Minutes of the
Basic Energy Sciences Advisory Committee Meeting
July 9–10, 2009
Marriott North Bethesda Hotel and Conference Center,
Bethesda, Maryland

BESAC members present:

Simon Bare
Nora Berrah
Sue Clarke (Thursday afternoon and Friday only)
Peter Cummings
George Flynn
Bruce Gates
John Hemminger, Chairman
Sharon Hammes-Schiffer
William McCurdy, Jr.
Daniel Morse
John Richards
John Spence
Douglas Tobias
John Tranquada

BESAC members absent:

Sylvia Ceyer
Frank DiSalvo
Mostafa El-Sayed
Laura Greene
Michael Hochella
Bruce Kay
Kate Kirby
Martin Moskovits
Kathryn Nagy
Kathleen Taylor

Also participating:

Linda Blevins, Senior Technical Advisor, Office of the Deputy Director for Science Programs, Office of Science, USDOE
William Brinkman, Director, Office of Science, USDOE
Michael Burke, Manager, Materials Center for Excellence, Westinghouse Electric
Altaf Carim, Program Manager, Scientific User Facilities Division, Office of Basic Energy Sciences, USDOE
David Carlson, Chief Scientist, BP Solar
George Crabtree, Associate Director, Materials Science Division, Argonne National Laboratory
Patricia Dehmer, Deputy Director for Science Programs, Office of Science, USDOE
Linda Horton, Director, Materials Science and Engineering Division, Office of Basic Energy Sciences, USDOE
Shane Kosinski, Acting Deputy Director, ARPA-E, USDOE
Harriet Kung, Associate Director of Science for Basic Energy Sciences, USDOE
Alex Malozemoff, Chief Technical Officer, American Superconductor Corp.
Celia Merzbacher, Vice President, Semiconductor Research Corp.
Frederick M. O'Hara, Jr., BESAC Recording Secretary
Katie Perine, BESAC Committee Manager, Office of Basic Energy Sciences, USDOE
Eric Rohlfing, Director, Chemical Sciences, Geosciences, and Biosciences Division, Office of Basic Energy Sciences, USDOE
Marvin Singer, Senior Advisor, Chemical Sciences, Geosciences, and Biosciences Division, Office of Basic Energy Sciences, USDOE

Rachel Smith, Oak Ridge Institute for Science and Education

About 120 others were in attendance in the course of the two-day meeting.

Thursday, July 9, 2009
Morning Session

Chairman **John Hemminger** called the meeting to order at 9:03 a.m. **Rachel Smith** made safety and convenience announcements. Hemminger welcomed the members to a new era of BESAC, one in which Patricia Dehmer is not on the agenda. He thanked Dr. Dehmer for all she had done for the scientific community of the United States. [Applause.]

Dr. Hemminger announced that there would be a new charge to the Committee from William Brinkman, the new Director of the Office of Science (SC). He asked the Committee members to study that charge between sessions. The members were asked to introduce themselves.

William Brinkman was introduced to update the Committee on the activities of the Office of Science.[1] He noted that this was his first talk to an Office of Science advisory committee. **Dr. Brinkman** outlined the three themes that describe the work supported by the Office of Science:

- Science for discovery, unraveling nature's deepest mysteries;
- Science for national need through conducting basic research on energy, understanding the Earth's climate, and supporting national security;
- Provision of national scientific user facilities, the 21st century tools of science.

Dr. Brinkman presented the SC budget as a pie chart composed of the different SC programs. He noted that the funding for the Office of Basic Energy Sciences was about one third of the total SC budget. He reviewed the user facilities funded by SC as well as the distribution of users among the facilities. Finally, he noted that the number of light source users has risen from 200 in 1982 to about 9,000 (estimated) for 2009.

SC does a lot to support education. In FY08, participants in opportunities at the DOE labs included: more than 300,000 K-12 students; 21,000 educators; 3,000 graduate students; and 4,200 undergraduate students. These activities were funded by DOE and other federal and nonfederal sources. SC will support more than 4,400 graduate students and 2,700 post docs in FY09. In FY09, the Office of Workforce Development for Teachers and Scientists (WDTS) will support about 550 undergraduates in research internships at the DOE laboratories (and 1,175 in the FY2010 request) and about 280 K–16 educators. The DOE National Science Bowl attracts about 22,000 high school and middle school students every year.

[1] Dr. Brinkman's full presentation is available at: http://www.er.doe.gov/bes/besac/Meetings.html#0923

With American Recovery and Reinvestment Act (ARRA) funds and the FY2010 request, SC initiated the DOE SC Graduate Fellowship Program, supporting more than 160 graduate students in fields important to SC missions. And SC proposes to increase the Graduate Fellowship Program to support approximately 400 graduate students in the out-years.

SC has also initiated a program to support people early in their careers (no more than 10 years since receiving a Ph.D.). The Early Career Research Program will support the development of individual research programs by outstanding scientists, and it will stimulate research careers in the disciplines supported by SC.

The FY 2009 appropriation for the Office of Basic Energy Sciences was $1.57 billion. An additional $555.4 million in Recovery Act (ARRA) funding was also appropriated. Dr. Brinkman noted that this constituted the largest block of SC's appropriation ($4.79 billion) and ARRA funding ($1.6 billion). SC's FY 2010 request to Congress ($4.94 billion) is a substantial increase over the previous year's request. The House mark came in a few million dollars more than was requested; the Senate mark was less than the request as of this meeting.

A new type of enterprise is being proposed in the budget request to spur scientific advance: Energy Innovation Hubs. Eight hubs were proposed, two of which were to be in the Office of Science:

- Fuels from Sunlight; and
- Batteries and Energy Storage.

