Moving Towards a More Secure Energy Future –
Fundamental Research at the US-DOE

EERE's Venture Capital Day
DOE Headquarters
August 21, 2007

John S. Vetrano
Materials Sciences and Engineering Division
Office of Basic Energy Sciences
Office of Science, U.S. Department of Energy
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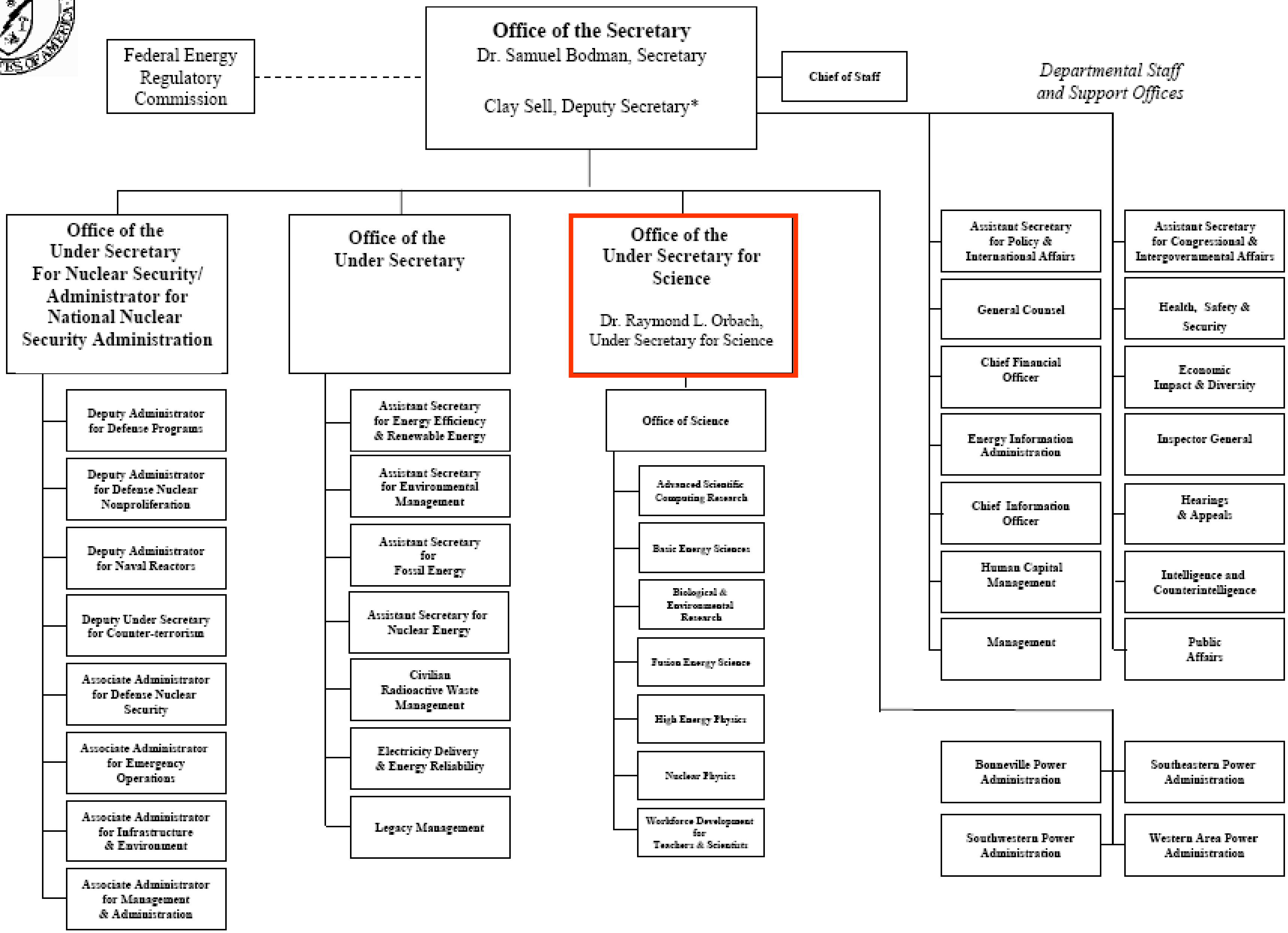
John.vetrano@science.doe.gov

