U.S. DEPARTMENT OF ENERGY

OFFICE OF SCIENCE

# *Tackling Our Energy Challenges in a New Era of Science: The Role of Scientific User Facilities*

*June 10, 2009*
*National Users Facility Organization Annual Meeting*
*Argonne National Laboratory*

*Harriet Kung*
*Office of Basic Energy Sciences*
*Office of Science, U.S. Department of Energy*

# Outline

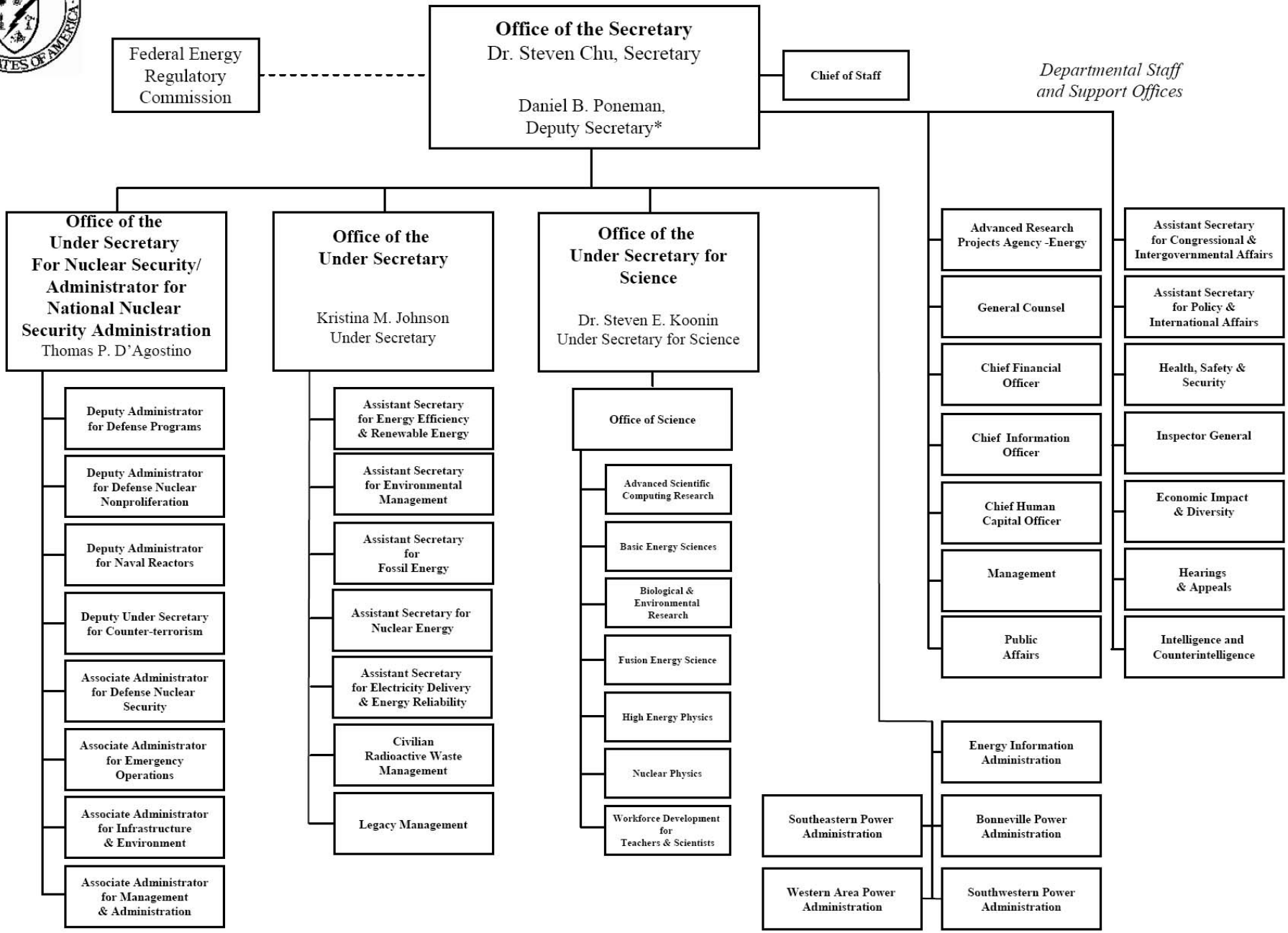
- *Office of Science Overview (from Pat's charts)*

  **http://www.science.doe.gov/SC-2/Deputy_Director-speeches-presentations.htm**

- *Science-driving Facilities; Facilities-driving Science: BES Photon Science Example*

- *BES Strategic Planning for a New Era of Science*

# DEPARTMENT OF ENERGY



# DOE's Priorities and Goals

Priority: Science and Discovery: Invest in science to achieve transformational discoveries
- Organize and focus on breakthrough science
- Develop and nurture science and engineering talent
- Coordinate DOE work across the department, across the government, and globally

Priority: Change the landscape of energy demand and supply
- Drive energy efficiency to decrease energy use in homes, industry and transportation
- Develop and deploy clean, safe, low carbon energy supplies
- Enhance DOE's application areas through collaboration with its strengths in Science

Priority: Economic Prosperity: Create millions of green jobs and increase competitiveness
- Reduce energy demand
- Deploy cost-effective low-carbon clean energy technologies at scale
- Promote the development of an efficient, "smart" electricity transmission and distribution network
- Enable responsible domestic production of oil and natural gas
- Create a green workforce

Priority: National Security and Legacy: Maintain nuclear deterrent and prevent proliferation
- Strengthen non-proliferation and arms control activities
- Ensure that the U.S. weapons stockpile remains safe, secure, and reliable without nuclear testing
- Complete legacy environmental clean-up

Priority: Climate Change: Position U.S. to lead on climate change policy, technology, and science
- Provide science and technology inputs needed for global climate negotiations
- Develop and deploy technology solutions domestically and globally
- Advance climate science to better understand the human impact on the global environment

# *Priority: Science and Discovery*

## *Invest in science to achieve transformational discoveries*

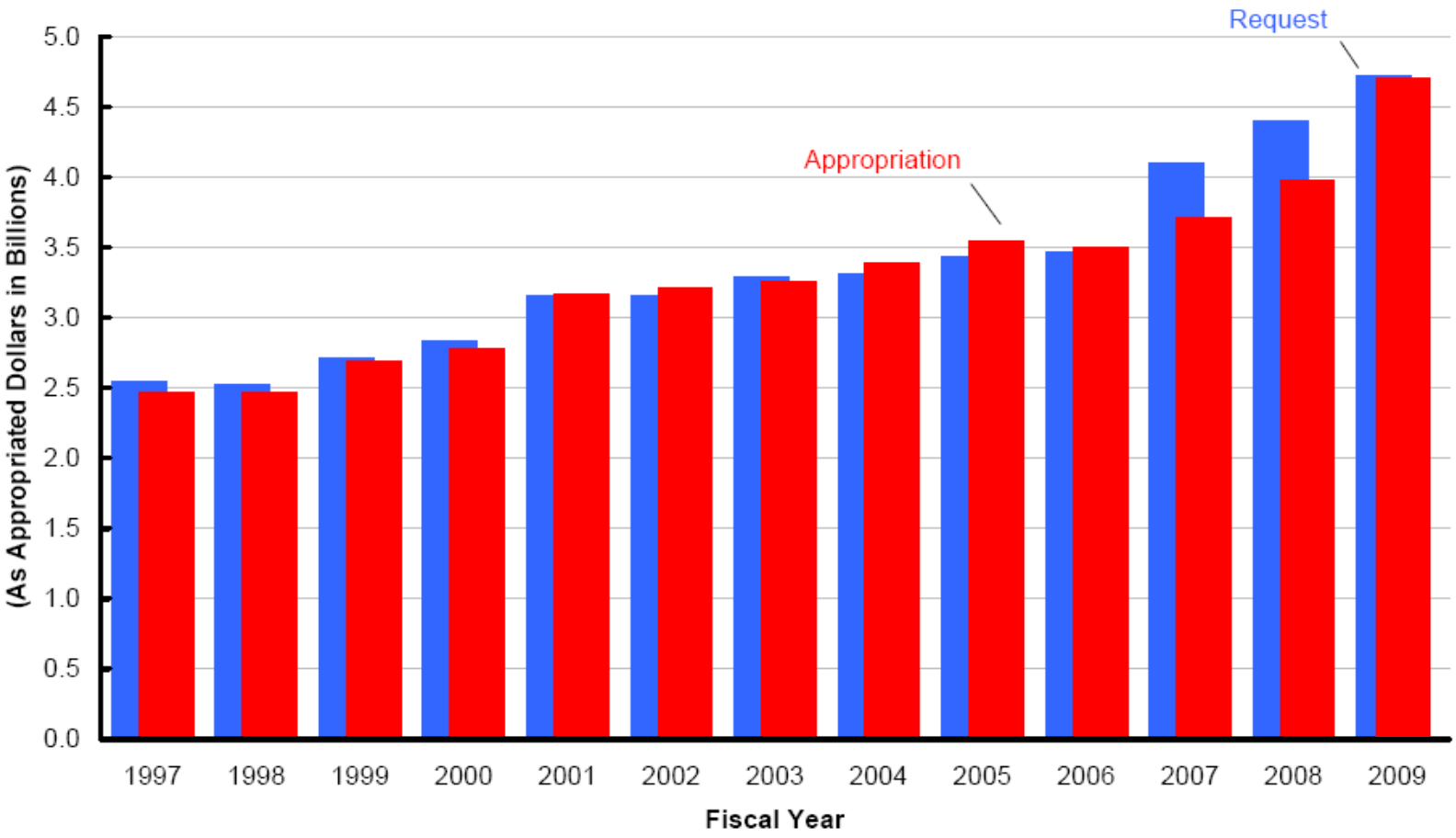
- Focus on transformational science
  - Connect basic and applied sciences
  - Re-energize the national labs as centers of great science and innovation
  - Double the Office of Science budget
  - Embrace a degree of risk-taking in research
  - Create an effective mechanism to integrate national laboratory, university, and industry activities
- Develop science and engineering talent
  - Train the next generation of scientists and engineers
  - Attract and retain the most talented researchers
- Collaborate universally
  - Partner globally
  - Support the developing world
  - Build research networks across departments, government, nation and the globe

# DOE's Office of Science

*The Office of Science is one of the nation's largest supporters of peer-reviewed basic research, providing 40% of Federal support in the physical sciences and supporting ~25,000 Ph.D.s, graduate students, undergraduates, engineers, and support staff at more than 300 universities and at all 17 DOE laboratories.*

- *Science for discovery*
  - Unraveling Nature's deepest mysteries—from the study of subatomic particles; to atoms and molecules that make up the materials of our everyday world; to DNA, proteins, cells, and entire natural ecosystems
- *Science for national need*
  - Advancing a clean energy agenda through basic research on energy production, storage, transmission, and use
  - Advancing our understanding of the Earth's climate through basic research in atmospheric and environmental sciences and in climate modeling
  - Supporting DOE's missions in national security
- *National scientific user facilities, the 21st century tools of science*
  - Providing the Nation's researchers with the most advanced tools of modern science including accelerators, colliders, supercomputers, light sources and neutron sources, and facilities for studying the nanoworld, the environment, and the atmosphere

