Biological and Environmental Research Advisory Committee Meeting
March 22–23, 2016
Gaithersburg Marriott Washingtonian, Gaithersburg, Maryland

BERAC Members Present

Sarah Assmann (Tuesday only)
Dennis Baldocchi
James Ehleringer
James Hack
Bruce Hungate
Anthony Janetos
Andrzej Joachimiak
Cheryl Kuske
L. Ruby Leung
Gerald Meehl
Jerry Melillo (via telephone)
Gloria Muday
David Randall
James Randerson
Karin Remington
G. Philip Robertson
Karen Schlauch
Daniel Segre
Gary Stacey, Chair
David Stahl
Judy Wall
John Weyant
Minghua Zhang

BERAC Members Absent

Jacqueline Shanks
Huimin Zhao

Also Participating

Todd Anderson, Director, Biological Systems Science Division, Office of Biological and Environmental Research, Office of Science, USDOE
Kelly Beierschmitt, Deputy Laboratory Director, Idaho National Laboratory
Allison Campbell, Associate Laboratory Director, Pacific Northwest National Laboratory
Melinda Comfort, Office of the General Counsel, USDOE
Joanne Corcoran, BERAC Committee Manager, Office of Biological and Environmental Research, Office of Science, USDOE
Peter Davies, Director of Geoscience, Climate, and Consequence Effects, Sandia National Laboratories
Patricia Dehmer, Deputy Director, Office of Science, USDOE
Gary Geernaert, Director, Climate and Environmental Sciences Division, Office of Biological and Environmental Research, Office of Science, USDOE
Joseph Graber, Program Manager, Office of Biological and Environmental Research, Office of Science, USDOE
Jay Hnilo, Program Manager, Office of Biological and Environmental Research, Office of Science, USDOE
Susan Hubbard, Associate Laboratory Director, Lawrence Berkeley National Laboratory
Chi-Chang Kao, Director, Stanford Linear Accelerator Laboratory National Accelerator Laboratory
Jay Keasling, Associate Laboratory Director, Lawrence Berkeley National Laboratory
Martin Keller, Director, National Renewable Energy Laboratory
Lara Kueppers, Deputy Director, Next Generation Ecosystem Experiments - Tropics, Lawrence Berkeley National Laboratory
Thom Mason, Director, Oak Ridge National Laboratory
Alice Murray, Associate Laboratory Director, Savannah River National Laboratory
Cherry Murray, Director, Office of Science, USDOE
Shaima Nasiri, Program Manager, Office of Biological and Environmental Research, Office of Science, USDOE
Frederick O'Hara, BERAC Recording Secretary
John Sarrao, Associate Laboratory Director, Los Alamos National Laboratory

Martin Schoonen, Associate Laboratory Director, Brookhaven National Laboratory
Adam Schwarz, Director, Ames National Laboratory
John Shanklin, Biology Department, Brookhaven National Laboratory
Henry Shaw, Deputy Associate Laboratory Director, Lawrence Livermore National Laboratory
Rick Stevens, Associate Laboratory Director, Argonne National Laboratory
Daniel Stover, Program Manager, Office of Biological and Environmental Research, Office of Science, USDOE
Sharlene Weatherwax, Associate Director of Science, Office of Biological and Environmental Research, Office of Science, USDOE
Tris West, Senior Technical Advisor, Office of Biological and Environmental Research, Office of Science, USDOE

About 60 others were in attendance during the course of the two-day meeting.

Tuesday, March 22, 2016
Morning Session

Before the meeting, **Melinda Comfort**, Office of the General Counsel, USDOE, presented the annual ethics briefing to the Committee.

The meeting was called to order at 8:59 a.m. by **Gary Stacey**, the Committee Chair. He recognized the new members of the Committee and asked all the members to introduce themselves.

Sharlene Weatherwax introduced **Cherry Murray**, the new Director of the DOE Office of Science (SC), to speak about the SC budget request.

DOE is a mission agency, covering energy, science, nuclear safety and security, and environmental cleanup. SC funds high-risk, high-payback scientific research. The Advanced Research Projects Agency–Energy (ARPA–E) deals with high-risk science and technology. The applied technology offices deal with environmental cleanup and technologies that are close to development and deployment.

The Office of Science (SC) is the largest supporter of the physical sciences in the United States. Its FY-16 budget is $5.35 billion, 42% of which goes to R&D, and 40% of that to research universities; 13.5% of the FY-16 budget goes to construction, and 38% to facility operations. In 2015, there were 34,000 users of its user facilities. The FY-17 budget request is for $5.67 billion, a 6.1% increase. Under the terms of the 21st Annual Conference of Parties (COP21) agreement, the United States is pledged to double its clean-energy research budget.

The President's FY-17 proposed budget for DOE requests $13.1 billion for nuclear security, $7.2 billion for energy technology, $5.8 billion for science research, and $6.1 billion for environmental management. In pass-back, additional funding for R&D and energy technology is expected to be added.

The FY-16 budgets and requested increases for the SC programs are

- Advanced Scientific Computing Research (ASCR): $621 million; +6.8%
- Basic Energy Sciences (BES): $1.849 billion; +4.7%
- Biological and Environmental Research (BER): $609 million; +8.7%
- High Energy Physics (HEP): $795 million; +2.9%
- Fusion Energy Sciences (FES): $438 million; -9.1%
- Nuclear Physics (NP): $617 million; +3.0%

The proposed budget for FY-17 includes $100 million funding for mission innovation. In BER, that will amount to $35 million that will be used for biosystems designed to introduce beneficial traits into plants and microbes for clean-energy applications ($20 million) and new investments so the Bioenergy Research Centers (BRCs) can translate 10 years of BRC research to industry ($5 million per BRC).

An open call for core research is proposed. In BER, that will be for new platform microbes for biofuels and bioproducts engineering and for biofuel crop modeling for incorporation into a predictive framework.

In BES, the FY-17 budget will support

- Increased funding for Energy Frontier Research Centers (EFRCs),
- A new activity in computational chemical sciences,
- Advancement of the mission innovation agenda that targets materials and chemistry for energy efficiency and for use in extreme environments,
- Both energy innovation hubs (a Joint Center for Energy Storage Research and the Joint Center for Artificial Photosynthesis),
- Maintaining international competitiveness and discovery science, and
- Upgrades to the light sources.

In BER, the funding will support genomic sciences, mesoscale-to-molecules research, climate system modeling, atmospheric system research, environmental systems science, climate and environmental data analysis and visualization, and user facilities.

