revisited earlier points about siloed intra- and interagency funding when considering the recommendation to increase and sustain resources in mission areas and integrative science across and between mission areas.

A question was raised about the visibility of BER contributions. For example, it is difficult to document the impact of user facilities, though they are valuable to everyone. Information about the Subcommittee's metrics for global impacts was also requested. **McCann** agreed there are multiple ways to show impact, and there are issues of visibility when considering BER's facilities. For example, prior to this report, the fact that BER facilities underpinned six Nobel Prizes had not been documented. Global metrics are covered in the report's partnerships section.

Discourse shifted to BER's funding balance across national labs, universities, and user facilities, especially in the Environmental Systems Science (ESS) program. **McCann** indicated funding allocation was discussed. The final report will contain details. **Torn** noted balancing FOAs providing direct funding to national laboratories and universities was a consistent concern and interest. Investments in facilities and research infrastructure is very important to universities and cross-institution activities.

Replying to a series of questions about equity and the report's Integrative Science content, **McCann** explained recommendations evolved from interviews with world-leading experts. Some recommendations are actionable while others are messages the Subcommittee hopes BER will transmit, such as the scale of funding investments or the need for cultural change at the national laboratories to increase opportunities for diverse individuals and create an inclusive environment. **McCann** was unsure whether equity in the context of international partnerships was discussed. All BERAC members are invited to provide feedback on this. **Weyant** conceded matters of international equity in partnerships were not considered as comprehensively as they might have been. All voices must be heard if BER aims to pursue the most important and impactful

global research. Since this report was started, there has been more national focus on MSIs and outreach to historically underrepresented groups in BER.

Concerns were voiced about the phrasing of Climate Science recommendations. Specifically, using the word “maintain” belies the need for visionary efforts. **McCann and Fridland** appreciated these remarks and will consider alternative phrasing. In this context, “maintain” was meant in terms of BER maintaining international leadership status.

The Subcommittee was invited to comment on risks to infrastructure posed by extreme events. There is relatively little international work in this area; BER is well poised to lead efforts, offer guidance, and develop new technology to re-envision energy infrastructures. **Reed** noted this topic was discussed by the Climate Change working group. The Earth and Environmental System Modeling (EESM) portfolio addresses this issue, as do a suite of nine projects in the MSD program. **Fridlind** revisited Destination Earth; this interactive tool aims to cover multiple aspects of risks at once. **Xie** weighed in on E3SM as an example of DOE cutting-edge, higher resolution computational technology for climate modeling.

A BERAC member advised BER cannot lead in all areas; are there areas where other groups are better prepared to lead? Additionally, did the Subcommittee evaluate the effectiveness of existing interagency activities? **McCann** said the report catalogues interagency efforts. The recommendation that BER program managers be able to engage more easily with international counterparts arose because resources are limited, and some problems must be divided for the good of the collective scientific commons. Ease of contact will aid U.S. investment decisions. The same can be said for communication among U.S. agencies.

A suggestion was made to create academic hubs distributed across the U.S. to act as both a sponge and buffer for international partnerships and to broaden opportunities for international entities to interact with the DOE. **McCann** appreciated these remarks, noting the need for further conversation about specific mechanisms.

BSSD Committee of Visitors (COV) Report – Dr. Steve Allison (University of California, Irvine)

[Presentation posted]

Discussion and Vote

Responding to a question about inviting new capabilities or facilities, **Allison** explained there are many mechanisms for doing so. However, when a top-down directive is issued, there is a temptation to invite certain labs or communities to submit proposals because all parties cannot generate rapid responses. Issuing calls to the entire community will increase transparency.

Building on remarks about DOE’s Open Call, **Allison** noted this FOA offers program managers greater flexibility in funding unsolicited proposals. However, if the Open Call is intended to be used this way, the community would benefit from additional guidance.

Conversation segued to DEI policies addressing harassment and misconduct. **Allison** referred to newer NIH and NSF policies that sanction investigators with findings against them. The COV discussed enacting similar policies.

BERAC voted to approve the BSSD COV Report. None present voted against the report or abstained.

National Security Presidential Memorandum (NSPM)-33 Update – Ms. Helena Fu (DOE)
[Presentation posted]

Discussion

Questions were raised about outreach to stakeholders regarding NSPM-33 impacts on research. Of note, unlike national laboratories, academic institutions each have their own policies. **Fu** said the Office of Science and Technology Policy (OSTP) has been reaching out to research groups and associations to determine impact. OSTP has also instituted office hours, and several researchers, associations, and universities have reached out to discuss specific implementation and language issues. While NSPM-33 was under development, there was heavy engagement of institutional leaders and association leads. However, a community-level understanding of why the policy is in place and how concerns are being addressed is lacking. The way information is communicated is important as is how the security community is integrated into the dialogue. The United States Innovation and Competition Act (USICA) and America Creating Opportunities for Manufacturing, Pre-Eminence in Technology, and Economic Strength (COMPETES) Act contain language about a risk assessment center and an information-sharing analysis organization, respectively. These entities may provide a neutral space for stakeholders to share information. More dialogue is needed to understand how security policies are impacting researchers and to create effective, workable solutions for universities and national laboratories. All should carefully consider what information is sent into the open, and recommendations are welcome.

