U.S. DEPARTMENT OF ENERGY | Office of Science

Hydrogen Storage Research in the Office of Basic Energy Sciences

Fuel Cell Technologies Annual Merit Review

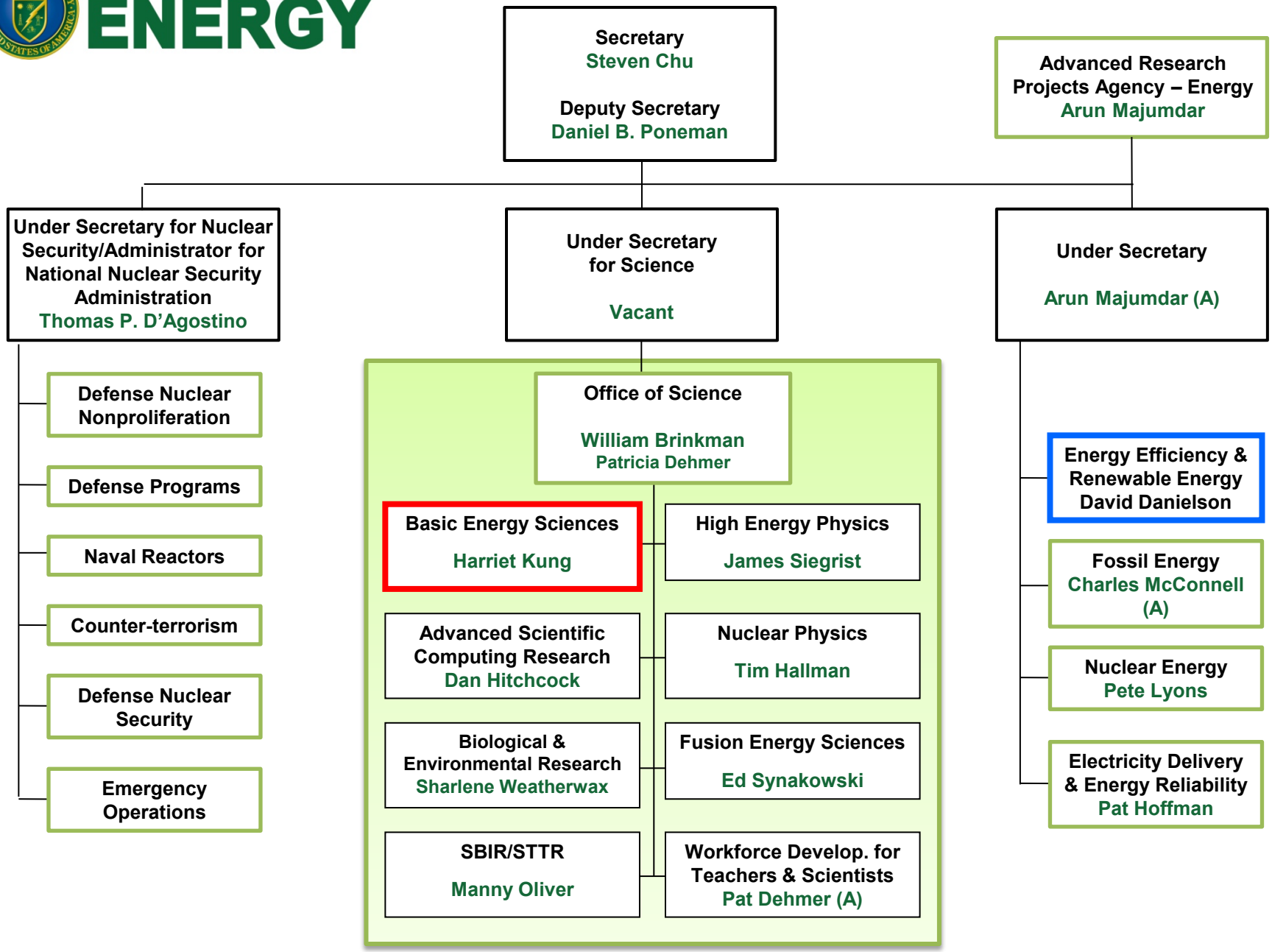
May 16, 2012

Presented by: John Vetrano

Program Manager and Technical Coordination

Office of Basic Energy Sciences

U.S. DEPARTMENT OF ENERGY



Basic Energy Sciences

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

The Program:

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

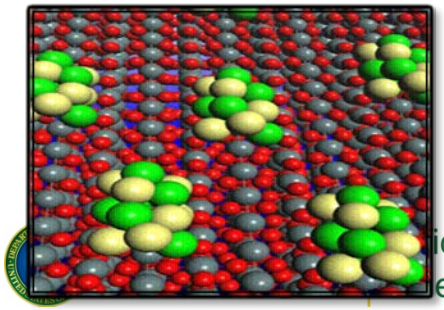
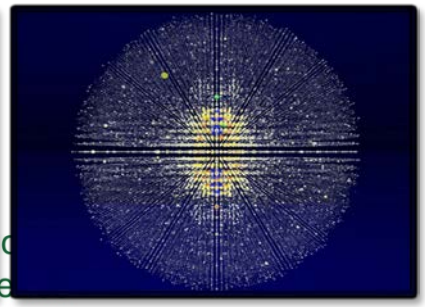
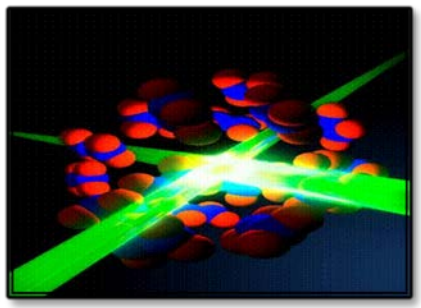
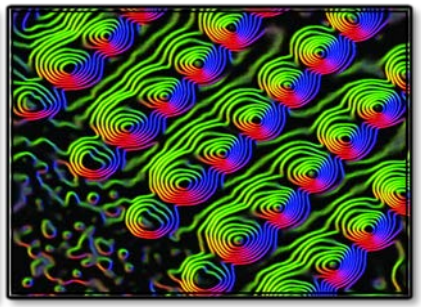
Chemical sciences, geosciences, and energy biosciences—exploring the fundamental aspects of chemical reactivity and energy transduction over wide ranges of scale and complexity and their applications to energy technologies

Supporting:

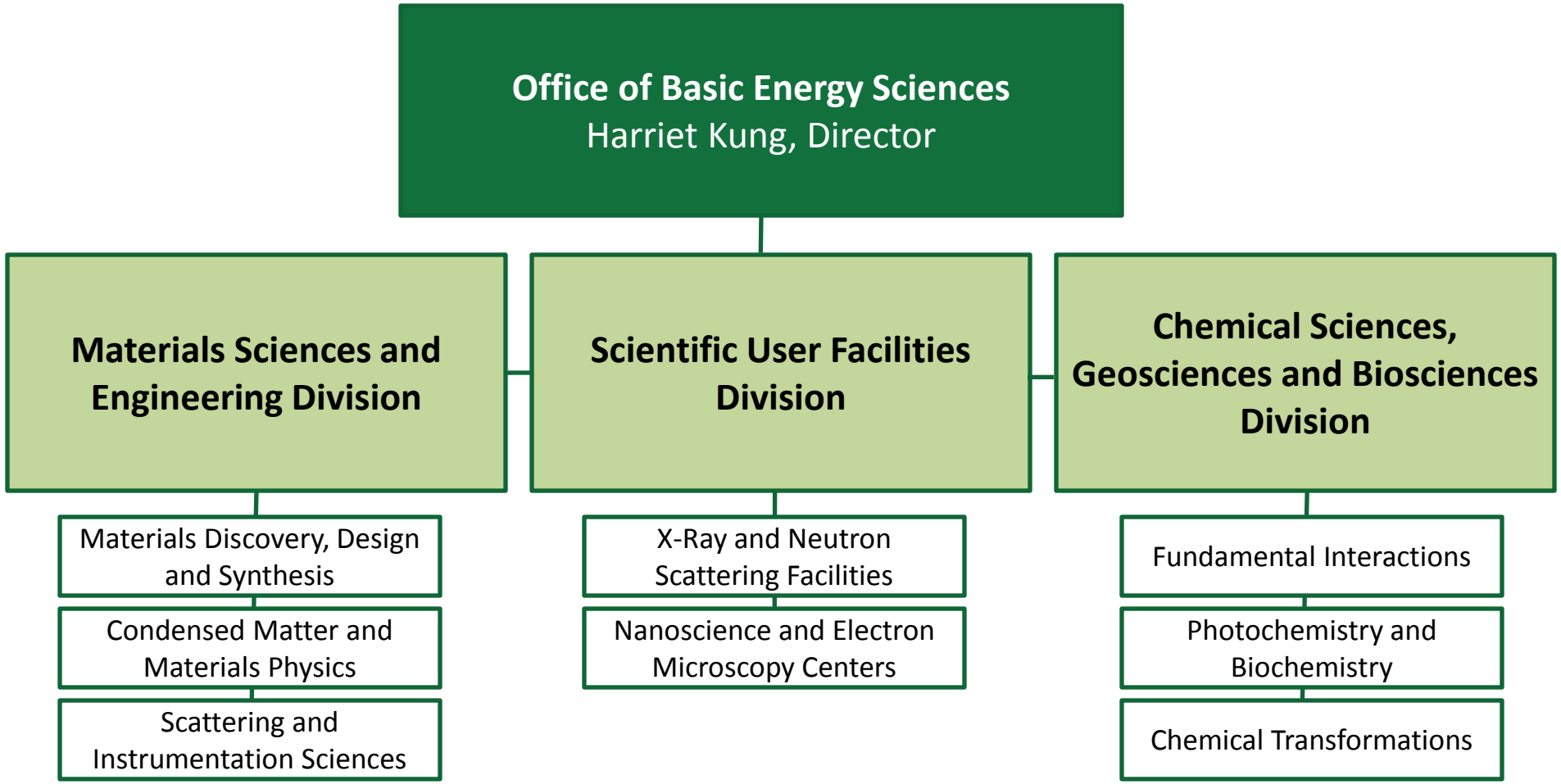
- 46 Energy Frontier Research Centers
- Solar Fuels Hub
- The largest collection of facilities for electron, x-ray, and neutron scattering in the world

