Minutes for the
Basic Energy Sciences Advisory Committee (BESAC) Meeting
February 26-27, 2009
Hilton Washington DC North/Gaithersburg
Bethesda, Maryland

BESAC members present:

Simon Bare
Nora Berrah
Sylvia Ceyer
Peter Cummings
Sue Clark
George Flynn
Bruce Gates
Laura Greene
John Hemminger, Chairman
Bruce Kay
Kate Kirby
William McCurdy, Jr.
Martin Moskovits
Kathryn Nagy
Kathleen Taylor
Douglas Tobias
John Tranquada

BESAC members absent:

Frank DiSalvo
Mostafa El-Sayed
Sharon Hemmes-Schiffer
Michael Hochella
Daniel Morse
John Richards
John Spence

Also participating:

Michelle Buchanan, Oak Ridge National Laboratory
George Crabtree, Argonne National Laboratory
Patricia (Pat) M. Dehmer, Deputy Director of Science Programs, Office of Science
Don DePaolo, Lawrence Berkley National Laboratory/UCB
Wolfgang Eberhardt, BESSY-Berlin
Murray Gibson, Argonne National Laboratory
Jim Horowitz, Basic Energy Sciences
Alan Hurd, Los Alamos National laboratory
Wayne Hendrickson, Columbia University
Franz Himpsel, University of Wisconsin-Madison
Marc Kastner, Massachusetts Institute of Technology
Michael Klein, University of Pennsylvania
Harriet Kung, Director, Office of Basic Energy Sciences
Ray Johnson, BESAC Technical Writer/Recording Secretary
Pat Looney, Brookhaven National Laboratory
Pedro Montano, Office of Basic Energy Sciences
Michael Norman, Argonne National Laboratory
Rick Osgood, Columbia University
Eric Rohlfing, Basic Energy Sciences
John Sarrao, Los Alamos National Laboratory

Rachel Smith, Oak Ridge Institute of Science and Educations (ORISE)
Karen Talamini, Office of Basic Energy Sciences
Katie Perine, Office of Basic Energy Sciences

Approximately 135 others were in attendance in the course of the two-day meeting.

Thursday, February 26, 2009

BESAC Chair **John Hemminger** called the meeting to order at 8:47 a.m. and introduced **Rachel Smith,** who made administrative, safety and convenience announcements. Afterwards, he thanked each member and Sub-Committee for attending.

Dr. Hemminger said this BESAC meeting would be unlike others because it would be the first as part of President Barack Obama's administration and the release of the first part of his budget.

He asked **Patricia Dehmer** to update the Committee with news from the Office of Science. Her presentation[1] included President Obama's plans for science, energy and the environment; Energy Secretary Steven Chu's plans for the Department of Energy (DOE); and budgets. All of these topics were influenced by the economic recession, volatile energy prices and the increased sense of urgency about climate change as a global issue.

In discussing the administration's energy plan, **Dr. Dehmer** said that within 10 years, we need to save more oil than we currently import from the Middle East and Venezuela combined; put one million plug-in hybrid cars – cars that can get up to 150 miles per gallon – on the road by 2015; generate 10 percent of our electricity from renewable sources by 2012 and 25 percent by 2025; and implement an economy-wide, cap-and-trade program to reduce greenhouse gas emissions 80% by 2050.

Next, **Dr. Dehmer** discussed DOE's top five priorities and goals. These are:

- Science and discovery: invest in science to achieve transformational discoveries.
- Change the landscape of energy demand and supply: increase energy efficiency and develop and deploy clean, safe, low carbon energy supplies.
- Economic prosperity: create millions of green jobs and increase competitiveness.
- National security and legacy: maintain nuclear deterrent and prevent proliferation.
- Climate change: position the United States to lead on climate change policy, technology and science.

Important in accomplishing these goals is connecting basic and applied sciences, re-energizing the national labs as centers of great science and innovation, and creating an effective mechanism to integrate national laboratory, university and industry activities.

[1] Dr. Dehmer's full presentation is available at: http://www.er.doe.gov/bes/BESAC/Meetings.html#0209

Dr. Dehmer discussed the Office of Science FY 2009 budget. She noted that the Omnibus Appropriations Bill had passed the House. The conference mark for BES is $1,571,972. This compares with the FY 2009 Current Appropriation of $1,252,756. (See Dr. Dehmer's presentation for full budget details). With the conference mark, all SC programs are on a doubling path, as planned in the American Competitiveness Initiative that began in FY 2007.

Dr. Dehmer then looked at a 12-year history of requests versus appropriations for SC programs. For the most part, over the past few years, appropriations for SC programs have been lower than the requests. The recently passed American Recovery and Reinvestment Act of 2009 (ARRA, P.L. 111-5, signed by President Obama on February 17, 2009) contained some $40 billion in funding for Department of Energy programs. Of that total, $1.6 billion is for the Office of Science categories. The largest slice of DOE's funding is allocated to the Office of Energy Efficiency and Renewable Energy. "There is incredible pressure to use the money well and wisely," **Dr. Dehmer** said.

