U.S. DEPARTMENT OF ENERGY | Office of Science

Basic Energy Sciences Overview

Fusion Energy Sciences Advisory Committee Meeting
February 2, 2017

Harriet Kung
Associate Director of Science
For Basic Energy Sciences
U.S. Department of Energy

Basic Energy Sciences (BES)

The Program:

Materials sciences & engineering—exploring macroscopic and microscopic material behaviors and their connections to various energy technologies

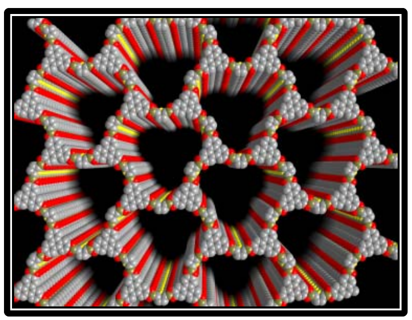
Chemical sciences, geosciences, and biosciences—exploring the fundamental aspects of chemical reactivity and energy transduction over wide ranges of scale and complexity and their applications to energy technologies

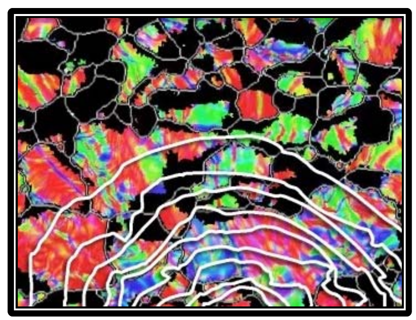
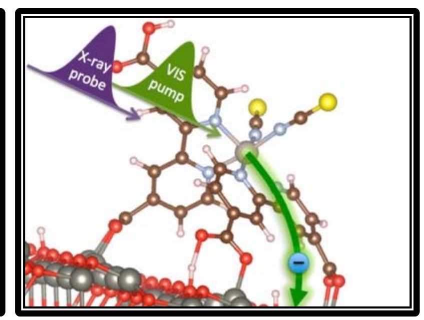
Scientific User Facilities—5 X-ray light sources, 2 neutron sources, and 5 Nanoscale Science Research Centers -- the largest collection of facilities for electron, x-ray, and neutron scattering in the world

The Scientific Challenges:

- Synthesize, atom by atom, new forms of matter with tailored properties, including nano-scale objects with capabilities rivaling those of living things
- Direct and control matter and energy flow in materials and chemical assemblies over multiple length and time scales
- Explore materials & chemical functionalities and their connections to atomic, molecular, and electronic structures
- Explore basic research to achieve transformational discoveries for energy technologies

Understanding, predicting, and ultimately controlling matter and energy flow at the electronic, atomic, and molecular levels



BES Strategic Planning Activities –
Engaging BES Advisory Committee and Scientific Community

- **Science for Discovery**

- **Science for National Needs**

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

Science

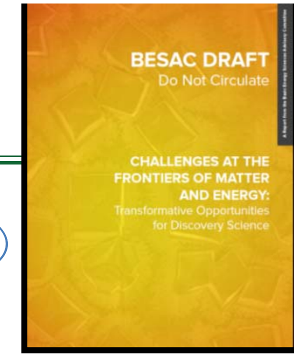
https://science.energy.gov/bes/news-and-resources/reports/

Science for Discovery:
BESAC Grand Challenges Reports (2007, 2015)

Instrumentation & Tools

Human Capital

Synthesis



2015

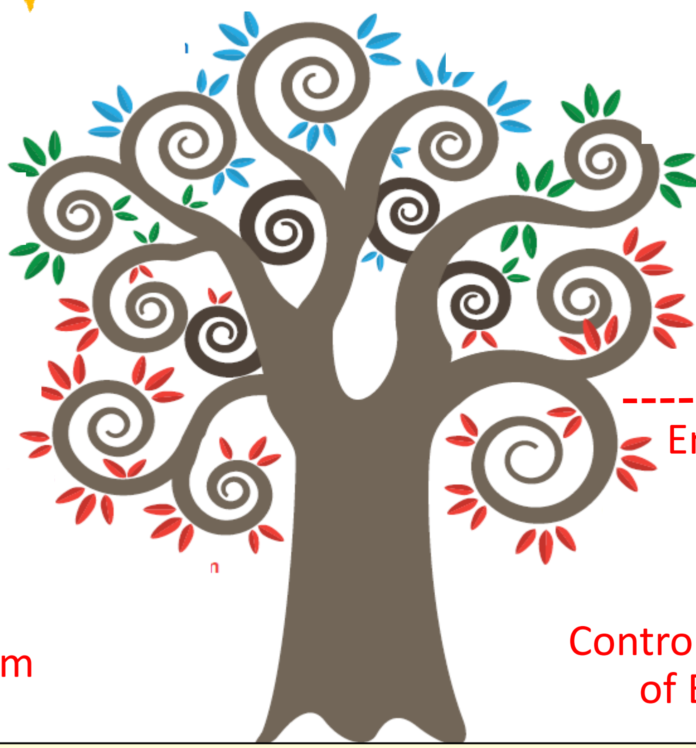
Beyond Ideal Materials and Systems

Mastering Hierarchical Architectures

Harnessing Coherence in Light and Matter

Imaging Matter across Scales

Data, Algorithms and Computing



Efficient Synthesis for Tailored Properties

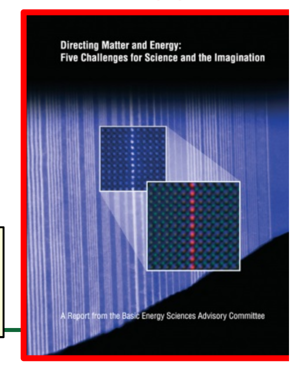
Correlated Systems

Systems Away from Equilibrium

Energy and Information on the Nanoscale

Control at the Level of Electrons

2007



2007 Directing Matter and Energy: Five Challenges for Science and the Imagination
2015 Challenges at the Frontiers of Matter and Energy: Transformative Opportunities for Discovery Science

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Science for National Needs:
BESAC & BES “Basic Research Needs (BRN) …” Workshops (2002 --)

2002

https://science.energy.gov/bes/community-resources/reports/

BRN to Assure a Secure Energy Future (BESAC)

- **BRN for Hydrogen Economy (2003)**
- **BRN for Solar Energy Utilization (2005)**
- **BRN for Superconductivity (2006)**
- **BRN for Solid State Lighting (2006)**
- **BRN for Advanced Nuclear Energy Systems (2006)**
- **BRN for Geosciences (2007)**
- **BRN for Clean and Efficient Combustion (2007)**
- **BRN for Electrical Energy Storage (2007)**
- **BRN for Catalysis for Energy Applications (2007)**
- **BRN for Materials under Extreme Environments (2007)**
- **BRN for Carbon Capture (2010)**
- **New Science for Sustainable Energy Future (2008)**
- **Computational Materials Science and Chemistry (2010)**
- **Science for Energy Technology (2010)**
- **Controlling Subsurface Fractures and Fluid Flow (2015)**
- **BRN for Environmental Management (2016)**
- **BRN for Quantum Materials (2016)**

BES Research and Funding Modalities

Increasing scope and size

- Core Research (>1,000 projects)
  Single investigators ($150K/year) and small groups ($500K-$2M/year) engage in fundamental research related to any of the BES core research activities. Investigators propose topics of their choosing, including the Early Career Research Awards and SciDAC Awards (joint with ASCR).

- Energy Frontier Research Centers (36, 2009 --)
  $2-4M/year research centers for 4-year award terms; focus on fundamental research described in the Basic Research Needs Workshop reports.

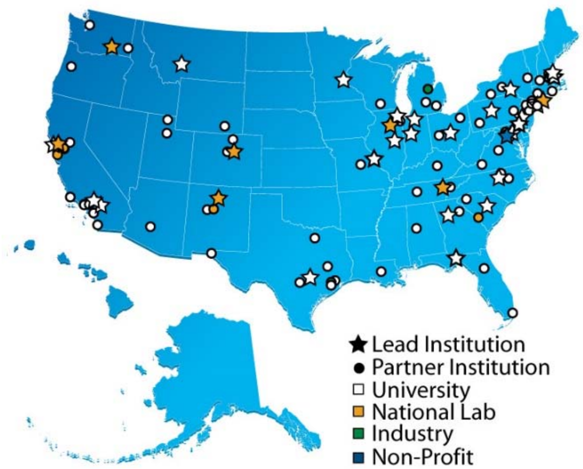
- Computational Materials Sciences (5, 2015 --)
  $2-4M/year research centers for 4-year award terms; focus on delivering open-source software for materials by design in preparation for exascale computing

- Energy Innovation Hubs (2, 2010 --)
  Research centers for 5-year award terms, established in 2010 ($15-25M/year), engage in basic and applied research, including technology development, on a high-priority topic in energy that is specified in detail in an FOA. Project goals, milestones, and management structure are a significant part of the proposed Hub plan.

