Science for Energy Technology: Strengthening the Link between Basic Research and Industry

Simon R. Bare

NUFO Annual Meeting

June 8, 2010

Honeywell

BES Reports – Strategic Planning and Budgets

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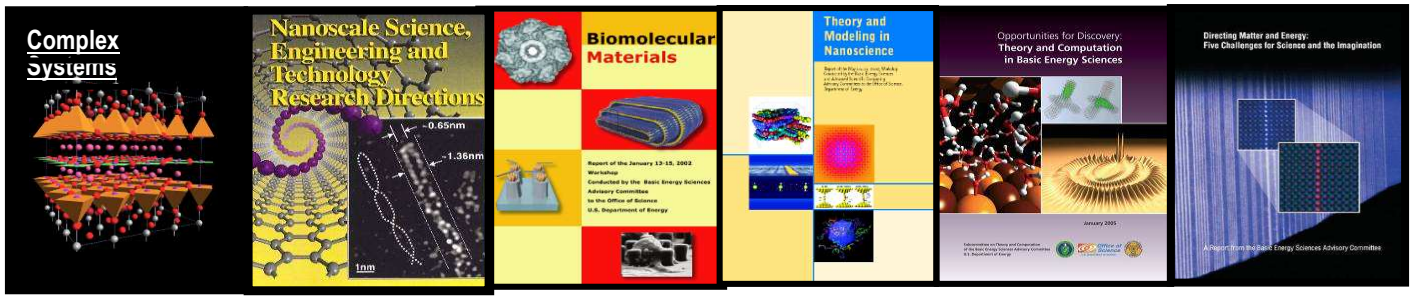
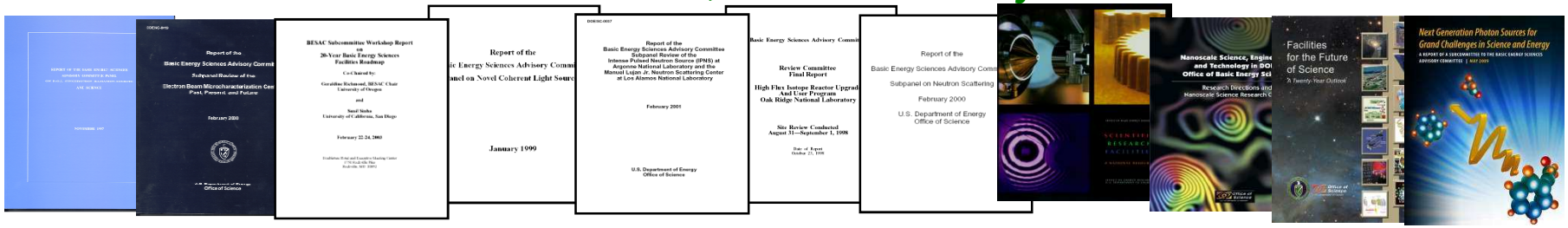
- ***Science for Discovery***



- ***Science for National Needs***

http://www.sc.doe.gov/bes/reports/list.html

- ***National Scientific User Facilities, the 21st century tools of science***



Dr. W. Brinkman's Charge to BESAC

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- Summarize the science themes that emerged from the BESAC reports Basic Research Needs for a Secure Energy Future and the follow-on BES BRN topical reports with an emphasis on the needs of the more applied energy technologies. Identify grand challenge science drivers that are likely to have an impact in the energy arena in the near term.
- Identify how the suite of BES-supported and managed scientific user facilities can impact basic and applied research on energy.
- 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.