The ARRA categories for funding in SC are:

- Facility Construction – Funds to accelerate completion of a number of ongoing construction projects for major scientific user facilities, major items of equipment for those facilities and laboratory infrastructure. General Plant Projects (GPP) are included to update laboratory infrastructure and establish new laboratory research space, renovate existing laboratory space, demolish inadequate facilities and improve utility systems across SC labs.
- Facility Operations/Infrastructure – Funds to increase operations, experimental support and infrastructure improvements at scientific user facilities across SC.
- Research – Funds to support selected research programs across SC and are chosen to minimize out-year mortgages. Energy Frontier Research Centers are included.
- Computing – Funds to support advanced networking; mid-range distributed computing; and computation partnerships in areas important to DOE energy missions.
- Fellowships – A program to support graduate students and early career scientists was proposed by SC and is under discussion within DOE.

Dr. Dehmer noted the report of a subcommittee to the BES Advisory Committee, the "Next Generation Photon Sources for Grand Challenges in Science and Energy." Because of these kinds of reports, and the prior workshops and basic research needs reports prepared over the previous eight years, BES is extremely well positioned to take advantage of a "tsunami" of discretionary funds that the Secretary will have to invest. "We look forward to exciting times in the next few months."

Dr. Hemminger asked the Committee and Sub-Committee members if they had any questions for **Dr. Dehmer**.

Marc Kastner said he agrees with **Dr. Dehmer** that "this is a wonderful time."

Bruce Gates asked what degree of climate change is affecting DOE.

Dr. Dehmer said the Office of Science is looking at atmospheric modeling and climate change.

Kate Kirby said this "looks good for students." She asked if the funding will be distributed quickly for graduate students.

Dr. Dehmer said "we will have to put some thought into this and it will 'lag behind' other projects in priorities.

Dr. Hemminger said he believes details will be coming out very quickly.

At 9:35 a.m., **Hemminger** introduced **Harriet Kung** to provide news from the Office of Basic Energy Sciences (BES).

Dr. Kung also presented[2] some thoughts on the new administration and DOE, BES budget and staffing updates, status of various initiatives, and the NAS catalysis program review.

In discussing the new administration appointments, **Dr. Kung** noted that President Obama had selected Dr. Steven Chu, Director of the Lawrence Berkeley National Laboratory, to be Secretary of Energy. Nominees for other top DOE positions were still to be named.

Dr. Kung noted several statements in support of energy and scientific research, including the the statement in the President's Inaugural Address, "We will harness the sun and the winds and the soil to fuel our cars and run our factories." And Secretary Chu's statement, "As a scientist, I understand the seriousness of the economic and climate challenges we face. But I remain optimistic that scientific research will once again bring us transformative solutions."

Continuing **Dr. Dehmer's** comments on the ARRA funding, **Dr. Kung** noted that BES plans to invest the additional funding to:

1. accelerate construction projects and the completion of major items of equipment;
2. implement augmentation of capital equipment; and
3. support priority research.

Expanding core research programs, Energy Frontier Research Centers (EFRCs), and supporting world class scientific user facilities are also high priorities. **Dr. Kung** could not discuss any details of the FY 2010 budget until the full DOE budget request is released sometime later in the spring.

[2] Dr. Kung's full presentation is available at: http://www.er.doe.gov/bes/BESAC/Meetings.html#0209

In discussing H.R.1105, the Omnibus Appropriations Act of 2009, **Dr. Kung** noted that the Senate Report contained language to move $59.5 million of basic solar research from the Office of Basic Energy Sciences to the Office of Energy Efficiency and Renewable Energy. This language did not survive in the as-passed bill (P.L.111-8). Full funding is provided (in P.L. 118-8) to support the operations of the major scientific user facilities and the five Nanoscale Science Research Centers, as well as additional instrumentation for the Spallation Neutron Source and the Linac Coherent Light Source.

Dr. Kung presented an updated organization chart of the Office of Basic Energy Sciences. She said there were many openings in the different divisions and BES is actively seeking to fill these positions. She requested that BESAC members assist in finding suitable candidates. Some of the recent hires have been Committee Manager **Katie Perine,** Program Analyst/BESAC and **Ehsan Khan**, Program Manager in the Materials Sciences and Engineering Division, reporting to **Jim Horwitz**.

Next, **Dr. Kung** provided an update on Energy Frontier Research Center (EFRC) and Single-Investigator and Small-Group Research (SISGR) initiatives. **Dr. Kung** said it will take "dream teams" of highly-educated researchers, equipped with forefront tools and focused on the most pressing challenges to increase the rate of discovery. To make progress most rapidly, these teams must work to close gaps between needs and capabilities in synthesis, measurement, theory and computation. U.S. leadership requires BES to lead a vigorous national effort to recruit the best talent, and to inspire today's students and young researchers to be the discoverers, inventors and innovators of tomorrow's energy.

The EFRC initiative is tackling energy challenges in a new era of science and engaging the talents of the nation's foremost researchers. BES announced the initiation of EFRCs to accelerate the scientific breakthroughs needed to create advanced energy technologies for the 21st century. The EFRCs will pursue the fundamental understanding necessary to meet the global need for abundant, clean and economical energy.