Department of Energy



* The Deputy Secretary also serves as the Chief Operating Officer

26 Oct 06

Department of Energy

- Office of the Secretary
  - Dr. Samuel Bodman, Secretary
  - Clay Sell, Deputy Secretary*
- Federal Energy Regulatory Commission
- Chief of Staff

Departmental Staff and Support Offices

- Assistant Secretary for Policy & International Affairs
- Assistant Secretary for Congressional & Intergovernmental Affairs
- General Counsel
- Health, Safety & Security
- Chief Financial Officer
- Economic Impact & Diversity
- Energy Information
- Inspector General
- C
- Hearings & Appeals
- ligence and erintelligence
- Public Affairs
- neville Power Administration
- Southeastern Power Administration
- Southwestern Power Administration
- Western Area Power Administration

Office of the Under Secretary For Nuclear Security/ Administrator for National Nuclear Security Administration

- Deputy Administrator for Defense Programs
- Deputy Administrator for Defense Nuclear Nonproliferation
- Deputy Administrator for Naval Reactors
- Deputy Under Secretary for Counter-terrorism
- Associate Administrator for Defense Nuclear Security
- Associate Administrator for Emergency Operations
- Associate Administrator for Infrastructure & Environment
- Associate Administrator for Management & Administration

Office of the Under Secretary

- EERE
- EM
- FE
- NE
- RW
- OE
- Legacy Management

Office of the Under Secretary for Science

Dr. Raymond L. Orbach, Under Secretary for Science

- Office of Science
  - Advanced Scientific Computing Research
  - BES
  - Biological & Environmental Research
  - Fusion Energy Science
  - High Energy Physics
  - Nuclear Physics
  - Workforce Development for Teachers & Scientists

FY 2008 Request $1.5 B

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26 Oct 06

Our Mission:

- Foster and support ***fundamental research programs*** to expand the scientific foundation for new and improved energy technologies and for understanding and mitigating the environmental impacts of energy use

- Plan, construct, and operate ***major scientific user facilities*** for "materials sciences and related disciplines" to serve researchers at universities, federal laboratories, and industrial laboratories

Office of Basic Energy Sciences

Patricia Dehmer, Director

Mary Jo Martin, Administrative Specialist

BES Budget and Planning

- Robert Astheimer, Technical Advisor
- Margie Davis, Budget Analyst

BES Operations

- Linda Blevins, International/Intergovernmental
- Richard Burrow, DOE Technical Office Coordination
- Don Freeburn, DOE and Stakeholder Interactions
- Ken Rivera, Laboratory Infrastructure/ES&H
- Karen Talamini, Program Analyst/BESAC

Materials Sciences and Engineering Division

Harriet Kung, Director
Christie Ashton, Program Analyst
Ann Lundy, Secretary

Materials Discovery, Design, and Synthesis

Arvind Kini
Vacant, Prog. Asst.

- Materials Chemistry – Richard Kelley, James McBreen, BNL
- Biomolecular Materials – Arivinda Kini
- Synthesis and Processing Science – Tim Fitzsimmons, Bonnie Gersten
- Tech. Coordination Program Management – John Vetrano

Condensed Matter and Materials Physics

Jim Horwitz
M. Agnant, Prog. Asst.

- Exp. Cond. Mat. Phys. – James Horwitz, D. Finnemore, Ames, Daniel Friedman, NREL
- Theo. Cond. Mat. Phys. – Dale Koelling, Randy Fishman, ORNL, James Davenport, BNL
- Physical Behavior of Materials – Refik Kortan
- Mechanical Behavior and Radiation Effects – John Vetrano

Scattering & Instrumentation Sciences

Helen Kerch
C. Howard, Prog. Asst.