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

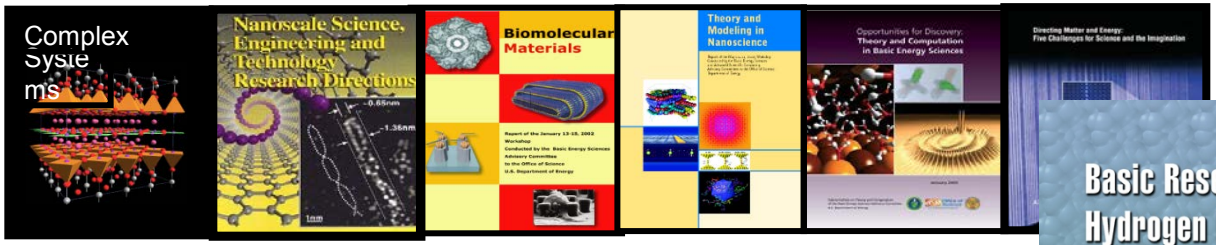
Office of Basic Energy Sciences



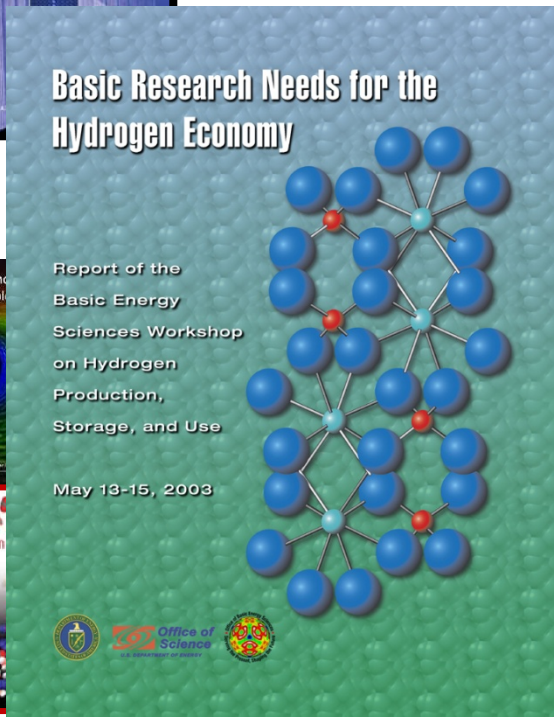
Research grouped by scientific topics
-- not by specific energy technologies