Each hub would comprise a world-class, multidisciplinary, and highly collaborative R&D team working largely under one roof. These teams would focus on solving critical technology challenges that prevent large-scale commercialization and deployment of the energy systems needed to address our nation's greenhouse-gas-emission, energy-security, and workforce-creation goals. The House budget funds only one such hub.

The $1.6 billion in ARRA funding for the Office of Science is being used to preserve and create jobs and promote economic recovery and to provide investments needed to increase economic efficiency by spurring technological advances in science and health. These funds were to be spent quickly and wisely. SC looked into projects that were shovel-ready, enhanced research infrastructure and supported high-priority R&D, were low risk, and created no out-year mortgages [with two exceptions: Energy Frontier research Centers (EFRCs) and the Graduate Fellowship/Early Career Awards].

Some of the projects funded were:

- the acceleration of ongoing line-item construction projects;
- the acceleration of major items of equipment (MIEs);
- upgrades to SC user facilities;
- laboratory general plant projects; and
- scientific research.

These budgets strike a decent balance between facilities and research, Dr. Brinkman said.

A new charge[2] is being presented to BESAC requesting the conduct of a follow-on study to those of the past 7 years that links basic research with more applied problems in energy technologies. Three main parts of the study will be:

1. Summarize the science themes that emerged from recent BESAC reports with an emphasis on the needs of more applied energy technologies. Identify grand-challenge science drivers that could impact the energy arena in the near term.

2. Identify how the suite of BES-supported and -managed scientific user facilities can impact basic and applied research for energy.

3. Identify other major impediments to successful achievement and implementation of transformative energy technologies, including potential deficits in human capital and workforce development, and possible solutions to these problems.

Two reports are expected from this initiative:

1. a short report along the lines of the *New Era for a Secure and Sustainable Energy Future;* and
2. a more detailed technical report to provide justification. This new study should be regarded as the "technology companion study" to the Grand Challenges report.

Dr. Brinkman concluded with a brief discussion of recent climate trends. The Intergovernmental Panel on Climate Change (IPCC) has pointed out unequivocally that global temperatures are rising. Science needs to solve this problem as well as the problem of an adequate energy supply. Carbon dioxide and other greenhouse gases released into the atmosphere have been increasing. Putting 50 gigatons of CO_2 into the ground is a real challenge. Sequestration is an issue that we need to understand. Carbon capture and sequestration could easily double or triple the cost of electricity. Smart and inventive ways of keeping these costs down must be found. Limiting climate change and decreasing the nation's dependence on foreign oil are the big science challenges.

Dr. Brinkman answered questions posed by the panel.

Question: Which hub was funded?
Answer: $35 million dollars was allocated for a hub to be selected by the Secretary of Energy.

Question: How would the drive toward applications change Basic Energy Science?
Answer: Researchers need to recognize how to use their findings. But they also have to look at needs and then solve those needs.

Hemminger introduced **Harriet Kung**[3] to describe the activities of BES. **Dr. Kung** welcomed the new Director of SC and noted the new appointments of Daniel Poneman as

[2] The charge letter from Dr. Brinkman to Professor John C. Hemminger, "Companion Study on Grand Challenges for Applied Issues of Energy Science," is available at: http://www.er.doe.gov/bes/besac/reports.html

Deputy Secretary, Kristina Johnson as Undersecretary, and Steven Koonin as Undersecretary for Science. She introduced **Linda Horton** as the new Director of the Materials Science and Engineering Division, and pointed out that **Mary Galvin** had also joined BES as a program manager.

Since the most recent meeting of BESAC, BES has received its FY2009 appropriation and received ARRA funds. In the core research programs, $100 million was for the Energy Frontier Research Centers, $55 million for Single-Investigator and Small-Group (SISGR) awards for grand challenge science and energy research (including one-time funding for midscale instrumentation and ultrafast science), about $10 million for facility-related research, and $17 million for the Experimental Program to Stimulate Competitive Research (EPSCoR). Scientific user facilities operations, construction, and instrumentation received the full requested funding.

BES will invest $555.4 million of ARRA funds in the NSLS II ($150.0 million), the user support building at the Advanced Light Source (ALS; $14.7 million), ultrafast scientific instrumentation ($33.6 million), Nanoscale Science Research Centers ($25.0 million), four synchrotron radiation light sources ($24.0 million), EFRCs ($277.0 million), and early career awards and fellowships (for which solicitations have already been posted; $31.1 million).

The 2010 budget request includes:

- Research
  - the core research program, including increases for grand challenges;
  - Energy Frontier Research Centers;
  - two Energy Innovation Hubs (fuels from sunlight and batteries and energy storage); and
- Facilities
  - scientific user facility operations at the synchrotron light sources, neutron-scattering facilities, and the Nanoscale-Science Research Centers;
  - construction and instrumentation at the NSLS-II; and
  - instruments and power upgrade at the SNS.

As of the day before this meeting, the House Energy and Water Development Committee markup totaled $1.675 billion, $10.5 million below the request for BES. While the House mark indicates that the Committee believes in hubs, the Committee provided funding for only one.

Dr. Kung compared the features of EFRCs with those of hubs. EFRCs conduct basic research, pursue knowledge for integrating future research, are funded with $2 to $5 million for 5 years, have a broad funding opportunity announcement (FOA), have strong ties to the core research program, and are made up of one lead institution with partners. The hubs integrate basic and applied science, focus on transformative energy technologies, are funded with $10 million for startup and $25 million per year, have a specific FOA, include industrial collaboration, and are co-located. Hubs and EFRCs are

[3] Dr. Kung's full presentation is available at: http://www.er.doe.gov/bes/besac/Meetings.html#0923

similar in that they both work outside the box; address grand energy challenges; are selected by open competition; and are led by universities, national laboratories, or industries.