# SC Request vs. Appropriation (As Appropriated $s)

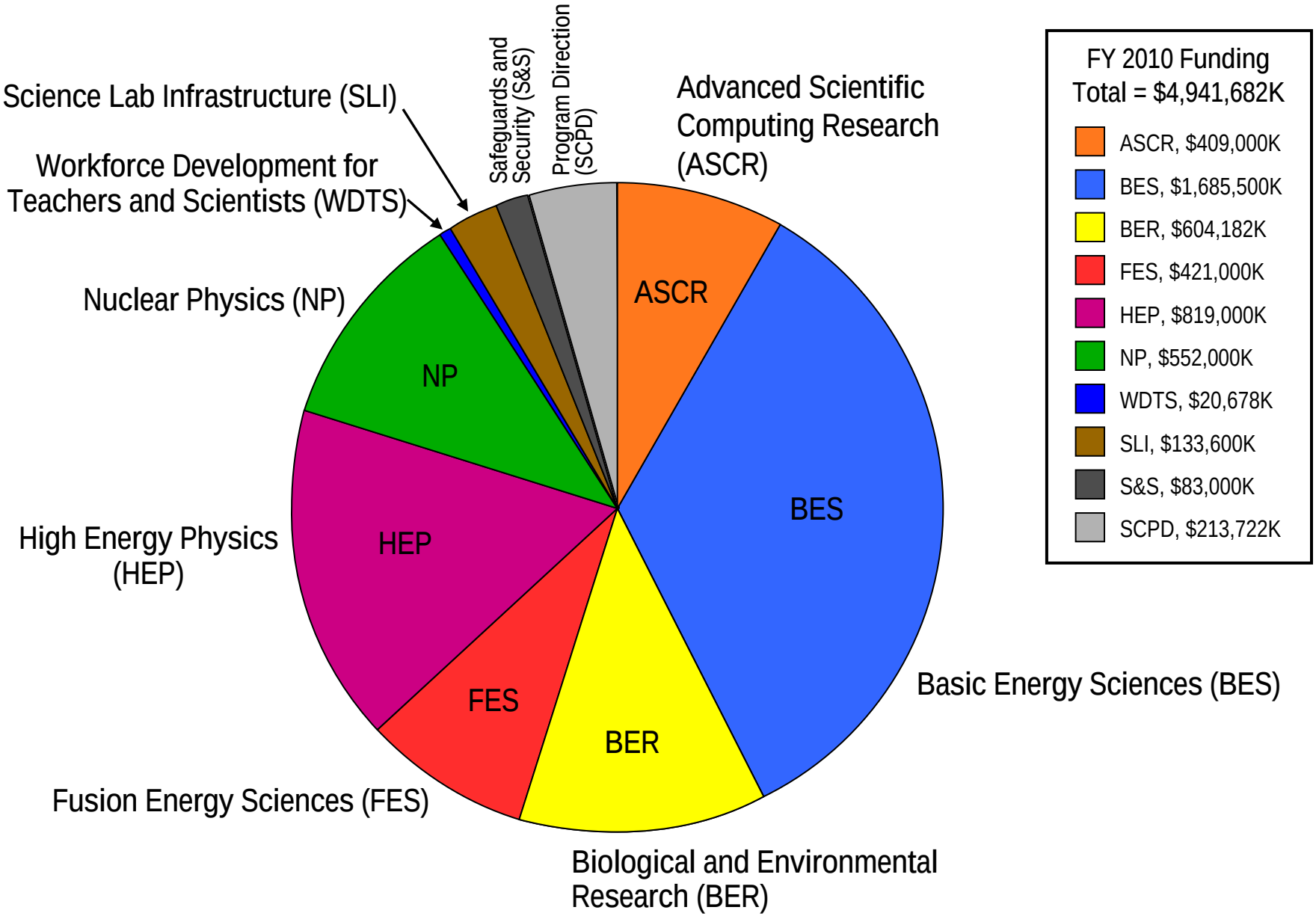


## Office of Science
### FY 2010 Budget Request to Congress
(dollars in thousands)

| | FY 2008 Current Approp. | FY 2009 Base Approp. | FY 2009 Recovery Act | FY 2010 Request | FY 2010 vs. FY 2009 Base Approp. | |
|---|---|---|---|---|---|---|
| **Office of Science** | | | | | | |
| Basic Energy Sciences | 1,252,756 | 1,571,972 | +555,406 | 1,685,500 | +113,528 | +7.2% |
| Advanced Scientific Computing Research | 341,774 | 368,820 | +157,110 | 409,000 | +40,180 | +10.9% |
| Biological and Environmental Research | 531,063 | 601,540 | +165,653 | 604,182 | +2,642 | +0.4% |
| High Energy Physics | 702,845 | 795,726 | +232,390 | 819,000 | +23,274 | +2.9% |
| Nuclear Physics | 423,671 | 512,080 | +154,800 | 552,000 | +39,920 | +7.8% |
| Fusion Energy Sciences | 294,933 | 402,550 | +91,023 | 421,000 | +18,450 | +4.6% |
| Science Laboratories Infrastructure | 66,861 | 145,380 | +198,114 | 133,600 | -11,780 | -8.1% |
| Science Program Direction | 177,779 | 186,695 | +1,600 | 213,722 | +27,027 | +14.5% |
| Workforce Development for Teachers and Scientists | 8,044 | 13,583 | +12,500 | 20,678 | +7,095 | +52.2% |
| Safeguards and Security | 75,946 | 80,603 | —— | 83,000 | +2,397 | +3.0% |
| SBIR/STTR (SC funding) | 92,997 | —— | +19,004 | —— | —— | —— |
| **Subtotal, Office of Science** | **3,968,669** | **4,678,949** | **+1,587,600** | **4,941,682** | **+262,733** | **+5.6%** |
| Congressionally-directed projects | 120,161 | 93,687 | —— | —— | -93,687 | -100.0% |
| SBIR/STTR (Other DOE funding) | 47,241 | —— | —— | —— | —— | —— |
| Coralville, Iowa project rescission | -44,569 | —— | —— | —— | —— | —— |
| Unallocated Recovery Act funding | —— | —— | +12,400 | —— | —— | —— |
| Less security charge for reimbursable work | -5,605 | —— | —— | —— | —— | —— |
| Use of prior year balances | -3,014 | -15,000 | —— | —— | +15,000 | +100.0% |
| Other adjustments* | -53,188 | -15,000 | +12,400 | —— | +15,000 | +100.0% |
| **Total, Office of Science** | **4,082,883** | **4,757,636** | **+1,600,000** | **4,941,682** | **+184,046** | **+3.9%** |
| Advanced Research Projects Agency-Energy (ARPA-E) | —— | 15,000 | —— | —— | -15,000 | -100.0% |
| **Total, Science Appropriation** | 4,082,883 | 4,772,636 | +1,600,000 | 4,941,682 | +169,046 | +3.5% |

* Other adjustments includes a rescission of a prior year Congressionally-directed project (-$44,569,000 in FY 2008), an offset for Safeguards and Security costs charged to reimbursable customers (-$5,605,000 in FY 2008), use of prior year balances (-$3,014,000 in FY 2008 and -$15,000,000 in FY 2009), and $12,400,000 of currently unallocated Recovery Act funding.