- X-ray Scattering – Helen Kerch, Helen Farrell, INL
- Neutron Scattering – Helen Kerch
- Electron and Scanning Probe Microscopies – Jane Zhu
- Ultrafast Science and Instrumentation – Jim Glownia (8/07)
- Exp. Program to Stimulate Competitive Research – Kristin Bennett

Scientific User Facilities Division

Pedro Montano, Director
Linda Cerrone, Program Analyst
Secretary (Vacant)

Operations

- X-ray and Neutron Scattering Facilities – Roger Klaffky
- Nanoscience Centers & E-beam Centers – Altaf (Tof) Carim
- Accelerator and Detector R&D
- Facility Coordination, Metrics, Assessment

Construction

- Linac Coherent Light Source – Tom Brown
- NSLS II – Tom Brown
- Spallation Neutron Source Upgrades – Tom Brown
- TEAM – Altaf (Tof) Carim
- Instrument MIEs (SING, LUSI, etc.) – Tom Kiess
- ALS User Support Bldg – Tom Brown

Chemical Sciences, Geosciences, and Biosciences Division

Eric Rohlfing, Director
Diane Marceau, Program Analyst
Michaelene Kyler-King, Program Assistant

Fundamental Interactions

Michael Casassa
R. Felder, Prog. Asst.

- Atomic, Molecular, and Optical Sciences – Elliot Kanter, ANL
- Ultrafast Chemical Sciences
- Gas-Phase Chemical Physics – Frank Tully, SNL
- Condensed-phase and Interfacial Mol. Sci. – Gregory Fiechtner
- Computational and Theoretical Chemistry – Richard Hildebrandt

Photo- and Bio-Chemistry

Richard Greene
Vacant, Prog. Asst.

- Solar Photochemistry – Mark Spitler, NREL
- Photosynthetic Systems
- Physical Biosciences – Michael Kahn, PNNL

Chemical Transformations

John Miller
T. Russ, Prog. Asst.

- Catalysis Science – Raul Miranda, Paul Maupin, Michael Chen, ANL
- Heavy Element Chemistry – Lester Morss, Norman Edelestein, LBNL
- Separations and Analysis – William Millman, Larry Rahn, SNL
- Geosciences – Nicholas Woodward, Patrick Dobson, LBNL, Marsha Bollinger, AAAS

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Materials Sciences and Engineering Division

$311 M
Materials Core Research

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Scientific User Facilities Division

$706 M Facilities Operations
$160 M New Constructions
$18 M Facilities Research

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Chemical Sciences, Geosciences, and Biosciences Division