Dr. Kung reviewed the status of two BES facilities, the LCLS at the Stanford Linear Accelerator, and the NSLS-II, at Brookhaven National Laboratory. Planning for the LCLS goes back to 1992. On April 21, 2009, the world's first hard X-ray laser achieved its first light, ushering in a new era of research. The first proposal call for the atomic and molecular (AMO) beam line received 28 proposals with 219 scientists from 16 countries involved. The second proposal for the AMO and soft X-ray (SXR) beam lines received 62 proposals with 469 scientists from 15 countries.

Construction of the NSLS-II at Brookhaven National Laboratory is just getting under way. The groundbreaking ceremony took place June 15, 2009. ARRA funding of $150 million is being used to accelerate construction, and all funds have been obligated. This initiative will accelerate the creation of more than 200 local jobs on Long Island in FY2009. Overall, the project will create 1000 jobs, use 40,000 cubic yards of concrete, use 2,500 tons of steel, and produce 400,000 square feet of workspace.

Turning to the Energy Frontier Research Centers, Dr. Kung noted that the center directors held their first meeting the day before this BESAC meeting. The EFRCs will pursue collaborative basic research that addresses both energy challenges and science grand challenges. Five years of strategic planning culminated with the issuance of the EFRC FOA in October 2008, which received 261 full proposals. The centers received $277 million from the ARRA and $100 million from the Omnibus Appropriations Act of 2009. In April, 2009, 46 EFRC awards were announced. Those projects will start in August 2009. In all, $777 million of funding will be devoted to the EFRCs over 5 years.

The BES team that will manage this program will be led by Altaf Carim. Management reviews will be held in 2010, operation reviews will be held in 2011, and science reviews will be held in 2012. In 2014, a workshop will be held, producing a report hearkening back to the 2002 workshop report.

Dr. Kung answered several questions from the panel.

Question: What is the status of the hubs in the FY2010 budget?
Answer: In the House markup, $35 million was allocated for one innovation hub.

Question: What is the fate of the other seven?
Answer: The Senate mark was still being awaited.

Question: Will a hub be connected to a national laboratory?
Answer: It is anticipated that a national laboratory, university, or other entity could be the lead.

Question: Are the technology offices were involved in the new charge?

Answer: Yes.

A break was declared at 10:47 a.m. The meeting was called back into session at 11:16 a.m.

Patricia Dehmer clarified that the ARRA funding, SC-wide, for the Graduate Student Fellowship Program and Early Career Awards would total about $97.5 million: about $12.5 million for Graduate Student Fellowships and about $85 million for Early Career Awards. The initial awards will be funded using ARRA money. In subsequent years, the SC programs will add funding to maintain these programs.

Dr. Hemminger noted that there will be an additional charge[4] to the Committee for a committee of visitors (COV) to SC's WDTS office.

George Crabtree[5] was asked to give a final report on the Subcommittee on Next-Generation Photon Sources for Grand Challenges in Science and Energy (the Photon Report). The report[6] came out in May and resulted from a workshop.

The New Era concept was first discussed with BESAC on February 21-22, 2008, and the first New Era meeting was held on July 24-25, 2008. The charge to the Subcommittee had three parts:

- to summarize the Basic Research Needs and Grand Challenge reports;
- to recommend implementation plans to address the challenges; and
- to identify grand challenge energy and science drivers for future light sources and the "photon attributes" required to pursue them.

The *New Science for a Secure and Sustainable Energy Future* report (the New Era report) of December 2008 addressed the first two charges, and the Photon Workshop on Oct 27-28, 2008, and the *Next Generation Photon Sources for Grand Challenges in Science and Energy* (the Photon Report) issued in May 2009 addressed the third by detailing the science that could be done by advanced photon sources. The Photon Workshop discussed free electron lasers, energy-recovery linacs, high-harmonic lasers, and next-generation storage rings. It held extensive discussions for 1.5 days.

A draft report was revised by BESAC in February 2009. As a result, the draft was altered to

- connect to messages of the New Era report and energy;
- project a visionary outlook;
- reflect a single voice and style;

[4] The charge letter from Dr. Brinkman to Professor John C. Hemminger, "Committee of Visitors of the Office of Workforce Development for Teachers and Scientists," is available at: http://www.er.doe.gov/bes/besac/reports.html

[5] Dr.Crabtree's full presentation is available at: http://www.er.doe.gov/bes/besac/Meetings.html#0923

[6] The full report, "Next Generation Photon Sources for Grand Challenges in Science and Energy," is available at: http://www.er.doe.gov/bes/besac/reports.html

- emphasize "beyond the source photons" by considering other characterization methods, supporting capabilities, data analysis, and other capabilities and equipment;
- engage science communities beyond materials and chemistry;
- employ dream teams to solve grand science and energy challenges; and
- address how to train the next generation of scientists.

The report asks, what is sustainable energy? It means the conversion of energy among photons, electrons, and chemical bonds. These are atomic, molecular, and nanoscale phenomena that need to be looked at in ultrafast picosecond or femtosecond time scales. To do that, fourth-generation light sources need advances in peak brightness, average brightness, short pulses, coherence, and polarization control. Two areas of "killer applications" were identified:

- the temporal evolution of electrons, spins, atoms, chemical reactions down to femtoseconds; and
- spectroscopic and structural imaging of nanoscale objects with "uncertainty-principle" precision.

One source will not cover both of these scientific needs. One needs at least two with different types of photons. Also needed is a commensurate investment in detectors, end stations, theory, and data handling. The application to interdisciplinary science requires "dream teams" because one wants to have cross-platform photon, neutron, and electron scattering.