EFRCs will pursue collaborative fundamental research that addresses both energy challenges and science's grand challenges in areas such as:

- Solar energy utilization
- Catalysis for energy
- Electrical energy storage
- Solid state lighting
- Superconductivity
- Geosciences for nuclear waste and CO_2 storage
- Advanced nuclear energy systems
- Combustion of 21st century transportation fuels
- Hydrogen production, storage and use
- Materials under extreme environments
- Conversion of biological feedstock to portable fuels
- Others

The timeline for the EFRC solicitation is as follows:

- February, 2008: Rollout in the FY 2009 Budget Request and at BESAC;
- April, 2008: EFRC Funding Opportunity Announcement (FOA) issued;
- July, 2008: BES received 251 letters of intent;
- October, 2008: BES received 261 full proposals;
- February, 2009: Merit reviews were conducted;
- April, 2009: Awards to be announced.

Regarding SISGRs, **Dr. Kung** discussed tackling energy challenges in a new era of science. SISGRs will significantly enhance the core research programs in BES and pursue the fundamental understanding necessary to meet the global need for abundant, clean and economical energy. Awards are planned for three years, with funding in the range of $150-$300K per year for single-investigator awards and $500-$1,500K per year for small-group awards. The areas of interest include:

- Grand challenge science: ultrafast science; chemical imaging, complex and emergent behavior;
- Use-inspired discovery science: basic research for electrical energy storage; advanced nuclear energy systems; solar energy utilization; hydrogen production, storage, and use; geological CO_2 sequestration;
- Other basic research areas identified in BESAC and BES workshop reports with an emphasis on Nanoscale phenomena; and
- Tools for grand challenge science: mid-scale instrumentation; accelerator and detector research (exclude capital equipment supports).

The SISGR solicitations had 879 whitepapers, with 88% from universities, 11% from DOE labs and 1% from other institutions. Energy sources (i.e. advanced nuclear energy system, solar energy utilization and geological sequestration of carbon dioxide) accounted for 31% of the papers; Grand Science Challenges and Tools (ultrafast science, chemical imaging, mid-scale instrumentation and complex systems and emergent behavior) accounted for 28%. In addition, energy storage (16%), cross-cutting (15%) and energy efficiency (10%) were included.

The timeline of the SISGRs began in February 2008, with BES discussing the SISGR plan at BESAC. In April 2008, BES issued a SISGR Web notice. By October 2008, BES received approximately 880 whitepapers. By March 2009, it is tentatively scheduled that BES will notify PIs of whitepaper decisions. In April 2009, full proposals are tentatively due to BES. In June 2009, BES is tentatively scheduled to issue SISGR awards.

Dr. Kung then noted the December 2008 report, *New Science for a Secure and Sustainable Energy Future.* She said the report is "serving the present and shaping the future." The present pace of change for clean energy technologies is not sufficient to meet future needs. BES must lead a major campaign focused on increasing the rate of discoveries and establishing U.S. leadership in next-generation carbon-free energy technologies. She also stated that significant discoveries will come at the intersection of control science with complex functional materials. BES must move aggressively in these

directions lest the U.S. fall behind in the global competition for the discoveries that underpin future energy sources, systems and processes.

Dr. Kung noted the October, 2008 BESAC Workshop, *Solving Science and Energy Grand Challenges with Next Generation Photon Sources*, and presented a number of statistics regarding the BES light sources:

The four BES light sources hosted 8,492 users in FY08 – APS (39%), NSLS (25%), ALS (23%) and SSRL (13%). The size and demographics of the user community have changed dramatically since the 1980s when only a few hundred intrepid users visited the synchrotron light sources each year. **Dr. Kung** said now the "user" is a researcher who proposes and conducts peer-reviewed experiments at a scientific facility or conducts experiments at the facility remotely. A user does not include individuals who only send samples to be analyzed and pay to have services performed or who visit the facility for tours or educational purposes. Users do not include researchers who collaborate on the proposal or subsequent research papers, but do not conduct experiments at the facility. For annual totals, an individual is counted as one user at a particular facility no matter how often or how long the researcher conducts experiments at the facility during the year. The users included 31% first-time users, and 27% female users. Almost all of the research was nonproprietary (97%).

Constrained budget appropriations have hindered the growth in the number of users. **Dr. Kung** said the BES programs provide complete support for the operations of the facilities. Furthermore, BES continues as the dominant supporter of research in the physical sciences, providing as much as 85% of all federal funds for beam lines, instruments and PI support. Many other agencies, industries and private sponsors provide support for instrumentation and research in specialized areas such as protein crystallography.

For the four BES light sources, the majority of users continue to be from academia. The number of users from the host institutions has grown from the early days, reflecting a commitment on the part of the host institutions to these user facilities. Notably, the fraction of industrial users has declined over the past 18 years, reflecting the trend of industry to move away from fundamental research.

Dr. Kung's slides included a graph showing that California, Illinois and New York account for most of the domestic BES light source users. California, which has the most, is host state for SSRL and ALS. Illinois is host state for APS, and New York is host state for NSLS. The number of foreign users of the light sources is second, behind California, and greater than New York and Illinois.