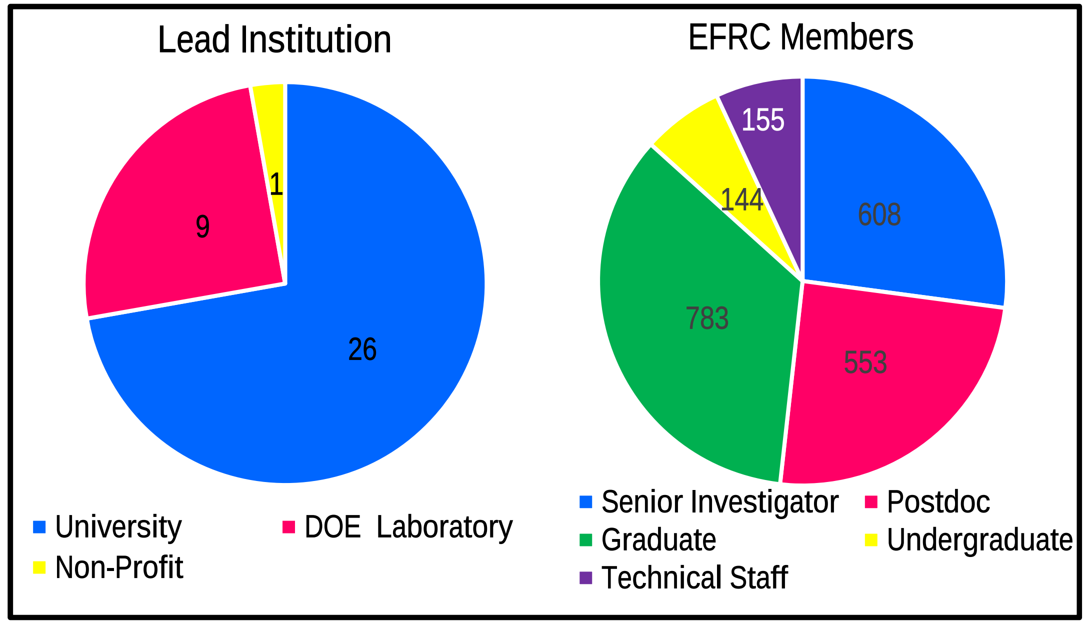
Energy Frontier Research Centers (EFRCs)

- **HISTORY:** 20 community workshops since early-2000s with over 2,000 participants describing "basic research needs" for energy applications and "grand-challenge science"
- **ESTABLISHMENT OF EFRCs IN 2009**
  - 46 awards: 30 funded at $100M/year; 16 fully funded by ARRA at $277M
  - $2-5M/year each for a 5-year term
- **RECOMPETITION IN 2014**
  - 32 awards funded at $100M/year (22 renewal, 10 new)
  - $2-4M/year each for a 4-year term, with competitions now every 2 years
  - Solicitation topics were informed by additional community workshop reports including mesoscale science and computational materials and chemistry.
- **Targeted FOA in 2016**
  - 4 new awards funded at $10M/year
  - $2-4M/year each for a 4-year term
  - Solicitation topics in environmental management research areas as informed by BRN-EM (2016)

Energy Frontier Research Centers
Status as of August 2016 (36 EFRCs)



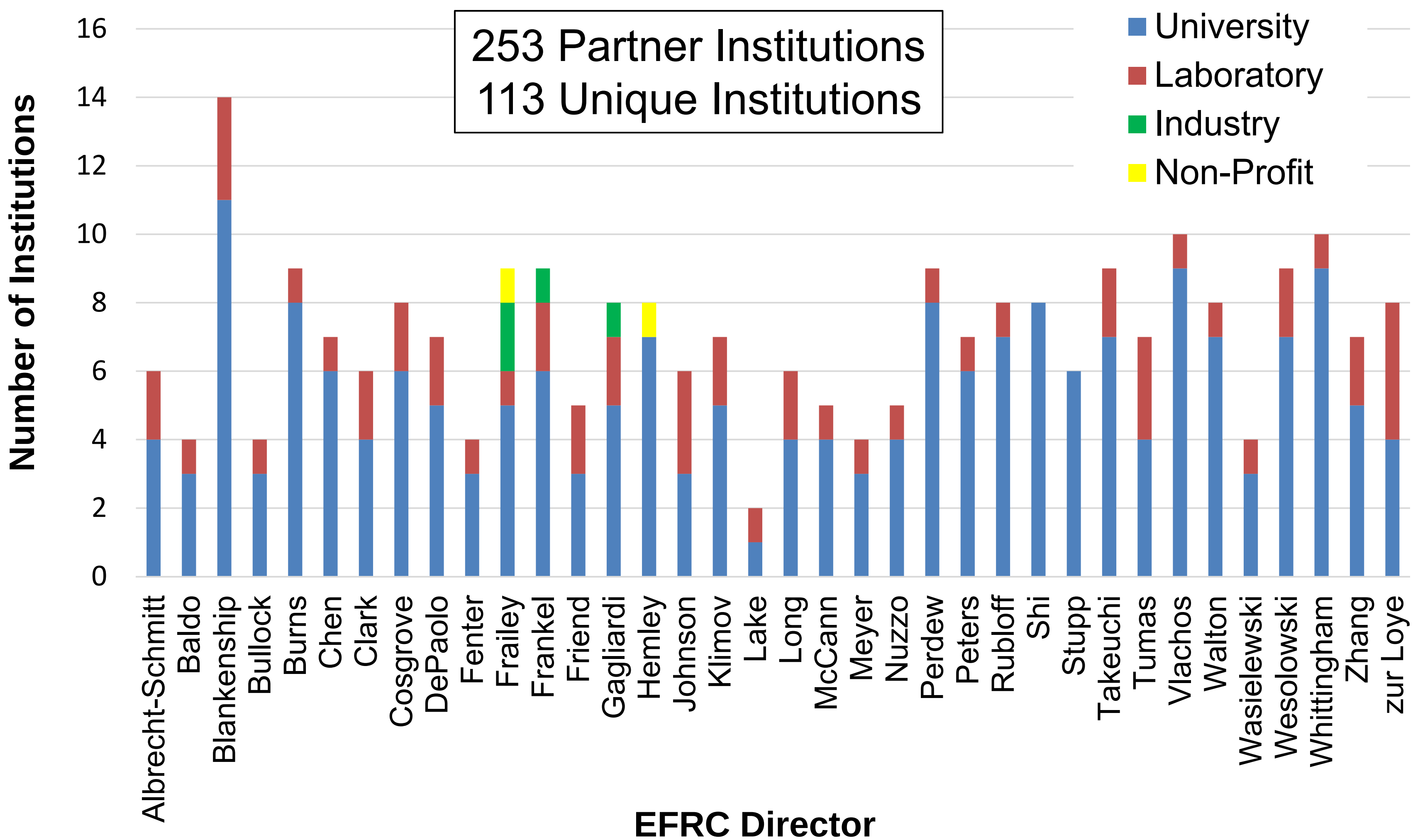
Over 110 participating institutions, located in 34 states plus the District of Columbia



Accomplishments since 2009

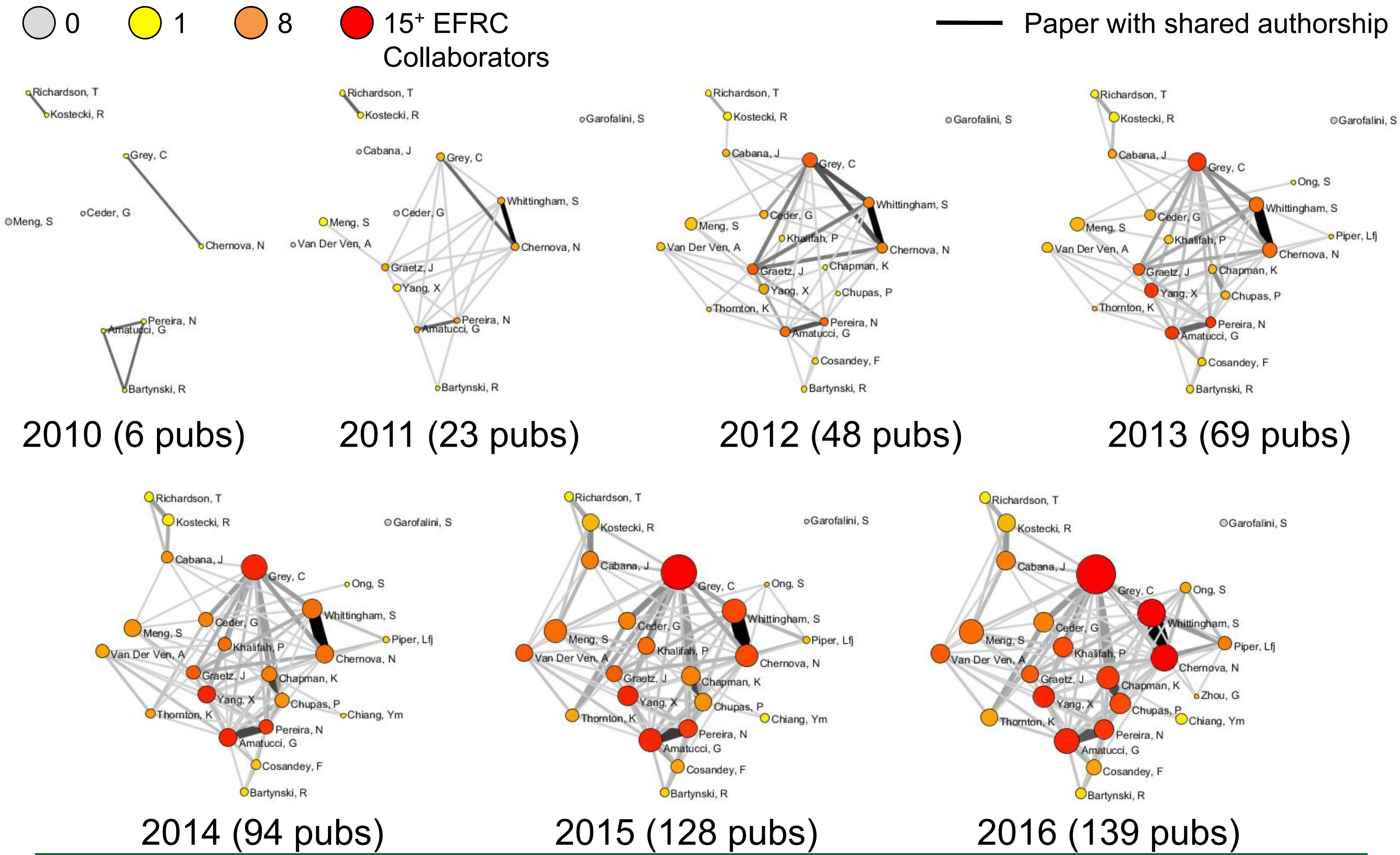
- Over 8,200 peer-reviewed papers (> 360 in *Science* and *Nature Journals*)
- 24 PECASE and 26 DOE Early Career Awards
- 44 EFRCs have created over 380 US and 250 foreign patent applications, more than 490 patent/invention disclosures, and at least 100 licenses
- ~90 companies have benefited from EFRC research
- (May 2014) EFRC students and staff now work: > 300 university faculty and staff; > 475 industrial; > 200 national labs, government, and non-profit

FY 2016: EFRC Partner Institutions



NorthEast Center for Chemical Energy Storage (NECCES)

M. Stanley Whittingham, Binghamton University



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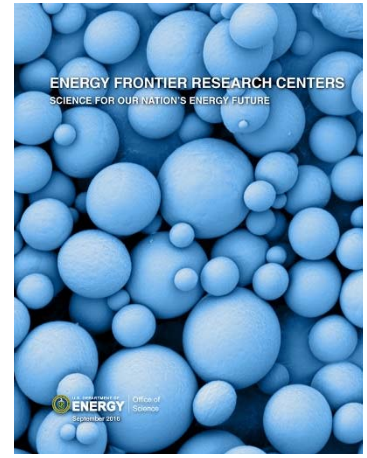
Width of line (edge) = number of co-authored papers
Size of circle (node) = number of total papers authored

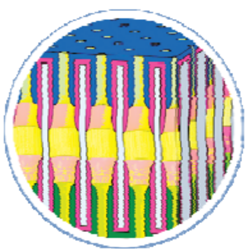
EFRC Communications

The 2016 EFRC booklet describes the history and outcomes from the first seven years of the EFRC program, including representative scientific highlights, academic publications, intellectual property, and science commercialization.