The subcommittee revised the report structure, moving new-science opportunities to an appendix and adding information about the workshop charge. Since the report was issued, there has been a significant outreach effort. The report was distributed on the BES website and to the members of BESAC, the Photon Workshop participants, and the members of the New Era Subcommittee. Some presentations have been made at the Joint NSLS and CFN (Center for Functional Nanomaterials) Users Meeting, National Users Facility Organization, 3rd World Materials Research Institute Forum, and Jefferson Lab Users Group Meeting.

Following Dr. Crabtree's presentation, several members of the Committee congratulated the Subcommittee on a wonderful job. Several questions were asked.

Question: What would the next steps be for the community?
Answer: The next steps would be an assessment of the readiness of the technology and the conduct of a machine study.

Question: Is a workshop envisioned?
Answer: A focused workshop was envisioned, but the timeline has not been set.

Dr. Hemminger commended Crabtree and his Subcommittee for the dedicated, hard work that went into this report.

Altaf Carim[7] was asked to update the Committee on the Energy Frontier Research Centers (EFRCs). The EFRCs interlock scientifically with existing BES programs. They are neither completely separate and disconnected, nor are they overlapping and duplicative. EFRCs will operate differently from single-investigator grants, small-group awards, facilities operation, etc. BES has had a few examples of funded programs on a similar scale, but no prior portfolio of this magnitude.

The EFRCs present challenges by their interdisciplinarity, size, number, and visibility. For these reasons, a matrix management team was established in BES. The EFRCs have been grouped partly on the basis of topical relationships. But the groupings also involve a variety of practical and administrative considerations. Some activities, such periodic directors' meetings, will involve all EFRCs, while others may be organized by groups or subsets of the groups. Periodic meetings are expected to be held to discuss best practices etc. In addition, there will be some mid-cycle reviews, including reverse-site peer reviews, onsite peer reviews, EFRC science forums, energy-frontier workshops, and BES topical-contractor meetings.

The first EFRC directors meeting was held on July 8, 2009. Its primary objective was to share information and expectations regarding management and operations of the EFRCs. The major objectives of this meeting were to familiarize EFRCs with BES management structure and expectations; foster interaction of EFRC directors with each other and with BES points of contact; allow information gathering, documentation, and distribution; provide a timeline for meetings, reviews, and other activities; initiate a discussion of reporting and change control needs; address communications (operating out of the Office of Advanced Scientific Computing Research) expectations and issues; and share information on complementary tools and opportunities. It must be emphasized that the EFRC directors must have the authority and responsibility to actively manage their own centers. At the same time, the overall EFRC portfolio will be actively managed by BES.

Dr. Carim answered several questions from the Committee.

Question: What was the total number of full proposals?
Answer: 261.

Question: What manpower resources would be dedicated to ERFC management?
Answer: All of the manpower would be matrixed in with people having other responsibilities.

Question: What are the management expectations?
Answer: Pursuing good science, using peer review, an added emphasis on priority research directions, and addressing the energy grand challenges. These awards are to be more than just individual grants. They must have interaction and synergy.

Question: Do the EFRC awards indicate a movement towards the application of technology?

[7] Dr. Carim's full presentation is available at: http://www.er.doe.gov/bes/besac/Meetings.html#0923

Answer: No. The EFRCs span the spectrum of use-inspired research.

Question: How will the reviews be carried out?
Answer: External peer reviewers are expected to be used in some of the reviews. The mid-cycle review is not seen as a determinant of renewal.

A break for lunch was declared at 12:09 p.m.

Thursday, July 9, 2009
Afternoon Session

The meeting was called back into session at 1:35 p.m., and **Simon Bare**[8] was asked to report on the Committee of Visitors (COV) to the Division of Materials Science and Engineering (DMSE) that was carried out in April 2009. The 2.5-day COV found that things were working very well in the Division. Proposal-review procedures are of highest quality and consistency: there were a sufficient number of reviews, and they were flexible enough to allow program managers to make fair and informed decisions. The funding decisions fully reflected the criteria documented in program solicitations, the quality of science constituting the most important factor. The science is of the highest quality with national and international recognition. The basic-research-need (BRN) reports and workshops have been extremely valuable in identifying new scientific opportunities commensurate with the core mission of BES. The level of staffing of DMSE has increased since the previous COV, which expressed concern about staffing. New program managers were quickly fully integrated into the Division and are performing admirably.

In considering who gets funded, generally there is a good balance between established names and early-career scientists. Progress reports are important and are taken seriously by program managers. Division-wide, awards are of appropriate size, scope and duration (within the constraints of limited funding). The mechanism of monitoring projects is appropriate and working well.

In considering what gets funded, there is a laudable commitment to balance the funding of excellent science between "hot" topics and other mission-relevant fields. Contractors meetings are an effective method for program managers and principal investigators (PIs) to interact and transfer information. DMSE is a *unique* source of critical research funding in many areas.

In reviewing the EPSCoR program, the 2006 COV was very critical. There has been a noticeable process improvement in the evaluation and monitoring in the EPSCoR program. The additional numerical criteria are very useful for rating EPSCoR proposals. Several items were found to be lacking. Many excellent proposals were not supported due to inadequate funding levels. Reduced funding limited the ability of DMS&E to

[8] Dr. Bare's full presentation is available at: http://www.er.doe.gov/bes/besac/Meetings.html#0923

create new programs (e.g., four major funding initiatives with no awards). In particular, there is little funding for mid-scale instrumentation at universities.

The recommendations of the COV are:

- High priority should be given to implement the proposed Portfolio Analysis and Management System (PAMS).
- The influx of new money is an opportunity to implement ambitious new programs and directions and to increase the average grant size.
- The staffing level should be reviewed to ensure that it continues to be commensurate with increased workload as a result of increased funding and proposal pressure.
- Communication to the research community should be improved by improving and keeping current the BES website. In addition, the proposal-submission and award process should be made more transparent through an increased emphasis on putting additional information on the BES website.