Finally, **Dr. Kung** discussed the National Academy of Science Review of the BES Catalysis Science Program. The review was mandated by Section 973 of the Energy Policy Act of 2005 (EPAct 2005, P.L. 109-58, signed by the President August 8, 2005). In response to that requirement, in 2007, BES requested that the National Academy of Sciences Board on Chemical Sciences and Technology conduct the review. The report

concludes that "BES has done well with its investment in the Catalysis Science Program. Its investment has led to a greater understanding of the fundamental catalytic processes that underlie energy applications, and it has contributed to meeting long-term national energy goals by focusing research on catalytic processes that reduce energy use or explore alternative energy sources."

At 10:25 a.m., **Dr. Hemminger** declared a 30-minute break.

At 10:58 a.m., **Dr. Hemminger** called the meeting back to order and requested each Committee and Sub-Committee member introduce themselves and their respective affiliations. He noted the approval of the BESAC report, *New Science for a Secure and Sustainable Energy Future* for which **Crabtree** and **Marc Kastner** served as co-chairs. He added that the report was a "very thought provoking report," was nicely done and had substantial implications. He said that we will discuss tomorrow options to getting these reports out as soon as possible.

Dr. Hemminger called on **George Crabtree** to introduce the Photon Workshop Process and discuss the development of the report.

Crabtree's presentation included the New Era concept, the photon workshop and report preparation. The New Era Subcommittee of BESAC includes **Crabtree** and **Kastner**, as well as several people in attendance at the meeting. **Michelle Buchanan, Thomas Mallouk, John Sarrao, Michael Klein, Arthur Nozik, Julia Phillips, Sue Clark, Frank DiSalvo, Don DePaolo, Simon Bare, Wayne Hendrickson, Wolfgang Eberhardt, Franz Himpsel, Michael Norman, Andrea Cavalleri, Carl Lineberger, Yet-Ming Chiang, Pat Looney** were acknowledged for their hard work on the project. In addition, **Roger Klaffky, Michael Casassa, Jim Horwitz** offered technical support.

The background of the project was examined, with Crabtree stating the New Era concept was first discussed with BESAC at the February 21-22, 2008 meeting. The first New Era meeting was held July 24-25, immediately following the summer BESAC meeting. There was a three-part charge:

- Summarize basic research needs and Grand Challenge reports
- Recommend implementation plans to address the challenges
- Identify grand energy and science drivers for future light sources and the "photon attributes" required to pursue them. Parts I and II concern new science reporting, which will be discussed Friday morning. Part III will be discussed this morning, and concerns the photon workshop report.

As mentioned earlier, **Eberhardt** and **Himpsel** served as co-chairs for the Photon Workshop October 27-28. The guidelines were to solicit broad community input, focus on science drivers and photon attributes required to pursue them. No specific machine designs were to be considered. Rather, a survey was to be prepared of photon attributes of existing and envisioned classes of photon sources: third generation storage rings,

energy recovery, free electron lasers, high harmonic generation lasers and lastly, "killer applications" that are especially compelling.

Crabtree discussed the organization of the workshop, with the morning plenary sessions for background, breakout groups on nine science areas and plenary reports of the breakout groups. There was also a post-workshop writing day for the breakout chairs. In addition, there was a photon workshop website developed for ongoing communication among participants.

After the workshop was held, the breakout groups refined the content and organized the science drivers into five cross-cutting challenges and three stages of difficulty. Recent reports on future light sources from the U.S., Europe and Asia were consulted. There were comments on drafts from breakout chairs and New Era Sub-Committee members. The final revision was received on February 16.

At 11:00 a.m., **Hemminger** requested all comments by the Committee and Sub-Committee be held until later in the afternoon. He introduced **Franz Himpsel** to discuss the Photon Workshop, *Next Generation Photon Sources for Grand Challenges in Science and Energy*, held October 27-28, 2008.

Himpsel told the Committee how the report was "split up" and said he would be discussing the "greatest opportunities." He will be covering Sections 1-4 of the report and **Wolfgang Eberhardt** will do the others.

Himpsel began his presentation[3] by discussing the third charge from BESAC to the New Era Committee. The charge stated that we must identify new science and the photon attributes of the next generation light sources required to carry it out, such as: energy range (from vacuum UV to hard X-rays), coherence, time resolution (femtosecond regime), brilliance (average, peak) and polarization (circular, linear).

There were approximately 100 participants in the workshop, providing overview talks concerning energy and life sciences; next generation light sources concerning free electron lasers, energy recovery linacs, high harmonic lasers and next generation storage rings. The breakout groups had extensive discussions and highlighted their one and a half day meetings with a write-up.

The breakout groups discussed a variety of subjects, with some of the coordinators being BESAC members (**Hemminger** and **Nora Berrah**). The group generated an extensive number of scientific opportunities, which is detailed in Section Four of the report. Among the subjects are Nanoscale electrons and spins; Correlated electrons; Catalysis and chemistry; Nano-materials for energy applications; Life sciences; Atomic and molecular physics; Matter under extreme environments and environmental science, earth science; Novel structural and electronic materials and the cross-cutting issues.

