U.S. Department of Energy

Office of Science

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Connecting University Faculty to the DOE Research Infrastructure

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Director

Office of Workforce Development for Teachers & Scientists

November 10, 2008

www.science.doe.gov

DOE's Far-Reaching Scale and Scope

No Other Organization in the World Matches the Scale and Scope of DOE's Investments in its Mission Areas

Energy Security ($4 billion)

Promoting America's energy security through reliable, clean, and affordable energy

Nuclear Security ($9 billion)

Ensuring America's nuclear security

Scientific Discovery and Innovation ($3.9 billion)

Strengthening U.S. scientific discovery, economic competitiveness, and improving quality of life through innovations in science and technology

Environmental Responsibility ($7.5 billion)

Protecting the environment by providing a responsible resolution to the environmental legacy of nuclear weapons production

Office of Science Missions

- **Future of Science**
  - The Department of Energy's Office of Science is the steward of national science facilities that maintain U.S. world-leadership status in the physical sciences
  - Understand Key Questions: the beginning of time, the nature of energy and matter from quarks to the cosmos
  - Develop Scientific Workforce: Using the unique capabilities of the DOE laboratories for teacher professional development; enhancing the size and diversity of the scientific workforce
- **Competitiveness**
  - Keeping U.S. Research and Development at the forefront of global science
  - Scientific Computation – accelerate innovation through virtual prototypes
  - Nanotechnology centers provide a unique capability for US universities and industry
- **Energy Security**
  - Develop new sources of energy through transformational technologies, e.g., fusion and novel methods of converting biomass to ethanol
  - Develop stronger, lightweight materials and improve combustion and catalytic processes to reduce energy consumption and improve efficiency

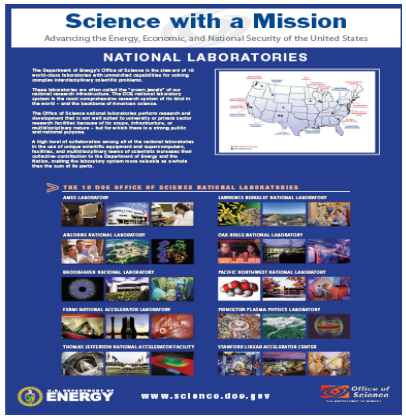
Federal Research Funding Rankings

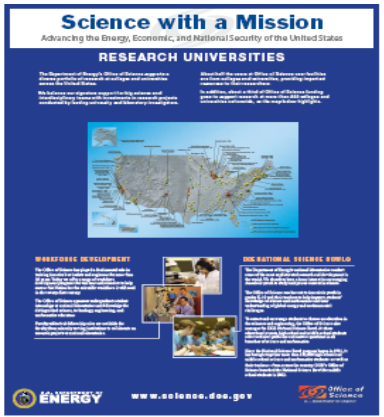
Federal R&D Budget -- FY 2008 Data [1] (dollars in millions)						Crosscut	Crosscut	Crosscut
	Basic Research	Applied Research	Development	Facilities/ Equipment	Total R&D	Networking And Info. Technology R&D	National Nanotechnology Initiative	Climate Change Science Program
1	HHS 16,037	HHS 12.540	DOD 68,315	NASA 2,146	DOD 74,234	DOD 1,018	NSF 373	NASA 1,025
2	NSF 3,687	DOD 4,478	NASA 6,755	DOE 1,130	HHS 28,737	NSF 904	DOD 345	NSF 205
3	DOE 3,315	DOE 2,723	DOE 1,990	NSF 482	NASA 12,245	HHS 541	DOE 258	DOC 186
4	NASA 2,226	NASA 1,118	DHS 335	DHS 181	DOE 9,158	DOE 473	HHS 173	DOE 126
5	DOD 1,422	AGRIC. 974	TRANSP. 194	HHS 123	NSF 4,548	NASA 82	COMMERCE 86	AGRIC. 61

[1] Source: FY 2008 Budget of the United States, Analytical Perspectives volume, R&D Chapter

The Office of Science…

- …supports basic research and research capabilities that underpin DOE mission in energy, environment and national security through long-term, high-risk, high-payoff multidisciplinary research programs
- …constructs and operates 32 world leading large-scale user facilities open to the scientific community, including the international science community
- …provides over 40% of Federal support for the physical sciences
- …directly supports (FY ‘08) the research of 21,000 Ph.D.’s, graduate students, and undergraduates; and indirectly supports 23,000 more at the large-scale facilities - developing and nurturing a highly trained scientific workforce
- …manages 10 of the 17 DOE national laboratories
- …funds research at more than 300 universities, involving 5,600 Ph.D’s, 2,500 post-docs, 3,900 graduate students, and 800 technicians and support staff





