DOE Office of Science
Research Related to Smart Grid and Transmission for Renewables

The Office of Science is engaged—both independently and in cooperation with multiple DOE technology programs—in a variety of current and planned research activities relevant to addressing the technological challenges facing the nation's electricity infrastructure. Community-driven research needs workshops led by Office of Science programs have played a critical role in identifying the specific research opportunities discussed below.

Current Research

The DOE Office of Science currently supports basic research in several areas that will enable the scientific and technical breakthroughs needed to overcome barriers to advanced smart grid and transmission technologies:

- *Electrical Energy Storage (EES)*. Today's batteries and electrochemical devices suffer from limited energy and power capacities, lower than desired rates of charge and discharge, calendar and cycle life limitations, low abuse tolerance, high cost, and poor performance at high or low temperatures. Overcoming these performance deficiencies would improve the dispatchability of intermittent sources, facilitate load-leveling and peak-shaving for a more efficient and reliable electric grid system, and accelerate the development of robust electric vehicles. Research opportunities exist to create designer materials at the molecular level that could yield a new class of high-cycle, high-density electric batteries.

  Although ongoing core research activities within the Basic Energy Sciences (BES) program are relevant to EES, a specific BES focus area in EES does not yet exist. The FY 2009 President's Request included $33,369,000 for new basic research in electrical energy storage. Five areas of basic research for batteries and electrochemical capacitors were identified for this new investment: efficacy of material structure in energy storage; charge transfer and transport; electrolytes; probes of energy storage chemistry and physics at all time and length scales; and multi-scale computational modeling.

- *High-Temperature Superconductors*. Dramatic improvements to the grid's efficiency, capacity, and reliability could be possible with new superconducting materials that minimize distribution losses. Up to a factor of ten increase in superconductor performance could potentially be achieved through the development of a fundamental understanding of the mechanism of high temperature superconductivity.

  Although a specific BES focus area in superconductivity does not exist, BES supports approximately 100 different research projects related to superconductivity as part of its core research activities at DOE laboratories and universities. Funding in FY 2009 under the Energy Frontier Research Centers and Single-Investigator and Small-Group Research activities in BES will significant increase BES research in superconductivity (see "Future Plans" below).

- *Advanced Mathematics for Optimization of Grid Control and Cybersecurity*. Optimization of grid control and cybersecurity require advanced mathematical techniques and modeling to understand the roles and relevance of complex, multi-scale system components and their interactions. Grid operations and planning activities rely critically on mathematical models

that increase in complexity with the number of users and the diversity of power sources. Grid optimization comprises combinations of planning, control, operations, contingencies, market dynamics, policy, and socially imposed constraints, all in an environment characterized by enormous uncertainty and significant risk. Similarly, cybersystems also involve large numbers of components with different structures and scales, ranging through individual machines, a local network, the network at a DOE lab, and the full Internet. Understanding, assessing, planning for, and predicting risk are central elements in cybersecurity, including factors such as cost, impact, policy, and privacy.

In FY 2008, the Advanced Scientific Computing Research (ASCR) program initiated a new research activity in the Applied Mathematics program with announcement of a funding opportunity, *Multiscale Mathematics and Optimization for Complex Systems*, with particular focus on techniques for formulating, analyzing and solving challenging optimization problems arising in complex natural and engineered systems including grid control and cybersecurity. Two awards were made in FY 2008 and another eleven were notified of a delay in funding decisions due to uncertainty in the FY 2009 budget.

Workshop Reports

The Office of Science has conducted a number of community-driven, basic research needs workshops to identify research opportunities with significant potential impact on electric grid applications.