[3] Dr. Himpsel's full presentation is available at: http://www.er.doe.gov/bes/BESAC/Meetings.html#0209

The findings are five cross-cutting challenges, with three stages of difficulty. The first stage (Stage A) is designing materials, controlling processes and the synthesis-analysis-prediction loop. The second stage (Stage B) is real-time evolution of chemical reactions, movement of electrons and spin, as well as individual nano-objects. The third stage (Stage C) is statistical laws of complex systems, small and fast.

Himpsel showed a comparison with the NSF study (Light Source Panel Report, September 15, 2008). The science case was probing picoseconds properties of magnetic materials. There are some exciting new scientific frontiers in areas such as lenseless imaging and ultrafast dynamics and spectroscopy that are enabled by these properties. Exploiting this scientific frontier in the U.S. is essential for our competiveness in strategic areas of science, engineering, workforce development and could have significant commercial impact.

He also noted the Berkeley Workshop Report (*Toward Control of Mater: Basic Energy Science Needs for a New Class for X-Ray Light Sources, LBNL, September, 2008*) and listed the scientific areas addressed by new light sources: Chemical Physics; Atomic, Molecular and Optical Physics; Magnetization and Spin Dynamics; Correlated Materials; and Exploration of Nanoscale Dynamics and Complexity. **Himpsel** said "no light source in existence, under construction, or on the drawing board can deliver the beams required for the cutting edge science described in this document."

Himpsel also noted the White Paper report was prepared by scientists from Argonne National Laboratory (ANL), Brookhaven National Laboratory (BNL), Lawrence Berkeley National Laboratory (LBNL) and SLAC National Accelerator Laboratory, including the University of California and Stanford University, *Science and Technology of Future Light Sources*, December, 2008. The white paper contains a brief history of X-Ray science, as well as a summary of the scientific drivers for future X-Ray sources.

Himpsel identified two "killer-apps" science drivers for new light sources:

- Femtosecond time resolution, which opens completely new territory where atoms can be followed in real time and electronic excitations can be resolved down to their intrinsic time scale.

- Sub-nanometer spatial resolution, which opens the length scale where quantum confinement dominates electronic behavior and where catalytic activity begins. Spectroscopy of individual nanometer-scale objects, rather than conglomerates, will eliminate blurring of the energy levels induced by the size and shape distribution and thereby reveal active sites in catalysis and the traps where electrons are lost in photovoltaics.

Hemminger said he would like to request **Wolfgang Eberhardt** begin his presentation after lunch. The meeting was adjourned at 11:58 a.m.

At 1:37 p.m., **Hemminger** introduced **Wolfgang Eberhardt** to continue the discussion regarding the report of the Sub-Committee to the BES Advisory Committee. **Eberhardt** said storage rings are the foundation of success of synchrotron radiation research. The insertion devices are the sources of high brilliance radiation. Next, **Eberhardt** looked at the average brilliance versus the amount of photon energy and the influence of the electron beam emittance. He also questioned how we can improve X-ray sources. **Eberhardt** compared third generation X-ray sources to fourth generation. Specific characteristics are given in **Eberhardt's** presentation[4].

In summary, the next generation of photon sources is very compelling. Eberhardt concluded that the source parameters needed are not covered by a single type of source.

At 3:07 p.m., **Hemminger** asked the Committee/Sub-Committee members to look at the report and consider how it could be improved.

Hemminger said we need high-level comments, not word-smithing. He said "if something is edited out, it can be put back in after discussion. We can discuss and transmit these via email." Edits should be sent to **Crabtree**.

Sylvia Ceyer said the report needs to address the hard core chemistry questions. "We can get broad information about photon stabilities. This is what we need in the future."

Martin Moskovits congratulated everyone who drafted the report. "Every section begins with an application. You can see the correlation. Most of this information will be very valuable. The one thing I did not see in the report was an outreach to the new population of users who discover these tools."

Hemminger agreed that new user outreach should be included. He also questioned if all user communities had been addressed.

Dr. Kung noted that the report will help the Office of Science to formulate plans for the next 10 years.

Kate Kirby said she was having a hard time with the report. She questions if the current agenda can be transformed into new science. She believed that the language is not consistent. It needs to be parallel and more synergistic, she said.

Crabtree said the Committee/Sub-Committee will work "in sync" to make sure both reports are "connected." He suggested having two reports, one being more high-level and technical. Both will be somewhat different.

Simon Bare said he agreed completely with **Kate Kirby's** comments.

William McCurdy Jr., said there have been workshops and gatherings to make a list of the numerous opportunities. In these reports, he believes it lacks "answering the

[4] Dr. Eberhardt's full presentation is available at: http://www.er.doe.gov/bes/BESAC/Meetings.html#0209

questions." We need to make the connections between the nine areas and how X-rays affect each. The goal is to make clear that it is more than just a light source, more complicated.

Nora Berrah agrees there needs to be more details.

Hemminger asked **Crabtree** if he would provide a synopsis tomorrow morning of everything discussed thus far. **Hemminger** said he has heard the report was fragmented instead of a book of wisdom. He heard it was written in more than one voice. The challenges need to be highlighted and strengthened. We should not concentrate solely on facility science. We need to integrate all sciences. This report should act as an advisory, showing more action, how we plan to get tasks accomplished. The report should include more visionary themes and topics.