The Bioenergy Research Centers were established in 2007 and were renewed for 5 years following merit review in September 2012; FY-17 is the final year of the funded period. Increased funding is expected to accelerate innovation in translation of research results to industry. A competitive funding opportunity announcement (FOA) will be issued in FY-16 for merit review and selection in FY-17 (the management teams of the BRCs are expected to turn over).

In Fusion Energy Sciences, support is provided for the DIII-D National Fusion Facility (DIII-D) and the National Spherical Torus Experiment Upgrade (NSTX-U) programs; the U.S. research involvement in international machines; general plasma-science activities; and the U.S. contributions to ITER.

In High-Energy Physics, the plan developed by the Particle Physics Project Prioritization Panel (P5) is being followed, focusing on construction and project-support increases to implement the P5 strategy and accelerator stewardship.

In Nuclear Physics, the Relativistic Heavy-Ion Collider, the 12-GeV upgrade to the Continuous Electron Beam Accelerator Facility (CEBAF), the Facility for Rare Isotope Beams (FRIB, which is under construction), and the Gamma-Ray Energy Tracking Array (GRETA) are being supported.

In FY-17, SC is expected to contribute to five DOE crosscuts. BER will contribute to the Exascale Computing Initiative for $10 million and to the Energy-Water Nexus (EWN) for $24.3 million.

SC uses workshops, federal advisory committee reports, and National Academies studies to engage the scientific community in planning.

BERAC has been issued a new charge on strategic research directions.

In developing the FY-17 budget, SC is grappling with a number of issues and priorities. It seeks to balance discovery research versus science for clean energy and departmental crosscuts. It seeks to balance research funding versus scientific user facility construction versus operations. The Exascale Computing Initiative is important for national and economic security. A defining moment in fusion sciences is occurring this year. Upgrades of the CMS [Compact Muon Solenoid] and ATLAS [A Toroidal LHC Apparatus] detectors at the Large Hadron Collider (LHC) are being requested at the same time as construction of the Long-Baseline Neutrino Facility/Deep Underground Neutrino Experiment (LBNF/DUNE). How to fit all these into the budget is a huge challenge. This challenge will be addressed through enhanced communications with Congress and research universities and through instituting best practices in national-laboratory management.

In addition to SC, ARPA-E is also focused on transformative science. Within SC, 72% of the applied technology and 30% of the scientific programs are focused on clean energy. SC got a 2% increase in discovery science funding. Secretary Moniz wants the new $100 million directed toward the interests of mission innovation.

In FY-14, SC user facilities had 33,671 total users; 65% of those came from universities, 23% came from national laboratories, 8% came from other research institutions, and 4% came from the private sector. Among the construction projects proposed in the FY-17 budget are five upgrades to user facilities. In the FY-16 budget, 30% of construction funding went to universities.

Exascale computation is a grand challenge. DOE is partnering with industry to codesign machines and codes for exascale computing.

May 2, 2016, is a make-or-break moment for the fusion community. The program is 10 years into the ITER project, and the question is whether the United States is in for the long haul or not. The nation committed to $1 billion of support for ITER, and it has now contributed $4 billion to $6 billion. Congress is not happy. How to fit it into the budget is a major question. At the same time, there is also the LBNF. How to get that built is another major question. International support for that project is being sought.

SC partially funds ten science laboratories. Each of these national laboratories gets funds from all programs, and all programs fund all laboratories.

Robertson noted that COP-21 is asking for an increase in R&D funding and asked whether that will be in the FY-18 budget. Murray replied that the Office is seeking a factor-of-two increase over 5 years. FY-18 will, therefore, also see an increase. With the presidential election, that increase may be complicated.

Zhang asked if he had heard correctly that she would be the director of SC for only 1 year. Murray replied, yes. She has only a 2-year leave from Harvard University, and she had used one of those years on sabbatical. Moreover, the directorship is a presidential appointment, and her resignation is expected at the end of the current administration. The Office is issuing documents (e.g., the Quadrennial Technology Review and the Quadrennial Energy Review) on policies that can be carried over to following administrations. It took almost 3 years to select a new Director of SC this time. The time to make a new appointment is taking longer and longer according to a National Academy of Sciences study.

Sharlene Weatherwax was asked to present an update on the operations of the Office of Biological and Environmental Research (BER).

Two new staff members have joined BER: Tris West as a senior technical advisor and Amy Swain as a program manager for the Biological Systems Science Division.

Six new members have joined the Committee: Jerry Melillo, Karen Schlauch, Gloria Muday, Cheryl Kuske, Bruce Hungate, and Daniel Segre.

Three significant awards to BER researchers were announced: Ben Preston won the 2015 Charles S. Falkenberg Award from the American Geophysical Union, Allison Campbell won election as President-Elect of the American Chemical Society, and Philip Robertson was elected a 2015 American Association for the Advancement of Science Fellow.

In addition, one of the 2013 Presidential Early Career Awards for Scientists and Engineers went to Michelle O'Malley of the University of California at Santa Barbara.

In the FY-16 enacted budget, Biological Systems Science Research received $214.8 million, Climate and Environmental Sciences Research received $199.0 million, Climate and Environmental Facilities and Infrastructure received $115.7 million, and Biological Systems Facilities and Infrastructure received $79.5 million. BER's total appropriation for FY-15 was $592.000 million; for FY-16, it is $609.000 million; in the FY-17 president's request, it is $661.920 million, an increase of $52.920 million or 8.7% over the previous year's enacted appropriation. BER has a privileged position in receiving a proposed increase. Within the $339.1 million in the FY-17 request for Biological Systems Science, $258.6 million is for research, and $80.5 million is for facilities. Within the $322.9 million in the FY-17 request for Climate and Environmental Science, $204.8 million is for research, and $118.0 million is for facilities.

On the biology side, the focus is on the genomics of bioenergy research, biosystems design, microbiome research for bioenergy, and bio-imaging technology.

The BRCs filed their 500th invention disclosure on March 3, 2016. They have been amazingly productive.

BER supports fundamental microbiome research in experimental systems biology, genome-enabled environmental research, and predictive computational modeling with partnerships with DOE national laboratories, academia, and field-research facilities. The program will initially focus on biomass-focused agricultural systems and on terrestrial ecosystems particularly vulnerable to climate change, including permafrost, taiga, wetlands, and arid ecosystems.