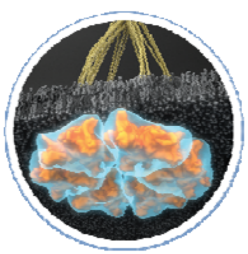
Solar concentrators based on quantum dots

Core-shell quantum dots were rationally designed for efficient light collection and transmission



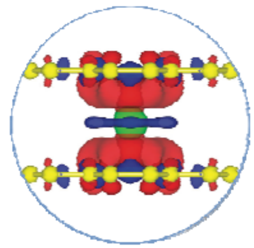
Building precision nanobatteries by the billions

Batteries constructed in nanopores promise to deliver energy at much higher power and longer life



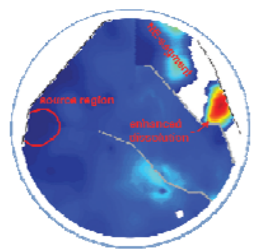
Examining the enzyme complex that makes cellulose fibrils

Imaging and computational modeling revealed new structural insights



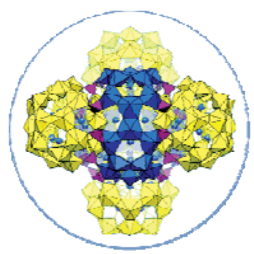
Accurately modeling materials for energy applications

Optimal method identified for multiscale simulations of carbon nanostructures



Viability of long-term carbon sequestration in the subsurface

The Bravo Dome gas field was used to estimate CO_2 dissolution rates over milennia



Nanoscale control of uranium for solvent-free recovery

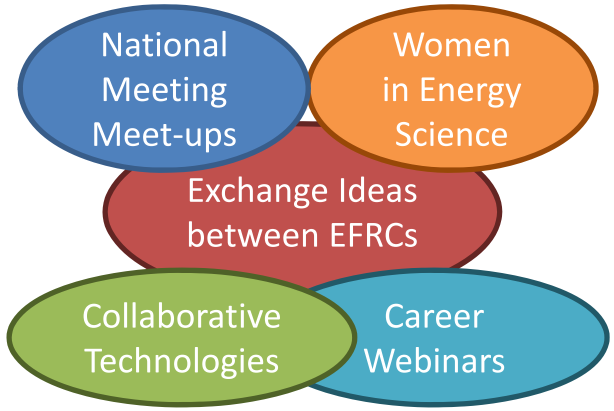
Water-soluble uranium-oxygen clusters are large enough to be filtered using commercial membranes

EFRC Workforce Development Opportunities

Frontiers in Energy Research Newsletter

http://www.energyfrontier.us/newsletter

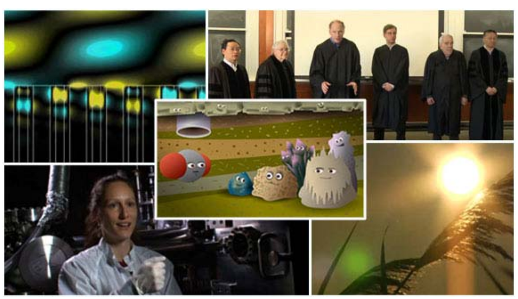
Early Career Network



Graduate Student and Postdoctoral Researcher Competition

http://www.energyfrontier.us/content/2015-student-and-postdoc-competition

Life at the Frontiers of Energy Research Video Contest

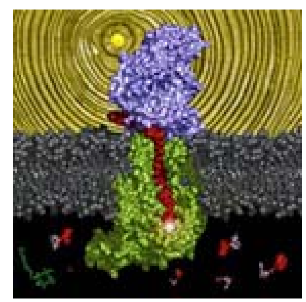


http://www.energyfrontier.us/video-contest

Ten Hundred and One Word Challenge

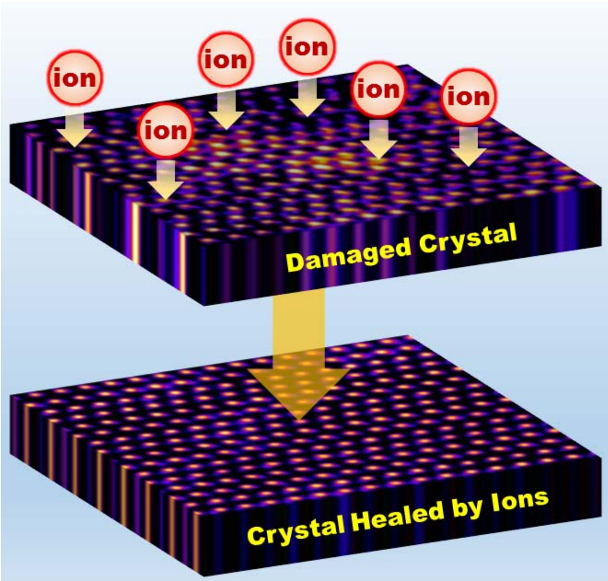
http://www.energyfrontier.us/1001-word-challenge-winners

Poetry of Science Contest



http://www.energyfrontier.us/poetry-winners

Ionization Induces Healing of Defects in Silicon Carbide



Projected scanning transmission electron microscopy images of pre-damaged crystal (top) and improved structural order after 21 MeV Ni ion irradiation (bottom).

Y. Zhang, R. Sachan, O.H. Pakarinen, M.F. Chisholm, P. Liu, H. Xue, and W. J. Weber, "Ionization-induced annealing of pre-existing defects in silicon carbide," *Nature Commun.* **6**, 8049 (2015). DOI: 10.1038/ncomms9049

Scientific Achievement

Energy transferred to electrons in silicon carbide (SiC) by energetic ions via ionization can effectively heal pre-existing defects and restore structural order.

Significance and Impact

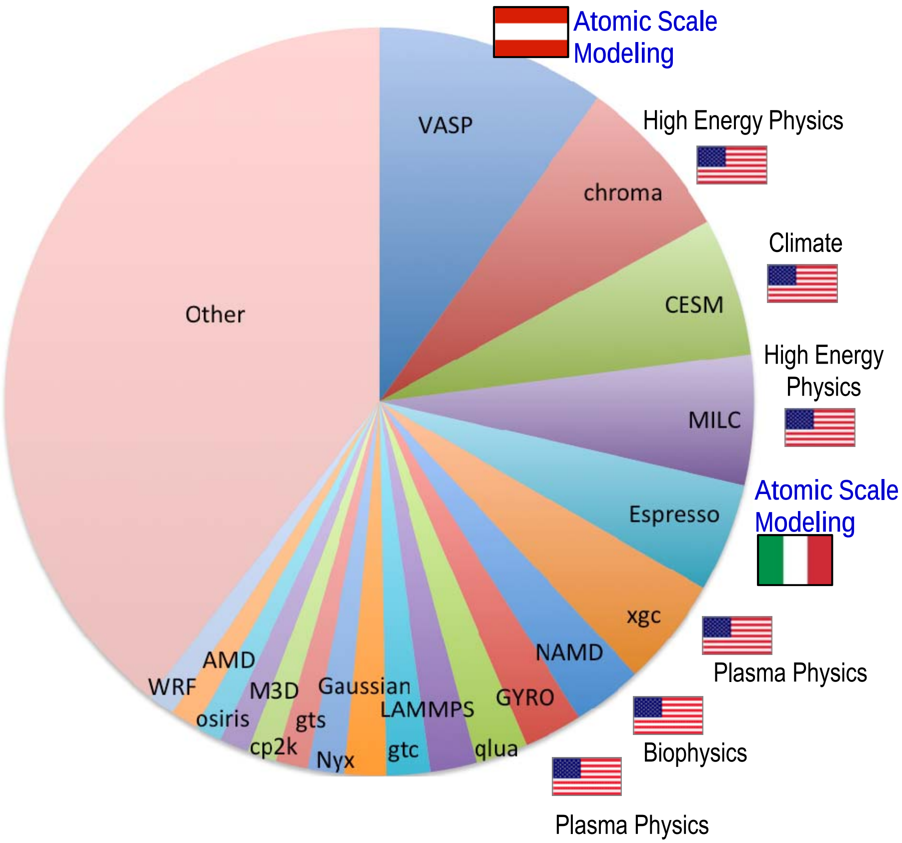
Because SiC is a critical material for nuclear applications and power electronics for space applications, ionization-induced self-healing may contribute to increased radiation tolerance in extreme radiation environments.

Research Details

- Defects were introduced into single-crystal SiC by implantation with 900 keV Si ions.
- Irradiation of these samples with ions having high electronic energy loss (4.5 MeV C to 21 MeV Ni) healed pre-existing defects.
- Healing was validated by ion channeling, scanning transmission electron microscopy and atomistic simulations.
- Energy transfer of 1.4 keV/nm to electrons was sufficient to activate this process.

Computational Materials Sciences

2015 Top Application Codes at NERSC

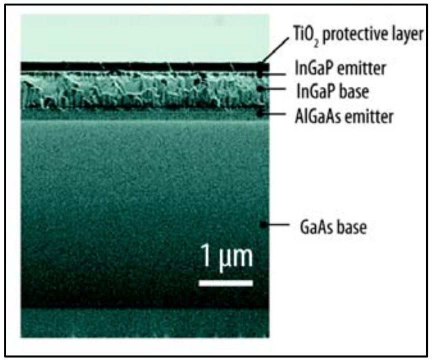


The U.S. trails other countries in development of computational codes in chemistry and materials sciences.