The increased use of white papers as a pre-proposal mechanism is encouraged. The travel budget for program managers should be further increased to allow them to attend national and international meetings and to visit PIs on site. The EPSCoR Study Group recommendations (which were produced in response to the 2006 COV report) should be fully implemented.

On the Office of Management and Budget (OMB) Program Assessment Rating Tool (PART), a rating of excellent was received in all program areas for the four goals of the Division.

The COV had significant discussion regarding flexibility of the current system and desire to impose more rigid structure. A template could be provided to potential proposers to replace the free-form approach currently being used. Other COVs should consider this issue, which might warrant action after further consideration.

The COV commends all Division staff and program managers for their dedication, skill and professionalism. The COV's conclusion was that the best science is being funded and the science and individuals are of both a national and an international caliber.

The Committee had a brief discussion regarding the PAM system.

Question: Is there progress on the implementation of the PAM System?
Answer: PAMS is being phased in.

Question: Will the specification and analysis of the demographics of PIs and proposers be specified to the vendor of the software.
Answer: Yes, but it has to be an optional response.

Dr. Hemminger asked whether an update on this process at the November BESAC meeting would be timely. Linda Blevins agreed that it would be timely and offered to bring someone from Information Technology (IT), also.

Dr. Gates moved to accept the report. Dr. Berrah seconded the motion. The vote was unanimous in favor of the motion.

Linda Horton thanked the COV for the report and pointed out how helpful it will be for her as she begins the job of division director.

Dr. Hemminger announced that Janos Kirz had agreed to chair the COV to the Facilities Division. The WDTS program will become more visible, and BESAC has been asked to conduct a COV of that office. The Graduate Research Fellowship Program will make that office very pertinent to BES and BESAC. He asked for expressions of interest in serving on that COV.

Dr. Hemminger initiated a discussion of the new charge presented by Drs. Brinkman and Kung earlier in the meeting. The question is, are there topics or approaches that BES should be working on? Interaction with the technology offices and with industry would be very important. But BES should not become a job shop for industry. That balance is what the new charge is about.

Two reports have been suggested: one to explain what BES does, and one to educate the scientific community about the BES portfolio. It was noted that the New Era report laid out the connections between research and industrial applications, and it covered a long time scale (about 50 years). Some Committee members expressed concern that the charge pushes BES toward the technology arena. A workshop or two with industry representatives might help basic researchers to focus on specific areas that basic research could address. But BESAC does not want to get into what the technology offices do. It could point out short-term showstoppers. Basic researchers do not want to be viewed as firefighters who come up with technical solutions in six months or less. On the other hand, knowing what the showstoppers are would be very helpful.

Dr. Hemminger said that any suggestions on how BESAC could move this process forward would be appreciated. In the charge letter, Dr. Brinkman asked for a timescale. A short report produced by the end of the calendar year seemed reasonable.

Alex Malozemoff[9] was asked to discuss the science needed for a superconducting power grid. Superconductors were discovered in 1911, and high-temperature superconductors (HTS) in 1986. HTS materials require less cooling, driving the commercial economics. These HTSs have zero DC electrical resistance, yielding high electrical efficiency and a power capacity of more than 100 times that of copper wire of the same dimensions. This high power density leads to reduced size and weight and allows cooling with environmentally benign liquid nitrogen. Second-generation wires are the foundation of electric power grid applications (cables, generators, and motors).

[9] Dr. Malozemoff's full presentation is available at: http://www.er.doe.gov/bes/besac/Meetings.html#0923

There has been an underinvestment in the electric power grid while demand for electric power has steadily increased. This underinvestment has spawned a host of technical problems. The grand challenges in the electric power grid are:

- The demand is growing relentlessly;
- Power outages and disturbances cost more than $40 billion per year;
- Environmental issues are gaining stature.

Superconductors can enhance the efficiency of the electric power grid. Up to 10% of the U.S. electric power is now lost in the AC power grid. Superconductor equipment could cut this by half and reduce delivery bottlenecks.

Superconductors could also enhance energy efficiency through electrification of transportation. A 5% penetration of plug-in vehicles would create a 50% increase in the growth rate of demand. Here, superconductors could play a key role in enabling urban grids to handle this demand. As energy costs rise, there will be more pressure for reurbanization, which would require more power capacity in dense urban areas. However, overhead lines are nearly impossible to permit, and the underground infrastructure is clogged. Underground power cables are needed that have a high capacity with the same cross-section as current cables, are compact and light, are non-interfering, and carry low voltage for easy permitting. Superconductors are the ideal solution.

HTS may also contribute to increased availability of wind power. Off-shore wind is a strong and steady energy source, but only 2% of total wind power is now off-shore. There is an opportunity to double windpower production. Cost is the obstacle. An increased power rating is the key to economics. Above 5 MW, the conventional generator is simply too large and heavy. HTS generators offer the needed breakthrough in size and weight.

American Superconductor's 36.5-MW motor was successfully demonstrated at full power in December 2008. Compared to a copper motor, it is less than half the size and weight, has a higher efficiency, and less noise. With Midwest wind generation, hundreds of gigawatts of green power need to be carried to market with DC power cables. Long-length, high-power cables can be installed under ground. Second-generation HTS wires are being produced, but their cost still limits the range of application. The cost is now $200/kA-m and needs to go to $25/kA-m. The reduction of costs in cryogenics is also important. Now, refrigeration stations are required at intervals of several kilometers of AC HTS cable and 10 km for DC HTS cable. Those intervals need to be increased by a factor of 10.