- *Computational Research Needs in Alternative and Renewable Energy*. This report is based on a workshop held jointly with DOE Office of Energy Efficiency and Renewable Energy (EERE) in September 2007, to identify computational research needs and opportunities in alternative and renewable energy, with a focus on EERE mission objectives and Office of Science capabilities. "Energy Distribution—Grid Futures and Reliability" was one focus for which five research challenges were indentified, including modelling of distributed energy sources and management of smart grid infrastructure. Recommendations from this report have been incorporated, where possible, into existing ASCR research. http://www.sc.doe.gov/ascr/Research/AM/ComplexSystemsWorkshopReport.pdf

- *Basic Research Needs for Electrical Energy Storage*. This report is based on a workshop held April 2–4, 2007, to identify basic research needs and opportunities underlying batteries, capacitors, and related EES technologies, with a focus on new or emerging science challenges with potential for significant long-term impact on the efficient storage and release of electrical energy. The workshop was conducted in coordination with EERE and the Office of Electricity Delivery and Energy Reliability (OE). http://www.sc.doe.gov/bes/reports/files/EES_rpt.pdf

- *Mathematical Research Challenges in Optimization of Complex Systmes*. This report is based on a workshop held in December, 2006, to identify mathematical research challenges arising in four applications of interest to DOE including power grid control and optimization; and risk assessment for cybersecurity. OE participated in this workshop. http://www.sc.doe.gov/ascr/Research/AM/ComplexSystemsWorkshopReport.pdf

- *Basic Research Needs for Superconductivity*. This report is based on a workshop held May 8–10, 2006, to examine the prospects for superconducting grid technology and its potential for significantly increasing grid capacity, reliability, and efficiency to meet the growing demand for electricity over the next century. The workshop was conducted in coordination with representatives from the OE.
  http://www.sc.doe.gov/bes/reports/files/SC_rpt.pdf

Coordination

The Office of Science is actively coordinating with EERE and OE to foster research programs in several of the areas described in the previous section.

- *Electrical Energy Storage.* The FY 2009 Budget Request identifies $2,000,000 per year for BES research specifically coordinated with DOE applied research in electrical energy storage. EERE has committed $3,000,000 per year and OE has committed $250,000 per year for this coordination. Potential uses for this money include joint solicitations and targeted funding in the area of nanoscale materials and architectures for electric energy storage.

- *Electrical Energy Storage.* BES developed a Small Business Innovative Research (SBIR) topic with OE on "Solid State Electrolyte Development for Advanced Energy Storage Devices" for FY 2008. The effort will continue in the FY 2009 SBIR solicitation.

- *Superconductivity.* The OE Superconductivity Program is focused on the implementation of high temperature superconductors as a replacement for copper in the electric grid. OE conducts an annual review of the superconductivity program. BES assists in the review of this program.

- *Optimization of Complex Systems, Control Theory and Risk Assessment.* This R&D Integration area was new for FY 2008 with $2M in ASCR applied mathematics. OE does not directly participate in this topic area but has expressed interest in regular updates of ASCR efforts.

Future Plans

The Office of Science is poised to significantly expand its portfolio of fundamental research with direct relevance to grid applications.

- *Energy Frontier Research Centers (EFRCs).* The FY 2009 BES Budget request included $100,000,000 to launch the EFRCs, which will support high-risk, high-reward basic research to provide the basis for transformative energy technologies of the future. EFRCs will provide a unique opportunity for universities, DOE laboratories, for-profit companies, and non-profit entities to partner in fundamental basic research critical to future energy technologies. These multi-year collaborations will bring together the skills and talents of a critical mass of investigators to enable energy-relevant basic research of a scope and complexity that would not be possible with the standard single-investigator or small-group award. Research in electrical energy storage and superconductivity were specifically included in this $100,000,000 initiative and these areas are represented among the approximately 260 proposals recently received under the EFRC Funding Opportunity

Announcement.
http://www.sc.doe.gov/bes/EFRC.html

- *Single-Investigator and Small-Group Research.* The FY 2009 Budget includes new funding to support proposals from individual investigators and small groups of investigators to 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. Research in electrical energy storage and superconductivity are among the nearly 800 proposals received under this effort.
http://www.sc.doe.gov/bes/SISGR.html

- *Expanded Optimization and Risk Assessment of Complex Systems Program.* The House appropriations report for FY 2009 would have increased the ASCR budget in this area from $2M per year to $5M. This funding would enable ASCR to increase the number of awards in this area from five to thirteen and to add bi-annual joint Principal Investigator meetings with the applied programs, including The Office of Electricity Delivery and Energy Reliability.