Research at the Office of Science is An Investment in America's Future

The Office of Science Enhances U.S. Competitiveness Through…

Transformational Science

Basic research for advanced scientific breakthroughs that will revolutionize our approach to the nation's energy, environment, and national security challenges

National Scientific Facilities

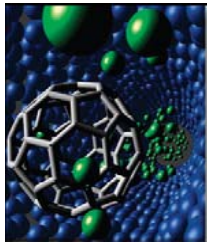
World-leading research capabilities that maintain U.S. leadership in science & technological innovation

A Scientific Workforce for the Nation's Future

Supporting, training, & educating the nation's current and future scientific & technical workforce: Ph.D.'s, post-docs, graduate students, & science educators

Transformational Science

Office of Science Programs Offices:



Basic Energy Sciences (BES)

Advancing the basic sciences for energy security

- Materials Sciences and Engineering
- Chemical Sciences, Geosciences, Energy Biosciences
- Major Scientific User Facilities

Advanced Scientific Computing Research (ASCR)

Extending the frontiers of science

- Mathematical and Computational Sciences
- High Performance Computing and Networking Facilities and Testbeds

Biological and Environmental Research (BER)

Harnessing the power of our living world

- Systems biology on microbes and plants
- Climate Change Research
- Environmental Remediation
- Low-does Radiation and Radiochemistry

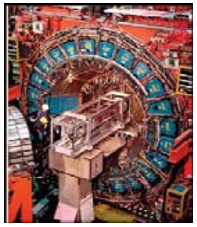
Workforce Development for Teachers and Scientists (WDTS)

- DOE National Science Bowls
- DOE Academies for Creating Teacher Scientists

Fusion Energy Sciences (FES)

Bringing the power of the stars to Earth

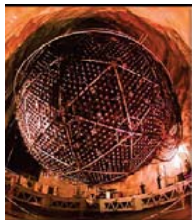
- ITER
- Plasma Science
- Tokamak and Alternative Concept Experimental Research
- Theory and Simulation



High Energy Physics (HEP)

Exploring the fundamental interactions of energy, matter, time, and space

- Elemental particle physics
- Dark matter and dark energy
- Accelerator science and technology
- Theoretical physics



Nuclear Physics (NP)