BES Strategic Planning Activities

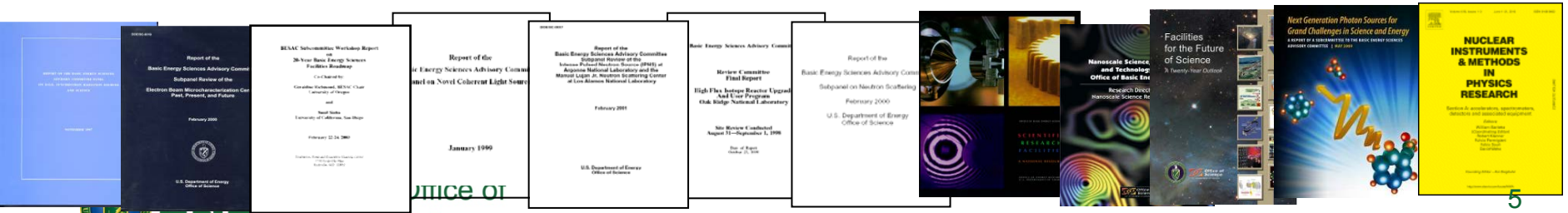
- *Science for Discovery*



- *Science for National Needs*



- *National Scientific User Facilities, the 21st century Tools of Science & Technology*



Priority Research Directions

- Low-Cost and Efficient Solar Energy Production of Hydrogen Nanoscale Catalyst Design
- Biological, Biomimetic, and Bio-inspired Materials and Processes
- Complex Hydride Materials for Hydrogen Storage
- Nanostructured and Other Novel Hydrogen Storage Materials
- Theory, Modeling, and Simulation of Materials and Molecular Processes
- Low-Cost, Highly Active, Durable Cathodes for Low-Temperature Fuel Cells
- Membranes and Separation Processes for Hydrogen Production and Fuel Cells
- Analytical and Measurement Technologies
- Impact of the Hydrogen Economy on the Environment
- Safety in the Hydrogen Economy

Budget for Hydrogen-Related Research at BES

Hydrogen research is not a line-item request in the BES budget but funding for hydrogen-related research has been tracked internally since 2005. Currently there are approximately 100 projects

BES Funding for Hydrogen Research

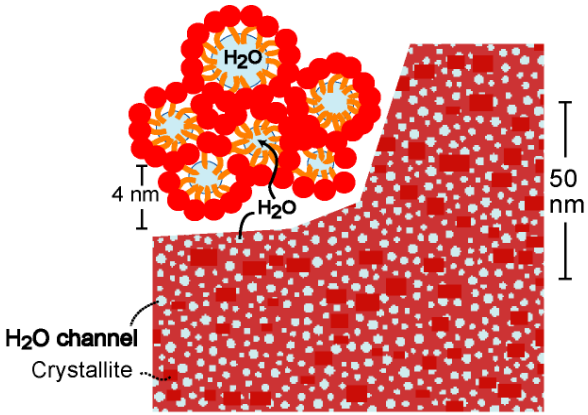
- FY2008 $36.4 M
- FY2009 $38.7 M
- FY2010 $38.7 M
- FY2011 $34.6 M

Increases in FY2009 were a result of new hydrogen-related Energy Frontier Research Centers and several proposals funded under the "Single Investigator and Small Group Research" (SISGR) program

Emphasis in FY2011

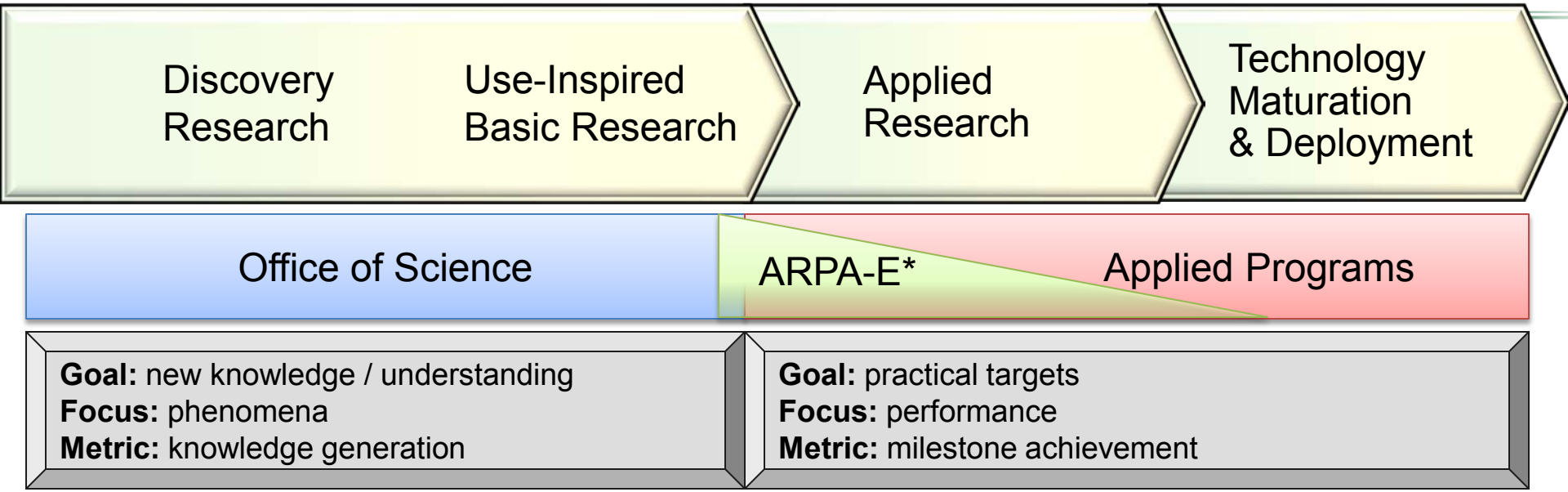
Continued focus on critical basic research needs for hydrogen production, storage, and use:

- Hydrogen Storage ($7.1M)
- Membranes ($7.1M)
- Nanoscale Catalysts ($9.8M)
- Solar Hydrogen Production ($6.9M)
- Bio-Inspired Hydrogen Production ($3.6M)



The Nanostructure of Nafion® Fuel-Cell Membrane

Continuum of Research, Development, and Deployment



- Basic research to address fundamental limitations of current theories and descriptions of matter in the energy range important to everyday life – typically energies up to those required to break chemical bonds.
- Basic research for fundamental new understanding on materials or systems that may revolutionize or transform today's energy technologies
- Basic research for fundamental new understanding, usually with the goal of addressing scientific showstoppers on real-world applications in the energy technologies
- Proof of new, higher-risk concepts
- Prototyping of new technology concepts
- Explore feasibility of scale-up of demonstrated technology concepts in a "quick-hit" fashion.
- 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
- Scale-up research
- Small-scale and at-scale demonstration
- Cost reduction
- Manufacturing R&D
- Deployment support, leading to market adoption
- High cost-sharing with industry partners

* ARPA-E: targets technology gaps, high-risk concepts, aggressive delivery times

Basic Sciences Underpinning Technology

- **Coordination between basic science and applied research and technology is an important mechanism by which to translate transformational discoveries into practical devices**

- **Many activities facilitate cooperation and coordination between BES and the technology programs**
  - Joint efforts in strategic planning (e.g., 10 BRN workshops)
  - Solicitation development
  - Reciprocal staff participation in proposal review activities
  - Joint program contractors meetings
  - Joint SBIR topics
  - Participation by BES researchers at the Annual Merit Review
  - "Tech Teams" formed across DOE

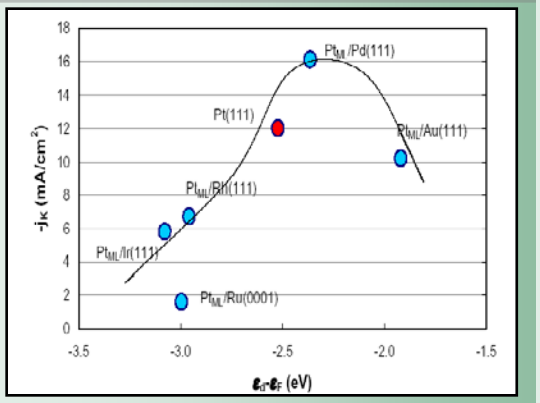
- **Co-funding and co-siting of research by BES and DOE technology programs at DOE labs or universities, has proven to be a viable approach to facilitate close integration of basic and applied research through sharing of resources, expertise, and knowledge of research breakthroughs and program needs.**

Platinum Monolayer Electro-Catalysts:
Stationary and Automotive Fuel Cells

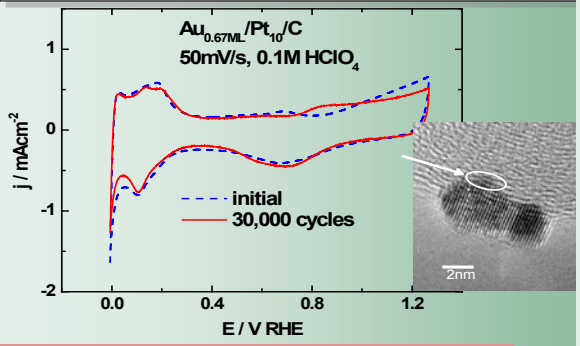
Basic Science | Applied R&D | Manufacturing/ Commercialization