$254 M
CSGB Core Research

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- Ultrafast Chemical Sciences
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- Condensed-phase and Interfacial Mol. Sci. — Gregory Fiechtner
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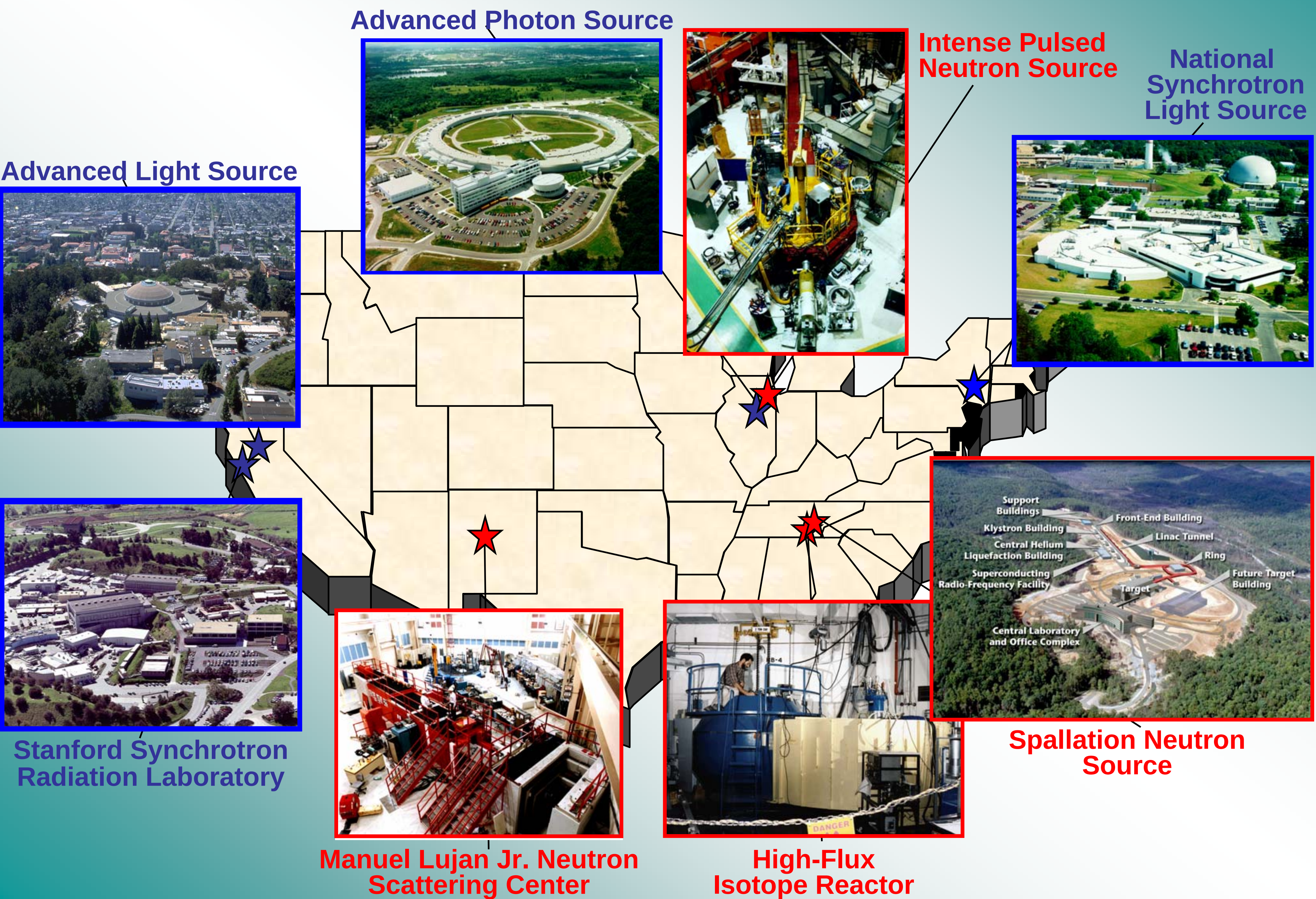
All funding levels based on FY2008 President's Requests

BES Neutron and X-ray Scattering User Facilities

Characterizing Nanoscale Materials for Energy Applications



DOE Nanoscale Science Research Centers

Center for Functional Nanomaterials
(Brookhaven National Laboratory)

Molecular Foundry
(Lawrence Berkeley National Laboratory)

Center for Nanoscale Materials
(Argonne National Laboratory)

Center for Nanophase Materials Sciences
(Oak Ridge National Laboratory)

Center for Integrated Nanotechnologies (Sandia & Los Alamos National Labs)

BES Research Portfolio

Distinguishing Features:

- Idea-driven fundamental research
- Underpin broadly-defined energy missions
- Addressing long-range grand challenges
- Scientific excellence and innovation
- Revolutionary and high risk-high payoff approaches
- Strive for flexibility and stability
- Competitive and peer review process

Deliverables:

- Knowledge broadly disseminated
- High impact results/publications
- New concepts/design for instrumentation
- Important discoveries impacting others' research

Serving the Present, Shaping the Future

impacting directions in basic and applied research and technology development

Relationships Between the Science and the Technology Offices in DOE

Discovery Research	Use-inspired Basic Research	Applied Research	Technology Maturation & Deployment

Discovery Research

- Basic research for fundamental new understanding (i.e., science grand challenges) on materials or systems that may be only peripherally connected or even unconnected to today's problems in energy technologies
- Development of new tools, techniques, and facilities, including those for advanced modeling and computation

Use-inspired Basic Research

- Basic research for fundamental new understanding, with the goal of addressing short-term 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