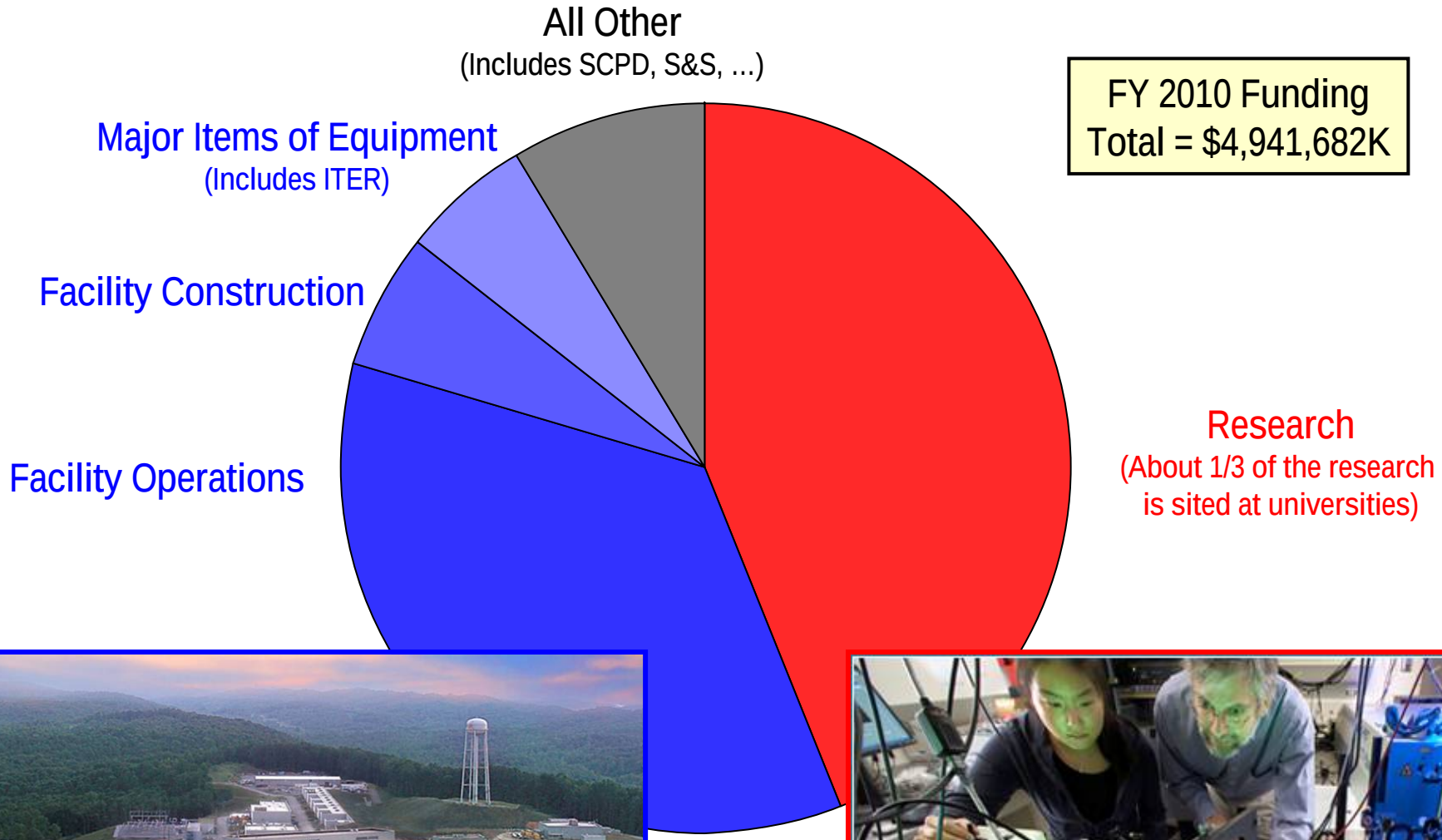
# Office of Science Programs



# Office of Science Research Programs

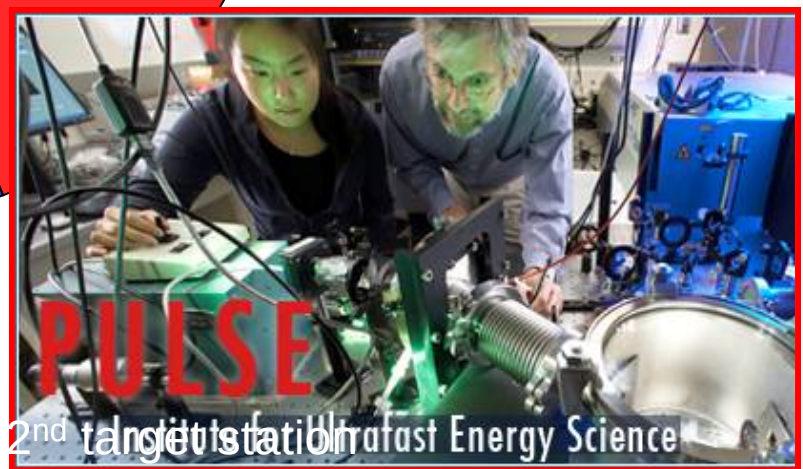
- Advanced Scientific Computing Research (FY 2010 budget request $409,000K)
  - *ASCR Mission: To discover, develop, and deploy applied mathematics, computational, and networking capabilities to analyze, model, simulate, and predict complex phenomena relevant to DOE missions.*
- Basic Energy Sciences (FY 2010 budget request $1,685,500K)
  - *BES Mission: To support fundamental research in condensed matter physics, materials sciences, and chemical sciences to understand, predict, and ultimately control matter and energy at the electronic, atomic, and molecular levels in order to provide the foundations for new energy technologies and for other DOE missions.*
- Biological and Environmental Research (FY 2010 budget request $604,182K)
  - *BER Mission: To understand biological, climate, and environmental systems by exploring genome-enabled biology and the physical, chemical, biological, and hydrological drivers of climate and environmental change and sustainability.*
- Fusion Energy Sciences (FY 2010 budget request $421,000K)
  - *FES Mission: To advance the fundamental understanding of matter at very high temperatures and densities and develop the scientific foundations needed for a fusion energy source.*
- Nuclear Physics (FY 2010 budget request $552,000K)
  - *NP Mission: To discover, explore and understand all forms of nuclear matter and to understand how the fundamental particles—quarks and gluons—fit together and interact to create different types of matter in the universe, including those no longer found naturally.*
- High Energy Physics (FY 2010 budget request $819,000K)
  - *HEP Mission: To understand how our universe works at its most fundamental level by discovering the most elementary constituents of matter and energy; probing the interactions among them; and exploring the basic nature of space and time.*

# Office of Science Functional Support



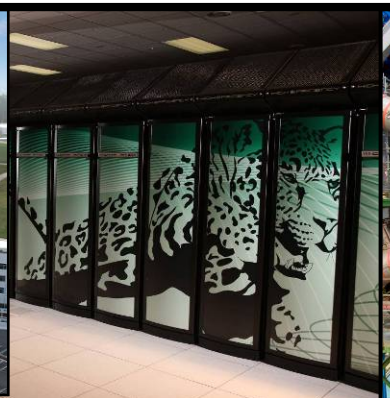
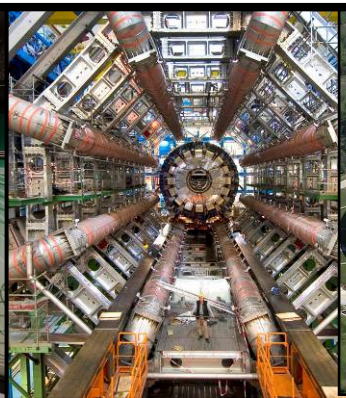

FY 2010 Funding
Total = $4,941,682K

Spallation Neutron Source shown with 2nd target station



# User Facilities

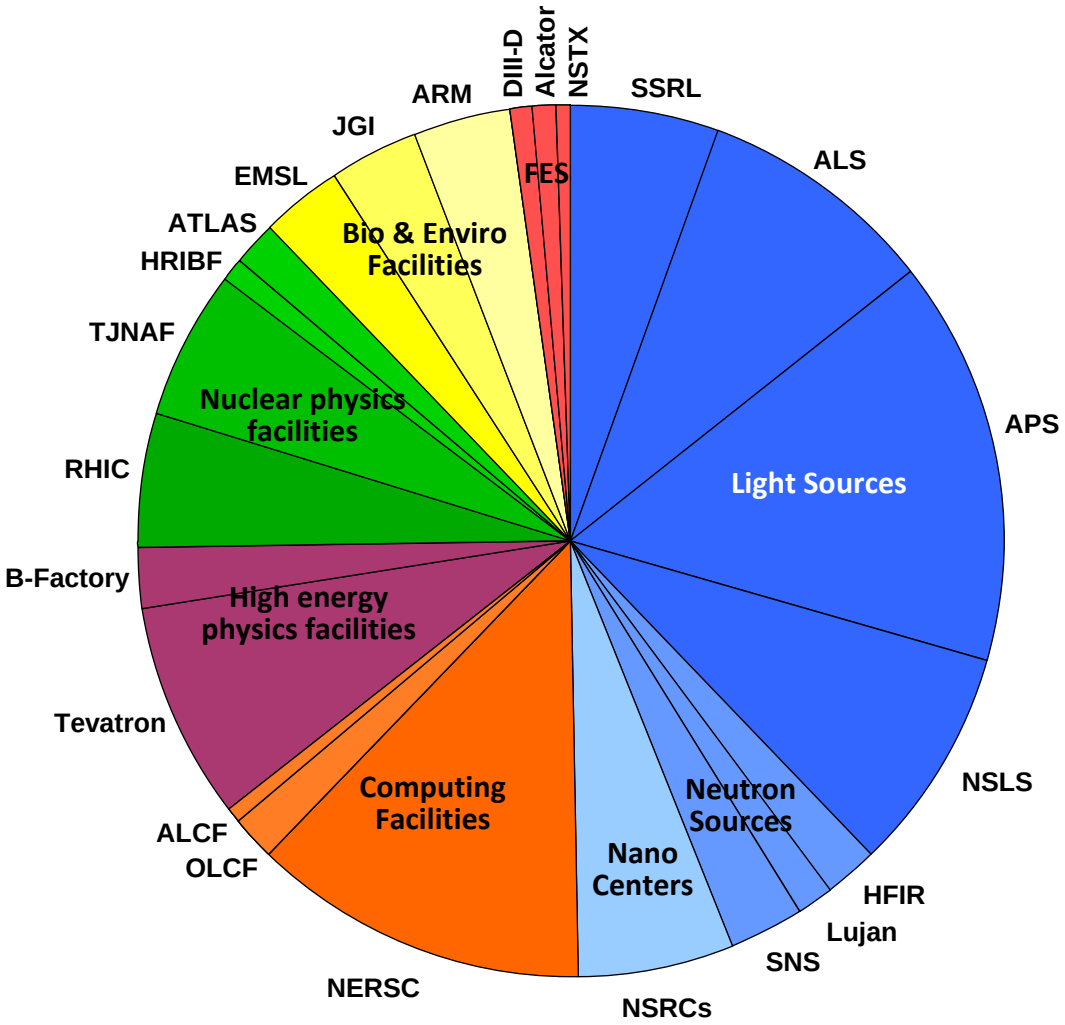
- Advanced computational resources – terascale to petascale computing and networks for open science
- Four synchrotron light sources, and two next-generation light sources in construction
- Three neutron sources for scattering
- Particle accelerators/colliders for high energy and nuclear physics
- Fusion/plasma facilities, including ITER which seeks to demonstrate a burning plasma
- Joint Genome Institute – for rapid whole genome sequencing
- Three Bioenergy Research Centers
- Five Nanoscale Science Research Centers – capabilities for fabrication and characterization of materials at the nanoscale
- Environmental Molecular Science Laboratory –experimental and computational resources for environmental molecular sciences

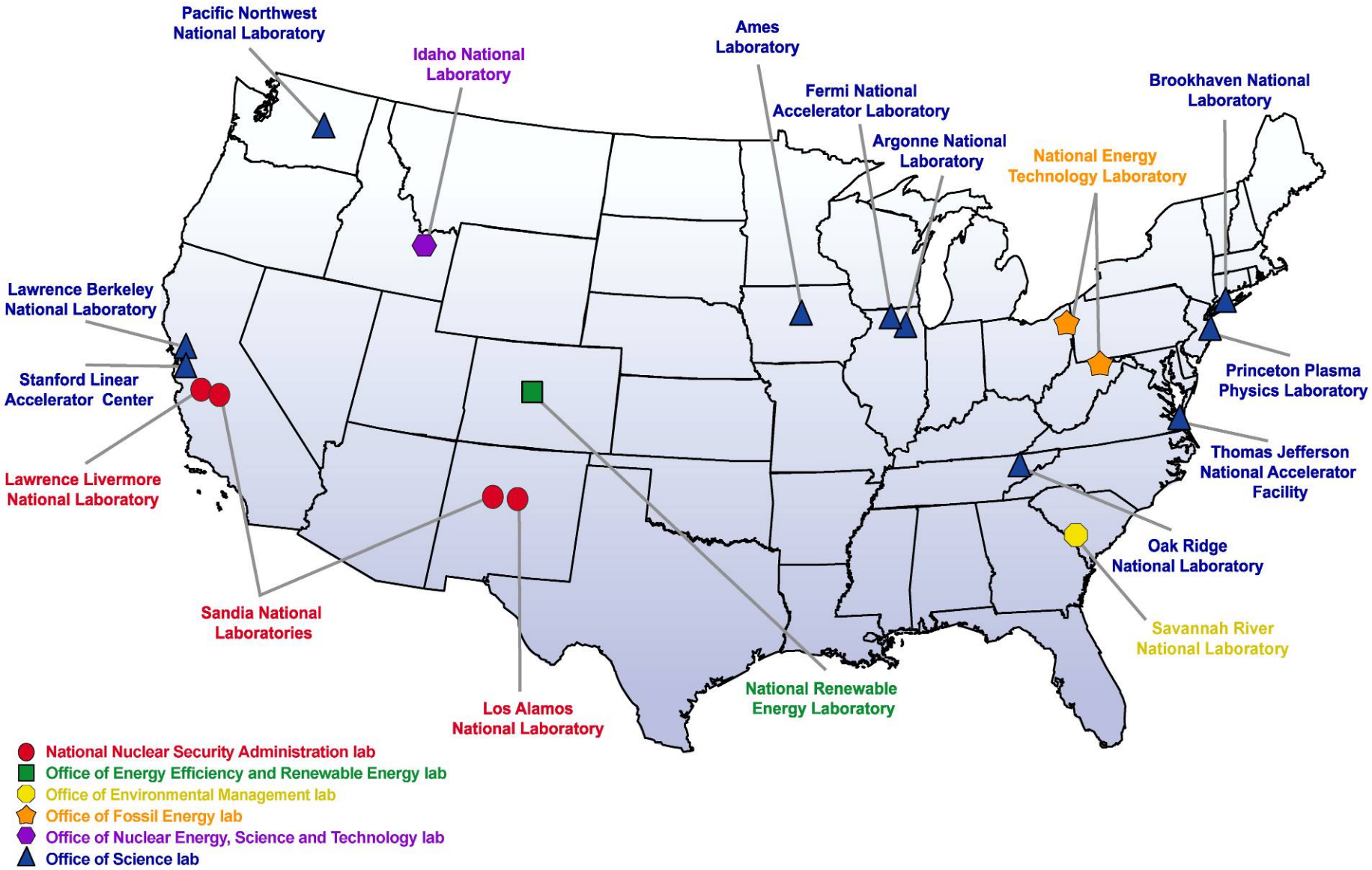
# Distribution of Users by Facility

~25,000 users at the facilities in FY 2010:
~1/2 from universities;
~1/3 from national labs;
and the remainder from industry, other agencies, and international entities.