Subcommittee on Science for Energy Technology

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Co-chairs

George Crabtree (Argonne National Laboratory)

Alexis Malozemoff (American Superconductor Corporation)

Simon Bare* (UOP LLC), Kurt Edsinger (EPRI), Richard Esposito (Southern Company), Charles Gay (Applied Materials, Inc.), Lori Greene (U. California, Irvine), Bernd Keller (Cree), Patrick Looney (Brookhaven National Laboratory), Celia Merzbacher (Semiconductor Research Corp.), Omkaram Nalamasu (Applied Materials, Inc.), Gregory Powers (Verenium), Bart Riley (A123 Systems), John Sarrao (Los Alamos National Laboratory), Thomas Schneider (NREL)

*** Member of BESAC**

John C. Hemminger
University of California, Irvine
BESAC Chair

Workshop on Science for Energy Technology

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- **Held January 18-21, 2010**
- **~100 experts from industry, academia, national laboratories**

Panel 1. Solar energy – Coordinator Charles Gay, Advanced Materials

Panel 2. Advanced Nuclear Technologies - Coordinator Kurt Edsinger, EPRI

Panel 3. Carbon Sequestration – Coordinator Richard Esposito, Southern Co.

Panel 4. Electricity Storage – Coordinator Bart Riley, A123 Systems

Panel 5. Electricity Delivery – Coordinator Thomas Schneider, NREL

Panel 6. Advanced Lighting - Coordinator: Bernd Keller, Cree

Panel 7. Biofuels – Coordinator Gregory Powers, Verenium

Panel 8. Efficient Energy Generation and Use - Coordinator: Om Nalamasu, Advanced Materials

Panel 9. DOE User Facilities – Coordinator Simon R. Bare, UOP

Generalists: John Sarrao, Pat Looney, Marc Kastner, Celia Merzbacher, Lori Greene

Panel 9: DOE User Facilities

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- **Panel members:**
  - Simon R. Bare, UOP LLC
  - Ernest Hall, GE Global Research
  - Chi-Chang Kao, NSLS, BNL
  - Dan Fischer, NIST
  - Ian Anderson, NIST
  - Jeff Cuttler, Canadian Light Source

- **Observers**
  - Lou Terminello, PNNL
  - Roger Falcone, LBNL
  - Gwyn Williams, JLab
  - Others

Two Reports

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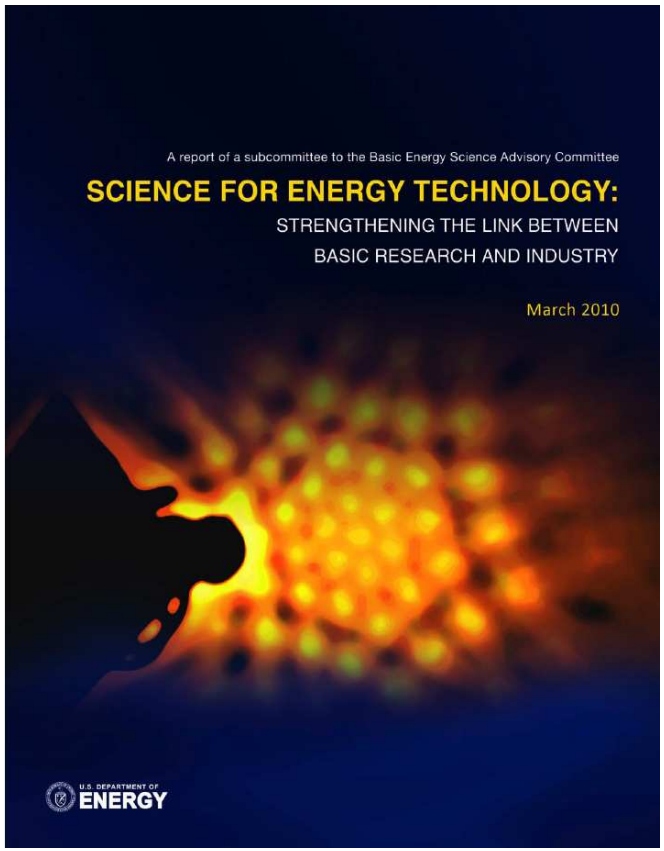
- **Concept report ~15 pages**
  - For wide distribution to decision makers in Congress, Administration, agencies, energy community
  - Inspiring, high level, exciting
  - Limited number of high level actionable items

Approved by BESAC, March 2010 – available online



- **Full report ~150 pages**
  - For Office of Science, technical, industrial and scientific communities