- High-accuracy software is needed to understand how the behavior of atoms and molecules (or quantum effects) impacts energy conversion and materials synthesis.
- At NERSC, the most used materials and chemistry research codes were developed by foreign countries, (e.g., VASP -- a commercial Austrian atomic scale modeling code requiring purchase of license).
- Top codes used at NERSC for other fields were developed in the U.S. and are all free, open-source community codes.
- BES support began in 2015, and is currently supporting 5 teams at $12M/yr to develop research codes and data for design of functional materials to be used by academia, labs, and industry – as part of the Exascale crosscut.

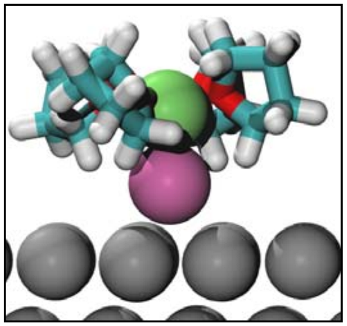
Energy Innovation Hubs

- Fuels from Sunlight:
  - Awarded to the Joint Center for Artificial Photosynthesis (JCAP); 1st phase award (2010 – 2014) funded at ~ \$25M/yr for hydrogen fuels research, including prototype development.
  - Based on peer review outcomes, JCAP was renewed for the 2nd term in 2015 at \$15M/yr to conduct research on CO_2 reduction to produce chemical fuels – a grand science challenge.
  - Led by Caltech with participating institutions: LBNL, UCI, UCSD, and SLAC.



Cross-sectional SEM image of a protected photoelectrode (Verlage, et. al. *Energy Environ. Sci.* 2015)

- Batteries and Energy Storage Hub:
  - Awarded to the Joint Center for Energy Storage Research (JCESR) and commenced operations in December 2012 at ~ \$25M/yr.
  - JCESR focuses on discovery science to enable next generation batteries—beyond lithium ion—and energy storage for transportation and the grid.
  - Led by ANL with participating institutions: LBNL, SNL, SLAC, PNNL,UI-UC, NWU, UCh, UI-C, UMich, MIT, Utah, United Tech, Dow, AMAT, JCI, CET.



Theoretical predictions of Mg deposition (from MgCl) on a Mg metal surface

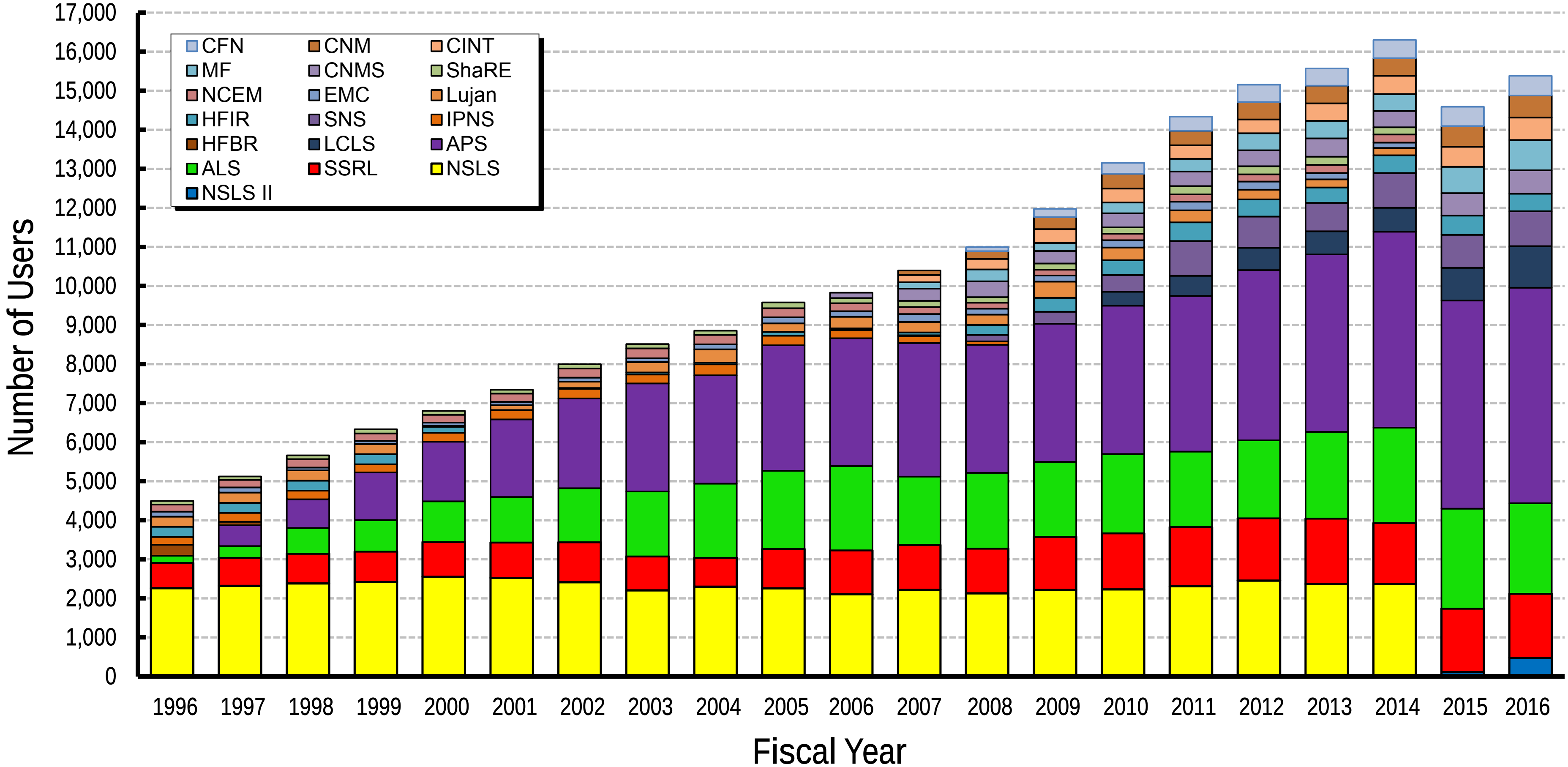
BES Scientific User Facilities

Unique research facilities *and* scientific expertise for ultra high-resolution characterization, synthesis, fabrication, theory and modeling of advanced materials

- ✷ Available to all researchers ***at no cost*** for non-proprietary research, regardless of affiliation, nationality, or source of research support
- ✷ Access based on external peer merit review of brief proposals
- ✷ Coordinated access to co-located facilities to accelerate research cycles
- ✷ Collaboration with facility scientists an optional potential benefit
- ✷ Instrument and technique workshops offered periodically
- ✷ A variety of on-line, on-site, and hands-on training available
- ✷ Proprietary research may be performed at full-cost recovery

- **Nanoscale Science Research Centers**
  - *Center for Functional Nanomaterials (BNL)*
  - *Center for Integrated Nanotechnologies (SNL & LANL)*
  - *Center for Nanophase Materials Sciences (ORNL)*
  - *Center for Nanoscale Materials (ANL)*
  - *Molecular Foundry (LBNL)*
- **Neutron Sources**
  - *High Flux Isotope Reactor (ORNL)*
  - *Spallation Neutron Source (ORNL)*
- **Light Sources**
  - *Advanced Light Source (LBNL)*
  - *Advanced Photon Source (ANL)*
  - *Linac Coherent Light Source (SLAC)*
  - *National Synchrotron Light Source-II (BNL)*
  - *Stanford Synchrotron Radiation Lightsource (SLAC)*

BES User Facilities Hosted Over 15,000 Users in FY 2016



- The newly constructed NSLS II started early operations in FY 2015.
- The three electron beam microcharacterization centers were merged administratively with their respective neighboring NSRCs in FY 2015.
- The BES operations at the Lujan Neutron Scattering Center ceased operations in FY 2014.