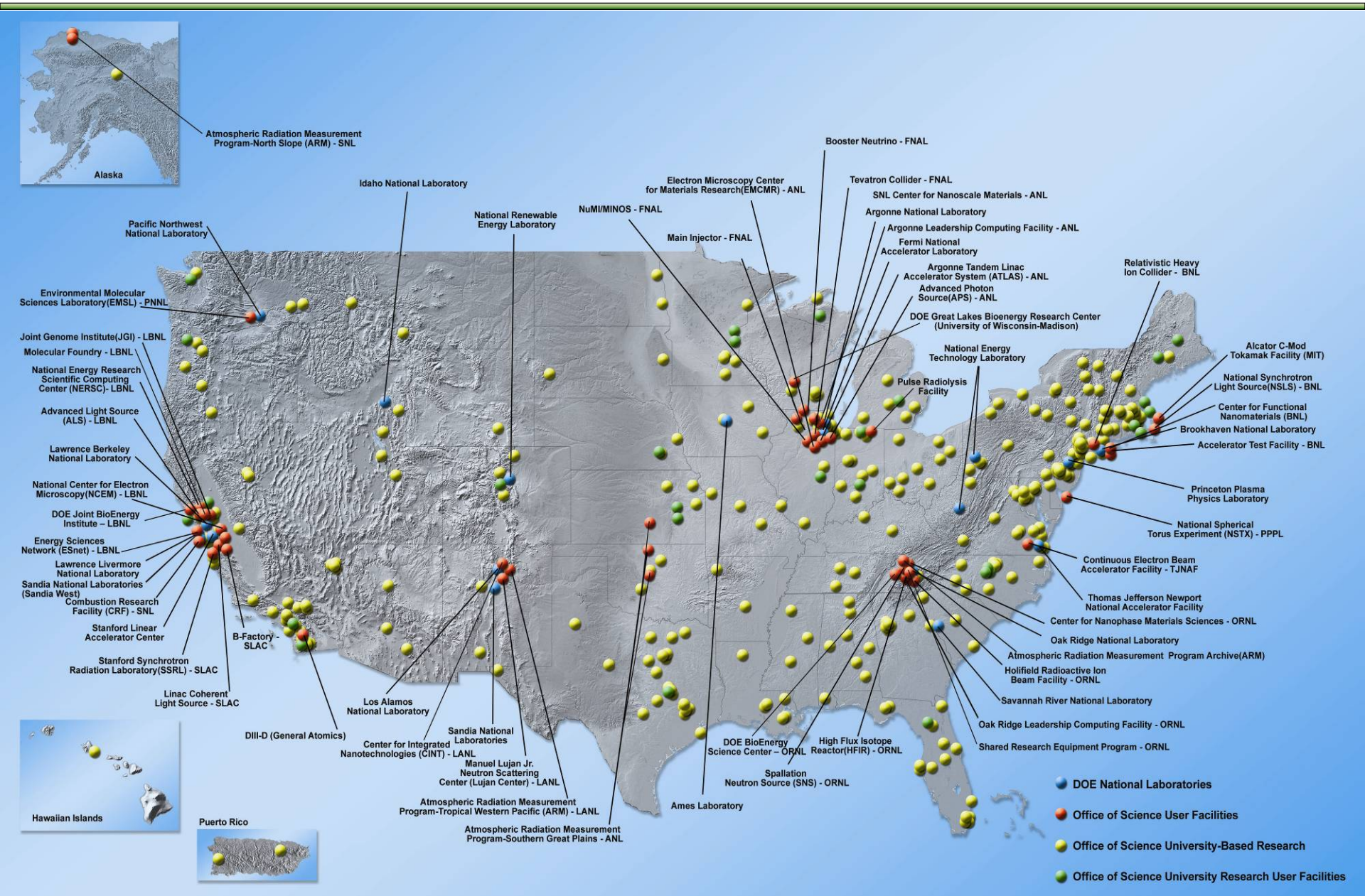
Breakdown by facility of ~25,000 users in FY 2010



# The Office of Science Oversees 10 Labs (▲)



# SC Labs, User Facilities, and Research Institutions



# Photon Science in BES: Science-driving Facilities; Facilities-driving Science

- BES program supports a robust program of fundamental research in photon science strategically structured to serve DOE's missions, primarily its energy mission.
- BES program supports the design, construction, and operation of a collection of major scientific user facilities, including four light sources. These facilities are a critical component of maintaining U.S. leadership in the physical sciences. Together these facilities hosted more than 8,500 users in FY 2007.
- BES continues as the dominant supporter of research in the physical sciences, providing as much as 85% of all federal funds for beamlines, instruments, and PI support. Many other agencies, industries, and private sponsors provide support for instrumentation and research in specialized areas such as protein crystallography.
- These user facilities illustrate the contributions of our Nation's government research institutions, both to our understanding of fundamental science and to the Nation's technological foundations; and to serve researchers at universities, federal laboratories, and industrial laboratories.

# BES Scientific User Facilities

Light sources

*Stanford Synchrotron Radiation Laboratory (SLAC)*
*National Synchrotron Light Source (BNL)*
*National Synchrotron Light Source II (BNL)*
*(start construction FY 2009)*
*Advanced Light Source (LBNL)*
*Advanced Photon Source (ANL)*
*Linac Coherent Light Source (SLAC) (under construction FY 2009)*

Neutron sources

*Manuel Lujan, Jr. Neutron Scattering Center (LANL)*
*High Flux Isotope Reactor (ORNL)*
*Spallation Neutron Source (ORNL)*

Electron beam sources

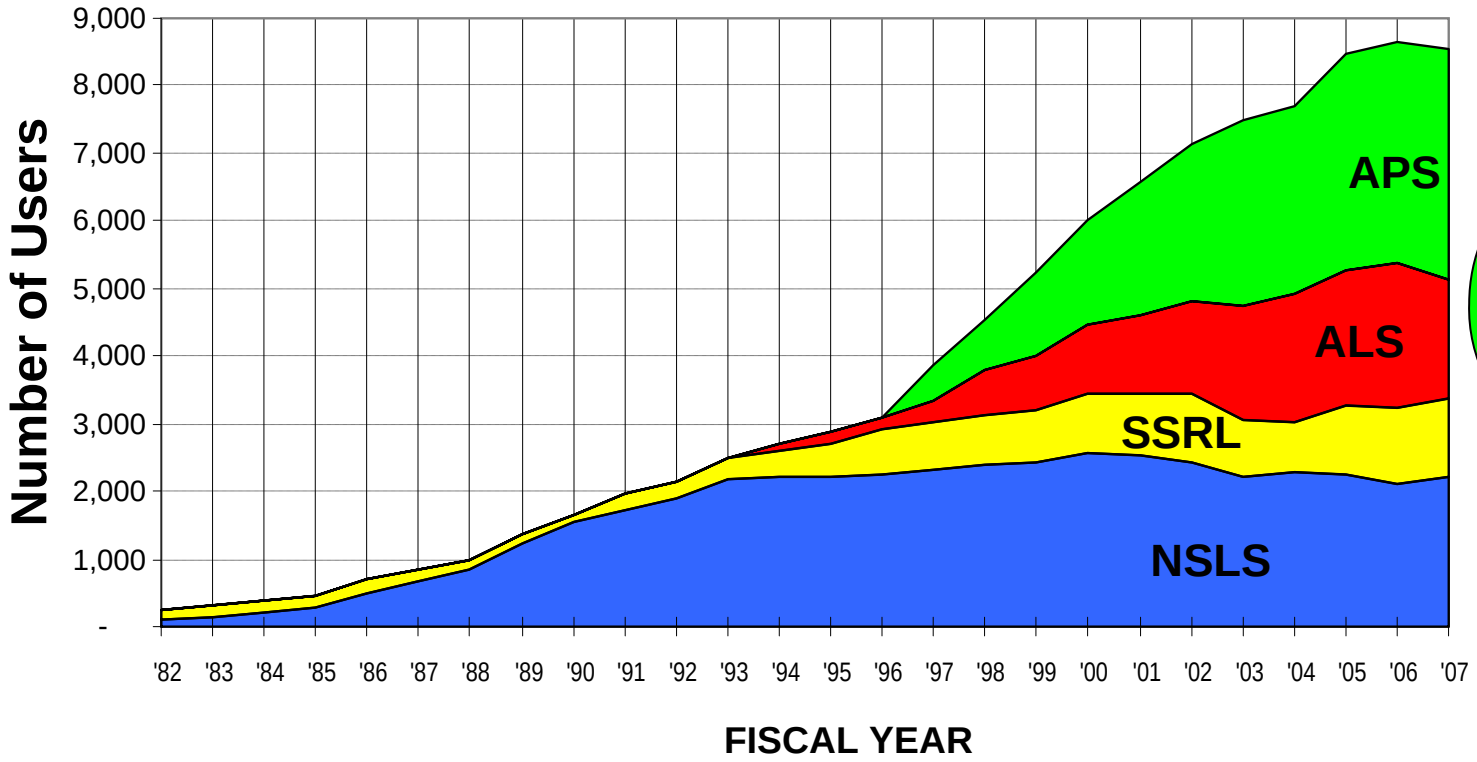
*Electron Microscopy Center for Materials Research (ANL)*
*National Center for Electron Microscopy (LBNL)*
*Shared Research Equipment Program (ORNL)*

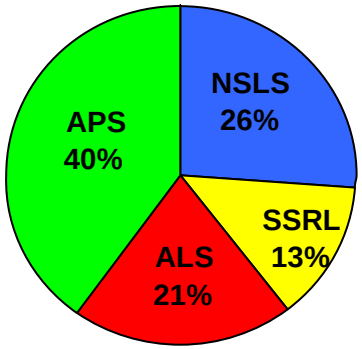
Nanoscale Science Research Centers

*Center for Nanophase Materials Sciences (ORNL)*
*Molecular Foundry (LBNL)*
*Center for Integrated Nanotechnologies (SNL/A & LANL)*
*Center for Functional Nanomaterials (BNL)*
*Center for Nanoscale Materials (ANL)*

Artist's drawings of National Synchrotron Light Source-II (top) and Linac Coherent Light Source (bottom)