In the Climate and Environmental Science Division, BER will support climate and systems modeling, environmental system science, the Atmospheric Radiation Measurement Facility, and the Environmental Molecular Sciences Laboratory.

In Accelerated Climate Model for Energy (ACME), BER advances modeling efforts to achieve the highest spatial resolution of all climate models of the world. It will be the first climate model compatible with next-generation computer architectures.

BER is participating in two Department-wide crosscuts. The first crosscut is the Energy–Water Nexus (EWN) to accelerate the nation's transition to more-resilient energy and coupled energy–water systems. The FY-17 goals are designing unified model and data analytics capabilities and deploying an integrated field laboratory with testbeds (which BERAC recommended). The second crosscut is the Exascale Computing Initiative (ECI), which is in collaboration with SC's ASCR program and the National Nuclear Security Administration (NNSA) Accelerated Strategic Computing Initiative (ASCI). BER will be responsible for determining the scope and management of climate modeling programs that require extreme-scale computational capabilities.

ASCR is conducting requirements-gathering workshops with each office in SC to prepare for next-generation computer procurements. The workshop will ascertain the full scope of BER computational science expected in the 2022–2025 timeframe and will cover exascale-era science requiring computing and data management spanning mid-range computing to the exascale. Half of the agenda topics are on the climate side, and half are on the biology side.

BER strategic science directions are guided by input from the research community, scientific workshops, the National Science and Technology Council, the National Academy of Sciences, and BERAC.

The new charge to BERAC poses several questions:

- To what extent has DOE BER successfully met or positioned itself to meet the challenges outlined in the 2010 report that are within the mission objectives of SC?
- What are the greatest scientific challenges that DOE will be facing in the long term (a 20-year horizon), and for which of these should BER take primary responsibility?
- How should BER be positioned to address those challenges?
- What new tools should be developed?
- What unique opportunities exist to partner with, or leverage assets from, other programs within SC or with other federal programs?
- What scientific and technical advances are needed to train a workforce of the future?

Recently, the national laboratories have been asked to provide to BER descriptions of their core capabilities, BER-relevant facilities, and views of themselves in 20 years. Oral presentations and questions and answers about these self-assessments are being conducted later at this BERAC meeting.

Stacey asked how the Office was going to roll out the new microbiome effort. Weatherwax replied that the nation has expertise at universities and national laboratories to harness.

Baldocchi asked whether the Office got pushback on the climate budget. Weatherwax replied that it gets Congressional questions asking for information. The Office supports basic science.

Zhang asked if she had anything to share about the FY-16 request. Weatherwax replied that the funding is going largely into basic science.

Joachimiak was pleased that a balanced research budget was being pursued.

Robertson asked how one transitioned the Integrated Field Laboratory into FY-17. Weatherwax answered that the Office is prepared to strip down its efforts. It asked for $30 million, and Congress did not like that, so it put in a slightly more modest request. The Office will take what it gets.

The break was declared at 11:01 a.m. The meeting was called back into session at 11:12 a.m.

Gary Geernaert was asked to provide an update on BER's Climate and Environmental Science Division (CESD).

The past two months have been the warmest January and February on record. As a result, the current Arctic sea-ice extent is 2 standard deviations below the average for 1981 to 2010. The Coast Guard and other agencies are concerned about how they will be affected by these changes.

The 2012 strategic plan for the CESD is being updated. The new one is to be released in 2017. It will identify grand challenges that are outside the Division's mission space that other agencies can pursue.

Climate-model diagnostics and validation combines major upgrades in advanced software code development, downscaling methodologies, and validation against Atmospheric Radiation Measurement (ARM) Program testbeds. A close look needs to be taken at parameterizations. That effort will require investments in software, multiscale physics, large-eddy simulation (LES), and major field activities.

Water flows affect the energy sector as much as vice versa. Therefore, the energy-water nexus is being investigated. Test beds will be used to see what models can accomplish.

Workshops matter a lot to BER's planning. They define the most sensible investment pathways and timings for those investments.

Five solicitations will be funded for FY-16. Nine major laboratory reviews will be conducted in 2016. And four principal investigator (PI) meetings will be held in 2015–2016.

The Environmental Molecular Sciences Laboratory (EMSL) has launched joint calls with the Joint Genome Institute (JGI); it is now going to issue a joint call with the ARM facility.

Version 1 of ACME is frozen and is now in debugging. The release of Version 1 is on track for summer 2017. Its governance structure is under discussion, especially the role of academia. Ruby Leung has been named chief scientist. The modeling centers are being involved so all changes flow across all the centers.

The ARM West Antarctic Radiation Experiment (AWARE) is being deployed to McMurdo, Antarctica, from January 2016 to December 2017 for a full-year campaign.

A number of science results from the program are notable:

- ARM Doppler cloud radar has been used to study stratocumulus cloud-top entrainment at a higher temporal resolution than other methods are possible of providing and is suitable for testing existing parameterizations. Calculating entrainment rate with radar-derived energy dissipation rates has the advantage of not requiring observations of height or mixing-length scales.
- Superparameterization improves the representation of moderate and extreme rainfall intensity in regions of organized convection.
- El Niño is a major component of the climate system. A major question is whether El Niño's components will intensify in the future. Ongoing research is identifying a time-invariant canonical El Niño–Southern Oscillation (ENSO) pattern in observed sea-surface temperature data, evaluating how well 33 coupled models replicate this pattern, noting that ENSO-driven precipitation response will intensify in the future, and decomposing the model-predicted rainfall response to ENSO into three terms.
- A long-term experiment has shown progress in microtopography and the modeling thereof, explicating pathways and transformations of dissolved methane and dissolved inorganic carbon in Arctic tundra watersheds.
- In a study of the wet–dry cycle of the Amazon evergreen forests, it was seen that moving into the dry season does not affect productivity much; new leaves form rapidly and are highly photosynthetic.
- Oxidation pathways of calcium and phosphate have been found to affect uranium mobility and transport. That same research has improved modeling of such mobility and transport.

Stacey asked if there should be any concern about the effects of ACME's expansion on other modeling efforts. Geernaert replied that the Office is including more components to cover a broader scope of agency interests and ACME represents a reshaping of already-planned modeling efforts.

Meehl noted that the new charge to the Committee refers to partnerships, one of which is the partnership with the National Science Foundation on modeling. He noted that the ACME effort can leverage that partnership.

Todd Anderson was asked for an update on the Biological Systems Science Division (BSSD).