In preparation – to be presented to BESAC in August, 2010

Relationship of BES to Industry

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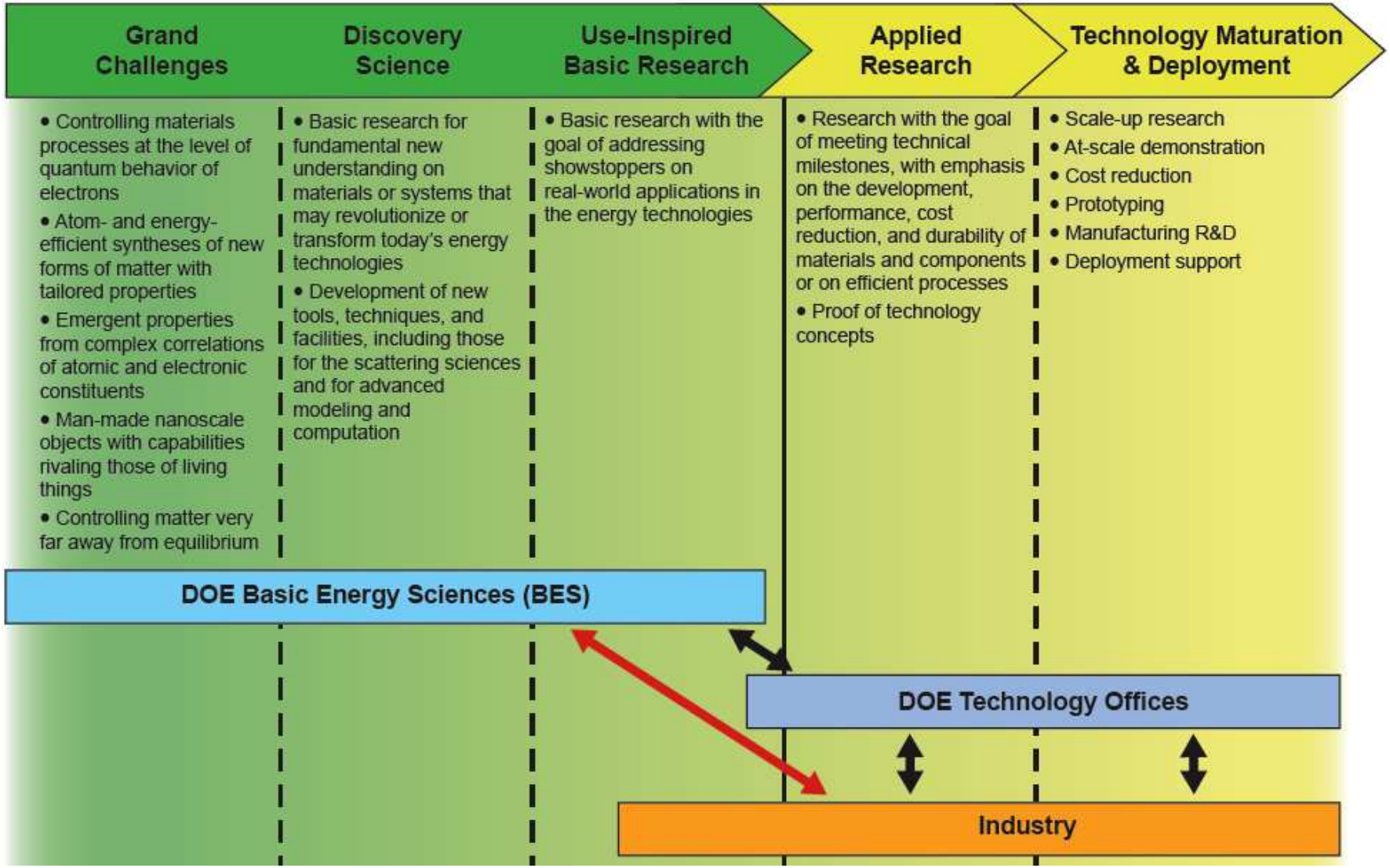

Workshop Priority Research Directions

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Panel 1: Solar Electricity
Coordinator: Charles Gay, Applied Solar
- Fundamentals of Materials and Interfaces in Photovoltaics
- Advanced Photovoltaic Analysis and Computational Modeling for Up-scaling
- Photovoltaic Lifetime and Degradation Science