Replying to an inquiry about the timeline for implementation, **Fu** stated the June deadline is an interagency deadline and not a deadline within which agency changes will be implemented. NSPM-33 identifies items that will need to be included on the disclosure form but does not dictate the form's format. There are ongoing interagency efforts to standardize forms.

Additional information was sought on the extent to which community members will be able to provide broader feedback on NSPM-33. **Fu** explained NSMP-33 is a committed path; the policy was issued by the previous administration, and this administration is moving forward. However, OSTP has been seeking input through office hours and has set up a mailbox for emails. When agencies issue forms, there will be a public comment period. Segregating issues specific to NSPM-33 from broader matters at play will be important.

A BERAC member expressed the hope that academic institutional requirements will be standardized since primary investigators (PIs) usually rely on their institutions as gatekeepers. Additionally, some science within BER, like climate and weather modeling, is considered to be without boundaries. Yet, the same stringent requirements will be applied to all science. Have discussions considered developing criteria for open science? **Fu** appreciated these remarks. NSPM-33 does not address questions of open science unlike the National Security Decision Directive 189 (NSDD-189). Personally, **Fu** believes a risk-based approach is needed for science and technology which constitute two separate things. Openness is a characteristic of a strong fundamental science ecosystem. Proprietary information is a different story. There are no easy answers for international partnerships.

Hungate dismissed the meeting for a break at 1:48 p.m. and reconvened at 2:00 p.m.

BERAC Science Talk – Dr. Kris Prather, (MIT)

[Presentation posted]

Discussion

In response to an inquiry about a mixed substrate experiment, **Prather** posited pathway energetics and/ or construction explain results. When the two pathways are separated, the maximum product output for both substrates is about the same as for either individual substrate. With both pathways present, output is higher in the presence of both substrates. Interestingly, the pathways share two enzymes. Results vary slightly with one- versus two-plasmid systems.

A BERAC member asked about factors limiting 4-methylpentanol production and use of supercritical CO₂. **Prather** explained production was not limited by toxicity but by conversion rates of select pathway enzymes. When product toxicity is limiting, studies have shown extracting the product from the aqueous phase can boost productivity, as is the case with CO₂ use.

A question was asked about metabolite and enzyme selection. Influenced by medicinal chemists at Merck who could explain how to make any compound, **Prather** decided to approach biosynthesis from a chemistry perspective at MIT. Although certain thematic pathways appear repeatedly, specific projects have been largely driven by opportunity. For example, Shell told the laboratory what an ideal ethanol molecule would look like. Conversations through conferences and zoom meetings are vital to informing decisions. DOE's ability to scan the horizon and identify important directions is critical, especially for young academics. The DOE's 2004 *Top Value Added Chemicals from Biomass* report guided Prather's initial work at MIT and has since factored into the laboratory's blueprint.

AI4ESP Workshop Report – Ms. Nicki Hickmon (Argonne National Laboratory, ANL)

[Presentation posted]

Discussion

Inquiries were made about implementing workshop principles in formal environmental modeling centers. Whenever the ARM facility initiates new activities, the intent is to incorporate multidisciplinary ideas using AI, model data fusion, and other innovations. **Geernaert** relayed the workshop was well attended by E3SM and DOE National Laboratory Scientific Focus Area PIs. Future reviews and science plans for these activities will likely need to take workshop priorities and ideas into account. **Hickmon** added groups are already collaborating on workshop short-term goals.

Conversation shifted to the longevity of current efforts, especially in the context of data stewardship. Modeling frameworks call for iterative improvements in data preparation, necessitating forward motion in both models and data solutions. **Hickmon** replied there is currently a call for standardization and adaptability in the iterative and linked process of model and data improvements. As more is learned about what kinds of data supports model function, there is greater need for better data archiving, including reproducibility of merge products. Complete solutions have yet to be identified.