The Division has completed the annual reviews of the three Bioenergy Research Centers (BRCs), conducted the Early Career Award panel reviews, and held the annual Genomic Sciences Program PI meeting. Upcoming activities include the panel review of the Plant Feedstocks for the Bioenergy Research FOA, the panel review of the Carbon-Cycling FOA, the Oak Ridge National Laboratory (ORNL) Bio-Imaging Project review, three national laboratory science-focus-area (SFA) reviews, and a workshop on biology activities that is expected to be held in September.

Three FOAs are expected in FY-16. The Plant Feedstock Genomics for Bioenergy: A Joint Research FOA from the U.S. Department of Agriculture (USDA) and DOE continues research on plant responses to pathogens and includes a focus on oil-seed crops. An FOA on Systems-Biology-Enabled Research on the Roles of Microbial Communities in Carbon-Cycle Processes is designed to understand the functioning of microbial communities in a wide range of environments and environmental conditions and to research the larger-scale ecosystem function. The Bioenergy Research Centers FOA will be informed by a recent BER workshop on bioenergy research. It is for FY-18 funds, with selection in FY-17. This is a large component of the division's budget.

The Bio-Imaging Technology Program is funding projects at four national laboratories and seven universities.

New workshops coming up include the ASCR–BER Workshop on Exascale Computational Requirements on March 29–31, 2016, in Washington, D.C., and the Workshop on Integrated Molecular Structure, Function, and Dynamic Imaging Technologies in mid-September of 2016, which will combine structural biology and imaging and define the instrumentation required.

The DOE Systems Biology Knowledgebase (KBase) is a data model on a high-performance-computing platform, doing high-end data analytics and propagating results across the community. It has a new feature: the KBase Software Development Kit for third-party-tool integration.

The BRCs are in their ninth year and have recently filed their 500th patent application. They are currently looking at traits to introduce into plants and at new ways to deconstruct cellulose. The BioEnergy Science Center (BESC) is optimizing biocatalyst–feedstock combinations to achieve high solubilization with minimal pretreatment. This effort has produced a two-fold increase in solubilization via mechanical disruption with greater benefits on partially fermented feedstock. The Great Lakes Bioenergy Research Center has found that a novel lipid pathway is responsible for the massive quantity of surface wax (tri-, di-, and monoglycerides comprising up to 32% of the fruit's weight) on bayberry fruit and is proposing a model for bayberry wax biosynthesis and making bayberry an energy crop. The Joint BioEnergy Institute (JBEI) has found a phenotype of *Saccharomyces cerevisiae* that exhibits improved xylose uptake rates that allow significant growth with xylose as the only carbon source.

In other research funded by the Division:

- Meta-omics techniques were used to track shifting microbial-community processes in warming permafrost, showing observable changes within 1.5 years.
- The genetic markers for senescence in perennial switchgrass were determined. Delaying senescence increases the growing season and productivity. This is another trait to exploit in this important energy crop.
- A yeast-gene drive has been engineered that can be safely contained and removed to avoid releasing these genetically modified organisms into the environment.
- New, highly effective biomass-degrading enzymes have been discovered in anaerobic fungi from herbivores' guts.
- Protein engineering of cyanobacterial APSK (adenosine 5-phosphosulfate kinase) has recapitulated the structural development of redox control in the plant enzyme, providing insight for engineering metabolic controls.

The JGI continues to be an essential resource for the agency and has been very productive. Eddie Ruben is resigning as the Director of JGI as of June 30. Candidates for his replacement are being considered.

Weyant noted that the charge has been made that biological experiments are less replicable than physics experiments and asked if that were true and whether the merger of biology and physics will overcome the perceived problem. Anderson replied that that is being addressed by KBase directly. Stacey observed that the National Institutes of Health (NIH) now require statements about how issues of reproducibility will be addressed to be included in funding requests.

Joachimiak stated that, in the sequence data, errors in annotation and instrumentation-produced errors are not being corrected.

Remington asked if there had been good participation at the KBase portion of the Genomic Sciences PI Meeting. Anderson responded that there was a full room, mostly walk-ins.

Wall noted that there should be a method of updating annotations in KBase. Anderson said that that has been discussed, making KBase a living database.

Schlauch commented that one KBase meeting session was not well attended.

The meeting was adjourned for lunch at 12:11 p.m.

Tuesday, March 22, 2016
Afternoon Session

The meeting was called back into session at 1:31 p.m.

Sarah Assmann was introduced to speak on The Next-Ome: Genome-Wide RNA Structure and Plant Abiotic Stress Response.

Weatherwax introduced a discussion of the BER-relevant capabilities of the national laboratories. Representatives from 13 national laboratories were present to review their missions and capabilities:

1. **Martin Schoonen** of Brookhaven National Laboratory (BNL).
2. **Thom Mason** of Oak Ridge National Laboratory (ORNL).
3. **John Sarrao** of Los Alamos National Laboratory (LANL).
4. **Henry Shaw** of Lawrence Livermore National Laboratory (LLNL).
5. **Peter Davies** described Sandia National Laboratories (SNL).

A break was declared at 3:50 p.m. The meeting was called back order at 4 p.m.

6. **Adam Schwarz** of the Ames Laboratory.
7. **Rick Stevens** of Argonne National Laboratory (ANL).
8. **Jay Keasling** and **Susan Hubbard** of Lawrence Berkeley National Laboratory (LBNL).
9. **Allison Campbell** of Pacific Northwest National Laboratory (PNNL).
10. **Alice Murray** of Savannah River National Laboratory (SRNL).

Gary Stacey took the floor to discuss the development of the BERAC report *Grand Challenges for BER: A Long-Term Vision*.

A workshop was held in 2010 with white papers and breakout sessions, both topical ones related to the white papers and cross-disciplinary ones. A writing committee put together a draft report. It dealt with complexity, scales, multidisciplinary research, computing and mathematics, risk, education, and human resources. After vetting by the Committee, the Grand Challenges report was issued in 2010.

The Committee is now charged to address these questions again. It needs to set up a subcommittee to conduct the process. They need to identify scientific drivers, assign the writing of white papers, design and conduct the workshop, appoint the writing committee, and deliver this report before the fall of 2017. He asked the Committee members to discuss these logistics overnight and to come to some decisions on the next day at this meeting.

Weyant asked how many people might make up the subcommittee. Stacey replied, eventually about 15, but one should start small and get started with conference calls.