Panel 2: Advanced Nuclear Energy
Coordinator: Kurt Edsinger, EPRI
- Materials Degradation Mechanisms
- Advanced Irradiation Effects Scaling
- Back End of the Fuel Cycle

Panel 3: Carbon Sequestration
Coordinator: Richard Esposito, Southern Co.
- Extraction of High Resolution Information from Subsurface Imaging and Modeling
- Understanding Multi-scale Dynamics of Flow and Plume Migration
- Understanding Millennium Timescale Processes from Short Timescale Experimentation

Panel 4: Electricity Storage
Coordinator :Bart Riley, A123 Systems
- Identification and Development of New Materials
- Invention of New Architectures for Energy Storage
- Understanding and Controlling Heterogeneous Interfaces
- Identification and Development of New Tools

Panel 5: Electric Power Grid Technologies
Coordinator: Thomas Schneider, NREL
- Power Electronic Materials
- High Power Superconductors
- Electric Insulating and Dielectric Materials
- Electrical Conductors

Panel 6: Advanced Solid State Lighting
Coordinator: Bernd Keller, Cree
- White Light Emission Through Wavelength Conversion
- High Efficiency Emission at High Current Density and Temperature
- Organic Light Emitting Diode Materials and Structures

Panel 7: Biofuels
Coordinator: Gregory Powers, Verenium
- Diversity of Biomass and Its Intermediates in the Manufacture of Biofuels
- Mass Transport Phenomena in Conversion of Biomass to Biofuels
- Biomass Catalyst Discovery, Characterization and Performance

Panel 8: Efficient Energy Generation and Use
Coordinator: Om Nalamasu, Applied Materials
- Enabling Materials Technologies for Renewable Power
- Fuel Cell Materials Understanding and Discovery
- Dynamic Optical and Thermal Properties of Building Envelopes

Example: Photovoltaics Harnessing Solar Energy

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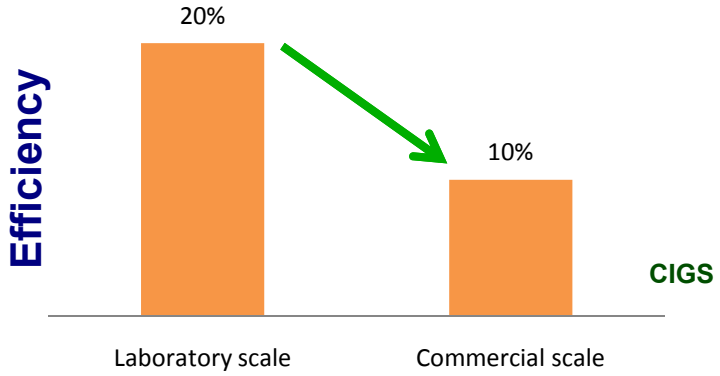
The Opportunity:

Solar energy – the most abundant renewable energy, could supply a large fraction of the world's energy needs

The Problem:

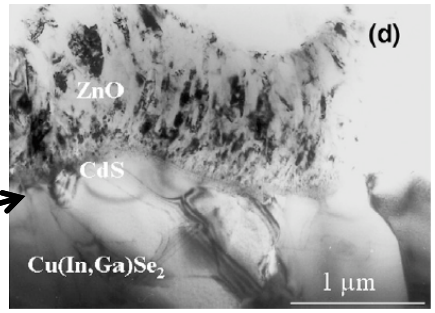
Photovoltaics - most promising converter of photons to electricity. Need 2x lower $/watt to compete commercially.