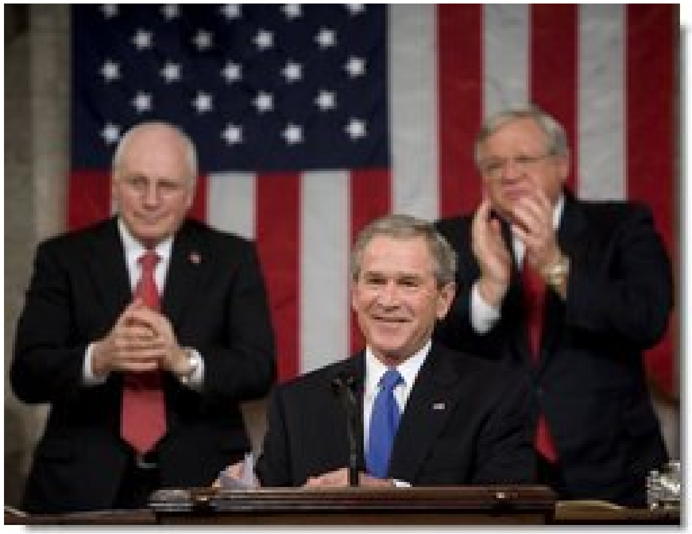
Office of Science
BES

Goal: new knowledge / understanding
Mandate: open-ended
Focus: phenomena
Metric: knowledge generation

Applied Energy Offices
EERE, NE, FE, TD, EM, RW, …

Goal: practical targets
Mandate: restricted to target
Focus: performance
Metric: milestone achievement