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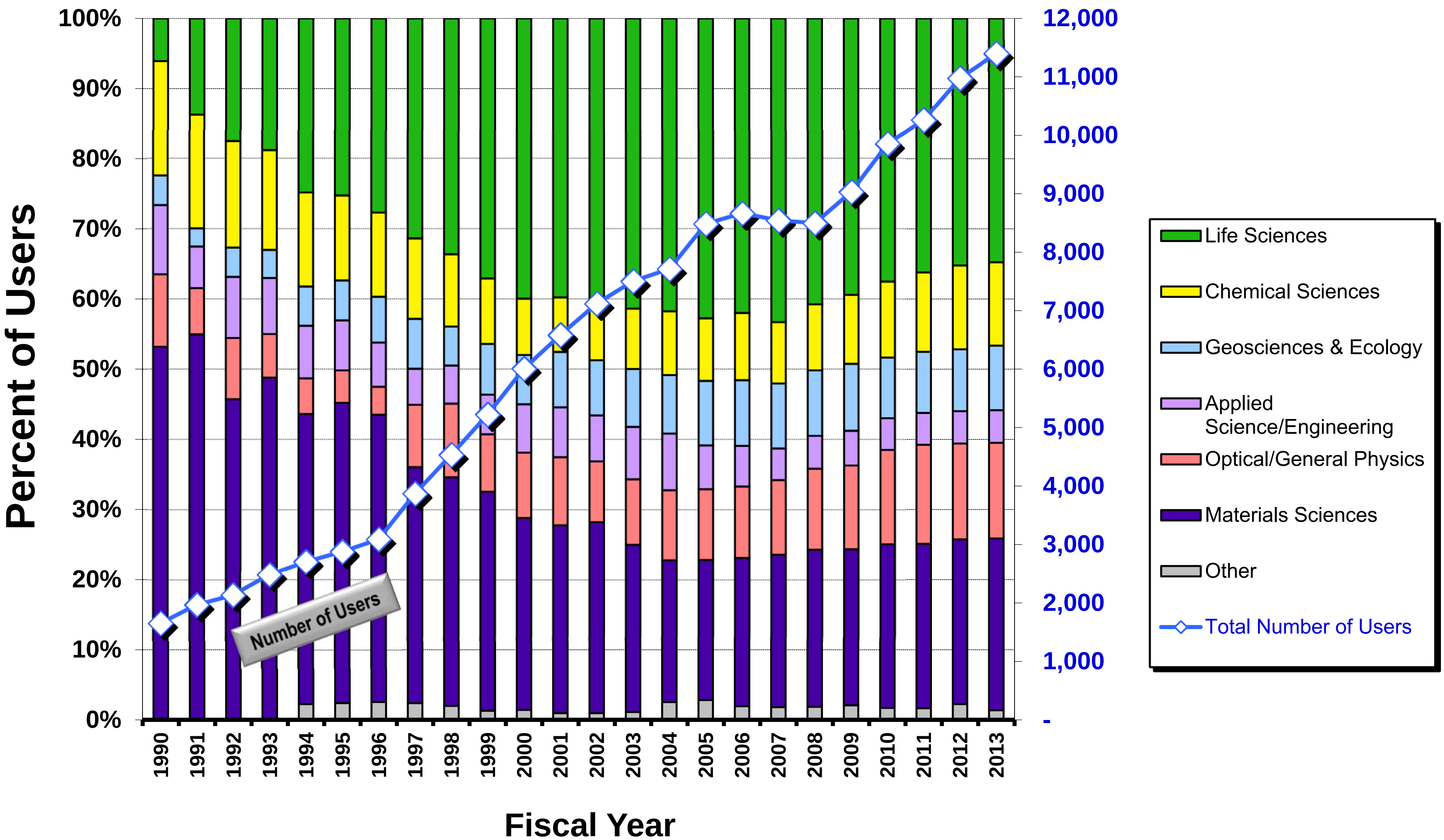
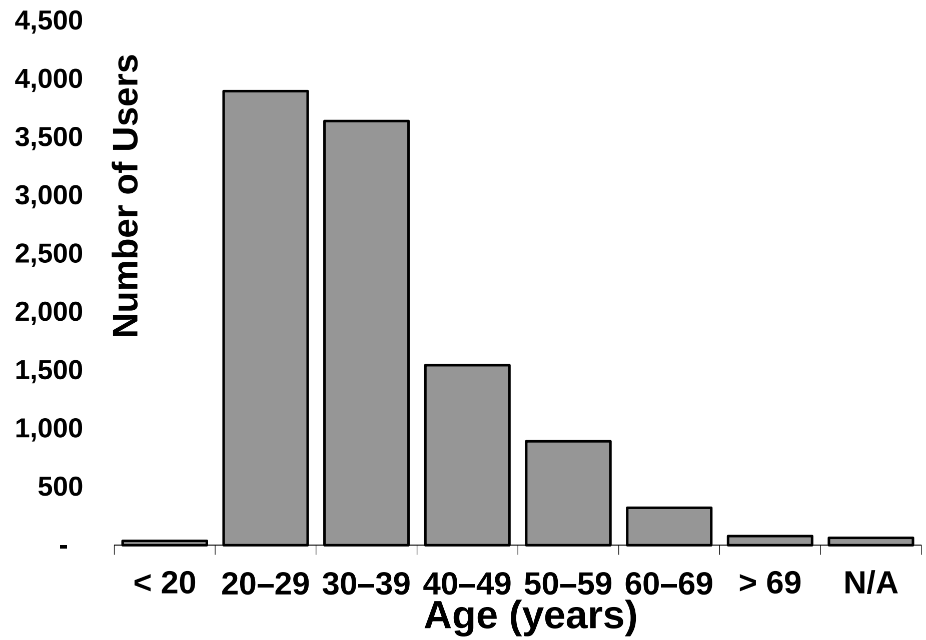
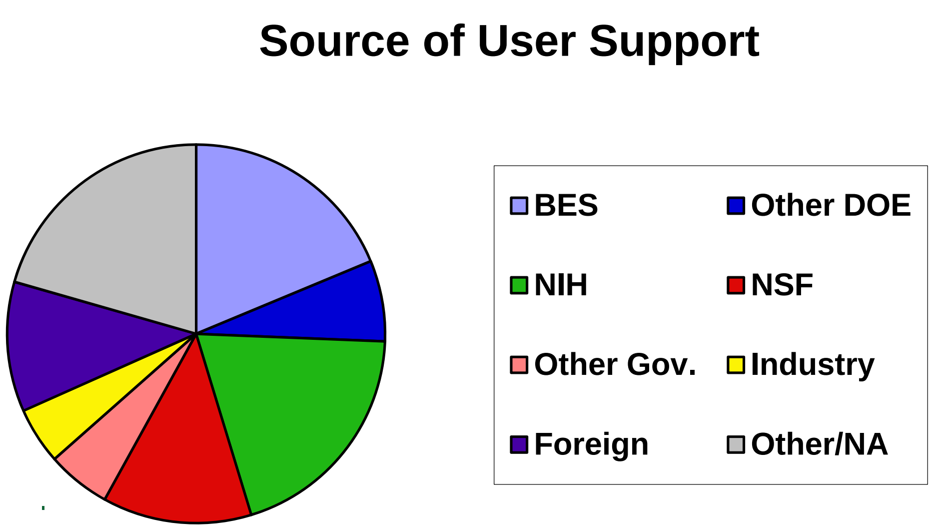
Users by Discipline at the Light Sources

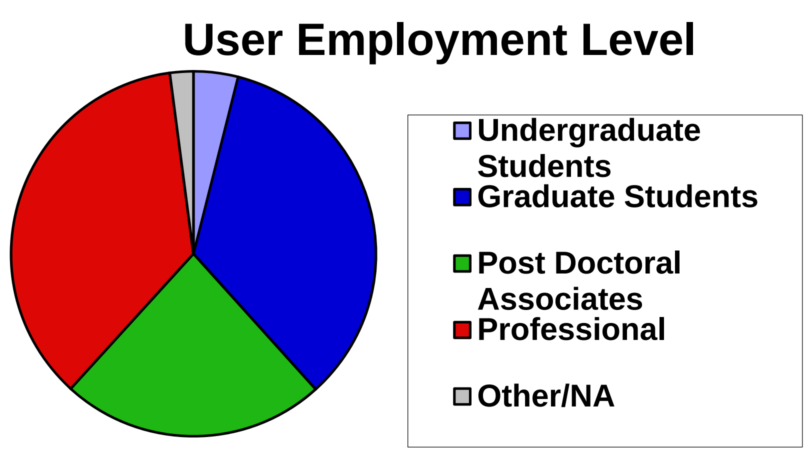


Light Source User Demographics for FY 2015

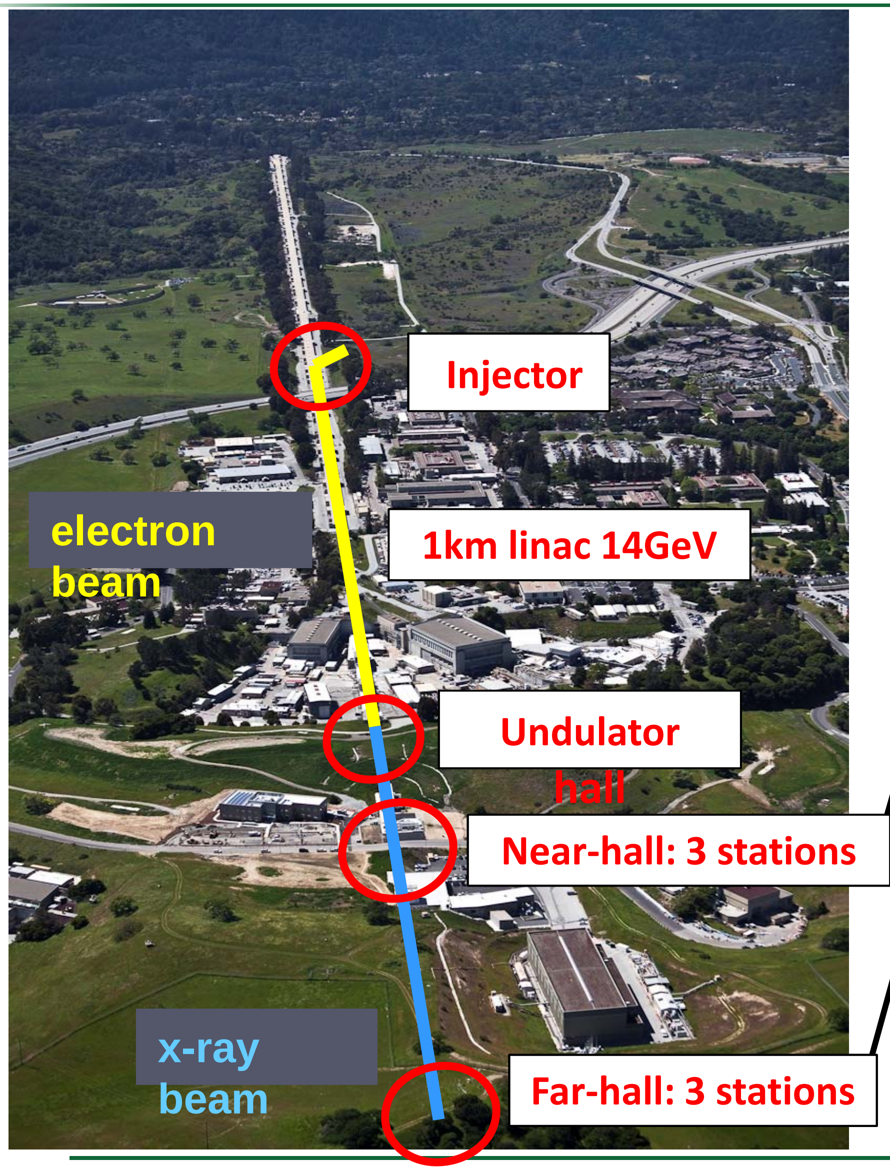
36%	First-Time Users
27%	Female
	Citizenship
49%	United States
29%	Foreign, Non-Sensitive Countries
22%	Foreign, Sensitive Countries
	Nature of Research
98%	Nonproprietary research only
1%	Nonproprietary & proprietary research
1%	Proprietary research only