But lose factor of 2 in efficiency from lab to commercial scale



Science needed:

Understand mechanisms of efficiency degradation in commercial-scale solar panels: which are critical features of complex microstructures



Example: Solid State Lighting (LEDs)

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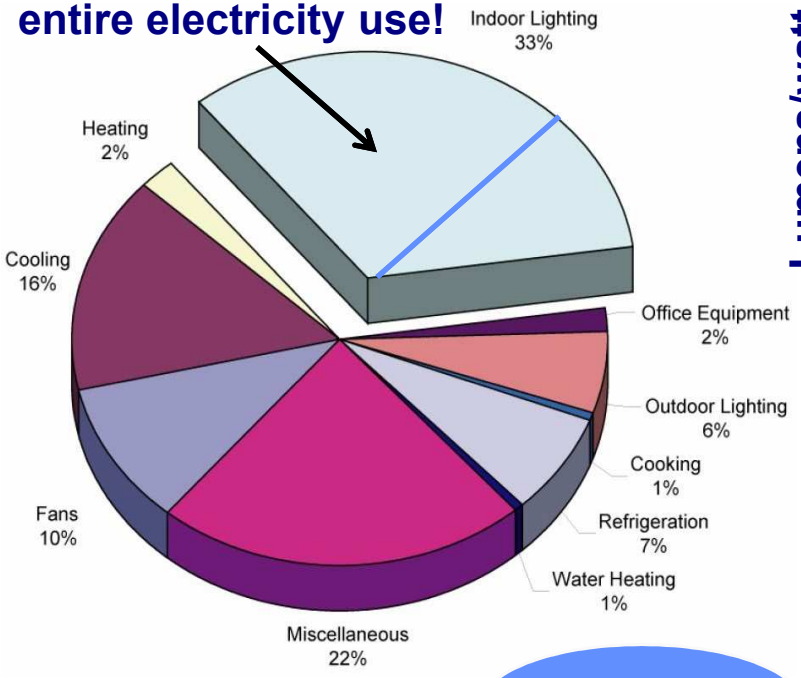
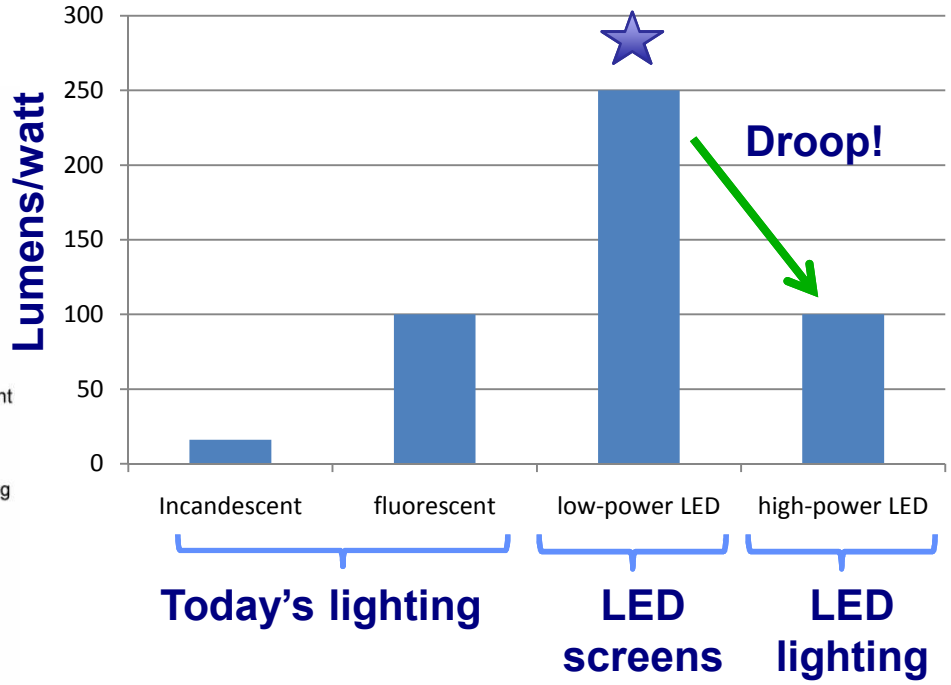
The Opportunity:

LEDs to save 22% of today's entire electricity use!