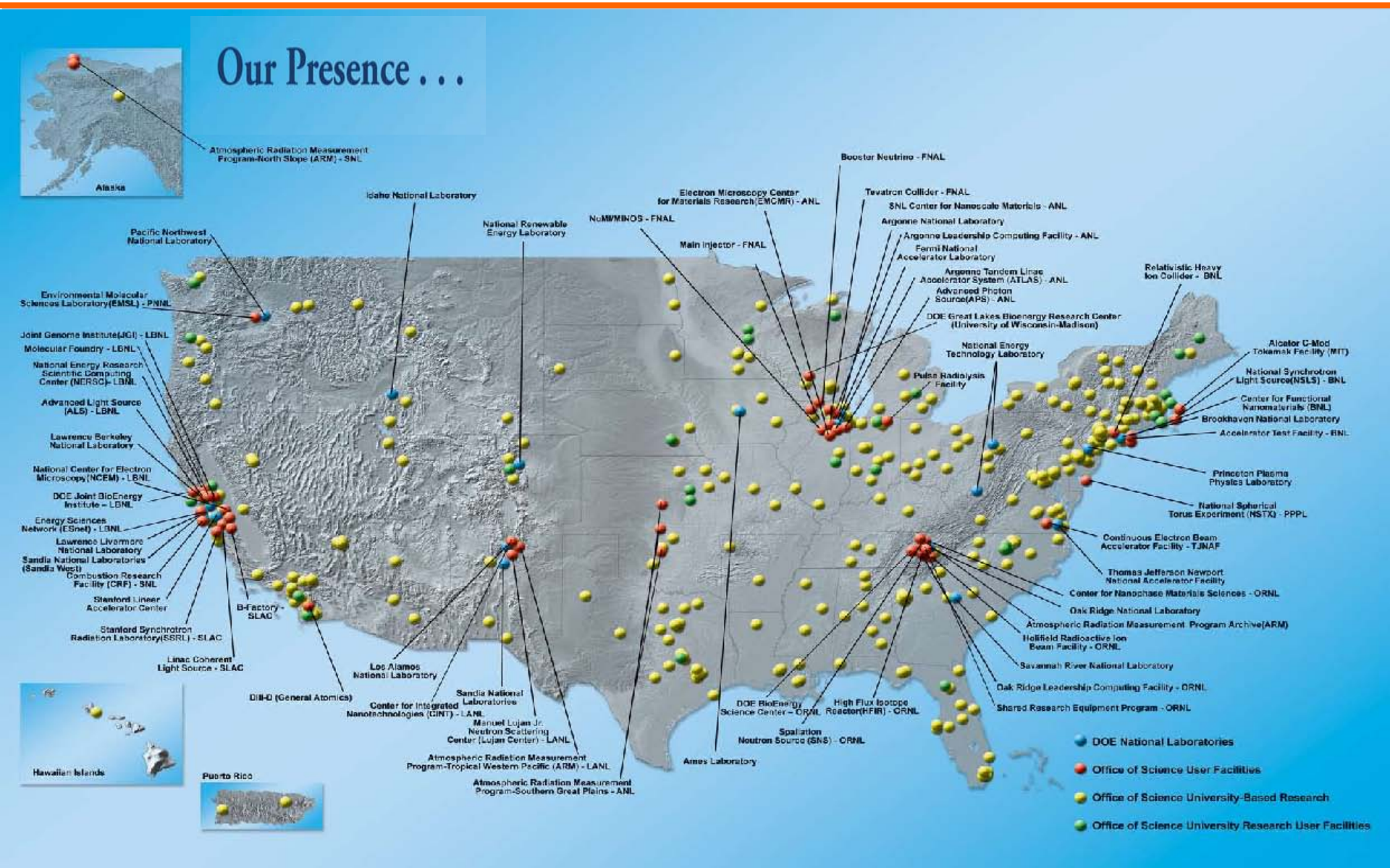
Exploring nuclear matter–from quarks to stars

- Medium and low energy nuclear physics
- Heavy ion nuclear physics – quark-gluon plasma
- Nuclear theory
- Rare Isotopes

U.S. Department of Energy

Office of Science

DOE Office of Science Supported Facilities & Universities



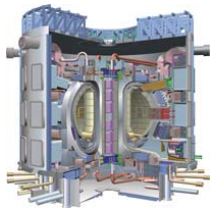
National Scientific Facilities

World-Leading Facilities for U.S. Science

Office of Science scientific facilities host 21,300 users annually from the U.S. and around the world

Basic Energy Sciences (BES)

Spallation Neutron Source, HIFR
Light Sources - APS, ALS, LCLS, NSLS II
5 Nanoscale Science Research Centers
Combustion Research Facility
EMC, CMM

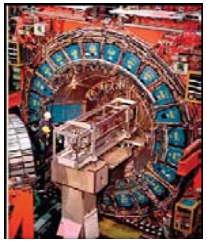


Fusion Energy Sciences (FES)

ITER
NCSX, NSTX, DIII-D, Alcator C-Mod
Plasma Science and Theory

Advanced Scientific Computing Research (ASCR)

Leadership Computing Facilities – ORNL, ANL
NERSC - LBNL
SciDAC
ESNet

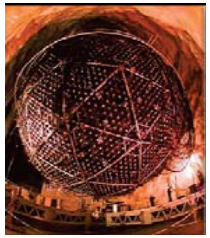


High Energy Physics (HEP)

Fermilab's Tevatron
Neutrinos at the Main Injector, Tevatron
Large Hadron Collider (LHC)
Land- and Space-based Detectors

Biological and Environmental Research (BER)

Three Bioenergy Research Centers
The Joint Genome Institute
Environmental Molecular Sciences Laboratory
ARM Climate Facilities



Nuclear Physics (NP)

Relativistic Heavy Ion Collider (RHIC)
Continuous Electron Beam Accelerator Facility (CEBAF)
Rare Isotope Beam Facility

The Essential Role of Basic Science

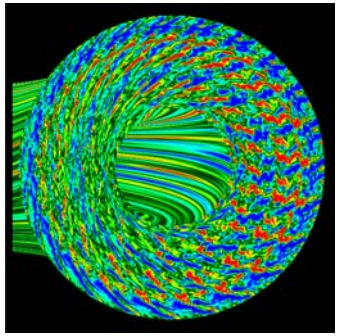
Incremental Changes in Current Technologies Will Not Suffice; Transformational Changes Are Needed.