Meehl noted that a lot background material in the prior report is still valid. Wall suggested updating the old report. Stacey pointed out that such topics as synthetic biology will need to be rewritten from scratch. It would seem as though the considerations of a 20-year forecast horizon would have changed in

6 years. The Committee should look forward to rewriting the whole report. Weyant commented that the 2010 report was an excellent report and sets a high bar.

At the previous BERAC meeting, a charge to reevaluate the BER Low-Dose Radiation Program had been received from the Secretary of Energy, and Randall had volunteered to head up the COV that would conduct that reevaluation, assisted by Wall. Stacey asked Randall and Wall for a brief update on the progress of the COV.

David Randall reported that he had a nearly complete roster for the COV Subcommittee, lacking only two more confirmations. A date of July 7, 2016, has been set for the review. **Judy Wall** said that several expert panels have been set up and that a format for discussions has been laid out. It is likely that the review will consist entirely of conference calls (no face-to-face meetings), and the dates for the expert-panel conference calls will be set soon.

The floor was opened to public comment. **John Shanklin** of BNL asked how the grand challenges will relate to the mission areas of BER. Weatherwax responded that, if the mission has not changed, the questions may not change, also. It is not clear if all mission areas will be addressed. The Subcommittee might address broad societal issues.

There being no further public comment, the meeting was adjourned for the day at 5:58 p.m.

Wednesday, March 23, 2016

The meeting was called back into session at 8:30 a.m. **Dan Stover** introduced **Lara Kueppers** to provide an update on the NGEE Tropics.

Tropical forests cycle more carbon in water than any other biome and play critical roles in determining the Earth's energy balance. But there are large uncertainties in tropical-forest response to a change in atmosphere and a warming climate. With the 21st century warming, novel climates emerge with the potential for drought. There are large source/sink carbon fluxes from the complex anthropogenic landscapes (deforestation, secondary regrowth, etc.). As a result, Earth science models do not even agree on the sign in their projections of land-carbon flux.

The tropical intact forest takes up about 1.3 PgC/year, and regrowth forests take up about 1.5 PgC/year while there are losses to deforestation amounting to about 3 PgC/yr.

The goal of NGEE-Tropics is to develop a predictive understanding of tropical-forest carbon balance and climate-system feedbacks to changing environmental drivers during the 21st century. The grand deliverable is a representative, process-rich tropical-forest-ecosystem model extending from bedrock to the top of the vegetative canopy–atmosphere interface, in which the evolution and feedbacks of tropical ecosystems and a changing climate can be modeled at the scale and resolution of a next-generation Earth system model grid cell. The overarching questions being addressed are

- How do tropical-forest ecosystems respond to changing temperature, precipitation, and atmospheric CO_2 concentration?
- How do disturbance and land-use change in tropical forests affect carbon, water, and energy fluxes?
- How will the response of tropical forests to climate change be modulated by spatial and temporal heterogeneity in belowground processes (i.e., water and nutrient availabilities)?

These questions have been broken down into more-tractable research objectives.

The modeling strategy is (1) to develop a new vegetation model built around a demographic core that represents different size classes of trees; (2) to develop improved process representations of plant hydraulics and tree stress, hydrology, plant and soil biogeochemistry (low-phosphorus availability), and effects of land-use; and (3) to test and validate at site scale across the tropics and with International Land Model Benchmarking (ILAMB) Project types of observations to test at larger scales.

The project is pursuing a trait-enabled modeling approach. In current Earth-system models (ESMs), plant traits are static and lack diversity, limiting forest response. That approach does not represent dynamic forests well. NGEEs will start with greater diversity, which is important to ecosystem processes. Plant interactions in response to climate change determine which types (and therefore which trait values)

are most successful. Trait filtering occurs through differential mortality, and mortality is linked vertically to carbon fluxes.

The aim is to start with an existing modeling framework and integrate into an ESM new data and expert knowledge, performing uncertainty analyses, and reiterating the process. Phase 1 will be to prioritize and demonstrate the approach. Phase 2 will implement and integrate. Phase 3 will integrate and apply to explore the future of tropical forests.

To guide parameterization, measurements will focus on high-impact parameters, uncertain parameters, and uncertain or poorly understood processes to produce new model benchmarks.

Pilot studies initiated in Phase 1 include a study of hydrology–carbon-cycle interactions in Manaus, Brazil; a study of trait trade-offs focused on Panama and beyond; and a study of nutrient–land-use interactions in Puerto Rico.

The Puerto Rico study is taking transects across soil type and forest development, taking a systems-biology approach to understanding phosphorus availability and plant acquisition via roots; looking at nitrogen availability and fixation, working to link leaf-level nutrient analysis and spectral signatures; and conducting airborne remote sensing to resolve individual canopy trees and their leaf spectra to enable scaling from ground-based data.

The ENSO-related drought has allowed the project to jumpstart its efforts. The drought is under way in Panama and Brazil and is related to many Phase 1 objectives. The project is seeking to quantify the impact of tropical-forest structure and function, provide data for models, and further strengthen pantropical collaborations.

Measures are being taken in two sites in Brazil and three in Panama to understand and test model predictions of plant hydraulics and photosynthetic responses to drought. ENSO-related forest-dynamics measurements are being taken in Africa, Asia, the Pacific, and the Americas. The LANL demographic hydraulic module ED2-Hydro is being run.

Data management and synthesis will have a dedicated archive to hold all project data sets. Templates are being designed for metadata reporting and files for ENSO and other future data sets to compare data sets across sites. Quality-assured and quality-controlled gap-filled, site-level drivers are being created for the model. Collaboration with colleagues will be used to develop a web portal to enable queries of project and partner data sets.

Partnerships are key to success. The project has partnerships with NGEE Arctic on data management, project management, and plant traits; with ACME on vegetation and soil biogeochemistry model development; with the Instituto Nacional de Pesquosas de Amazonia and with the Large-Scale Biosphere Atmosphere Experiment in Amazonia on field measurements, data synthesis, and modeling; with the ForestGEO global network and GEM network on forest measurements; and with the International Institute for Tropical Forestry, the Luquillo site of the Long Term Ecological Research (LTER) Network, and the Luquillo Critical Zone Observatory (CZO) in Puerto Rico on measurements of nutrient biogeochemistry and secondary forest development.

Transformational outcomes will include (1) a demographic, trait-enabled vegetation modeling framework that captures how forest complexity influences carbon-cycle responses under a changing atmosphere in a warming climate and (2) new model structures rigorously informed and benchmarked with existing data and with new data products. In the end, the aim is to significantly reduce uncertainties of tropical-forest ESM carbon-cycle feedbacks and a greatly improved understanding of the role of tropical forests in Earth-system functioning during the coming century.