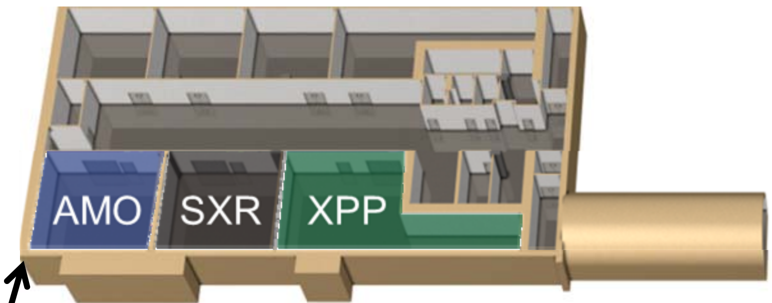


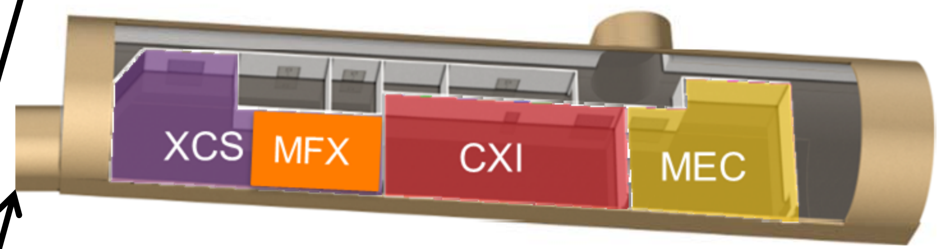




BES X-ray Free Electron Laser Source: Linac Coherent Light Source (LCLS)







MEC provides a unique set of tools that utilize the combined **LCLS ultra fast high brightness x-ray beams** and **high power optical laser beams** to study the transient behavior of matter in extreme conditions. Key scientific areas include warm dense matter physics, high pressure studies, and shock physics.

BES Reactor Neutron Source

BES operates the High Flux Isotope Reactor (HFIR) at Oak Ridge National Laboratory

- 85 MW light-water moderated and cooled reactor
- Principal mission – Neutron scattering
  - Secondarily produces a variety of isotopes for medical and industrial applications
  - Also provides a significant materials irradiation capability due to its unique flux trap design providing an intense fast neutron flux

- *More than 100* HFIR irradiation capsules have been completed for fusion since the 1970s
- Between *5,000-10,000 specimen* have been exposed over the last decade

Several specimen types to be loaded into the irradiation capsules in lower left

Nanoscale Science Research Centers

Synthesis
- Quantum dots, nanowires
- Functionalized nanoparticles
- High mobility & quantum materials
- Nanocrystalline diamond
- Ordered nanoparticle assemblies
- Combinatorial nanomaterials

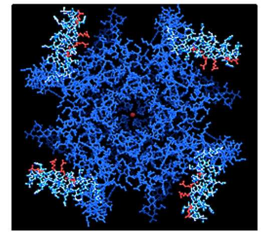
Fabrication
- E-beam lithography
- Dip pen, STM lithography
- Nanopatterned block copolymers
- Atom scale fabrication
- Nanometer scale 3D printing

Characterization
- Atomic resolution electron microscopy
- Ultrafast & THz optical
- X-ray scattering
- In-situ and in-operando
- Neutron scattering

Modeling/Prediction
- Comprehensive suite of codes on clusters and HPC integrated with experiments

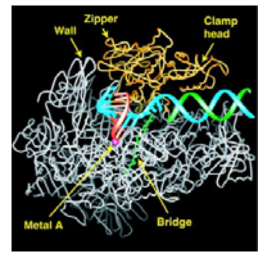
4 Nobel Prizes in 10 Years Using Light Source User Facilities

2003: Roderick MacKinnon (Chemistry) for "structural and mechanistic studies of ion channels."
Used NSLS beamlines X25 and X29.



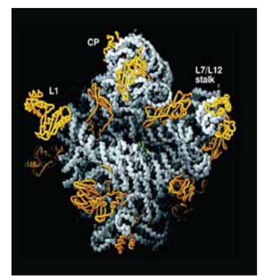
The overall view of a voltage-dependent potassium ion channel.

2006: Roger Kornberg (Chemistry) "for his studies of the molecular basis of eukaryotic transcription."
Used SSRL macromolecular crystallography beamlines.



The visualized transcription process.

2009: Venkatraman Ramakrishnan, Thomas A. Steitz, and Ada E. Yonath (Chemistry) "for studies of the structure and function of the ribosome."
Used all 4 DOE light sources.



The 50S subunit structure at 2.4Å resolution.

2012: Robert J. Lefkowitz and Brian K. Kobilka (Chemistry) "for studies of G-protein-coupled receptors."
Used APS beamline 23-ID.

The structure of the β2AR-Gs complex.

Lab-Industry Partnerships at the BES Scientific User Facilities Support U.S. Science and Economy

Manufacturing | **Energy** | **Information Technology** | **Pharmaceuticals**

ADSC Area Detector Systems Corporation, Toyota, GM, Volt, Moxtek Innovating Solutions, Cymer, Teledyne Scientific & Imaging, LLC A Teledyne Technologies Company, GlobalFoundries, Inpria, Sematech, Schott glass made of ideas, MDC, Bruker, Ford, Toyota Central R&D Labs., Inc.

Chevron, Dow, NuScale Power, Schneider Electric, SunPower, GE, Black Pak inc., AutoGrid, Baldor, Arkansas Power Electronics APEI International, Ambri, EaglePicher Technologies, LLC

Intel, IBM, Cisco, Samsung, Honeywell, Axsun a Volcano company, AZ Electronic Materials, Hitachi, Shin-Etsu, ASML, hp, UES Excellence in Science & Technology, TE connectivity, Panoramic Technology

MannKind Corporation, Amgen, Array Biopharma, AstraZeneca, Calithera Biosciences, Celgene, CalAsia Pharma, Emerald Biostructures, CrownBio, Gilead, Genzyme, Genentech, gsk GlaxoSmithKline, élan

Pfizer, AbbVie, Lilly, MedImmune, Plexxikon, Merck, Novartis, Illumina, Pioneer A DuPont Business, Structure Based Design, Inc., Takeda, Trius Therapeutics, Zenobia Therapeutics, Vertex, Roche

Maintaining World Leadership in BES Facilities

- Engage BES Advisory Committee in setting priorities
- Be mindful of international competitions
- Take a long view in planning: ~ 10 years for major upgrades

Status of Upgrade Planning:

Ring-based x-ray light sources

ANL Advanced Photon Source Upgrade (APS-U) (CD-1/3B)
LBNL Advanced Light Source Upgrade (ALS-U) (CD-0)

Free electron laser based x-ray light sources

SLAC LCLS-II (CD-3)
SLAC LCLS-II High Energy Upgrade (LCLS-II-HE) (CD-0)

Spallation based neutron scattering sources

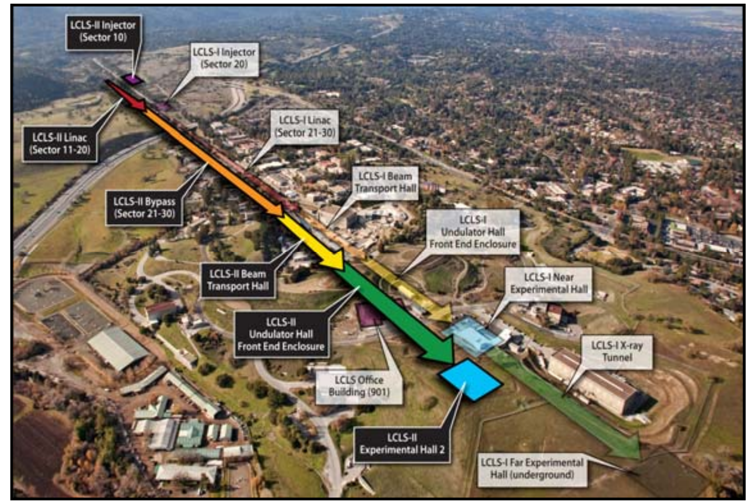
ORNL Spallation Neutron Source Proton Power Upgrade (CD-0)
ORNL Spallation Neutron Source Second Target Station (CD-0)

CD-0: Mission Need
CD-1: Alternatives Analysis
CD-3B: Long Lead Procurement
CD-3: Construction Start

LCLS-II and APS-U Underway

Linac Coherent Light Source-II (LCLS-II)

- LCLS-II will provide high-rep-rate, ultra-bright, transform-limited femtosecond x-ray pulses with polarization control and pulse length control to ~1 femtosecond. The hard x-ray range will be expanded to 25 keV.
- Added are a 4 GeV superconducting linac; an electron injector; and two undulators to provide x-rays in the 0.2–5 keV energy range.
- FY 2016 = $200,300K; FY 2017 = $190,000K for R&D, design, prototyping, long lead procurement, and construction of technical systems.
- The project is on track and ~42% complete; first light is planned for Jan 2020

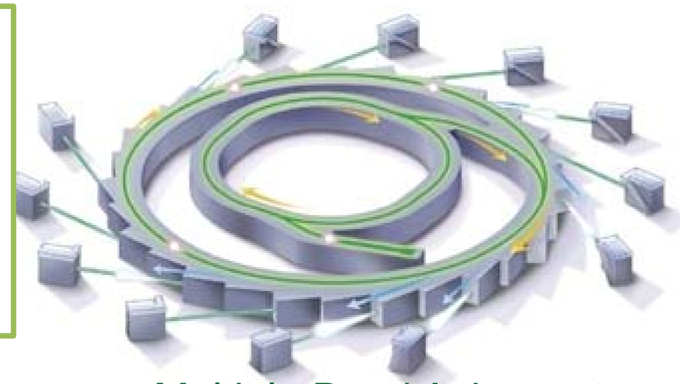


Advanced Photon Source Upgrade (APS-U)

- APS-U will provide a multi-bend achromat lattice to provide extreme transverse coherence and brightness.
- Initial conceptual design for the new lattice completed; conducting R&D and key component prototyping in support of the new design; beamline proposal selection complete
- FY 2016 = $20,000K; FY 2017 = $20,000K for R&D, design, and limited prototyping.
- CD-1 Refresh approved 2/2016; CD-3B, Long Lead Procurement approved 10/2016