Today's energy technologies and infrastructure are rooted in 20th Century technologies and 19th Century discoveries—internal combustion engine, electric lighting, alternating current.

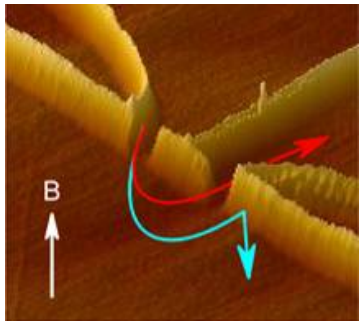
Current fossil energy sources, current energy production methods, and current technologies cannot meet the energy challenges we now face.

Incremental changes in technology will not suffice. We need **transformational discoveries** and truly **disruptive technologies.**

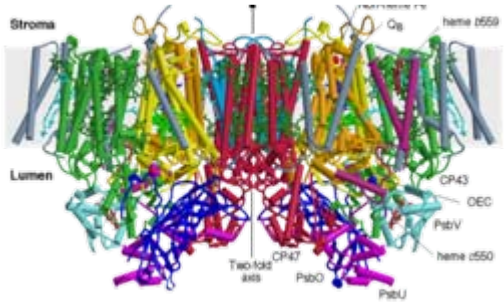
21st Century technologies will require the ability to direct and control matter down to the molecular, atomic, and quantum levels.

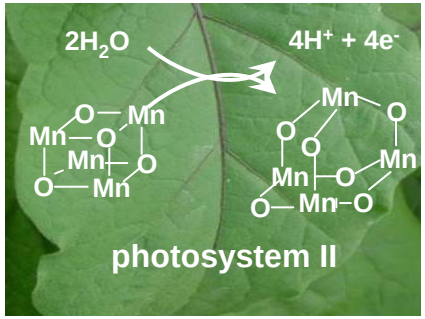


Computer simulation of plasma turbulence in a tokamak



Separating electrons by their spin for "spintronics" and other applications of electron control.

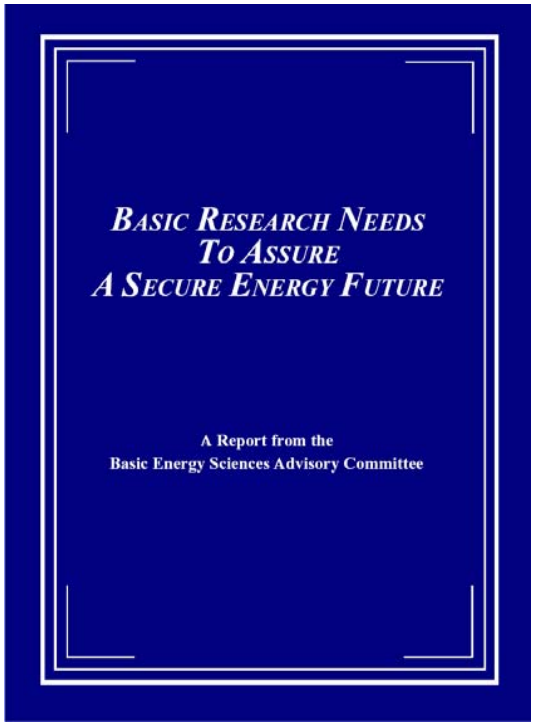




Bio-inspired nanoscale assemblies – self-repairing and defect-tolerant materials and selective and specific chemical reactivity.

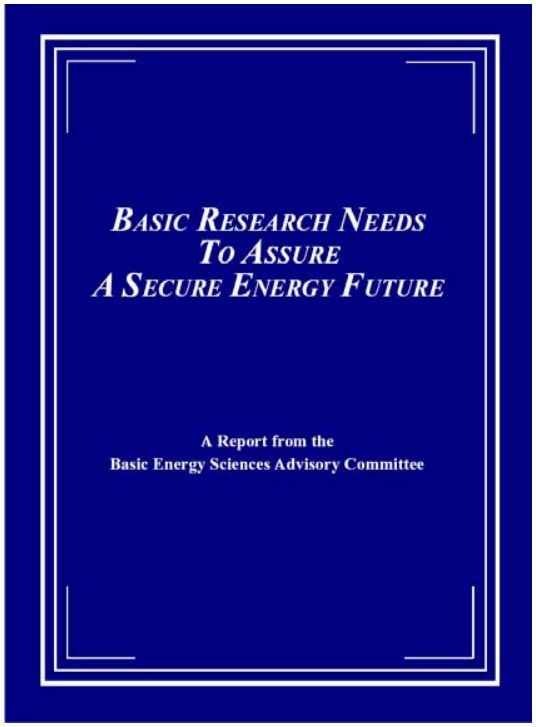
The First "Basic Research Needs …" Workshop