The Problem:



Science needed:

Example: Superconductors for High Capacity Grid

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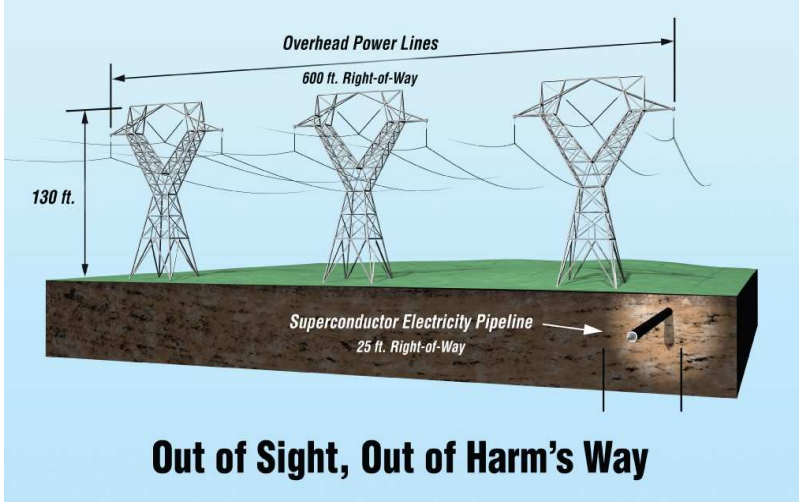
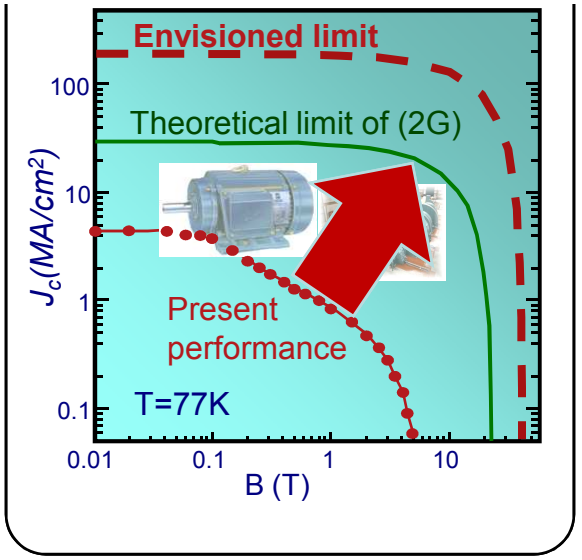
The Opportunity:

Superconductors enable high capacity, reliable grid, including efficient long-distance transmission of renewable energy



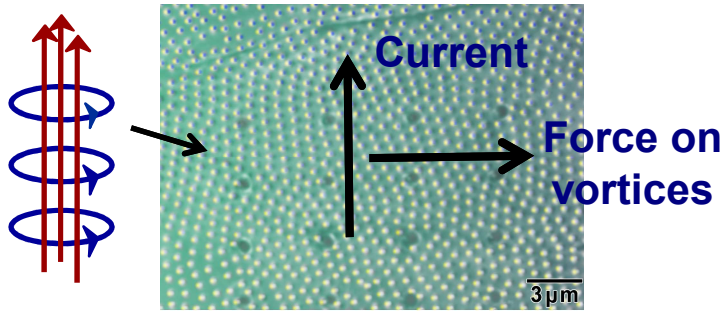
The Problem:

Superconductors need higher currents to be cost-effective



Science needed:

Vortices are nanoscale quanta of magnetic flux. Their pinning by defects controls current density. Need to understand mechanism.



Overarching Themes

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- Develop foundational scientific understanding of at-scale production challenges in existing materials and processes
- Beyond empiricism: fundamental understanding of lifetime prediction of materials in extreme environments, especially ageing, degradation and failure
- Discovery of new materials or chemical processes with targeted functionality

Crosscutting Needs

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- New materials by design with specific properties or functionalities
  - Numerical modeling
  - Science of synthesis
  - Characterization of outcomes
- Interfaces: understand, predict and control
  - Optical, electrical, mechanical and chemical behaviour
  - Solar cells, radiation hard materials, battery & fuel cell electrodes
- Dynamic behavior away from equilibrium
  - Chemical reaction kinetics, degradation & failure modes of materials, current flow in electric grid