BES
Two research advances

Pt core-shell nano-catalysts: high activity with ultralow Pt mass



Pt stabilized against corrosion in voltage cycling by Au clusters

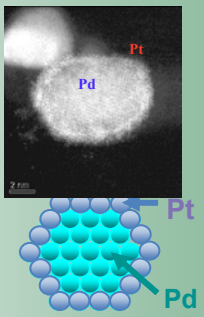


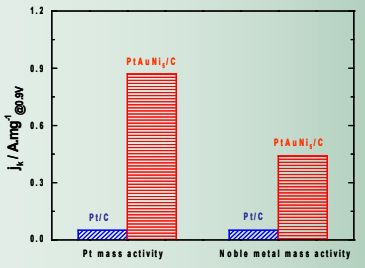
Science **315**, 220 (2007)

BES → EERE
Core-Shell Nanocatalysts

Active Pt ML shell – Metal/alloy core
Core tunes activity & durability of shell

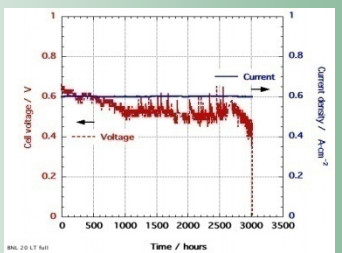
Model and actual image of a Pt Monolayer on Pd nanoparticle





Pt-mass weighted activity enhanced 20x

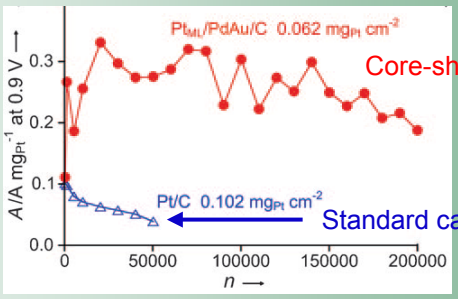
3000 hr Fuel Cell Durability Performance



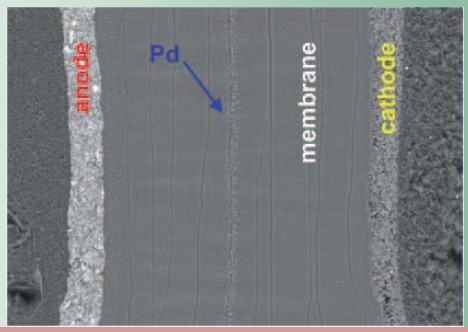
CRADA with Industry

Scale-up synthesis: **Pt-ML/Pd_9Au_1/C**

Excellent fuel Cell durability 200,000 cycles



Membrane Electrode Assembly >200K cycles
Very small Pt diffusion & small Pd diffusion



Angewandte Chemie ***49***, *8602 (2010)*

Fuel Cell Catalyst readied for automotive application

BES Hydrogen Storage Presentations

BES001; John Vetrano, BES: Overview of the BES Hydrogen Storage Activities
BES002; Taner Yildrim, NIST: From Fundamental Understanding to Predicting New Nanomaterials for High-Capacity Hydrogen Storage
BES003; Timo Thonhauser, Wake Forest University: Novel theoretical and experimental approaches for understanding and optimizing hydrogen-sorbent interactions in metal organic framework materials
BES004; Hani El-Kaderi, VCU: Design and Synthesis of Chemically and Electronically Tunable Nanoporous Organic Polymers for Use in Hydrogen Storage Applications
BREAK
BES005; Nidia Gallego, ORNL: Atomistic Mechanisms of Metal-Assisted Hydrogen Storage in Nanostructured Carbons
BES006; Ragaiy Zidan, SRNL: Elucidation of Hydrogen Interaction Mechanisms with Metal-Doped Carbon Nanostructures
BES007; Pingyun Feng, UCR: Synthetic Design of New Metal-Organic Framework Materials for Hydrogen Storage
BES008; Peter Pfeifer, UMC: Networks of Boron-Doped Carbon Nanopores for Low-Pressure Reversible Hydrogen Storage

- A **HUGE** thanks to Dr. Dawn Adin, AAAS Energy, Environment, and Agriculture Fellow at BES, who did all the hard work in organizing this session.
- 30 minute presentations; leave some time for questions
- There will also be a poster session this evening jointly between BES and EERE-Fuel Cell Technology PIs in the Grand Ballroom
- You are encouraged to visit posters and attend talks funded by both Offices

Questions?

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