Basic Research Needs to Assure a Secure Energy Future (October 2002)



- The report identified basic research directions required for major technological changes in the largest industries in the world—those responsible for energy production and use.
- The reports highlighted the remarkable scientific journey that took place during the past few decades. The resulting scientific challenges are describe a new era of science — an era in which materials functionalities are designed to specifications and chemical transformations are manipulated at will.
- In this new era of science, we design, discover, and synthesize new materials and molecular assemblies through atomic scale control; probe and control photon, phonon, electron, and ion interactions with matter; perform multi-scale modeling that bridges the multiple length and time scales; and use the collective efforts of condensed matter and materials physicists, chemists, biologists, molecular engineers, applied mathematicians, and computer scientists.
- The findings inspired 10 additional workshops over the next five years, which together attracted more than 1,500 participants.

The "Basic Research Needs …" Workshop Yielded Broad Consensus on Key Issues

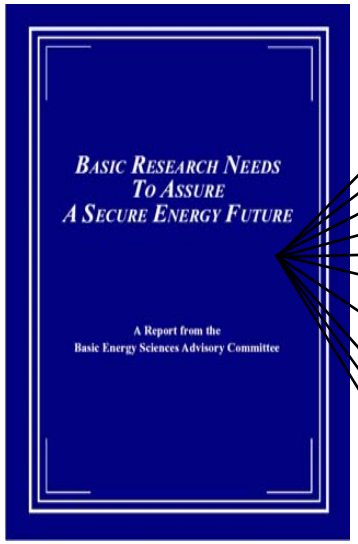


- Nanoscale science is key to solving long-standing scientific questions and technical problems.
- Characterizations with high physical, chemical, structural, and temporal precision are critical and will require continuous improvement of experimental capabilities.
- Similarly, theory, modeling, and simulation will require continuous improvement of computational capabilities.
- Energy problems are multidisciplinary. The traditional structure of research, with specific disciplinary groupings, will not be sufficient.
- A diverse range of energy sources will be required, and a broad range of fundamental research is needed to enable these.
- Basic science must be complemented by awareness of the engineering, design, and control issues.
- The education of the next generation of scientists is crucial and must include teaching the importance of energy security.

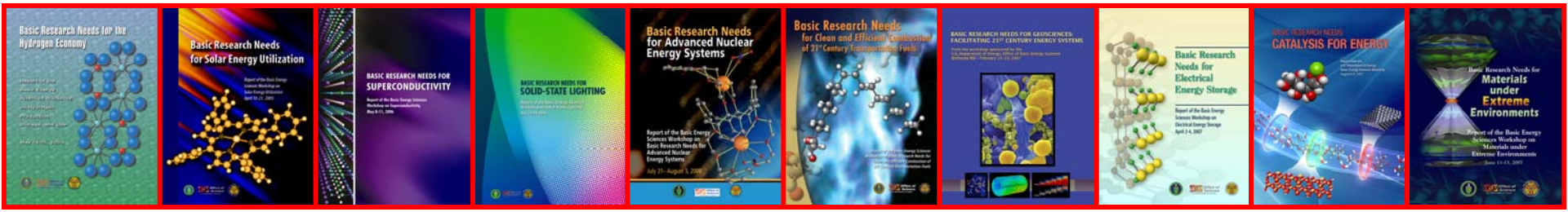
The 10 "Basic Research Needs …" Workshops

10 Workshops; 5 Years; More Than 1,500 Participants From Academia, Industry, and DOE Laboratories

Basic Research Needs to Assure a Secure Energy Future (BESAC)