In conclusion, superconductivity can play a major role in addressing the grand challenges of energy generation, delivery, and use. But important cost issues remain to attain a broad impact. There are major science opportunities to address these issues: discovering

new superconductors, understanding the mechanism of HTS, increasing critical-current density, understanding the flux-flow state, and achieving processing breakthroughs.

The Committee had several questions for Dr. Malozemoff following his presentation.

Question: Where is the innovative work being done, and can one justify working in this area?
Answer: This work is being done in many quarters, including university laboratories and national laboratories. Dr. Malozemoff said he believed that the commercial opportunity was huge but and required years of investment. There are reports that identify scientific opportunities.

Question: Where does the United States stand in this science?
Answer: The United States is not a world leader. A lot of work is being done in Japan. Some U.S. national laboratories are mobilizing, and several U.S. companies are world leaders in commercialization.

Question: Is the advantage of HTS lost when one puts the cable in the jacket?
Answer: Some of the problems do not occur if one uses direct current.

A break was declared at 3:25 p.m. The meeting was called back into session at 3:55 p.m.

David Carlson[10] was asked to discuss basic-science issues in the development of photovoltaics. Photovoltaics is one of the fastest growing industries in the world, about 45% compound growth over the last ten years. It is largely subsidized by governments, such as Japan, Germany, and Spain. Some forecast that photovoltaics will supply 10% of the world's electricity in 2032. Assuming a compound annual growth rate of 35% (the average over the past few decades), the cumulative photovoltaic power production would be about 3.5 TW (peak) by 2026. Three TW (peak) of solar electricity will reduce carbon emissions by about 1 gigaton per year.

About 325 companies are producing products or ramping up to commercial production. The total photovoltaic production this year is forecasted to be about 10 GW (peak), although demand may be for only 3.5 GW (peak).

The typical silicon solar cell is a pn junction with conducting electrodes on each side. These cells typically operate in the range of 14% to 17% efficiency. Efficiency loss results from lattice thermalization, junction voltage drop, recombination, and nonabsorbed photons. The theoretical limit for a crystalline silicon solar cell is about 29%.

Research is needed to lower the costs for photovoltaics. The major cost drivers are the need for:

- efficiency improvements;
- low-cost storage;

[10] Dr. Carlson's full presentation is available at: http://www.er.doe.gov/bes/besac/Meetings.html#0923

- high-quality, thin silicon wafers or sheets (10 – 50 μm) that can be produced at low cost;
- automated high throughput processes with intelligent process control;
- the replacement of silver contacts with lower-cost materials; and the production of reliable, high-performance photovoltaic modules and systems with low-cost materials.

Photovoltaic module prices have followed an experience curve with a slope of about 80% (a 20% decrease in price with every doubling on cumulative production). There has been steady progress in the improvement of conversion efficiencies for a number of photovoltaic technologies during the past few decades. However, for most photovoltaic technologies, there is a large gap between the best laboratory efficiencies and the efficiencies achieved in production photovoltaic modules.

The current paths to ultra-high conversion efficiencies are:
- multi-junction solar cells,
- multiple-absorption-path solar cells,
- multiple-energy-level solar cells,
- multiple-spectrum solar cells, and
- multiple-temperature solar cells.

All these approaches have theoretical efficiency limits greater than 60%. By combining techniques, the theoretical efficiency limit is greater than 80%.

A number of new device structures have appeared over the years, resulting in higher performance. Some devices use new materials in novel structures (e.g., dye-sensitized solar cells, bulk heterojunction organic solar cells, luminescent quantum-dot concentrators, and other types of structures).

There are environmental and sustainability issues associated with the production of solar cells. Some photovoltaic materials are highly toxic and must be processed with appropriate safeguards. And obsolete/damaged product should be recycled. Materials that are plentiful need to be used. Some photovoltaic materials may be constrained by availability when production reaches tens of GW (peak) per year. Further reliability improvements are required in the photovoltaic systems. Possible failure mechanisms must be identified for new photovoltaic materials and devices.

In conclusion, many believe that photovoltaics could become the major energy source for the world in the latter part of this century, but continued research and development are required in several areas to reduce photovoltaic system costs significantly. Initial costs of $0.25/kW-h have come down to $0.10 to $0.15. Additional reductions are needed. Conversion efficiencies must be improved. Long-term reliability must be ensured for new PV materials and devices; 25-year warranties are desirable. And future photovoltaic systems should be environmentally benign.

Following Dr. Carlson's presentation, the Committee asked several questions.

Question: How many units are actually out there?
Answer: About triple last year's production. Many systems are tested by accelerated methods. Field tests are needed.

Question: What are the basic-science barriers?
Answer: Nanostructure. Work with quantum dots has shown promise, but a lot of innovation is needed before such systems can be scaled up from the nanoscale to the field scale. In the next decade, low-cost thin silicon films are expected to be developed. Silicon is plentiful, and there is a good deal of experience with it. Other technologies will take a long time to mature.

Question: Transportation fuels are a huge issue for the United States. Is there a role for photovoltaics there?
Answer: Plug-in hybrids will be very successful, and costs will come down rapidly as the market increases. Solar carports and roofs will allow recharging while these vehicles are parked. The switch to electric cars could happen rapidly.

Michael Burke[11] was asked to discuss light-water-reactor sustainability. Nuclear power is generating about 20% of U.S. electricity. To sustain that capability and growth, older reactors will need to keep operating another 20 years. For plants to be re-licensed by the NRC, their operators have to demonstrate that they understand materials issues. With currently available models and data, we can only do some quantitative projections that allow categorization and prioritization of materials to see which fail first. A sparse data base prevents the full utilization of models. We need a bigger database, or a way of predicting materials properties.