BES User Facilities

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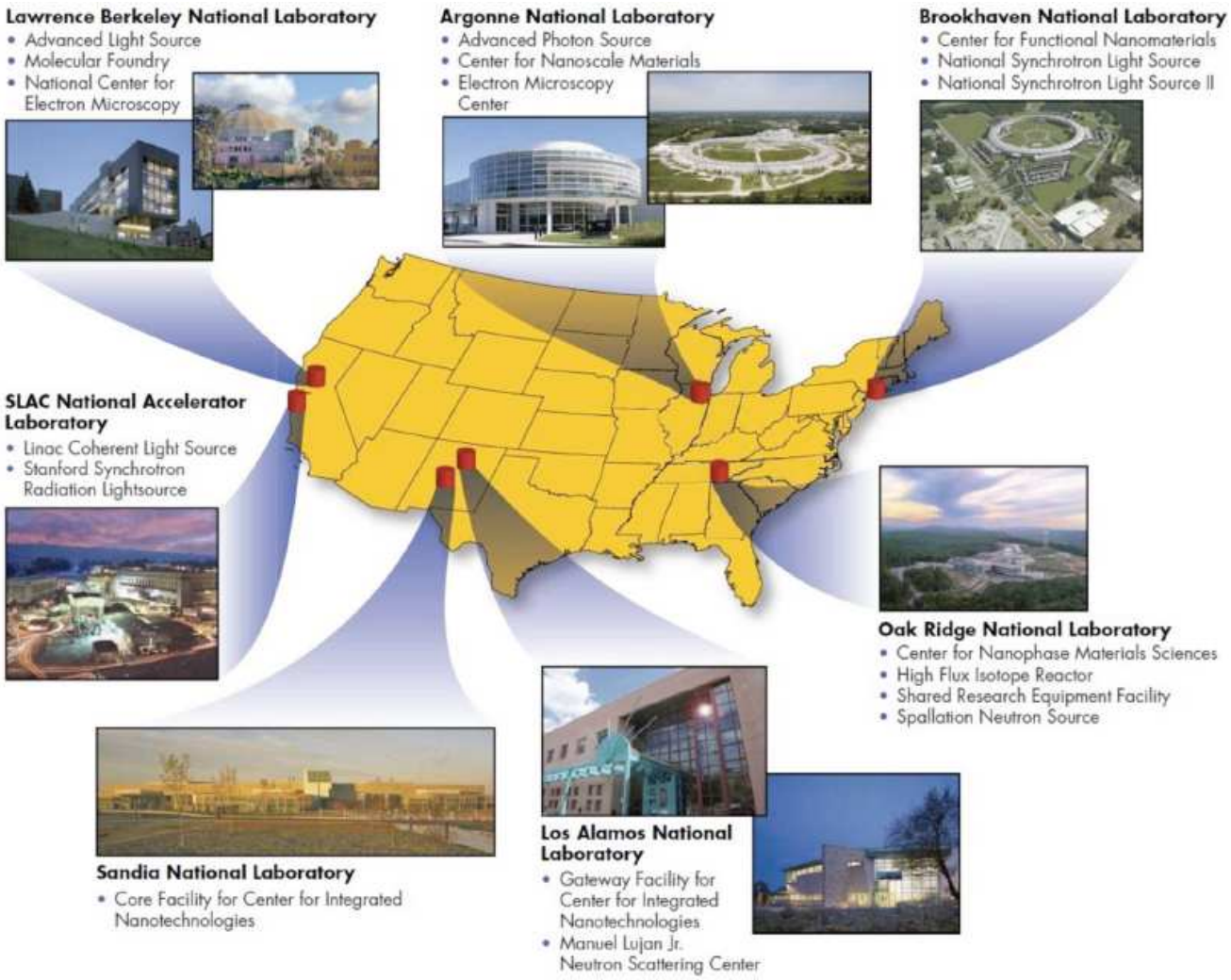
unique resources

structure
spectroscopy
imaging

nanoscale
synthesis and
characterization

stronger partnering
with industry on
clean energy
science roadblocks



BES User Facilities

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User Facilities

BES supports a suite of complementary user facilities that comprise a unique asset for basic research and industry scientists alike (see sidebar: BES-Funded Scientific User Facilities). These facilities are home to high intensity photon and neutron sources and advanced electron microscopes for measuring composition and structure of materials. Nanoscale science research centers offer state-of-the-art equipment for synthesis and characterization of materials on the scale of atoms and molecules. Using these tools, researchers are able to peer deep inside objects and probe surfaces in ever increasing detail, enabling an understanding of complex materials and chemistry with resolution and sensitivity that is not achievable by any other means. Facilities of this type are well beyond the resources of individual research institutions or companies.