Speaker perspectives were sought on three interrelated topics: 1) The field is dynamic, and community conclusions can change from one month to the next. How can findings be synthesized into conclusions, and who will tie relevant information together? The DOE could provide a framework for this; 2) Due to the rapidly evolving nature of the field, how can success metrics be altered to make preprints as valuable as published articles in academic settings?; and

3) There is a need for benchmark experiments. **Hickmon** agreed a unifying, multiagency framework is needed on a national if not international level with leadership that does not box in activities. A lot of progress is being made on issues of open source data and credibility. For example, the American Meteorological Society journal is working on incorporation of negative results. However, the workshop report recognizes the need for a new interdisciplinary work environment around sharing results and reproducibility that does so on a timescale of days to weeks.

A suggestion was made to use existing processes from urban studies as a framework for scaling from human to global activities to create a DOE testbed for community contributions. **Hickmon** concurred. DOE's Urban IFLs and the NVCL network will both address this point. There is currently no methodology or platform for incorporating the human aspect which will be the most important component to integrate into efforts. Working groups and interdisciplinary panels have called for consideration of this in codesign activities. Small working groups with knowledgeable experts are needed to define pathways.

Integrated Mountain Hydroclimate Workshop – Dr. Michelle Newcomer (LBNL)

[Presentation posted]

Discussion

Conversation opened with a question about next steps and experiments for examining the impact of urban environments on mountain hydrology. Systems are being studied within the U.S. and internationally. **Newcomer** said representation of anthropogenic effects like changes in land use and its impact on wildlife, snow droughts, wildfires, and downstream water delivery will be considered in detail in the workshop report. The workshop also highlighted the need for gathering longer-term observations and identifying analogous global sites for model building and intersite comparisons. There are opportunities to leverage the global information already available.

A BERAC member inquired about leveraging other agencies' monitoring stations. **Newcomer** observed workshop conversation addressed natural and *ad hoc* collaborations currently taking place. Funded business models can lead to collaborations as can unfunded efforts driven by scientists. Given the need for intersite comparisons, there is room for both models to grow by engaging end users and other stakeholders in discussion and being flexible in the types of comparisons allowed for projects.

Multi-Sector Dynamics Vision Report – Dr. Patrick Reed (Cornell University)

[Presentation posted]

Discussion

In response to a question about integrating human behavioral psychology into modeling, **Reed** commented there are many ways to do so. A traditional approach is to abstract a well-informed rational agent with perfect foresight and assume if things go poorly in the model for the agent, things will also not go well in the real world. In terms of control, such models can feed back information related to foresight. New types of agent modeling are truly transdisciplinary and use a mix of theories from economics and behavior. For example, modeling of the southeastern U.S. integrates economic and behavioral factors to show displacement of individuals who can no longer cope with climate extremes. Lower-income individuals with less ability to handle the same extremes move in and become stranded with housing assets closer to risks. Of note, one

can have great intentions when developing policy responses to risks, but actions can have unintended consequences in other market sectors.

Expressing enthusiasm for MSD, a BERAC member inquired how to get involved and suggested broader outreach to the urban human dynamics and earth systems communities. MSD has the potential to incorporate everything, from astrophysics to biology. Parties interested in the MSD Community of Practice can contact **Reed**. MSD does not aim to be everything; the report highlights focal areas and pays service to the many relevant bodies of literature to encourage cross-sector engagement. Information shared through webinars, summer trainings, special issues, and the American Geophysical Union is resonating with PhD students, postdoctoral scholars, and junior researchers. A webinar briefing recently engaged 60-70 participants from seven countries.

A point was raised that Puerto Rico is a classic example of MSD and also is the recipient of the largest U.S. recovery investment. DOE has just initiated a project called Puerto Rico 100 (PR100); BERAC may consider future engagement. **Reed** agreed Puerto Rico is an epicenter of transition and transformation. Beyond physical risks, there are financial risks with multiple impinging factors including infrastructure, legacy effects, and equity and justice.

BERAC Discussion

Hungate shared the international benchmarking charge letter from Dr. Chris Fall, DOE SC Director. When charges are delivered, BERAC is tasked with forming an expert subcommittee. There are no formal requirements for the subcommittee to include BERAC representation, and BERAC may reach out to community members best equipped to address the charge. **Weatherwax** added some charges are BER specific while others may cut across the SC and include members from each program's advisory committee on the resulting subcommittee. Charges are not always known in advance, and programs do not self-commission charges.

A question was asked about the *Grand Challenges for Biological and Environmental Research: Progress and Future Vision* report resulting from a previous BER charge. Submitted in 2017, the report's destination was unclear due to politics surrounding the administration change. **Weatherwax** stated DOE reports are frequently decadal to guide investments. Thus, reports tend to outlast administrations. The original Grand Challenges report was submitted in 2010 before findings were refreshed in the 2017 report. BER's forward-leaning rhetoric is beneficial because it takes time to assemble efforts and achieve the needed budget headroom. For example, the original Urban IFL workshop was held in 2013, and an FOA has just been issued. **West** reiterated the SC's pursuit of long goals tends to do well across administrations. The 2017 Grand Challenges report continues to be used. Once outdated, a third report will be needed for surveying the ensuing 20 years. The international benchmarking charge was issued by the previous administration. The Office of Advanced Scientific Computing Research (ASCR) has received a similar charge.