New next generation nuclear plants will undoubtedly require new materials. Nuclear plants are designed for long lives. But no material is "Impervium." Improved models for materials performance are needed. This can be done with basic science support in the form of integrated quantitative models of materials behavior and degradation; the understanding of metallurgical effects in alloy behavior; knowledge of property variation with respect to material variants; the extension of the materials property database; new materials for repair, coating and surfacing methodologies; and advanced sensing and monitoring technologies.

Reactor materials for existing and near-term plants are limited to ferritic low alloy steels for reactor, pressurizer, and steam-generator pressure vessels; nickel-based alloys for reactor-vessel-head penetrations, steam-generator tubing, and piping welds; stainless steels for reactor internals; and zirconium alloys for fuel cladding. The key driver for existing plant technology needs is the plant relicensing process. Plants are licensed to operate by the Nuclear Regulatory Commission (NRC). Licenses are held on a 20-year basis. Quantitative data are required to properly disposition inspection findings. Accurate data are needed to avoid excessively conservative reaction.

[11] Dr. Burke's full presentation is available at: http://www.er.doe.gov/bes/besac/Meetings.html#0923

For existing plants, the materials issues related to ferritic low-alloy steels are irradiation embrittlement and fatigue cracking of piping. The major issue for nickel-based alloys is stress corrosion cracking of head-penetration welds. The issues for stainless steels are hardening and embrittlement. And the major issue for zirconium alloys is the development of new materials with reduced oxidation/hydriding Crud[12] formation mitigation. The nuclear power generation industry currently manages all of these issues to keep plants operating at 90% of capacity factor.

The key issue for structural materials is to validate material survivability to long life. That for fuel-related materials is to withstand higher burnup. "Improved materials/confidence in materials" will be acceptable for a doubling or tripling of lifetime. What is needed is to consider examples of current technology and to identify basic-science opportunities that may improve materials performance and/or confidence in materials performance.

Ferritic steels become embrittled in neutron and thermal-cycling environments. Plant operations monitor vessel materials (with surveillance capsules) for embrittlement and feed properties back into analyses to support operations.

For reactor-internal materials, the basic science support needed includes a more extensive property database, an understanding of aged (and corroded) materials' response to continued long-time exposure, more-precise quantitative data, an understanding of metallurgical effects in alloy behavior, knowledge of property variations with respect to material and processing variants, information about high-dose behavior, and welding technology.

Following Dr. Burke's presentation, the Committee asked some questions.

Question: The prediction of materials failure is based on empirical models that do not represent all failure mechanisms and are conservative. So, is the result that we design conservatively?
Answer: Yes, that's right.

Dr. Hemminger suggested that the Committee use the evening to consider the charge given to it so that the charge could be discussed at the next day's session of the meeting.

The floor was opened for public comment. There being none, the meeting was adjourned at 5:16 p.m.

Friday, July 10, 2009
Morning Session

[12] Corroded products containing radioactive nuclear species. From "Chalk River unidentified deposits."

Dr. Hemminger called the meeting back into session at 9:03 a.m. and introduced **Shane Kosinski**[13] to describe the new Advanced Research Projects Agency – Energy (ARPA–E).

In 2006, the National Academy of Sciences (NAS) published *Rising Above the Gathering Storm*, which called for establishing an Advanced Research Projects Agency for Energy (ARPA-E). Steven Chu was on the committee that produced that report. The America COMPETES Act of 2007 (P.L. 110-69) authorized the establishment of ARPA-E, but the initiative did not receive funding until recently. President Obama launched ARPA-E in a speech at the NAS on April 27, 2009

ARPA-E's mission is

- To enhance the economic and energy security of the United States through
  - the reduction of energy imports;
  - improvement in energy efficiency; and
  - the reduction of energy-related emissions, including greenhouse gasses and
- To ensure U.S. technological leadership in developing and deploying advanced energy technologies.

ARPA-E is to pursue this mission by identifying and promoting revolutionary advances in fundamental sciences, translating scientific discoveries and cutting-edge inventions into technological innovations, and accelerating transformational technological advances in areas that industry by itself is not likely to undertake.

This initiative creates a new organization within DOE, reporting directly to the Secretary. Its hiring and management are unrestricted by civil service laws. It is a lean, flat organization with 70 to 120 program managers who know how to get technology to market. It uses existing DOE authorities and can engage universities, industry, and (when in consortia with others) federally funded research and development centers (FFRDCs).

ARPA-E is part of the President's national energy strategy, which is focused on breaking the nation's dependence on oil, producing more energy at home, promoting energy efficiency, closing the carbon loophole, and promoting U.S. competitiveness. In concert with the energy-innovation hubs, ARPA-E is intended to fill the gaps between basic science and applied science, between applied science and prototyping/demonstration, and between prototyping/demonstration and asset investors. It will be focusing on disruptive, transformational technologies; high-risk, high-potential programs; projects in need of rapid and flexible experimentation; marrying technical opportunities with mission gaps; and the breakthrough science that can transform a field. It will not fund basic research, lowest-technology-readiness projects; projects longer than 5 years; evolutionary improvements; large-scale commercial viability demonstrations; or projects which are the focus of other DOE program offices.