American Competitiveness Initiative

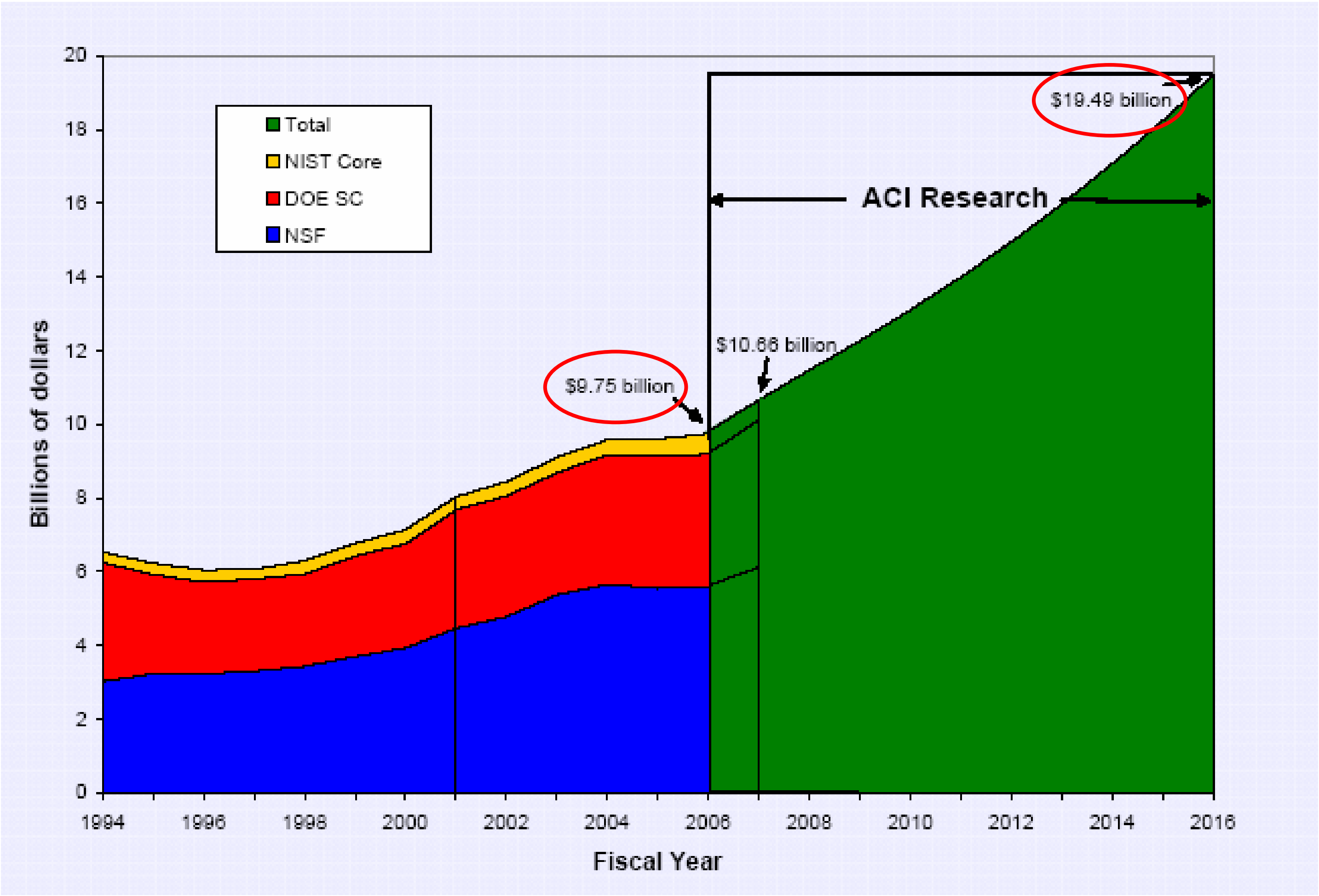


"We must continue to lead the world in human talent and creativity. Our greatest advantage in the world has always been our educated, hardworking, ambitious people – and we're going to keep that edge. Tonight I announce an American Competitiveness Initiative, to encourage innovation throughout our economy, and to give our nation's children a firm grounding in math and science."

"I propose to double the federal commitment to the most critical basic research programs in the physical sciences over the next 10 years. This funding will support the work of America's most creative minds as they explore promising areas such as nanotechnology, supercomputing, and alternative energy sources."

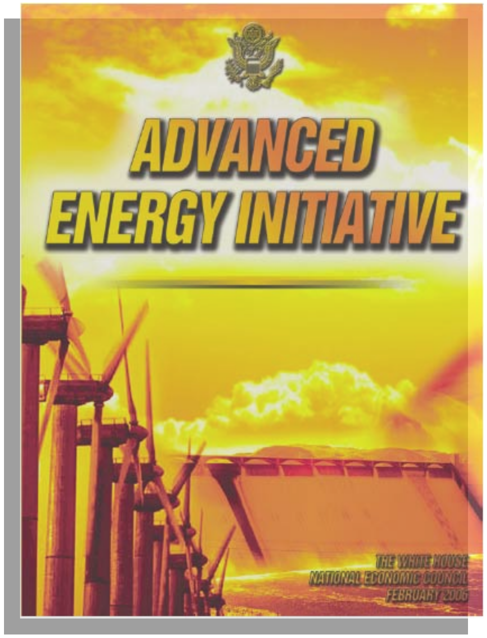
President George W. Bush
State of the Union Message
January 31, 2006

The President's American Competitiveness Initiative



Doubles, over 10 years, funding for innovation-enabling research at key Federal agencies that support high-leverage fields of physical science and engineering: the NSF, the DOE's Office of Science, and NIST.

The President's Advanced Energy Initiative
Accelerating Future Technologies



"…we must reduce our dependence on foreign sources of energy … "