# The 4 DOE Light Sources Hosted 8,538 Users in FY 2007

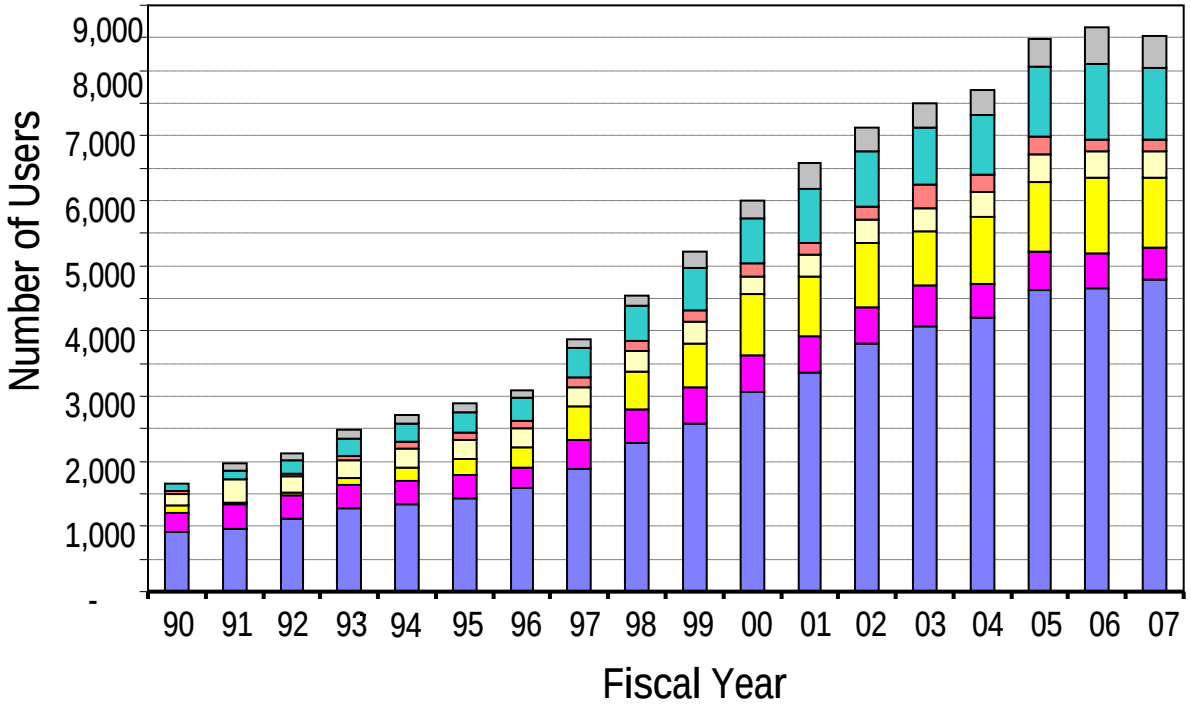



FY 2007

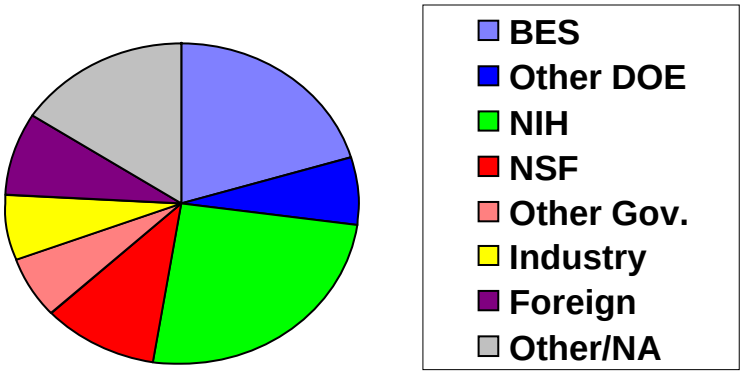
The size and demographics of the user community have changed dramatically since the 1980s when only a few hundred intrepid users visited the synchrotron light sources each year. Here, "user" is a researcher who proposes and conducts peer-reviewed experiments at a scientific facility or conducts experiments at the facility remotely. A user does not include individuals who only send samples to be analyzed, pay to have services performed, or visit the facility for tours or educational purposes. Users also do not include researchers who collaborate on the proposal or subsequent research paper but do not conduct experiments at the facility. For annual totals, an individual is counted as 1 user at a particular facility no matter how often or how long the researcher conducts experiments at the facility during the year.

# For the 4 BES Light Sources, the Majority of Users Continue to be from Academia

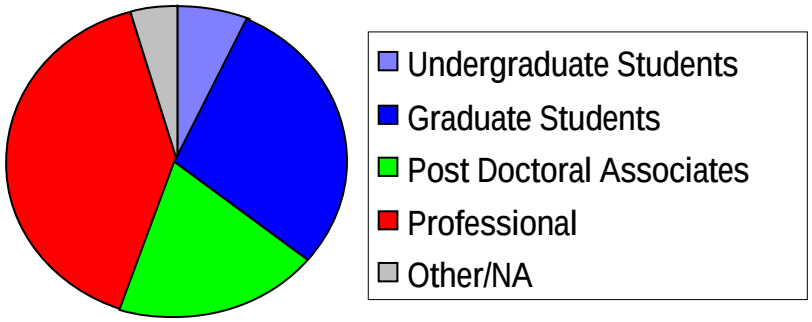



97% Nonproprietary research only
1% Nonproprietary and proprietary research
2% Proprietary research only

31% First-Time Users

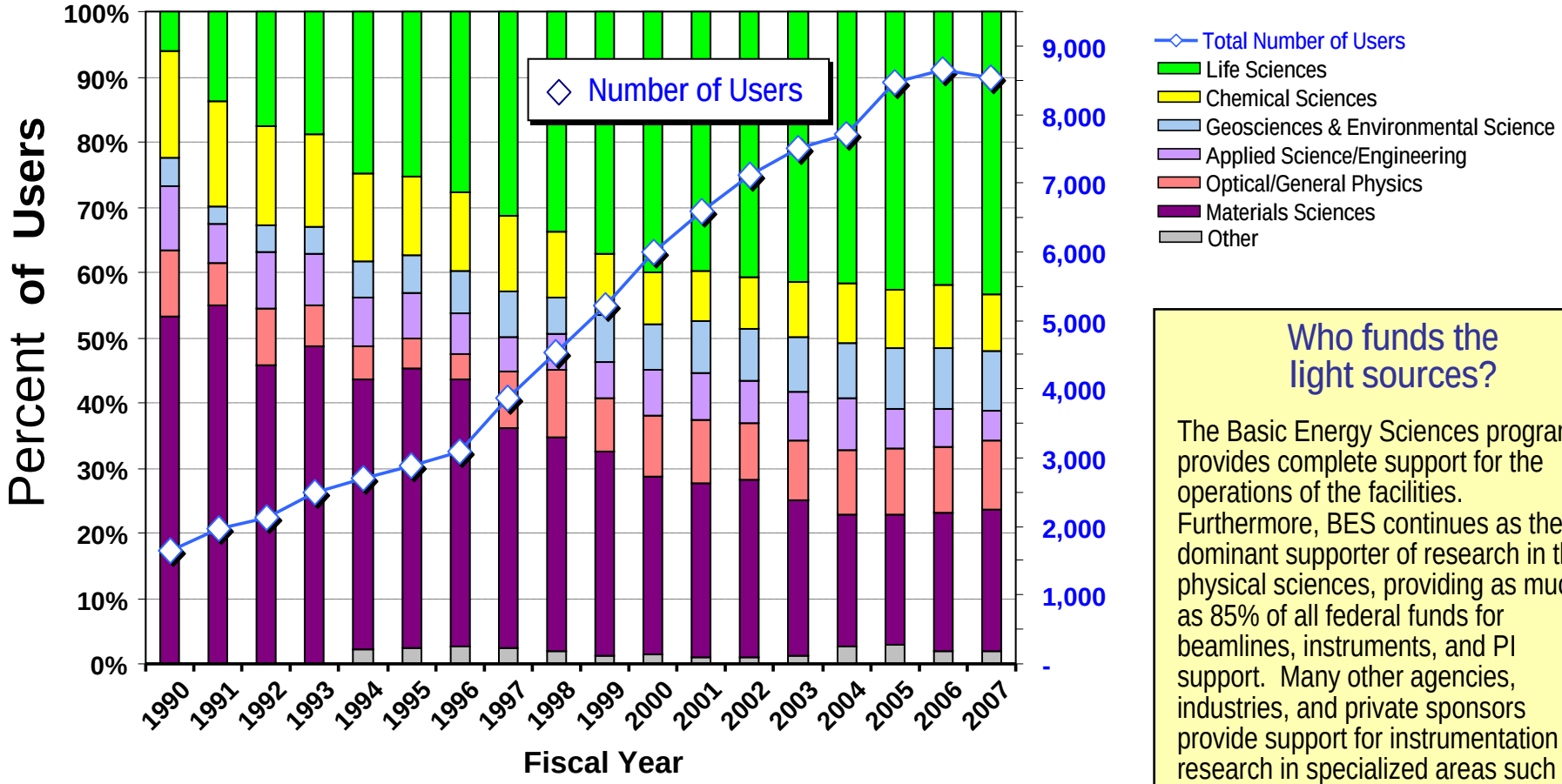



Source of User Support




User Employment Level

# Number of Users by Discipline at the 4 DOE Light Sources

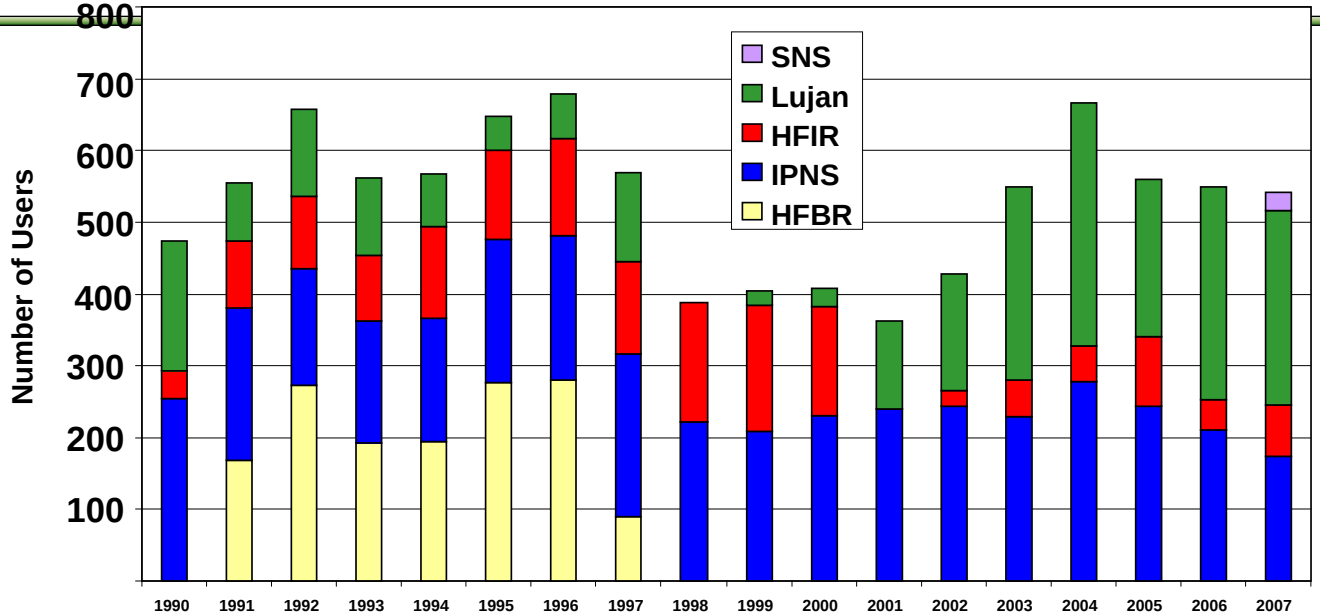



## Who funds the light sources?

The Basic Energy Sciences program provides complete support for the operations of the facilities. Furthermore, BES continues as the dominant supporter of research in the physical sciences, providing as much as 85% of all federal funds for beamlines, instruments, and PI support. Many other agencies, industries, and private sponsors provide support for instrumentation and research in specialized areas such as protein crystallography.