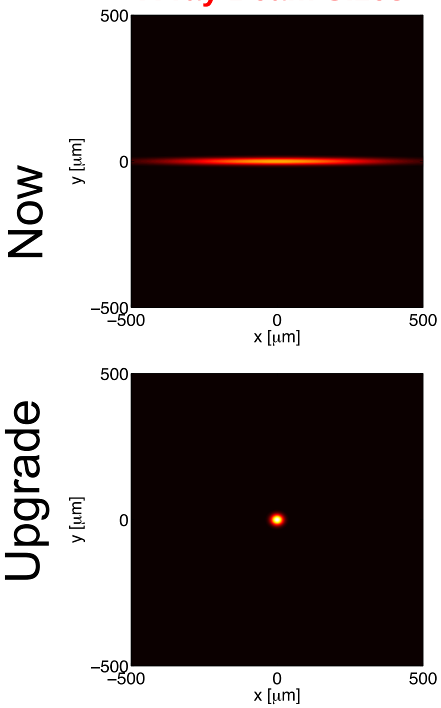
X-ray Synchrotron Light Source Upgrade
Multiple Bend Achromat Lattice Design

<u>Key Advantages of a Multiple Bend Achromat Ring</u>:
- Reduction of electron beam size & angular spread (i.e., emittance)
- Increases the x-ray beam brightness & coherent flux by 10^2-10^3
- Enables new optics-free coherent imaging techniques where resolution is limited by the x-ray wavelength λ & available signal, *not* by optics
- Coherent imaging can be extended to the hard x-ray regime

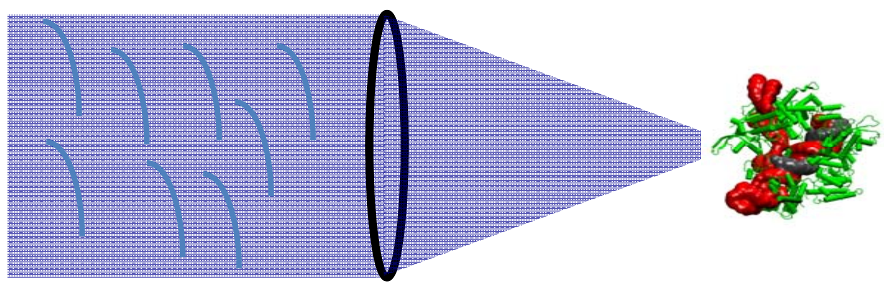


Multiple Bend Achromat Storage Ring

X-ray Beam Sizes

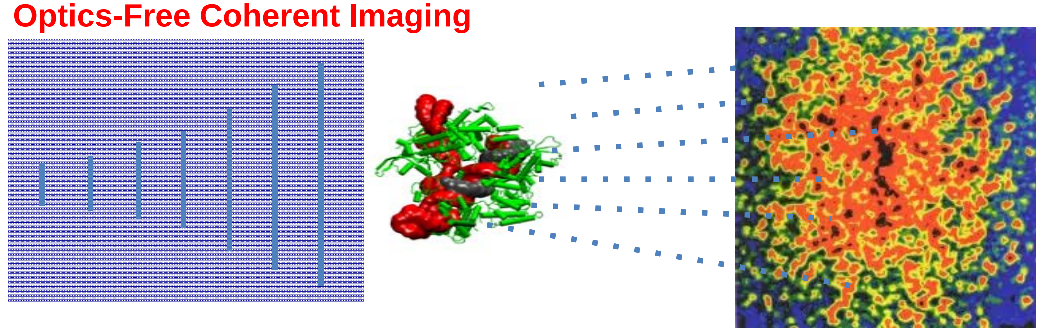


Incoherent Imaging w/Optics



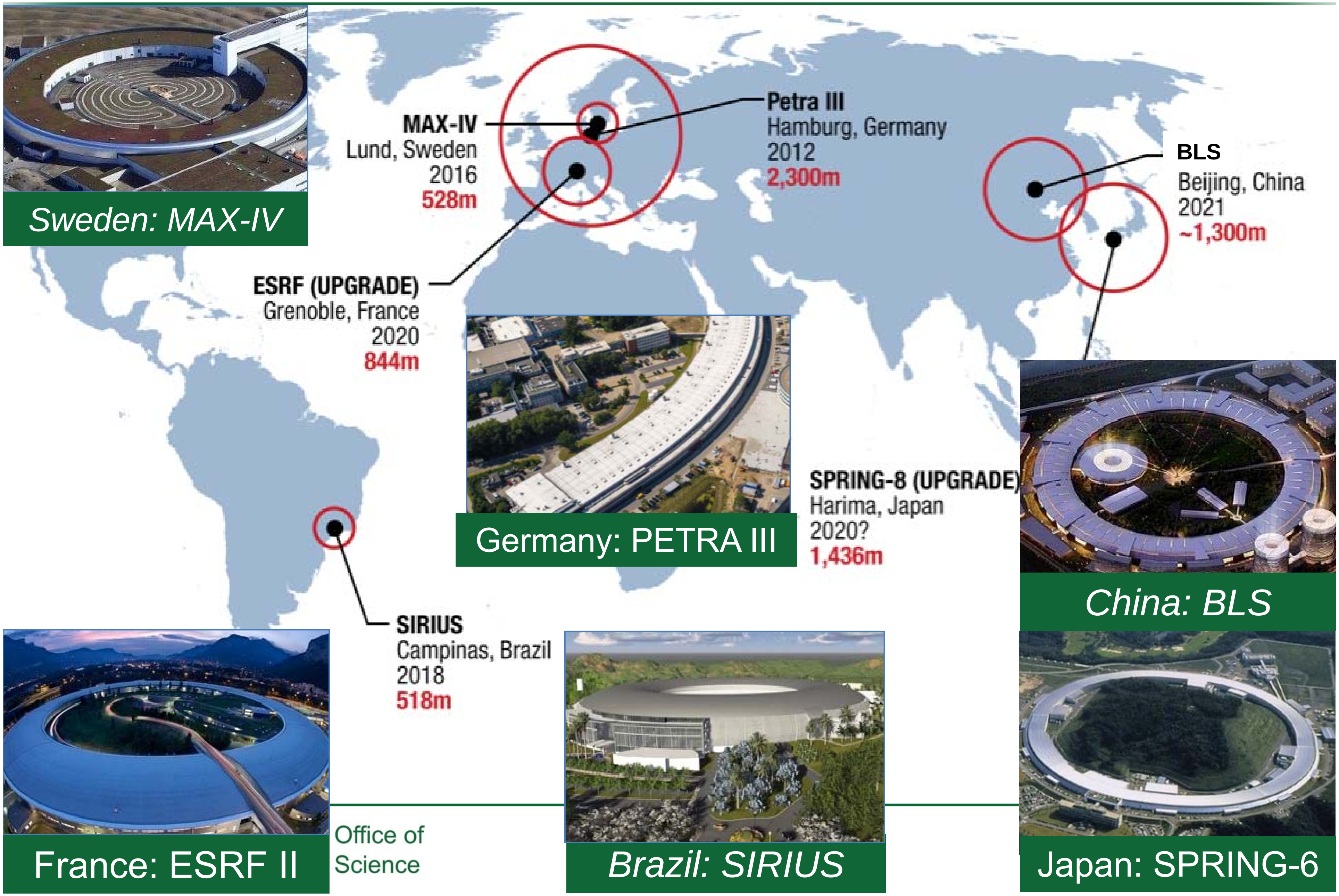
Resolution >> λ
Due to Optics Quality

Optics-Free Coherent Imaging



Resolution ~ λ
No Optics Needed
Uses HPC

International Landscape of X-ray Storage Ring Light Sources:
New Constructions (3) and Upgrades (3)



Office of Science

Four Competing X-Ray FELs Begin/Continue Operation in 2017

SACLA 2011
8.5 GeV, 30 Hz NC

First lasing in June 2011
Ops since March 2012
BL1: Soft X-rays to 100 eV
BL2&3: Hard X-rays to 20 keV

PAL XFEL 2016
10 GeV, 60 Hz NC

First lasing in June 2016
First user exps in Q3 2017

SWISS FEL 2017
5.8 GeV, 100 Hz NC

Commissioning in Q4 2016
Soft X-rays ops in 2017
Hard X-rays by 2020

EU XFEL 2017
17.5 GeV, 3000 x 10 Hz SC

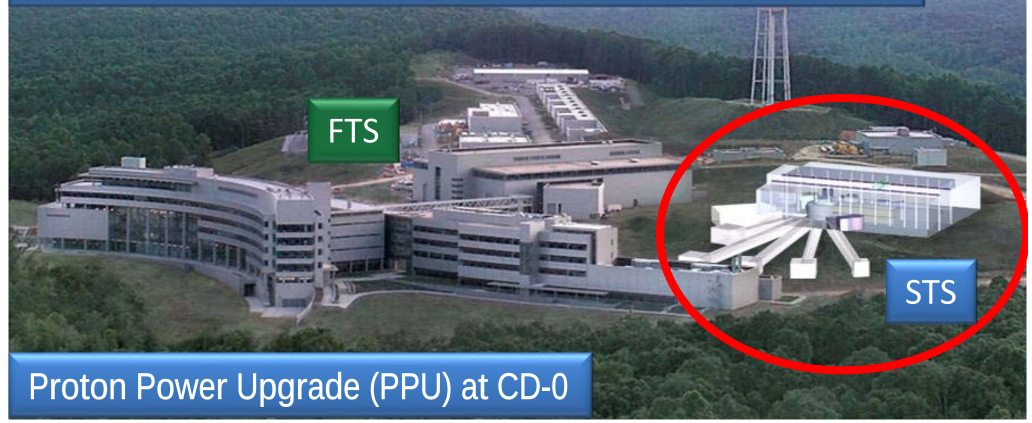
First e^- in SC linac in Jan 2017
First user exps in Q3 2017