Hungate asked if this “next-generation” experiment is the framework for future experiments or is the task completed. Kueppers replied that EU leaders do not expect to invest tens of millions of dollars a year into one experiment, but will partner with others’ investments.

Janetos stated that the course of tropical forests is influenced largely by how much gets chopped down, but that was not mentioned in the presentation. Kueppers said that that is out of the scope of the experiment, but it will be factored into the forest’s response.

Zhang hoped that people working on this can make use of ACME and that it has synergy with the Atmospheric Radiation Measurement (ARM) Program and its infrastructure (i.e., data archives).

Kueppers answered that the NGEE has a good partnership with ACME and has been talking with ARM about a new deployment in the tropics.

Ehleringer stated that Janetos's point is critical. Deforestation governs a lot of other parameters. He asked how objectives 1 and 3 will be linked. Kueppers replied that this is not a linking model. The project has been forced to use a scenario approach to see what the forest response would be. It will not predict land use itself.

Weatherwax introduced the remaining presentations of national laboratory plans.

1. **Martin Keller** of National Renewable Energy Laboratory (NREL).
2. **Chi-Chang Kao** of Stanford Linear Accelerator Laboratory (SLAC) National Accelerator Laboratory.
3. **Kelly Beierschmitt** of Idaho National Laboratory (INL

Joseph Graber was asked to review DOE's microbiome research.

The Office of Science and Technology Policy urged federal agencies to consider where microbiome research is going, so a National Science and Technology Council (NSTC) fast-track action committee was established on mapping the microbiome. The participants are USDA, NIH, DOE, NSF, Department of Defense (DOD), NOAA, NASA, Environmental Protection Agency (EPA), U.S. Geological Survey (USGS), and NIST. A broad definition of microbiomes was adopted: any multi-species assemblage of microorganisms existing in association with a plant, animal, or environment.

DOE's mission-driven fundamental research is aimed at identifying the foundational systems-biology properties of microbes, plants, and complex communities. The major objectives of DOE's Genomic Science Program are (1) to determine the molecular components, regulatory elements, and integrated networks needed to understand genome-scale functional properties; (2) to develop "-omics" experimental capabilities and enabling technologies needed to achieve a dynamic, systems-level understanding of organism and/or community function and add value to 5 years of biological data; and (3) to develop the computational capabilities, modeling capacity, and integrated knowledgebase to advance predictive understanding and manipulation of biological systems.

BER's support of microbiome research includes sustainable bioenergy production, thinking about plant–microbe–soil interactions, biomass-deconstructing associations, and phototrophic ecosystems. It supports environmental-process understanding in soils, sediments, subsurface aquifers, and permafrost and in the roles of microbial communities in biogeochemical dry-land processes and contaminant fate/transport. DOE user facilities and resources support that science through JGI, EMSL, and KBase.

The NSTC issued a report citing the major needs and priorities as being (1) improved high-resolution analytical technologies for probing functional processes in microbiomes; (2) high-performance computational resources, predictive-modeling capabilities, and systems-biology-oriented databases; (3) consideration of possible standard protocols, shared reference materials, and data formats; and (4) increased understanding of the roles of viruses in both host-associated and environmental microbiomes.

As a next step, the fast-track action committee decided to set up a long-term NSTC Microbiome Interagency Working Group (MIWG) cochaired by DOE and USDA. It will develop a federal strategic plan for coordinating research to advance the understanding of microbiomes and microbiome function and will continue current efforts in DOE microbiome research. The FY17 budget request is for $10 million in additional funding for microbiome-focused research.

Wall called attention to the great interagency cooperation and asked about cooperation with the European Union and China. Graber replied that the Working Group will have to consider this in consultation with the Department of State.

Baldocchi asked what types and sophistication of models were being talked about. Graber responded that metabolic mechanisms, microbial community processes, and biogeochemical processes are being looked at. Going from the genome to systems is too challenging. One needs to select mechanistic models that would be helpful and are also doable.

Remington asked about the marine ecosystem. Graber replied that the working group has been given guidance that it is not a marine organization. Remington noted that it has a lot of the globe to leave out of

consideration. Graber said that the working group needs to hand off that area to others who are better equipped and funded. Terrestrial systems are challenging enough. The investment needs to be focused.

Joachimiak noted that, if one eliminates oceans, the gap is huge. One needs to collaborate with other agencies. Graber agreed. The group needs to fully coordinate with research being done by many agencies.

A break was declared at 10:04 a.m. Leung left the meeting. The meeting was called back to order again at 10:16 a.m.

Weatherwax introduced **Jay Hnilo** to review the workshop activities on virtual data interpretation.

Today's research communities want an integrated work environment. Therefore, a workshop was conducted in August 2015 in Bethesda, Md., to assess the current and future data infrastructure requirements foundational for achieving CESD scientific mission goals and advancing a robust, predictive understanding of Earth's climate and environmental systems; 24 DOE scientists participated in the workshop, and several program managers were in attendance. A report has been published.

Prior to the workshop, a survey was conducted, 75 responses to the survey were received, and the findings were compiled. Breakout sessions were held at the meeting to discuss these findings.

The participants included 32 data providers, 4 resource providers, 6 software developers, 15 climate modelers, and 18 climate-model data analysts.

The survey result that rated highest in importance by the survey participants was an easy way to publish and archive data using one of the DOE data centers [e.g., the Carbon Dioxide Information Analysis Center (CDIAC) at ORNL]. Although it did not rank highest overall, access to enough computational and storage resources was chosen as the number one need by the highest percentage of participants. Other needs identified by survey respondents were a method of integrating and accessing large volumes of scientific data; quality-control algorithms for data; interfaces that ensure a high degree of interoperability for different formats and semantic levels among repositories and applications; the capture of provenance information for data; reproducibility; collaborative environments; and improved user-interface designs.

The workshop identified a large number of investments in the Earth System Grid Federation (ESGF) that are needed. Prominent among them was a uniform storage strategy being put into place among the major Coupled Model Intercomparison Project (CMIP) data-center sites. Next steps were identified for data analytics and disk space, including leveraging existing and future DOE leadership-class facilities, integrating server-side computing into ESGF, implementing a visualization/analysis platform; and enhancing the volume of spinning disk space at ESGF node sites.