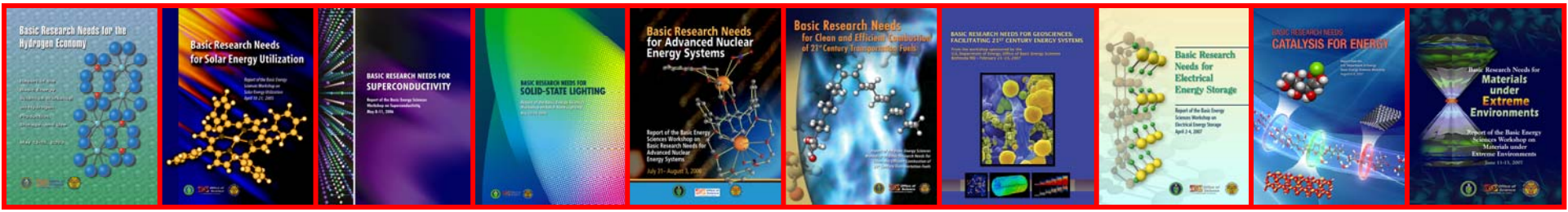
- Basic Research Needs for the Hydrogen Economy
- Basic Research Needs for Solar Energy Utilization
- Basic Research Needs for Superconductivity
- Basic Research Needs for Solid State Lighting
- Basic Research Needs for Advanced Nuclear Energy Systems
- Basic Research Needs for the Clean and Efficient Combustion of 21st Century Transportation Fuels
- Basic Research Needs for Geosciences: Facilitating 21st Century Energy Systems
- Basic Research Needs for Electrical Energy Storage
- Basic Research Needs for Catalysis for Energy Applications
- Basic Research Needs for Materials under Extreme Environments



Important Recurring Themes from the Workshops

Control of Materials Properties and Functionalities Through Electronic and Atomic Design

- New materials discovery, design, development, and fabrication, especially materials that perform well under extreme conditions
- “Control” of photon, electron, spin, phonon, and ion transport in materials
- Science at the nanoscale, especially low-dimensional systems
- Designer catalysts
- Designer interfaces and membranes
- Structure-function relationships
- Bio-materials and bio-interfaces, especially at the nanoscale
- New tools for spatial characterization, temporal characterization, and for theory/modeling/computation



One Additional Workshop: Science Grand Challenges

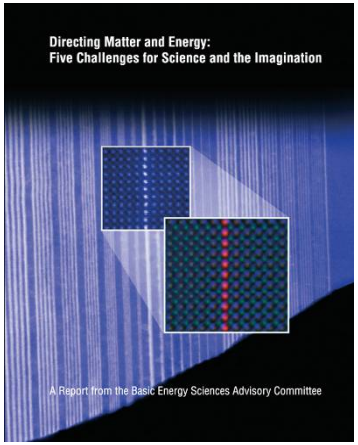
How Does Nature Execute Electronic and Atomic Design? How Can We?

Directing Matter and Energy: Five Challenges for Science and the Imagination

- **Control the quantum behavior of electrons in materials**
  Imagine: Direct manipulation of the charge, spin and dynamics of electrons to control and imitate the behavior of physical, chemical and biological systems, such as digital memory and logic using a single electron spin, the pathways of chemical reactions and the strength of chemical bonds, and efficient conversion of the Sun's energy into fuel through artificial photosynthesis.

- **Synthesize, atom by atom, new forms of matter with tailored properties**
  Imagine: Create and manipulate natural and synthetic systems that will enable catalysts that are 100% specific and produce no unwanted byproducts, or materials that operate at the theoretical limits of strength and fracture resistance, or that respond to their environment and repair themselves like those in living systems.

- **Control emergent properties that arise from the correlations of atomic and electronic constituents**
  Imagine: Orchestrate the behavior of billions of electrons and atoms to create new phenomena, like superconductivity at room temperature, or new states of matter, like quantum spin liquids, or new functionality combining contradictory properties like super-strong yet highly flexible polymers, or optically transparent yet highly electrically conducting glasses, or membranes that separate CO_2 from atmospheric gases yet maintain high throughput.



- **Synthesize man-made nanoscale objects with capabilities rivaling those of living things**
  Imagine: Master energy and information on the nanoscale, leading to the development of new metabolic and self-replicating pathways in living and non-living systems, self-repairing artificial photosynthetic machinery, precision measurement tools as in molecular rulers, and defect-tolerant electronic circuits.

- **Control matter very far away from equilibrium**
  Imagine: Discover the general principles describing and controlling systems far from equilibrium, enabling efficient and robust biologically-inspired molecular machines, long-term storage of spent nuclear fuels through adaptive earth chemistry, and achieving environmental sustainability by understanding and utilizing the chemistry and fluid dynamics of the atmosphere.