Three normal conducting (NC) linacs
One *pulsed* superconducting (SC) linac

SNS Will be Challenged by ESS

ORNL Spallation Neutron Source (SNS)
Operational since 2006 at up to 1.4 MW

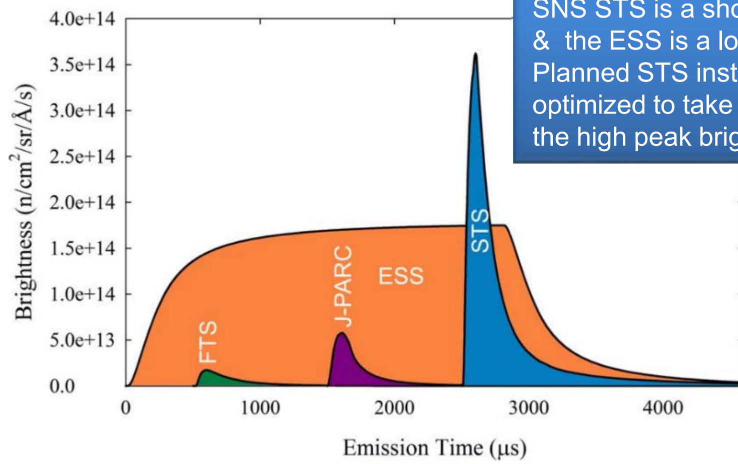
ORNL SNS Second Target Station (STS) Concept
2 MW on First Target Station (FTS) + 0.5 MW on STS



Proton Power Upgrade (PPU) at CD-0

19 European countries are building the 5 MW European Spallation Source (ESS) in Sweden

ESS construction in 1/2017, ops in ~2019



SNS STS is a short pulse source & the ESS is a long pulse design. Planned STS instruments are optimized to take advantage of the high peak brightness.

Relative time structure for short pulse sources SNS FTS and STS, and J-PARC, and the ESS long pulse design.

BESAC Report on Facility Upgrades (June 2016):
Neutrons & Photons (Status as of Q1 CY2017)

Project	ANL APS-U	LBNL ALS-U	ORNL SNS PPU	ORNL SNS STS	SLAC LCLS-II	SLAC LCLS-II-HE
Proposed Project	Hard X-ray ~Diffraction Limited 6 GeV MBA Ring	Soft X-ray ~Diffraction Limited 2 GeV MBA Ring	Proton Power Upgrade to 2.5 MW (W Target) 1.3 GeV SC Linac	High Resolution Neutron Science; Second Target Station	High Rep-Rate, Soft X-ray FEL, 4 GeV SC Linac	High Rep-Rate, Medium Energy X-ray FEL, 8 GeV SC Linac
Current Status of Facility	APS is operational since 1996; ring will be replaced	ALS is operational since 1993; ring will be replaced	SNS Linac is operational since 2006 at 0.94 GeV	SNS is operational since 2006	LCLS is operational since 2010; LCLS-II is under construction	LCLS is operational since 2010; LCLS-II is under construction
Worldwide Competition	EU ESRF Germany PETRA3,4 Japan SPring-6 China HEPS	Sweden MAX-IV Brazil SIRIUS CH SLS-II	EU ESS Japan JPARC China CSNS UK ISIS	EU ESS Japan JPARC China CSNS UK ISIS	EU XFEL Japan SACLA Korea PAL XFEL CH Swiss FEL	EU XFEL
Dark Time	~1 yr	~0.75 yr	0 yr	~0.5 yr	~1 yr	0 yr
Status Q1/17	CD-3b	CD-0	CD-0	CD-0	CD-3	CD-0

https://science.energy.gov/~/media/bes/besac/pdf/Reports/BESAC_Facility_Upgrade_Assessment_Approved_June_9_2016.pdf

BES At-a-Glance

Office of Basic Energy Sciences
Harriet Kung

Materials Sciences and Engineering Division (MSE)
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Linda Horton

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Chemical Sciences, Geosciences and Biosciences Division (CSGB)
Director
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Relevant Websites

BES: https://science.energy.gov/bes/

Reports: https://science.energy.gov/bes/community-resources/reports/

Research: https://science.energy.gov/bes/research/

User Facilities: https://science.energy.gov/user-facilities/user-facilities-at-a-glance/bes/

Questions?

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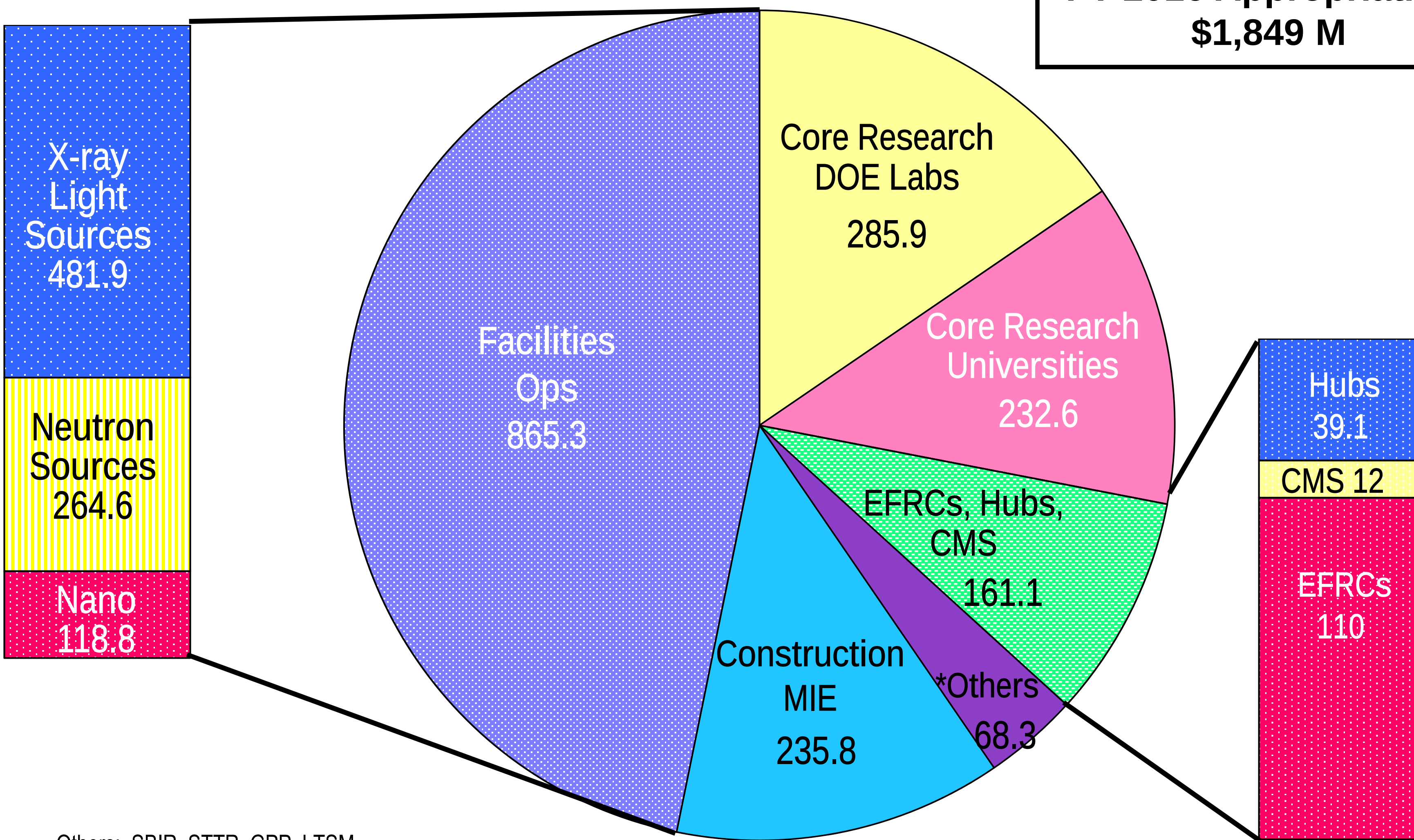
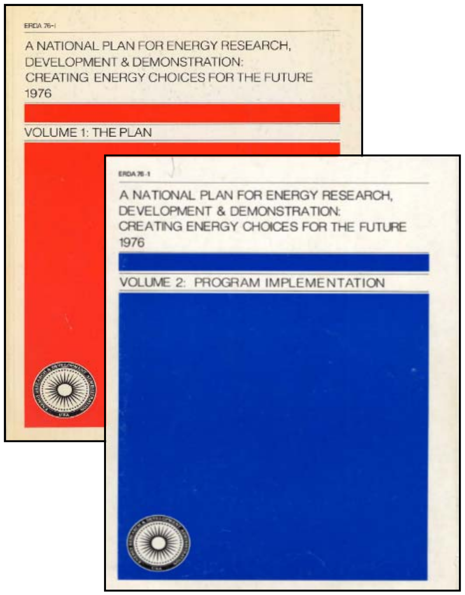
BES Budget At-a-Glance

FY 2016 Appropriation:
$1,849 M



Others: SBIR, STTR, GPP, LTSM

BES Organizational History



ERDA's 1976 R&D plan, *A National Plan for Energy Research, Development, and Demonstration: Creating Energy Choices for the Future (April 15, 1976)*.

- The formation of BES was part of the *Department of Energy Organization Act of 1977* to provide for basic energy research in non-nuclear areas.
- Basic research activities within the *Energy Research and Development Administration* (ERDA) were first grouped as the BES program in the FY 1977 Budget Request (released February 1976). The BES organization was formed in June 1977 in preparation for the creation of DOE in October 1977.
- While BES has gone through many changes in structure and program emphases, the mission of BES has not changed. As stated in 1976, "The primary purpose of the BES program is to increase knowledge of the physical phenomena relevant to the goal of meeting our nation's energy needs."

The research activities and subprograms of BES have undergone substantial changes over the past three decades. For a detailed evolution of the BES program, see: http://science.energy.gov/bes/about/organizational-history/

The origins of the federal research programs that became BES are rooted in the nation's research efforts to win World War II. The goals of the early U.S. science programs that evolved into BES were to explore fundamental phenomena, create scientific knowledge, and provide unique user facilities. In this sense, the BES program predates the establishment of the *Atomic Energy Commission* in 1946, which became part of ERDA on October 11, 1974, as a result of the *Energy Reorganization Act of 1974*.