A timeline was developed for making these improvements that calls for finalizing a strategic implementation plan in 2016; upgrading the methods by which data are published into ESGF by 2017, working with the community to establish metadata connections for quality assurance and quality control, with emphasis on CDIAC and ARM data, within ESGF by 2017; and continuing the infrastructure storage buildout at appropriate ESGF nodes by 2017.

Remington asked who was implementing in PYTHON. Hnilo replied that Lawrence Livermore National Laboratory was, but it is open source; it is very popular; it can handle high input.

Shaima Nasiri was asked to summarize several atmospheric systems research workshops.

The Atmospheric System Research (ASR) Program science plan is being updated. The ASR and CESD workshop reports are important sources of input to the science plan. Four ASR workshops were held during the past year, and there were other workshops on high-resolution modeling, ARM North Slope of Alaska priorities, aerial needs, and coordination.

The first ASR workshop studied the anthropogenic-biogenic interactions of secondary organic aerosols in climate models. It was hosted by PNNL in June 2015, there were 24 participants, and a workshop report has been published. The take-home messages were

- Analyses of measurements over the past 5 years, many of which were funded by ASR, have advanced several fundamental insights in key secondary-organic-aerosol (SOA) processes that relate to the burden and lifetime of SOA particles and their interaction with clouds and radiation.
- But current climate models do not include these advances, which could make large potential impacts in our understanding of the climate impacts of SOA particles.

- Key advances in the understanding of SOA processes include those associated with isoprene chemistry, reactions producing low-volatility products, SOA growth kinetics and mechanisms, anthropogenic-biogenic interaction mechanisms, effects of biomass burning on SOA, and SOA-water interactions.

Specific feasibility of these findings were discussed for remedying climate-model efficiencies and reducing the uncertainties in understanding the climate impacts of these particles. SOA model parameterizations in ESMs should be developed or improved to account for the new process-level understanding of SOAs. Cross-cutting measurements and modeling should focus on the remaining unknowns. Integrated model-measurement approaches can provide or improve model fidelity in addressing the new processes for both mechanistic accuracy and higher confidence for climate prediction.

The second ASR workshop studied absorbing aerosols and was hosted by DOE and Germantown in January 2015. It had 18 participants, and the workshop report is currently in progress. The workshop considered (1) what absorbing-aerosol knowledge gaps limit the understanding of these species and their roles in climate-relevant radiative, thermodynamic, and dynamic processes in the atmosphere; (2) what factors currently limit a robust representation of these absorbing-aerosol processes in large-scale models; (3) how may these knowledge gaps be addressed with current and feasible new DOE resources, including observations from the ARM facility; and (4) what specific additional resources would be appropriate, and what value would be added by them? The take-home messages were

- Biomass and biofuel combustion is a major source of absorbing aerosols that still lacks key understanding.
- Major contributors to model/measurement uncertainty in direct radiative forcing by absorbing aerosols include poor attribution of absorption to different absorbing aerosol types and possible measurement artifacts.
- The contributions of dust, black carbon, and brown carbon absorption across the solar and terrestrial spectrum, particularly as a function of altitude and with atmospheric conditions, are unknown.
- An integrated understanding of in situ and remote-sensing measurements (and limitations) should be developed to facilitate improved apportionment and source-specific process-level representation of absorbing aerosols in models.

The third ASR workshop was on marine low clouds and was hosted by BNL in January 2015. There were 17 participants, and a workshop report is currently in revision. Among other questions, it addressed:

- Why do models produce such a diversity of aerosol indirect effects on cloud radiative forcing?
- What do we need to close the CCN budget in marine boundary clouds?
- What are the processes that drive mesoscale organization in the marine boundary layer?
- What are the roles of mixing, evaporation, wind shear, and radiation on entrainment efficiency?
- How much and how frequently do marine low clouds precipitate, and how can we measure this precipitation accurately?

A range of marine-low-cloud approaches was developed.

The fourth ASR workshop was on convection and was hosted by PNNL in February 2016. There were 28 participants, and the workshop report is currently being written. Four themes were the topics of white papers, and, for each theme, the challenges and opportunities were identified and how ASR can meet them was considered. The take-home messages were that (1) organized convection is part of a sequence of events, all of which need to be better understood and better parameterized seamlessly and (2) the priorities for measurement and parameterizations are boundary-layer instabilities related to cloud growth, widths and intensities of convective updrafts, cold-pool dynamics, and ice-phase microphysics. Strategies for achieving these goals include developing new weather-based observational strategies for the Southern Great Plains, such as a spring-storm-season intensive operational period (IOP); using dual-polarization S-band radar, convection-penetrating aircraft, and a tropical-ocean IOP; developing hierarchical modeling approaches with built-in scale awareness of parameterizations; and identifying and assessing several paths to representing convection in next-generation climate models.

Daniel Stover was asked to report on the workshop on trait methods for representing ecosystem change.

Innovative modeling approaches are needed to improve the predictive understanding and representation of plant biological functions that interact with climate. Early generations of land models assumed a small number of plant functional types (PFTs), defined on the basis of similar characteristics and roles in ecosystem function. However, these formulations do not permit dynamic plant changes in response to environment.

Recently, trait-based approaches have been used that allow for dynamically representing plant characteristics. However, there is no consensus on optimal strategies for trait approaches. The ACME and NGEE projects are among the pioneers seeking to use traits for representing ecosystem dynamics for global climate models.

A workshop was set to advance a community discussion on trait-based methodologies used to represent ecosystem change in land systems and climate models with four guiding principles:

- Conceptual understanding of traits
- Current and future model treatment of plant traits
- Data sets available for model parameterization and validation
- Consequences for output of ESMs

There was a desire to engage the modeling and empirical communities to share current thinking and a 2-day workshop was held Nov 17–18, 2015, in Rockville, Md., with 36 attendees representing a mix of approaches from academic and national laboratories. Four breakout groups discussed approaches to this issue and to help inform optimal strategies and approaches for field, theory, and land modeling, specifically in the NGEE in the Arctic and tropics as well as in ACME.

Four breakout sessions discussed (1) plant functional traits and trait tradeoffs across species, PFTs, and biomes; (2) how plant traits are represented in models today; (3) datasets to inform dynamic plant-trait models; and (4) what the consequences are of including dynamic plant traits in Earth system models.