The organization of the report needs to have an expanded executive summary, have an introduction and display vision. **Hemminger** believes this will be the part of the report that will most likely be read.

Hemminger is concerned that over the past few years, we have been talking about what can get accomplished by doing the recommended tasks. He believes we need to concentrate on what will not be accomplished or can't be done if the recommended items are not addressed. We need to show examples, such as "we can't do X, without doing Y." This needs to be every prominent throughout the report.

Harriet Kung said it is highly desirable to have this report by April.

Hemminger said that in the past, the Committee/Sub-Committees have had a "homework assignment" to work out these issues. Several BESAC members have agreed to assist **George** and **Marc** to incorporate the changes we have discussed this afternoon. **George** will provide an update tomorrow morning concerning implementing these changes.

At 4:28 p.m., **Hemminger** asked for public comment.

Rick Osgood, Columbia University, suggested incorporating an emphasis on scattering in the report.

Murray Gibson, Argonne National Laboratory, said as a physicist, he agrees we should write about history, but need to put our focus on the future. He said imaging is important and has a great potential in the next 20 years in what could be the "imaging revolution."

Alan Hurd, Los Alamos National Laboratory, said the next generation photon scattering will see "explosive growth in the community." He added that it will be interesting to look at the data along with neutron scattering. The "pro-team" has started to grow in photons and neutrons. He suggested that BESAC look at this in the near future and urged authors to look at this with a global view.

Hemminger said he would start the meeting tomorrow morning with an hour set aside for the new science report and discuss what type of roll-out we should look at in getting this report distributed. He believes we need to advertise the report to keep pressure so that people appreciate the fundamentals of science.

With no additional public comment**, Hemminger** adjourned the meeting at 4:35 p.m.

Friday, February 27, 2009

At 8:32 a.m., **Hemminger** called the meeting to order. He said we would start the meeting off with a short discussion on the report the Committee discussed in November 2008. BESAC members should have had a copy to review. We must get the report in front as many people as possible

Hemminger introduced to **George Crabtree** to discuss the *New Science for a Secure and Sustainable Energy* issue[5]. **Crabtree** began with a discussion of U.S. dependence on imported oil. The gap between consumption and production will continue to grow. During the 1970s, production peaked and has continued to decrease over the past few decades, while consumption (millions of barrels per day) has continued to increase greatly. The cost to the economy has been a staggering $700B per year in 2008, during the recent peak prices. Currently, we are transferring $200B per year to foreign oil producers. We need to look at the unpredictability and the threat of interruption regarding the economy, lifestyle and national security. We must find alternatives to imported oil through biofuels, electricity and solar fuels.

Another problem is greenhouse gases and climate change. Approximately 66 percent of carbon dioxide emissions come from power plants and automobiles. These emissions have risen steadily over the past 50 years. There are also permanent changes in weather patterns, agricultural networks and coastal geography. The cost of accommodation is higher than preventative costs of reducing emissions.

In examining oil and carbon dioxide, it is "woven into our fabric" that we drive our cars on imported oil, with unfettered emissions of CO_2. Alternatives require fundamental changes in business as usual. We must find more sustainable, next generation, energy technology.

In sustainable next-generation energy technologies, solar electricity is a fully sustainable energy chain. It lasts a long time, does no harm to the environment and leaves no change. "The scientific breakthroughs needed are lower costs, higher efficiency photovoltaics, third generation materials and nanostructures, as well as electricity storage," **Crabtree** said.

In carbon sequestration, the breakthroughs needed are chemical reactivity with rocks in extreme environments, migration through porous rocks, geologic monitoring and predictive modeling, as well as leakage routes to the atmosphere. Although we have

[5] Dr. Crabtree's full presentation is available at: http://www.er.doe.gov/bes/BESAC/Meetings.html#0209

hundreds of years of coal supply, we will eventually reach limits. Sequestration gets a high sustainability score for not emitting carbon dioxide, but a "wait and see" score for underground storage. There are many unanswered science questions – we do not know how harmful it might be. The carbon capture and sequestration chain leaves many changes – coal is removed from the earth, carbon dioxide is injected into the earth.

With nuclear electricity, uranium resources are depleted and nuclear wastes must be stored. The breakthroughs needed are materials for extreme environments of high temperature, high radiation flux, high corrosivity as well as geologic monitoring and modeling. Similar tradeoff to sequestration: carbon dioxide in the atmosphere is traded for radioactive waste underground.

In replacing conventional oil, biofuels last a long time, do no harm and leave no change. Oil sands and shale and coal to liquids place additional carbon dioxide into the environment. The breakthroughs needed are cellulosic breakdown to sugar or fuel, as well as chemistry of oils sands and shale to fuel.

To electrify the transportation sector, breakthroughs needed include higher energy density batteries, and more effective catalysts, membranes and electrodes in fuel cells.

Sustainable energy requires controlling complex, functional, high-tech materials and chemistry. This is very different from traditional energy, which is based on commodity materials, disposable fuels and combustion. Sustainable energy includes the use of sunlight, wind, water, geothermal and biomass.