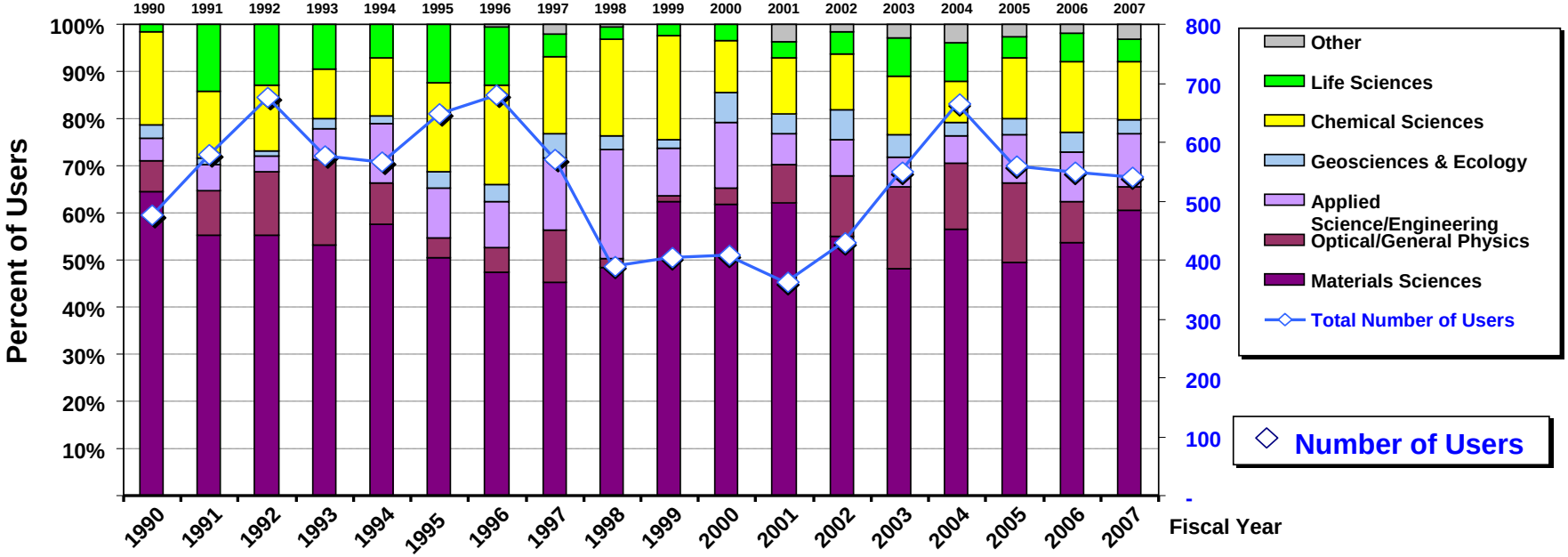
The number of researchers using the 4 light sources could reach ~11,000 annually when all the beam lines are fully instrumented. <u>Constrained budget appropriations in recent years have hindered the growth in the number of users of DOE light sources.</u>

# 4 DOE Neutron Sources — 541 Users FY 2007




**DOE High-Flux Neutron Sources**

- Spallation Neutron Source (SNS)
- High Flux Isotope Reactor (HFIR)
- Manuel Lujan Jr. Neutron Scattering Center (Lujan)
- Intense Pulsed Neutron Source (IPNS)
- High Flux Beam Reactor (HFBR)




User Profile by Discipline of Experiments

# BES Strategic Planning

10 workshops; 5 years; more than 1,500 participants from academia, industry, and DOE labs

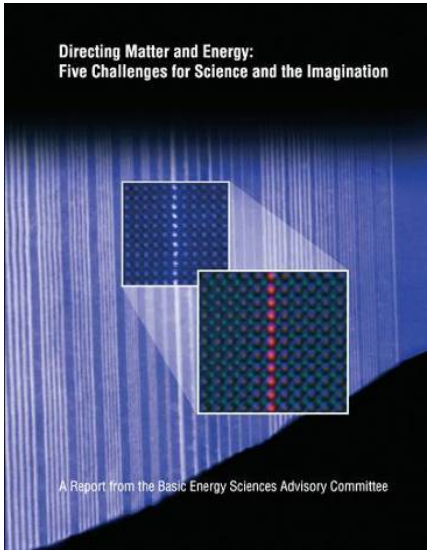
## Important Recurring Themes – Disruptive Technologies Require "Control"

*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

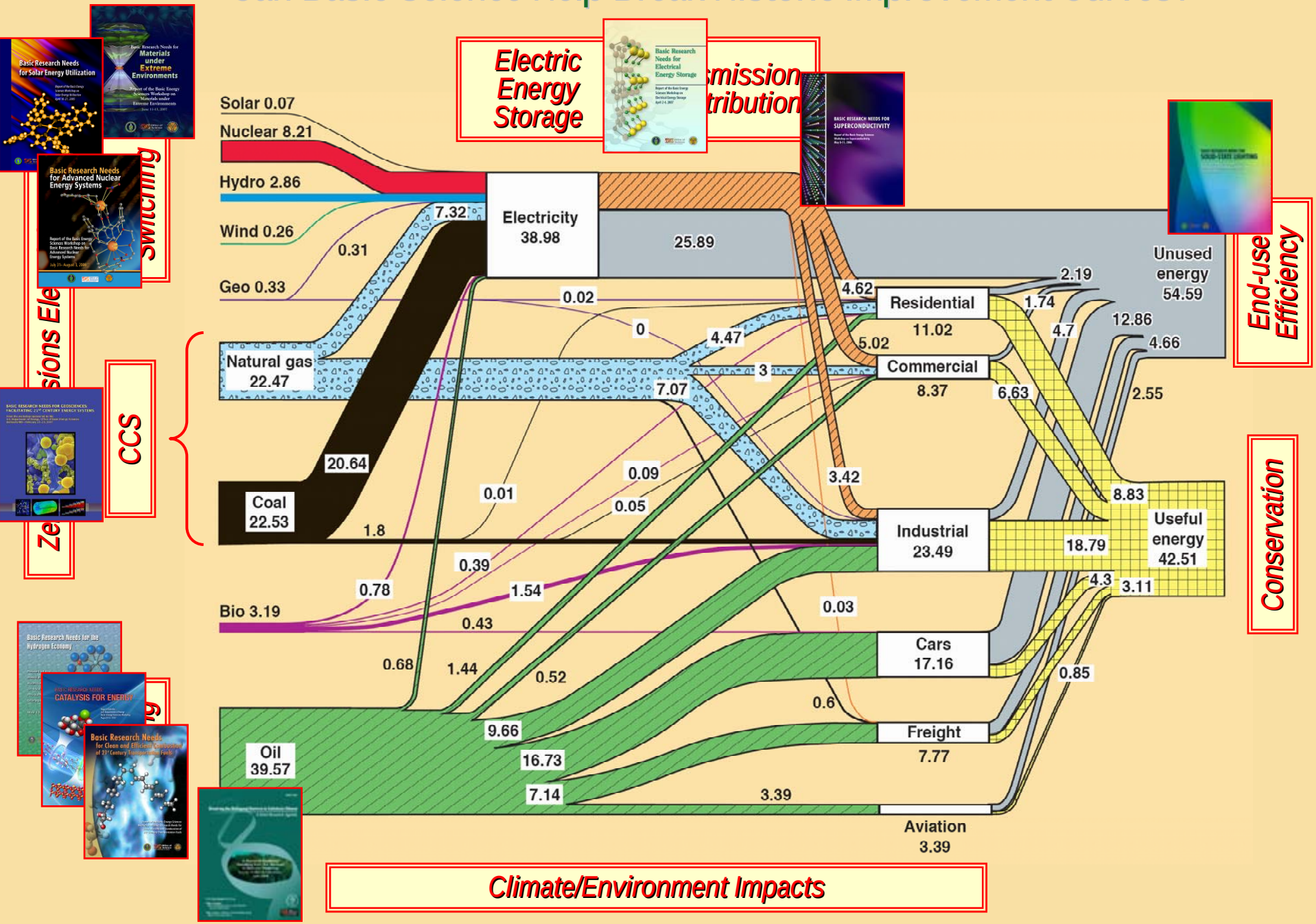
www.science.doe.gov/bes/reports/list.html

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



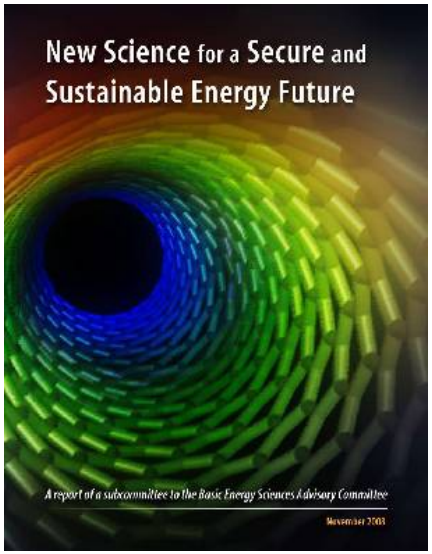

- Control the quantum behavior of electrons in materials
- Synthesize, atom by atom, new forms of matter with tailored properties
- Control emergent properties that arise from the complex correlations of atomic and electronic constituents
- Synthesize man-made nanoscale objects with capabilities rivaling those of living things
- Control matter very far away from equilibrium

# Can Basic Science Help Break Historic Improvement Curves?




Source: LLNL 2008; data are based on DOE/EIA-0384(2006). Credit should be given to LLNL and DOE.

# New Science for a Secure and Sustainable Energy Future




*Goals from the final BESAC Report:*

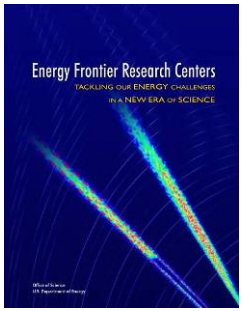
- Make fuels from sunlight
- Generate electricity without carbon dioxide emissions
- Revolutionize energy efficiency and use

*Recommendations:*

- Work at the intersection of control science and complex functional materials.
- Increase the rate of discoveries.
- Establish “dream teams” of talent, equipped with forefront tools, and focused on the most pressing challenges to increase the rate of discovery.
- Recruit the best talent through workforce development to inspire today’s students and young researchers to be the discoverers, inventors, and innovators of tomorrow’s energy solutions.