The definition of “trait” was found to vary among communities. There is a need to assess the trait mechanisms and the associated tradeoffs: biophysical based tradeoffs; those with benefits but countervailing costs; and those possible in theory but not necessarily in the real world. A better understanding is required of which traits are conserved vs. responsive to a changing environment. And there is a need to understand and represent both trait correlations driven by physical constraints and correlations reflecting strategic plant tradeoffs.

On data, the workshop found that there are numerous gaps in the data that are available to inform new models. Data are sparse for below-ground traits relevant to plant water and nutrient acquisition. Data are sparse for undersampled but climatically important regions, such as biome transition zones and tropical forests, where trait diversity is highest. Manipulative experiments provide a good insight on tradeoffs. Participants recognized that one needs to apply the tools of “big data” to assemble and interpret trait observations for the modeling community.

On modeling, the workshop found that pursuing multiple distinct modeling approaches will yield more-rapid advances than a single approach at this early stage. Analytically tractable models and ensembles of stochastic models both may be required to understand the emergent behavior and variability of real ecosystems.

Questions that still need to be addressed are

- What are key traits for climate change?
- What are optimal methods to appropriately represent these climate factors (e.g., carbon and energy fluxes)?
- Are there innovative methods to identify an optimal trait framework?
- At what point and in what manner does it make sense to incorporate further “trait” complexity into global models?

The next steps to be taken are to incorporate further trait observations important to well-understood processes, such as plant water stress, into ESMs; to carefully target key opportunities to collect trait data

on emerging model-development areas, such as below-ground processes; to represent dynamic trait filtering in response to environmental change; and to convene a workshop to develop new trait-modeling approaches with well-developed trait data.

The experimental and modeling communities need to be engaged.

Products from this workshop include an *EOS* article; a special issue of *New Phytologist* on trait-based methods to represent ecosystem processes in land models and climate models; a workshop Executive Summary; and an ACME–NGEE collaboration meeting.

Baldocchi noted that measures of traits tend to be on a mass basis and asked how one converts that to an area basis. Stover replied that they had found that they did not have as much data as they thought they did.

Muday asked how people find out about these workshops and who gets invited. Stover answered that this was a broad community. The organizers were limited by budget. The right people needed to be enlisted. What was wanted was a broad perspective. And the size of such a group needs to be limited to make discussions feasible.

Ehleringer asked if they had addressed the relevance of the number of functional types to the ESMs. Stover responded, no; that stage has not yet been reached. Some models have traits in them. The diversity and dynamic nature of the traits in system response are often limited.

Randerson asked what the vision was for a competition of models. Stover answered that a given model was not going to be set. Different models are needed for different traits. One idea is to have a jamboree of models.

Zhang asked if there were a plan to incorporate soil data. Stover replied, yes; that is definitely on the map.

Stacey reopened the discussion of the recent charge for producing a new long-term plan.

Ehleringer suggested selecting six people here at this meeting to meet in the next 30 days to determine if the report should be revised or redone *in toto* and whether to have a workshop or not. Robertson responded that that is a reasonable approach. An assessment needs to be made as to whether the areas are still relevant and how to address challenges still on the table.

Randall pointed out that there have been a lot of developments in modeling. Updating the report would be practical, but some areas need to be revisited.

Stacey pointed out that it may be more difficult to revise the report than to redo it. Remington stated that the writing team should rephrase rather than regurgitate.

Stacey asked if the money were there for a workshop. Weatherwax replied, yes, for multiple workshops or conference calls. Stacey said that this is an opportunity for BERAC to act proactively on things not in the 2010 report or to push things that were not emphasized enough in the 2010 report. A lot of people read these reports.

Weyant suggested that the “Committee of Six” could put together a new outline (which could be fluid). Moreover, things that were thought to be simply linked have turned out to have more complex linkages and interactions.

Muday asked if the Committee were constrained to the specific topics mentioned in the charge letter. Stacey answered that the Committee can do anything that it wants to as long as it addresses all the parts of the charge. Stahl asked if discussion points might emerge from the outline. Ehleringer replied, yes. A larger workshop could address issues noted by the Committee of Six.

Weyant observed that it is good to have a small group to get things moving. It is good to have a large group to get a broad perspective.

Stacey noted that the report is due in September 2017. If there were to be a workshop, it would have to be scheduled well in advance.

Remington suggested that there could be small working groups that could provide community input.

Stacey said that, in 2010, a small subcommittee selected themes that then had additional subcommittees assigned to explore and write white papers that fed into a major workshop. Any outline from an initial, small group would be different from the final outline.

Remington suggested that a request for information (RFI) could be issued to get ideas from younger researchers.

Randerson said that, in integrating modeling and experimentation, a model of greater resolution and sophistication has been built, as recommended in the 2010 report. Some issues arise at the small-scale but not at the large scale. Segre asked how one quantitatively assesses a "good" model and pointed out that how one reads and understands genomes has changed dramatically.

Weyant asked whether the Committee were restricted from things that can be done in 10 years. There should be some discussion on the time frame. Stacey pointed out that this is more of a grand-challenge vision document rather than a short-term, middle-term, or long-term planning document.

Wall noted that the scientific community does not do well in modeling carbon sequestration. Perhaps a few instances should be selected where good data is not in hand. Stacey agreed that a series of case studies could be included.

Zhang recommended that the draft of the report should come back before this full committee for review. Stacey said that it would.

Robertson recommended that the Committee maintain the notion of identifying grand challenges no matter how the report is organized.

Stacey said that a high-quality report should be promoted upon release.

Joachimiak offered that one of the grand challenges is how to automate genomic annotation.

Stacey said that the small subcommittee should reflect a broad range of topics and areas of expertise, and he asked for volunteers. Volunteers and their areas of expertise were

Karin Remington	Data and computation
Cheryl Kuske	Microbiomes
Gerald Meehl	Climate modeling
Andrzej Joachimiak	Radiation microbiology
James Randerson	Carbon cycle
Bruce Hungate	Ecosystem ecology
Philip Robertson	Terrestrial ecology
Minghua Zhang	Climate modeling

Stacey charged the small group to move forward and come back to BERAC with its recommendations. A conference call will be put together soon. All subcommittee members need to review the 2010 report.

Stacey opened the floor for discussion by the Committee members. There being none, the floor was opened to public comment.

Susan Hubbard said that the 2010 report had a number of ideas, but there are a lot of other ideas, also. There is an opportunity to identify crisp and actionable items.

There being no other public comment, the meeting was adjourned at 11:51 a.m.

Respectfully submitted,
Frederick M. O'Hara, Jr.
Recording Secretary
April 19, 2016