"We are now at the dawn of a new era," said **Crabtree**. "We are able to build materials with atom-by-atom precision, predict behavior of materials that have not been made and design materials for specific tasks. The breakthroughs to next generation sustainable energy technologies are now within reach."

There are challenges and opportunities that lie ahead. We must begin "weaning" ourselves from imported oil and carbon dioxide emissions. This will require structural changes, not just a refinement of business as usual. Next-generation sustainable energy technologies must operate at far higher performance, with far more complex, functional, high-tech materials. Developing these materials requires scientific breakthroughs, which means we must control materials performance and chemical change at atomic, molecular lengths scales and sub-femtosecond time scales. Lastly, scientific breakthroughs in materials and chemical change are key. We must replace the economic drain of imported oil with economic growth from exporting next-generation energy technologies. The next generation energy technologies will be born. "Will we be buying or selling these new technologies?" **Crabtree** asked. "We want to be sellers."

Since 2002 the BESAC and BES workshops have identified the roadblocks to next generation sustainable energy technologies. "We know what they are," **Crabtree** said. "The challenge now is to overcome them. Each one of these reports generated from the workshops is a treasure trove of information. They are long, 150 or more pages of good,

well-thought information. If you want a quick overview, read the executive summary, the introduction and the conclusions. These are short; you can read them in an hour for each report."

Crabtree closed his presentation by offering the following recommendations:

- "Dream Teams" of the best scientists working with the best tools and focused on the most important problems are needed to achieve breakthroughs and transformational change. (Take the best from around the country and have them work together.)

- The BES Energy Frontier Research Centers will launch these teams: an essential first step.

- BES must launch an aggressive program to recruit and train the best and the brightest students and early career scientists. (These problems are decades long. We need energy scientists and new talent right away.)

- A massive and sustained investment in BES is needed immediately to achieve the breakthroughs in materials and chemical change needed for next-generation energy technologies. (This needs to start immediately.)

"The problems are so difficult that they cannot be solved by single scientists working alone," said **Crabtree**. "The best scientists will not usually be located at a single institution – they must be drawn from across the country. EFRCs are a model for launching "Dream Teams," but this is only testing the water. We need to refine and enlarge the concept, until it has the critical mass and the momentum to actually solve the basic science roadblocks to next generation sustainable energy technologies."

Hemminger asked the Committee/Sub-Committee for comments. He said he appreciates **George** and **Marc's** hard work.

Bruce Gates said he was enthusiastic, but needs to see more evidence when using phrases like "fundamental research needed now." We haven't made the case, he said. You have asserted that we need the funding, but the evidence needs to be stated clearer."

Hemminger said this is going to continue to evolve, but agrees that there needs to be specific examples. He said "**George** provided superconductivity examples, and the breakthroughs that are needed. But, we need to explain why we need to do something different and provide more and better examples."

Hemminger added that the one question in **Crabtree's** presentation that should stand out the most is "Are we going to be buying or selling?"

At 9:17 a.m., **Hemminger** requested that **Marc Kastner** review the "outreach" to *New Science*.

With the outreach for the *New Science* report, **Kastner**[6] said the Sub-committee created a one-page summary and made an effort to get the report read by as many opinion- and decision-makers as possible. He said the New Era Sub-committee held a conference call to decide on the list of people who should receive the report. The organizations included APS, ACS, NRC/NAS/NAE, as well as organizations in Germany, Japan, and Belgium, among others. In addition, the report was sent to Senators Bingaman, Feinstein, several Representatives and opinion makers, such as former Lockheed Martin Chairman and CEO Norman R. Augustine, Tom Friedman and university presidents. **Kastner** stated that he had received a lot of help from MIT and the University of California.

He said MIT Geophysics Professor and Head of MIT's Earth, Atmospheric and Planetary Sciences Department Maria Zuber attended an Innovation Roundtable on December 15, 2008 and discussed the importance of science. She was invited by Speaker Nancy Pelosi and Congressman Rush Holt to testify at the House Democratic Steering and Policy Committee Hearing January 7, 2009. Zuber specifically mentioned and passed out copies of the BESAC report and urged funding for EFRCs.

The following is an excerpt from Zuber's the testimony from that appeared on the MIT Web site:

"Funding for research and education in science and technology should be a major priority in the economic recovery package Congress will soon be talking up," said MIT geophysics professor Maria T. Zuber in testimony she gave on Jan. 7 before the Steering and Policy Committee of the U.S. House of Representatives.

"Energy and climate could be our Sputnik challenge -- a new way to infuse our best talent into our science and technology system," said Zuber. The launching of Sputnik by the Soviet Union in 1957 spurred major U.S. investment in education in science, math and technology and led to a boom in those areas.

Zuber emphasized that while direct economic stimulus plans could lead to short-term economic benefits, it takes education and technological innovation to create lasting, long-term economic growth and job creation.

Hemminger, Crabtree and **Kastner** also briefed House and Senate staffers on February 3, 2009 (important Committees were represented); the following day, briefed the Center for Strategic and International Studies (CSIS) (big audience of 150 people); and Crabtree would testify before Senator Bingaman's committee.