# Energy Frontier Research Centers

## Tackling Our Energy Challenges in a New Era of Science



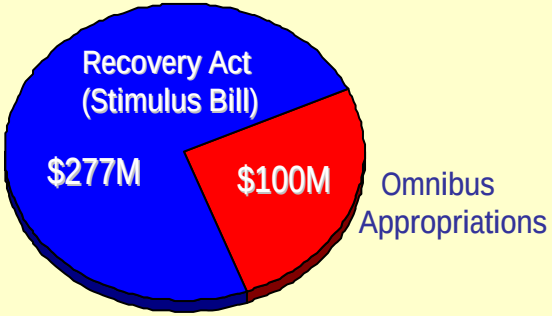

- To engage the talents of the nation's researchers for the broad energy sciences
- To accelerate the scientific breakthroughs needed to create advanced energy technologies for the 21st century
- To pursue the fundamental understanding necessary to meet the global need for abundant, clean, and economical energy

EFRCs will pursue *collaborative* basic research that addresses both energy challenges and science grand challenges in areas such as:

- Solar Energy Utilization
- Bio-Fuels
- Catalysis
- Energy Storage
- Geosciences for Nuclear Waste and $CO_2$ Storage
- Advanced Nuclear Energy Systems
- Materials Under Extreme Environments
- Hydrogen
- Combustion
- Superconductivity
- Solid State Lighting

| | |
|---|---|
| 2003-2007 | Conducted BRNs workshops |
| August 2007 | America COMPETES Act signed |
| Feb. 2008 | FY 2009 budget roll-out |
| April 2008 | EFRC FOA issued |
| Oct. 2008 | Received 261 full proposals |
| Oct. 2008 | FY 2009 Continuing Resolution started |
| Feb. 2009 | Recovery Act of 2009 (Stimulus) signed |
| March 2009 | Omnibus Appropriations Act 2009 signed |
| April 2009 | 46 EFRC awards announced |
| Aug. 2009 | EFRC projects to start |

FY 2009 EFRCs Funding Status:

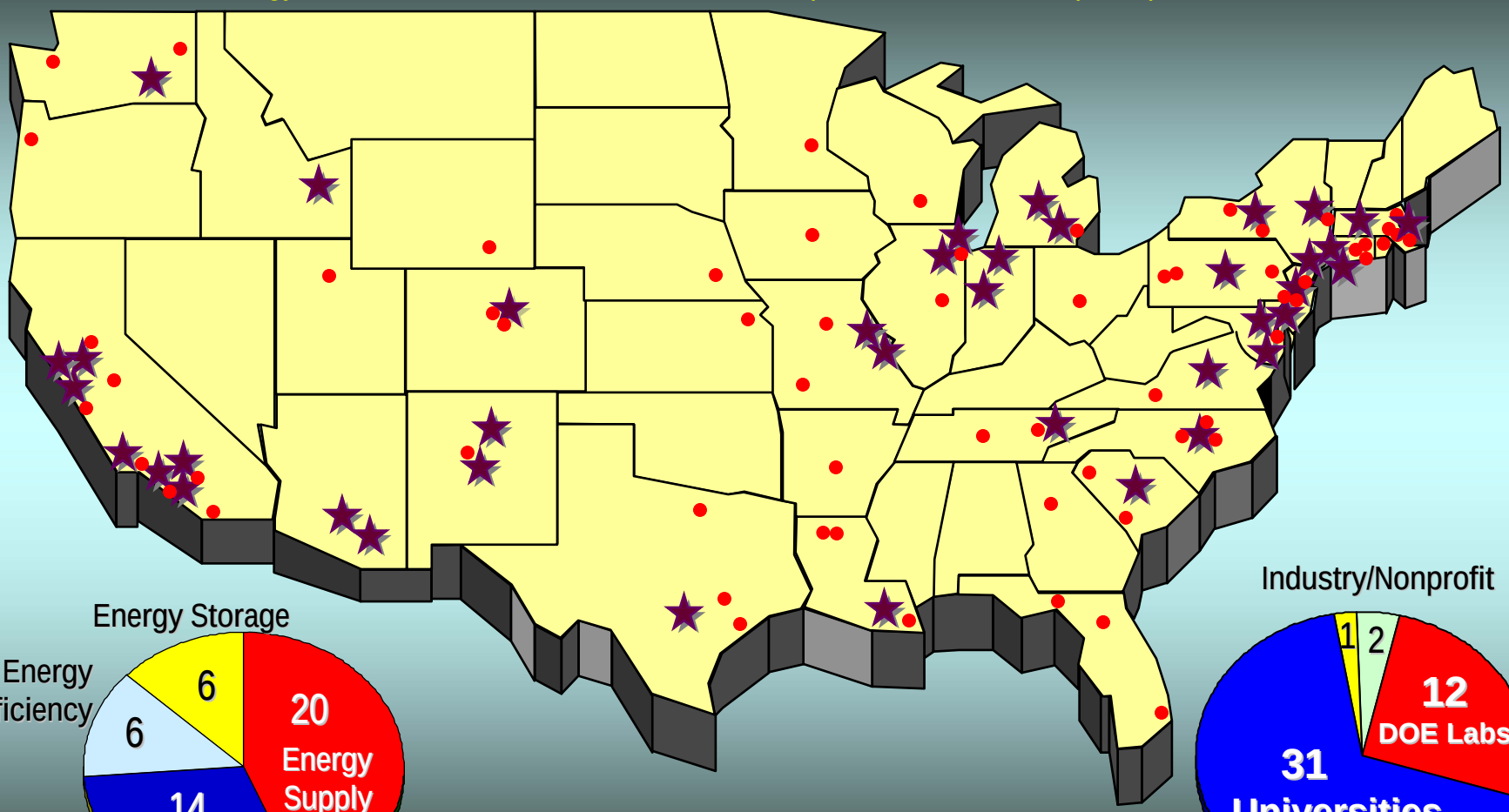


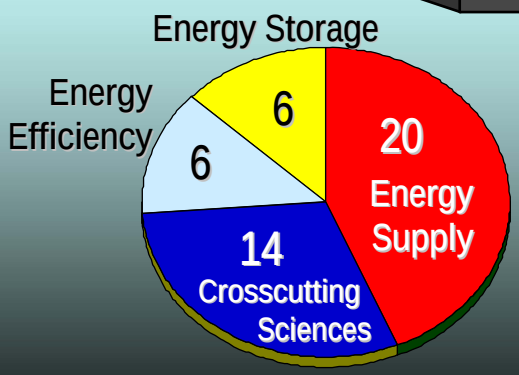

*Total EFRCs = $777M over 5 years*

# Energy Frontier Research Centers

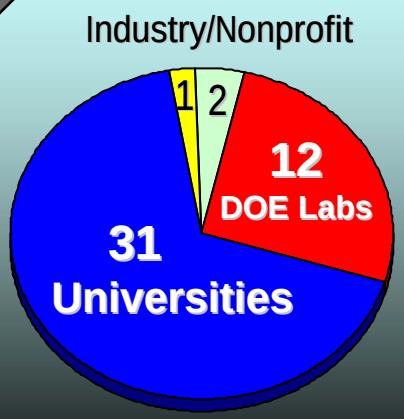
46 centers awarded, representing 103 participating institutions in 36 states plus D.C

Energy Frontier Research Center Locations ( ★ Leads; • Participants)






By Topical Category




By Lead Institution

# Solar Energy Utilization: Solar Electricity

**Neal R. Armstrong, Univ. of Arizona**

Center for Interface Science: Hybrid Solar-Electric Materials –Solar energy to electricity conversion using hybrid inorganic-organic materials focusing on interfacial chemistry.

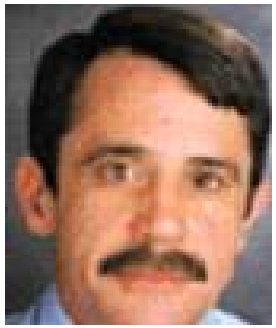
**Victor Klimov, LANL**

The Center for Advanced Solar Photophysics – Nanoparticle interactions with light to design materials for solar electricity conversion.

**James Yardley, Columbia Univ.**

Re-Defining Photovoltaic Efficiency Through Molecule-Scale Control – Understand the conversion of sunlight into electricity in nano particles and thin films in organic molecular systems.

Plan to use CFN



**Tom Russell, Univ. of Massachusetts**

Polymer-Based Materials for Harvesting Solar Energy -- Use novel, self-assembled polymer materials for the conversion of sunlight into electricity.

Will use HFIR and SNS

**Marc Baldo, MIT**

Center for Excitonics -- Understand the transport of charge carriers in synthetic disordered systems for conversion of solar energy to electricity and electrical energy storage.

Plan to use the CFN

# Solar Energy Utilization: Solar Electricity

**Peter Green, Univ of Michigan**

Solar Energy Conversion in Complex Materials -- Identify key features in complex materials to design the next generation solar conversion systems.

**Alex Zunger, NREL**

Center for Inverse Design -- Materials for solar energy conversion with an inverse design approach powered by theory and computation.

Will utilize the SSRL

**Donald Morelli, Michigan St. Univ.**

Revolutionary Materials for Solid State Energy Conversion -- Understand physical and chemical principles of advanced materials for the conversion of heat into electricity.

**Gang Chen, MIT**

Solid-State Solar-thermal Energy Conversion Center -- Create novel, solid-state materials for the conversion of sunlight and heat into electricity.

Will utilize HFIR, SNS and NSLS.

# Solar Energy Utilization: Solar Fuels

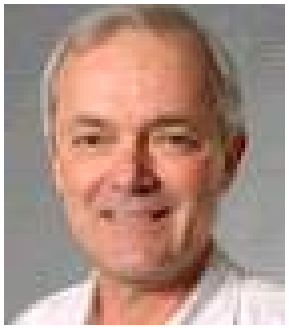
**Robert Blankenship, Washington Univ., St. Louis MO**

Photosynthetic Antenna Research Center -- Understand photosynthetic antenna system to convert sunlight into fuels.

Will use SNS and HFIR, and CINT

**Tom Meyer, Univ. of North Carolina**

Solar Fuels and Next Generation Photovoltaics -- Nanoscale architectures for improved generation of fuels and electricity from sunlight.



**Devens Gust, Arizona St. Univ.**

Bio-Inspired Solar Fuel Production - Adapt natural photosynthesis principles to bio-inspired approaches for solar fuels production.

**Michael Wasielewski, Northwestern Univ.**

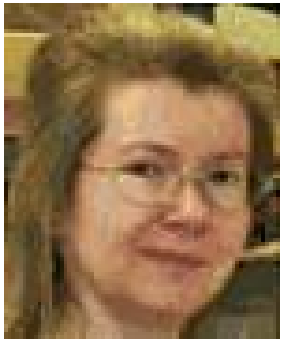
Argonne-Northwestern Solar Energy Research Center -- Revolutionize the design, synthesis, and control of molecules for solar fuels generation.

Will use CNMS and APS

# Bio-Fuels

**Richard Sayre, Donald Danforth Plant Science Center**

Center for Advanced Biofuels Systems -- Photosynthesis and production of energy-rich molecules in plants.



**Maureen McCann, Purdue Univ.**

Center for Direct Catalytic Conversion of Biomass to Biofuels -- Conversion mechanism of biomass to fuels or chemicals.

Plan to use APS and SNS

**Daniel  Cosgrove, Penn St. Univ.**

Center for Lignocellulose Structure and Formation – Physical structure of bio-polymers in plant cell walls for converting biomass into fuels.

# Energy Storage

**Michael Thackeray, ANL**

Center for Electrical Energy Storage -- Understand complex phenomena in electrochemical reactions critical to advanced electrical energy storage.

Will use APS and the CNM

**Grigorii Soloveichik, General Electric Global Research**

Center for Innovative Energy Storage -- Explore the fundamental chemistry of electrocatalysis and ionic transport for energy storage that combines the best properties of a fuel cell and a flow battery.