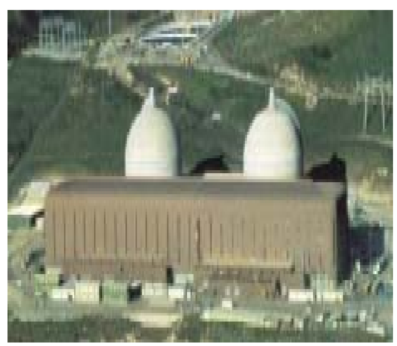
Changing the way we fuel our vehicles


Cellulosic Ethanol

Hydrogen

Batteries

Changing the way we power our homes and businesses


Nuclear Energy


Wind

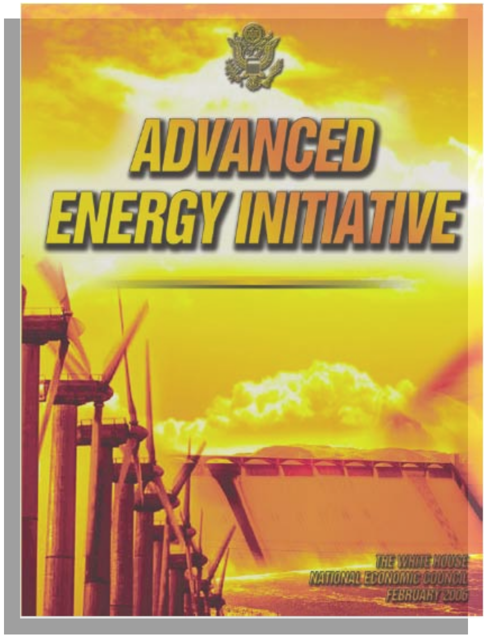

Solar Energy


Clean Coal

BES related basic research activities

The President's Advanced Energy Initiative

Accelerating Future Technologies



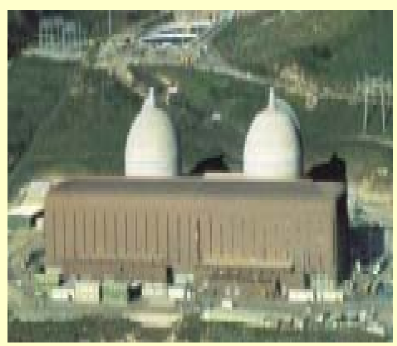
"…we must reduce our dependence on foreign sources of energy … "

Changing the way we fuel our vehicles

Hydrogen

Batteries

Changing the way we power our homes and businesses



Nuclear Energy

Solar Energy

BES related basic research activities

Overview of Relationships between BES Activities and the ACI & AEI

Grand Challenges → **Discovery Research** → **Use-Inspired Basic Research** → **Applied Research** → **Technology Maturation & Deployment**

Grand Challenges

- 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.
- Particularly challenging are the failures to understand systems that are ultrasmall or isolated or that display emergent phenomena of many kinds.

Discovery Research

- 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 advanced modeling and computation

Use-Inspired Basic Research

- Basic research for fundamental new understanding, usually 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

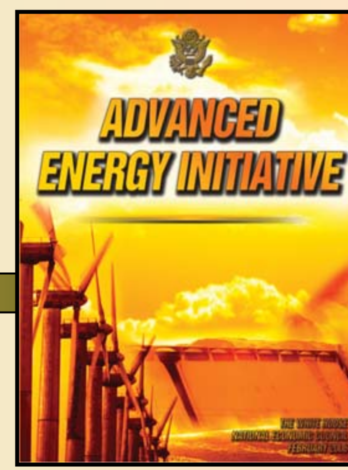
Technology Maturation & Deployment

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

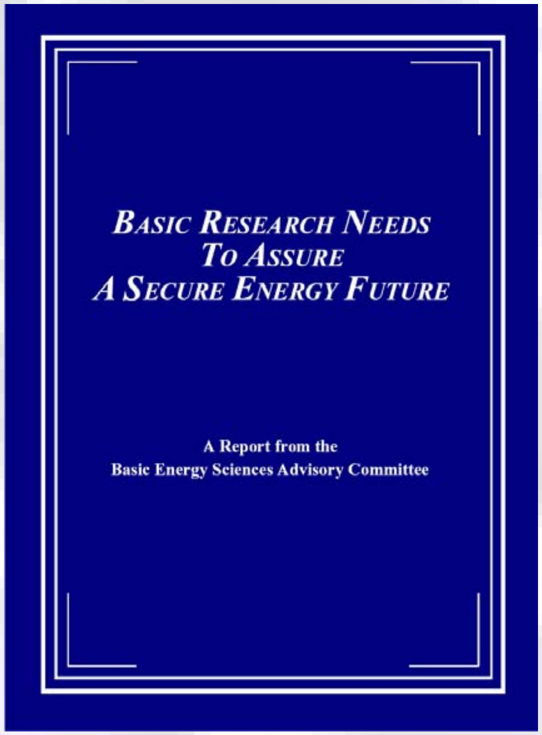
BESAC & BES Basic Research Needs Workshops

BESAC Grand Challenges Panel

DOE Technology Office/Industry Roadmaps



BES Energy Security Plan



"Considering the urgency of the energy problem, the magnitude of the needed scientific breakthroughs, and the historic rate of scientific discovery, current efforts will likely be too little, too late. Accordingly, BESAC believes that a new national energy research program is essential and must be initiated with the intensity and commitment of the Manhattan Project, and sustained until this problem is solved."*