The user facilities are ideally suited to addressing a wide range of science questions with significant technological impact. BES and the user facilities could consider a number of options that would allow the facilities to better serve the industrial user community without deviating from their mission to advance scientific understanding of materials and chemical processes. To the extent possible, it would be desirable to have more uniform procedures for access and use across the various user facilities to expedite coordinated use of multiple facilities by industry and other research organizations. Evaluation of proposals could take into consideration technological impact in addition to scientific merit. Peer review of proposals could include a greater number of industry reviewers. The facilities might consider setting aside a modest fraction of the facility time for "quick response" projects from industry and basic science users. User facility staff researchers could be incentivized and rewarded for assisting non-expert users from industry, and facilities could increase their outreach to industry by holding workshops to gain greater understanding of industrial needs and barriers to increased participation. These activities are within the technology transfer mission of the laboratories and could significantly enhance the development of clean energy technology.

User facilities could be encouraged to develop and broaden industrial participation. Some possibilities include greater industrial participation on Scientific Advisory Committees, or possibly the development of a separate Industrial Advisory Board. These would help to develop better communications with the facility Director and staff regarding industrial needs for access, as well as new capabilities, instrumentation and beamlines.

BES User Facilities: Recommendations

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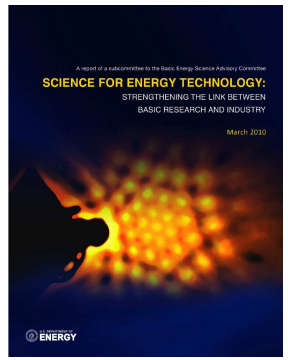
- To the extent possible it would be desirable to have more uniform procedures for access and use across the various user facilities
  - To expedite coordinated use of multiple facilities by industry and other research organizations
- Evaluation of proposals could take into consideration technological impact in addition to scientific merit
- Peer review of proposals could include a greater number of industry reviewers
- Facilities might consider setting aside a modest fraction of the facility time for “quick response” projects from industry and basic science users



BES User Facilities: Recommendations

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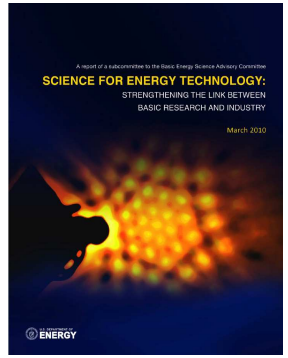
- User facility staff researchers could be incentivized and rewarded for assisting non-expert users from industry
- Facilities could increase their outreach to industry by holding workshops to gain greater understanding of industrial needs and barriers to increased participation
- User facilities could be encouraged to develop and broader industrial participation
  - Greater industrial participation on Scientific Advisory Committees
  - Development of Industrial Advisory Board



Full Report

- Many other issues of Industrial Users identified & discussed
- Cannot elucidate on these today
- Will have to wait for full report
  - BESAC Meeting August 5-6, 2010

Recommendations

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Massive and sustained investment in basic energy science needed immediately, to achieve the breakthroughs in clean energy technologies

The diversity of Priority Research Directions identified in the Workshop require a variety of programs integrating science and industry

Energy Innovation Hubs embody science-industry coordination needed to solve critical energy and environmental challenges

- Hubs on battery energy storage and other key topics should be funded and sustained until challenges are solved

DOE-BES scientific user facilities - a unique and powerful resource for solving clean energy science challenges.

- BES facilities should seek stronger industrial engagement to address these challenges.

An enormous opportunity to accelerate transformative solutions to critical energy challenges

Used for briefing to Congressional Staff