**Héctor Abruña, Cornell Univ.**

Nanostructured Interfaces for Energy Generation, Conversion, and Storage -- Understand the nature, structure, and dynamics of reactions at electrodes.

**Clare P. Grey, Stony Brook Univ.**

Northeastern Chemical Energy Storage Center -- Overcoming performance barriers of batteries through electrode designs.

Will use APS, NSLS and CFN,

**Gary Rubloff, Univ. of Maryland**

Science of Precision Multifunctional Nanostructures for Electrical Energy Storage -- Understand and build nano-structured electrode components.

Plan to use CINT

**Ken Reifsnider, Univ. of South Carolina**

Nano-Structure Design and Synthesis of Heterogeneous Functional Materials – Focusing on nano-structured materials functions at interfaces

# Energy Efficiency

**Jerry Simmons, SNL**

Solid State Lighting Science -- Understand energy conversion in tailored nanostructures for solid-state lighting.

Will use CINT

**John Bowers, UCSB**

Center on Materials for Energy Efficiency Applications -- Discover and develop materials that control the interactions between light, electricity, and heat at the nanoscale.

**Harry Atwater, Caltech**

Light-Material Interactions in Energy Conversion -- Tailor the properties of advanced materials to control the flow of solar energy and heat.

**Daniel Dapkus, Univ. of Southern California**

Emerging Materials for Solar Energy Conversion and Solid State Lighting -- Hybrid inorganic-organic materials for solar energy conversion and solid state lighting.

**Séamus Davis, BNL**

Center for Emergent Superconductivity -- Understand the fundamental physics of superconductivity for electricity transmission and grid-related applications.

Will use SNS, NSLS and APS

**Chung Law, Princeton Univ.**

Combustion Science -- Develop predictive combustion modeling capabilities for design and utilization of non-petroleum based fuels in transportation.

Will utilize APS

# Advanced Nuclear Energy Systems

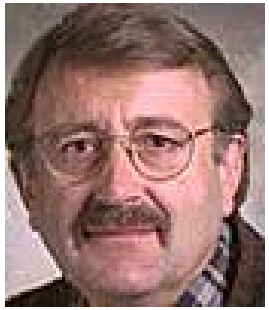
**Dieter Wolf, Idaho National Lab**

Center for Materials Science of Nuclear Fuel – Understand radiation-resistant and mechanical behavior of advanced nuclear fuel materials.

**Peter Burns, Univ. of Notre Dame**

Materials Science of Actinides – Understand physical and chemical behavior of nanoscale actinides-containing materials in extreme environments for advance nuclear energy systems.

Will use of the NSLS, APS and SNS



**Malcolm Stocks, ORNL**

Energy Frontier Center for Defect Physics in Structural Materials -- Understand the interactions and dynamics of defects in alloys under extreme radiation environments.

Will use APS and LCLS

**Michael Nastasi, LANL**

Extreme Environment-Tolerant Materials via Atomic Scale Design of Interfaces – Understand the behavior of materials subject to extreme radiation doses and mechanical stress.

Will use CINT

# Carbon Capture and Management

**Gary Pope, Univ. of Texas, Austin**

Frontiers of Subsurface Energy Security -- Understand the transport of CO2 in geological systems over multiple length scales.

Will use CINT

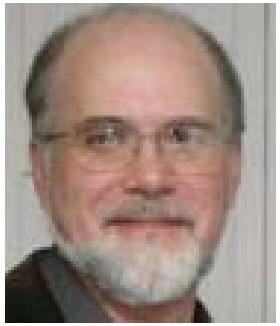
**Berend Smit, UC-Berkeley**

Center for Gas Separations Relevant to Clean Energy Technologies -- Design and synthesize new matter with tailored properties for carbon capture and sequestration.

**Donald DePaolo, LBNL**

Center for Nanoscale Control of Geologic CO2 -- Establish the scientific foundations for the CO2 storage.

Will use APS, Molecular Foundry, and SNS



**David Wesolowski, ORNL**

Fluid Interface Reactions, Structures and Transport Center -- Provide basic scientific understanding of phenomena that occur at interfaces in energy systems.

# Catalysis for Energy Applications

**Brent Gunnoe, Univ. of Virginia**

Center for Catalytic Hydrocarbon Functionalization -- Novel catalysts for the efficient conversion of hydrocarbon gases into liquid fuels.

**Morris Bullock, PNNL**

Center for Molecular Electrocatalysis -- Understand the chemical and electrical energy exchance mechanisms in electrocatalytic processes involving multi-protons and multi-electron redox reactions.

**Dion Vlachos, Univ. of Delaware**

Rational Design of Innovative Catalytic Technologies for Biomass Derivative Utilization -- Catalysts for converting biomass into chemicals and fuels.

**Jerry Spivey, Louisiana St. Univ.**

Computational Catalysis and Atomic-Level Synthesis of Materials -- Develop computational tools to model catalytic reactions and to design of new catalysts.

Plan to use CNMS, CINT, ALS, and APS

**Chris Marshall, ANL**

Institute for Atom-Efficient Chemical Transformations – Understand chemical mechanisms to extend the utilization of coal and biomass.

Will use APS

# Advanced Energy Materials

**Paul Barbara, Univ. of Texas, Austin**

Charge Separation and Transfer at Interfaces in Energy Materials and Devices -- Understand charge transfer processes of molecular materials.

**Vidvuds Ozolins, UCLA**

Molecularly Assembled Material Architectures for Solar Energy Production, Storage, and Carbon Capture

**Bartosz Grzybowski, Northwestern Univ.**

Center for Far-From-Equilibrium and Adaptive Materials -- Understand new classes of materials under conditions far from equilibrium for energy applications.

**David Mao, Carnegie Institute of Washington**

Center for Energy Frontier Research in Extreme Environments -- Materials that can tolerate transient extremes in pressure and temperature.

Will use synchrotron and neutron scattering facilities

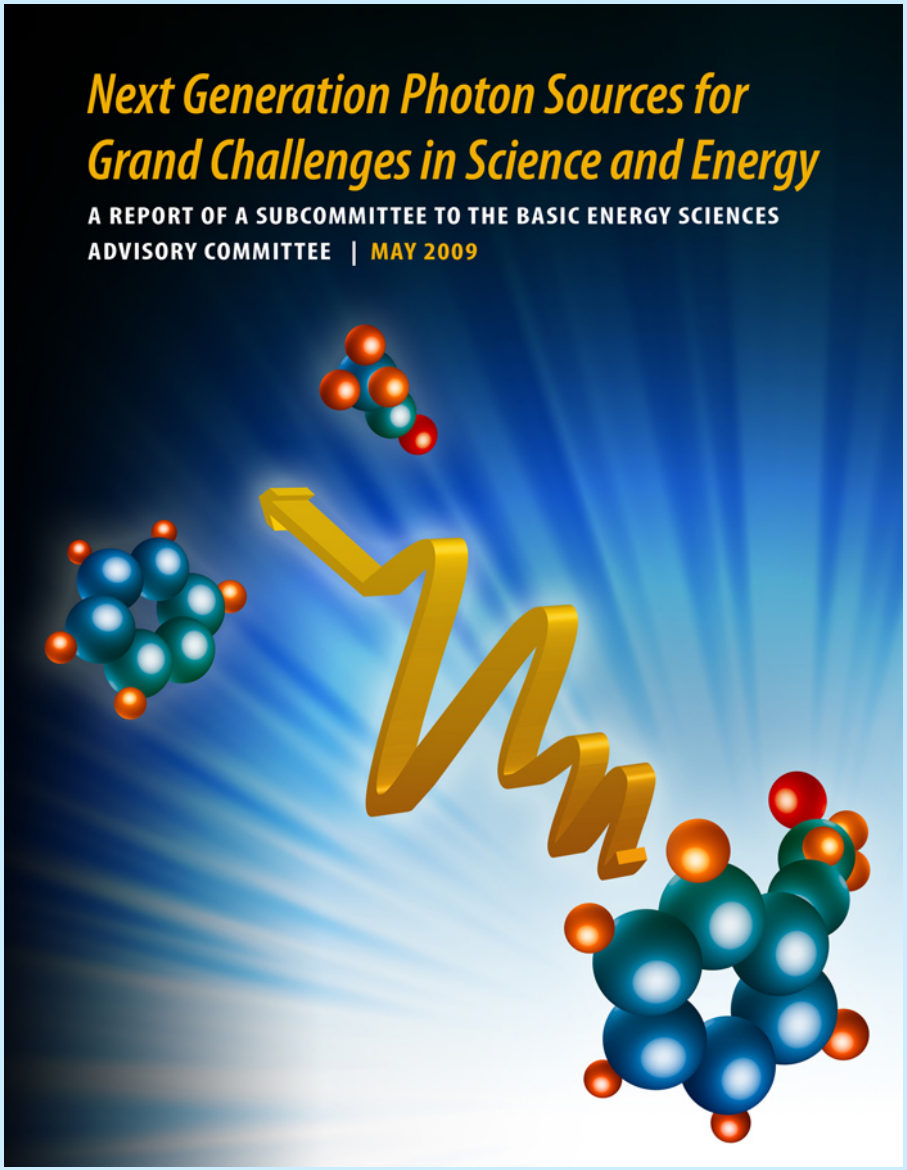
**Fritz Prinz, Stanford Univ.**

Center on Nanostructuring for Efficient Energy Conversion -- Design, create, and characterize materials at the nanoscale for a wide variety of energy applications.

# BESAC Workshop on Solving Science and Energy Grand Challenges with Next Generation Photon Sources

"Photon Workshop" October 27- 28, 2008
Wolfgang Eberhardt (BESSY) and Franz Himpsel (U Wisconsin), Co-Chairs
Workshop Charge

- *This workshop will identify connections between major new research opportunities and the capabilities of the next generation of light sources* ("photon attributes", such as coherence and femtosecond time resolution). Particular emphasis will be on energy-related research. The presentations and discussion sessions will highlight how time-resolved excitation, functional imaging, diffraction, and spectroscopy by photons can help solving major problems and develop "killer applications" in basic energy research. A variety of opportunities have been outlined by ten BESAC and BES reports on basic research needs and by a report on five "Grand Challenges" in directing matter and energy (see: http://www.sc.doe.gov/bes/reports/list.html ).
- Both accelerator-based light sources and novel laser based sources for the VUV to X-ray range will be considered. *The Photon Workshop will identify the science drivers for new photon sources but will not consider the design of machines or devices for producing the required photons. A strong coupling of theory and experiment will be emphasized.*
- A matrix will be prepared to define the most compelling connections between research opportunities and photon attributes. *For example, many science and energy grand challenges require probing very fast processes that happen over very small distances: femtoseconds over nanometers.* Typically, an electron in a solid takes a femtosecond to travel a nanometer, and atoms have a vibrational period of about 100 femtoseconds. *Lasers probe femtoseconds and synchrotrons resolve nanometers, but presently neither can do both.*
- The photon attributes to be considered by the workshop include *coherence length (longitudinal and transverse), time structure, energy, energy resolution, spectral brightness (average and peak), flux, spatial and momentum resolution, and polarization*.




http://www.sc.doe.gov/bes/reports/files/NGPS_rpt.pdf