The CSIS meeting stated "The pathway to a secure, low-carbon energy economy will undoubtedly require accelerated development of a suite of advanced technologies, underpinned by a sustained commitment to research and development. Many options hold great promise – solar photovoltaics, efficiency, battery and storage technologies – but their realization will rely on further advances in our understanding of basic science."

[6] Dr. Kastner's presentation is available at: http://www.er.doe.gov/bes/BESAC/Meetings.html#0209

Crabtree said The House convinced the Senate to add money to the Office of Science.

Hemminger asked the Committee/Sub-Committee for comments.

Kate Kirby congratulated **Kastner** on the success. She believes it captures the essence of science and gets people excited. "The Committee has done a fabulous job to get to the Government and Congress." She added that if universities see the future, the available funding will be tremendously valuable for future research."

Nora Berrah said it is a "wonderful document." She suggested that all Committee members become more active and involved in getting the message out.

At 9:30 a.m., **Hemminger** declared a break.

At 9:50 a.m., **Crabtree** presented comments from yesterday's meeting.

Crabtree said he appreciated all of the Committee and Sub-Committee members that worked with him and **Kastner** in the night before to incorporate new ideas into Photon Workshop Report.

Some of the comments included:

- Making a better connection between the New Era report and energy
- Integrated wisdom
- Visionary outlook
- Make the report have a single voice and style
- Beyond photons – integration of other characterization methods; supporting capability (e.g., for catalysis); theory; computation; data manipulation; end stations, optics, detectors; and dream teams
- Science communities beyond materials and chemistry (e.g., life, earth and environmental)
- Train next generation of scientists
- Add more sidebars relating to macromolecular crystallography (example of new communities); replicate photosynthesis by studying photosynthesis (energy); dynamics of life sciences; successes for industry

Additional comments and the "elevator messages" included:

- Controlling matter and energy in complex materials creates a tipping point for sustainable energy
- Observing phenomena on relevant length and time scales is beyond reach today (Observe → Understand → Control)
- Needs
    - Temporal evolution of electrons, spins, atoms, and chemical reactions, down to fs

    - Probing isolated nano-objects or nano-regions of inhomogeneous samples, by spectroscopy with an energy resolution smaller than the intrinsic line width, or by imaging with a spatial resolution at the atomic limit
- Today's photons fall short
    - Peak brightness for temporal resolution and dynamics (fs/attosec resolution)
    - Average brightness for spatial resolution (nm imaging of isolated objects)
    - Coherence for lenseless imaging, holography
- Photons are not enough, we need the source, optics, end-station and detector, as well as theory and experiment (including in situ synthesis and real-time observation)
- Tools of control science profit broader communities as well life science, earth science, environmental science
- Dream teams, workforce development

Crabtree said that the goal of the Sub-Committee would be to provide a more uniform style. The goal is to improve the report to make it more comprehensible for all audiences. The executive summary and introduction should be written to have a more "visionary" feel and needs to be more exciting and provide more background information. This section has been assigned to **John Sarrao. Michael Norman** will bring more clarification to Chapter 6 with support from Chapter 4 concerning photon science drivers. The grand themes of photon science will be written by **Crabtree** and **Sarrao**, with cross-cutting challenges from Chapter 3. After incorporating all of these comments, the conclusion will be re-written by **Crabtree**.

With that in mind, the second draft of the report will have a refined structure to include:
Section 1 - Executive Summary
Section 2 - Background
Section 3 - Cross-Cutting Challenges
Section 4 - New Scientific Opportunities
Section 5 - Photon Sources
Section 6 - Conclusions
Appendix 1: Related Studies.
Appendix 2: Photon Attributes for Individual Scientific Opportunities

Crabtree concluded by stating "we are taking the pieces we have already written and making minor edits, changing the order slightly and expanding on certain messages, using the standard Basic Research Needs format. **Franz** and **Wolfgang** will give this revision to a new writer and the report will have a fresh look for those who are not topic experts."

At 10:05 a.m., **Hemminger** thanked **Crabtree, Kastner** and all of the Committee and Sub-Committee members that had volunteered and "stepped up to the challenge and assisted in making this report the best it can be." He asked if there were additional comments regarding the revision.

Several members suggested a shorter, more condensed “elevator message” type of summary.

Hemminger asked if this should be a short one pager or a glossy five page version.

Kung said she would like to have the final “glossy” copy that would convey our future planning by mid-April.

Crabtree said that was “do-able.”

Hemminger asked for a show of hands from the Committee/Sub-Committee to move forward with the report. All Committee/Sub-Committee members, with the exception of Simon Bare, approved.

Hemminger said the report should be distributed to universities and PowerPoint presentations could possibly be developed to “get the message out.” He added that some of the reports would need to be more technical than others.

Hemminger opened the floor to public discussion.

Hemminger said he would welcome concrete suggestions, PowerPoint slides and other information to incorporate into the report. “I know there are some good ideas and great examples out there.”

There being no other public input, **Hemminger** adjourned the meeting at 10:29 a.m.

Respectfully submitted,
Raymond P. Johnson Jr.
March 19, 2009

[Revised MIS 6/26/09]