Revisiting earlier discussion of international partnerships and equity in the context of the international benchmarking report, **McCann** invited additional feedback. A respondent observed inequity on multiple levels. At U.S. institutions with international programs, minorities do not always have the opportunity to participate. Likewise, HBCUs and other universities not equipped for international partnerships are not always able to establish international programs. These issues are reprised in the international arena where partnerships are forged with the same institutional players. Some have addressed this problem by allowing local entities to dictate local expertise. Another approach is enable academia and governments to form clusters or nodes that eventually connect with each other. **McCann** indicated the subcommittee will consider barriers at both national and international scales and how these impact each of BER's mission spaces.

Another BERAC member asked whether report recommendations address specific inter-agency funding opportunities. **McCann** said there are specific recommendations, but investment levels are not itemized. All are encouraged to review the findings and recommendations.

Citing the international benchmarking report, BERAC members resonated with the need for and expressed interest in gathering community input towards a plant transformation facility. **Weatherwax** outlined several pathways towards such a facility. When there is a clear community need and only one way to address the issue, the community unites behind the prospective facility and submits a mission needs statement to kick-start a large-scale project. In other instances, a need for a more narrowly defined skill or capability is identified, giving rise to a facility that eventually grows in scope, perhaps evolving into a national laboratory. For example, the JGI was originally stood up to sequence chromosomes but now has a much broader mission. Since the community has already expressed the need for transformation facilities for both plants and microbes, the next step is a workshop to determine the scale of the need and corresponding ask. New capabilities may be added to existing facilities or the community may investigate whether a mission needs statement is needed. If a mission needs statement is needed, a funding request is unlikely to appear before FY25 because BER is already working on the FY24 budget. **Anderson** recalled the need for such a facility was expressed at the last BERAC meeting.

Conversation shifted to whether there is sufficient climate science to guide policy. One BERAC member stated infrastructure is at risk because no one fully understands the complexity of climate-driven events at the systems level. No agency is reaching across all stakeholders, including industry, to coordinate infrastructure support. Those on the ground are looking for guidance in the near-term. It is important to generate credible downscaling to guide policy and decision-makers in the immediate future. Another perspective offered was there is already a large number of U.S. activities aimed at assessing knowledge about climate change, such as the National Climate Assessment. States and cities have panels focused on climate change. BER's role could be to integrate with the existing ecosystem to support ongoing activities and advance capabilities in unique areas like MSD. A third opinion was climate adaptation is a cottage industry with small efforts such as the Urban IFLs dispersed across the nation. Experts may offer many explanations for the same extreme climate events. BER is well equipped to issue guidance for a more resilient infrastructure in the short-term, though mechanisms for doing so must be developed. A fourth individual cited a journal publication making the distinction between climate research and climate services. Both government and industry need decision-making tools, and industry can buy advice from various sources. The cost of the advice being unreliable is very high. This is a reason to look towards a well-documented, centralized source of information similar to the Destination Earth Project. A final viewpoint observed the distinction between understanding and building decision-relevant resources for evaluating potential impact versus creating an investment pathway for the coproduction and support of the decision itself. BER falls on the decision-relevant end of the spectrum in terms of generating insights. As illustrated, increasing problem resolution does not always make problems easier. A lot of fundamental science factors into determining the definition and prioritization of equity in the context of different spatiotemporal risks as well as the relevance of these risks to individuals making choices under pressure.

A point about the need for metrics to evaluate impact was revisited. How can BER better demonstrate success of research investments in a way the average Joe or a congressperson can understand? One solution may be to require progress reports beyond the end of funding to cap-

ture how efforts scale up through patent reports, pilot projects, or receipt of Small Business Innovation Research and Small Business Technology Transfer (SBIR/ STTR) grants. However, the administrative burden of this approach must also be considered.

West noted the COV report will be sent to the SC Director for review. BER will present a response at the next BERAC meeting.

Hungate posited BERAC could function in a primarily virtual format for future meetings. While meeting in person confers benefits, there are also concerns about the impact of travel. Hybrid meetings are also an option. A poll will be circulated to gather thoughts. A BERAC member suggested meeting in person every third or fourth meeting.

Weatherwax's observed today is both Earth Day and BERAC's 75th anniversary.

Public Comment

None.

Hungate adjourned the meeting at 5:07 p.m.

Respectfully submitted on May 5, 2022

Holly Holt, PhD

Science Writer, ORISE