How Nature Works → Materials by Design → Technologies for the 21st Century

Grand Challenges
How nature works

- Controlling materials processes at the level of quantum behavior of electrons
- Atom- and energy-efficient syntheses of new forms of matter with tailored properties
- Emergent properties from complex correlations of atomic and electronic constituents
- Man-made nanoscale objects with capabilities rivaling those of living things
- Controlling matter very far away from equilibrium

Discovery and Use-Inspired Basic Research
Materials properties and functionalities by design

- Basic research for fundamental new understanding on materials or systems that may revolutionize or transform today's energy technologies
- Development of new tools, techniques, and facilities, including those for the scattering sciences and for advanced modeling and computation
- Basic research, often with the goal of addressing showstoppers on real-world applications in the energy technologies

Applied Research

- Research with the goal of meeting *technical milestones*, with emphasis on the development, performance, cost reduction, and durability of materials and components or on efficient processes
- Proof of technology concepts

Technology Maturation & Deployment

- Scale-up research
- At-scale demonstration
- Cost reduction
- Prototyping
- Manufacturing R&D
- Deployment support

BESAC & BES Basic Research Needs Workshops

BESAC Grand Challenges Panel

DOE Technology Office/Industry Roadmaps

BES Energy Frontier Research Centers

Tackling our Energy Challenges in a New Era of Science

Energy Frontier Research Centers

Engaging the Talents of the Nation's Researchers for the Broad Energy Agenda

Energy Frontier Research Centers will bring together the skills and talents of multiple investigators to enable research of a scope and complexity that would not be possible with the standard individual-investigator or small-group award.

The DOE Office of Science, Office of Basic Energy Sciences, announced the Energy Frontier Research Centers (EFRCs) program. EFRC awards are $2–5 million/year for an initial 5-year period. Universities, labs, and other institutions are eligible to apply.

Energy Frontier Research Centers will pursue fundamental research that addresses both energy challenges and science grand challenges in areas such as:

- Solar Energy Utilization
- Catalysis for Energy
- Electrical Energy Storage
- Solid State Lighting
- Superconductivity
- Bioenergy and biofuels
- 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

A Scientific Workforce For Our Nation's Future

The total FY 2009 Request for the Office of Science will:

- Support about 23,700 Ph.D.s, graduate students, undergraduates and technical staff at the DOE national laboratories; an increase of 2,600 over FY 2008
- Support over 21,000 individual researchers from universities, national laboratories, and industry to use the Office of Science's world-leading suite of scientific user facilities this year; an increase of 1,000 over FY 2008
- Support over 12,500 individuals at universities through Office of Science grant programs

DOE has played an important role in training America's scientists and engineers for more than 60 years, making historic contributions to U.S. scientific preeminence

- Scientists and engineers at the DOE laboratories conduct independent research and collaborate with U.S. and international scientists.
- Many faculty, graduate students, postdocs, and undergraduates conducting research at the laboratories come from other countries.
- The Office of Science does not fund any classified research, however, some of the Office of Science laboratories conduct classified research funded by other sources.

Universities Should Be Involved with The Office of Science

Five Reasons Why Universities Should Participate in SC- sponsored Research:

1. Largest supporter of basic research in the physical sciences in the world
2. All research is competed and peer reviewed for quality and relevance
3. A culture of discipline and planning that is sustained over decades
4. Strong ties between “use inspired” basic research and its eventual application
5. A history of partnerships with industry, academia and other Federal agencies

Opportunities for Colleges & Universities

- **Apply to a Project**
  - Ex: SciDAC grant at: www.science.doe.gov/grants/FAPN06-04.html
- **Apply to an Office of Science Program**
  - Ex: Nuclear Physics at: www.sc.doe.gov/np/grants/grants.html
- **Apply to a National Laboratory**
  - Ex: Pacific Northwest National Laboratory at: www.pnl.gov/main/business/index.html
- **Apply to the FaST Program**
  - http://www.scied.science.doe.gov/scied/fast/about.html

Get involved:

- Join an Advisory Committee
- Visit a program manager
- Volunteer to be a peer reviewer
- Become an IPA
- Seek a joint appointment at a DOE laboratory
- Participate in a “Lehman Review”
- Participate in a program review
- Participate in a Committee of Visitors

Questions or Comments

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