[13] Dr. Kosinski's full presentation is available at: http://www.er.doe.gov/bes/besac/Meetings.html#0923

ARPA-E is connected to the Office of Science (SC). SC undertakes basic science and works with ARPA-E when a technology is ready for the next stage of rapid experimentation. ARPA-E can help move SC technologies toward deployment. It is connected to the DOE Applied Programs (Fossil, Energy Efficiency and Renewable Energy, etc.). ARPA-E will be flexible to accelerate high-potential technologies. Applied programs can pick up technologies from ARPA-E that are ready for demonstration and deployment. ARPA-E is connected to the national laboratories (FFRDCs). The national laboratories can compete for ARPA-E funding as part of consortia, and ARPA-E can harvest high-potential technologies from the national laboratories. ARPA-E will be connected to the Energy Innovation Hubs to harvest high-potential technologies from the hubs while the hubs can pull ideas from ARPA-E to address focus areas. At the same time, ARPA-E may fund alternative approaches in the hubs' focus areas. All DOE components can collaborate with ARPA-E

ARPA-E will seek projects that are potential breakthroughs, opportunistic, and focused. The Energy-Innovation Hubs will look at big problems and seek projects that are stable and long-term. ARPA-E's first funding opportunity was released April, 27, 2009, with total funding up to $150 million. It was intentionally broad on energy application and technologies and narrowly focused on transformational R&D. However it was focused on applicants who already have a relatively well-formed R&D plan for a transformational concept or new technology that can make a significant contribution. Concept papers were due June 10; about 3,500 were received.

The office is working with outside reviewers for the technical analysis of each concept paper. Program managers will make the final recommendations using technical analysis and other selection factors. Feedback will be supplied to applicants by the end of July, with a full application due 31 days later. Funding of the awardees is scheduled for early to mid-fall. Concept papers were submitted in a very broad range of energy topics with solar energy and biofuels being the largest categories. About half of the reviewers came from universities, and about one-sixth each came from national laboratories, government, and industry. Additional ARPA-E recovery FOAs will be issued in the near future.

High-potential program managers who are technically outstanding and entrepreneurial are now being recruited. They will be given 3-year appointments; Intergovernmental Personnel Act staff members (IPAs) will be considered.

Following Dr. Kosinski's presentation, the Committee had several questions regarding ARPA-E.

Question: What is the difference between basic science and basic research?
Answer: ARPA–E will fund basic research if it leads to a marketable product.

Question: How many program managers work for ARPA-E right now?
Answer: Three.

Question: How many of the 3,500 submissions will be invited to submit full proposals?
Answer: Well under 1000. All of the submissions will be retained, and those ideas will be reviewed and possibly tapped in the future.

Question: How many reviewers have been lined up?
Answer: 455, mostly in response to the Secretary's request to universities, national laboratories, and industry.

Question: How many awards are anticipated?
Answer: $150 million is available. Projects between $2- to $3-million are preferred. (So 50 to 75 awards may be made.)

Question: How does this differ from venture-capital projects?
Answer: Venture capitalists want to make money. ARPA–E wants to get products out in the marketplace. It wants to borrow some of the discipline of venture capitalists. Also, it is focused solely on energy.

Question: Is ARPR–E assessing what the venture capitalists are doing and vice versa? Are the two groups learning from each other?
Answer: ARPA–E will not fund anything that could or should be funded by venture capitalists.

Dr. Hemminger opened the floor for discussion about the charge letter[14].

A suggestion was made to include in the report primers on the science and technology of energy. There is a stunning lack of tutorial textbooks on energy. Perhaps the expertise of the national laboratories could be utilized since the labs perform a mixture of research ranging from fundamental science technology development. The brochure, *Basic Energy Sciences: Serving the Present, Shaping the Future*, which highlights connections between basic research and technology, was noted.

While in the past industry has been successful in doing long-term research and has brought products to market, industry is not doing science right now. So they should be willing, now, to share their problems and needs. Some believed that during the BRN workshops, industrial representatives were not fully sharing their insights. On the other hand, it was noted that companies pay to use beam lines and other DOE facilities. They can buy their way into DOE R&D.

Some believed that the essential message is the nature of basic research and how its results connect to technology. There is a link between fundamental knowledge and new technologies for energy. The case for basic research has to be made with appropriate examples. Perhaps the BRN report template should be inverted. Start with a product,

[14] The charge letter from Dr. Brinkman to Professor John C. Hemminger, "Companion Study on Grand Challenges for Applied Issues of Energy Science," is available at: http://www.er.doe.gov/bes/besac/reports.html

like a solar panel, and then work backwards to show how that produce it linked to basic research and why we need it.

It was suggested that users of BES facilities, especially industrial users be involved. The facilities are a major way to impact science. Involvement of outreach personnel from BES user facilities was also suggested. This might serve a role of "mutual education" for the scientists and industrial sector researchers.

Dr. Hemminger suggested that BESAC needs to organize a subcommittee to plan the workshop and to run the process. Someone from the industrial sector should be on the subcommittee. The challenge will be to select the topics to focus on. Dr. Hemminger asked for volunteers to serve in such a capacity.

Dr. Hemminger opened the meeting to public comment.

Celia Merzbacher commended DOE for what they are doing with this new charge. The need to address risky ventures must be kept in mind. One needs to go beyond what BES has done so well for a long time to enhance the value of what is currently going on. Conversations with industry are important. DOE should focus on the *how* more than on the *what*. It should interact with the larger industry community rather than just making a list of industry's needs of the type of research that BES should consider. A report issued by the President's Council of Advisors on Science and Technology (PCAST) on university–industry partnerships [*University-Private Sector Research Partnerships in the Innovation Ecosystem*] was very instructive and gave a lot of examples. Also, BES needs to bring in more industry people for the proposed study.

Alex Malozemoff said that the charge is not an encouragement of business as usual. There are gaps in moving from basic research to market products. One of those gaps is the one between BES and applied technology. There is a tendency to back away from that gap. This is an opportunity to add to the picture while maintaining science. BES can play a huge role and accomplish meaningful science. BESAC needs to think about how it can ensure that this work is done.

There being no further public comment, the meeting was adjourned at 10:57 a.m.

Respectfully submitted,
F. M. O'Hara, Jr.
Recording Secretary
August 7, 2009
(Edited 8/28/09 MIS)