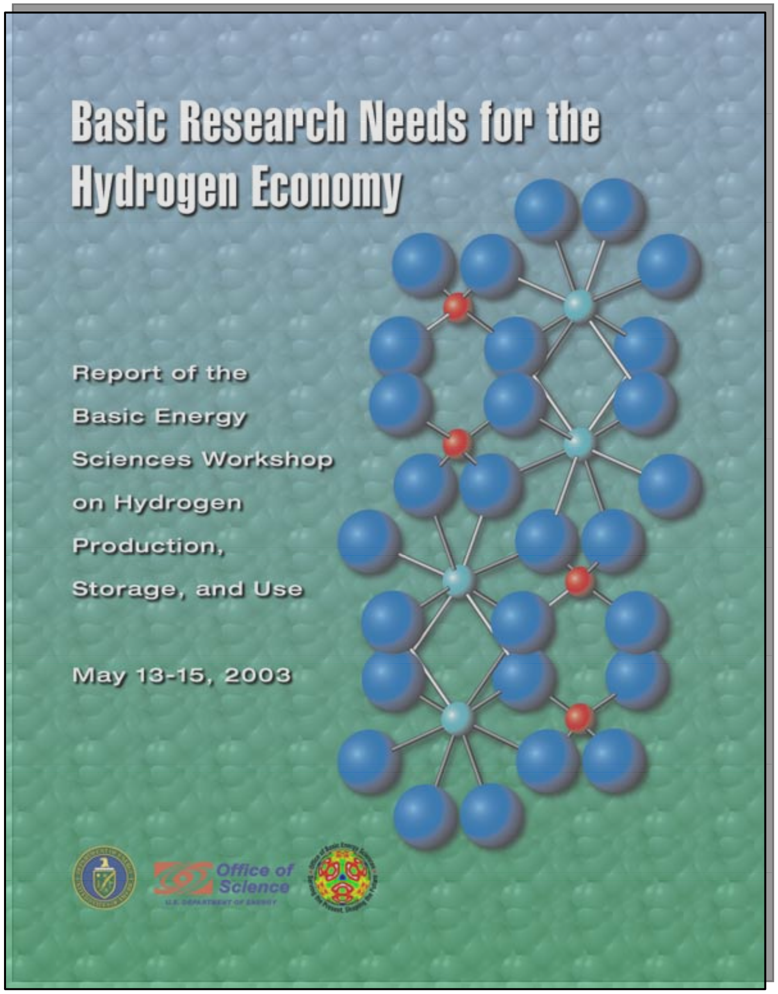
- Eliminate Environmental Concerns
- Diversify Energy Sources
- Increase Energy Efficiency
- Improve Distribution System

*BESAC: Basic Energy Sciences Advisory Committee, http://www.sc.doe.gov/bes/BESAC/BESAC.htm

“Basic Research Needs” Workshops

- Basic Research Needs to Assure a Secure Energy Future
  BESAC Workshop, October 21-25, 2002
  The foundation workshop that set the model for the focused workshops that follow.
- Basic Research Needs for the Hydrogen Economy
  BES Workshop, May 13-15, 2003
- Nanoscience Research for Energy Needs
  BES and the National Nanotechnology Initiative, March 16-18, 2004
- Basic Research Needs for Solar Energy Utilization
  BES Workshop, April 18-21, 2005
- Advanced Computational Materials Science: Application to Fusion and Generation IV Fission Reactors
  BES, ASCR, FES, and NE Workshop, March 31-April 2, 2004
- The Path to Sustainable Nuclear Energy: Basic and Applied Research Opportunities for Advanced Fuel Cycles
  BES, NP, and ASCR Workshop, September 2005
- Basic Research Needs for Superconductivity
  BES Workshop, May 8-10, 2006
- Basic Research Needs for Solid-state Lighting
  BES Workshop, May 22-24, 2006
- Basic Research Needs for Advanced Nuclear Energy Systems
  BES Workshop, July 31-August 3, 2006
- Basic Research Needs for the Clean and Efficient Combustion of 21st Century Transportation Fuels
  BES Workshop, October 30-November 1, 2006
- Basic Research Needs for Geosciences: Facilitating 21st Century Energy Systems
  BES Workshop, February 21-23, 2007
- Basic Research Needs for Electrical Energy Storage
  BES Workshop, April 2-5, 2007
- Basic Research Needs for Materials under Extreme Environments
  BES Workshop, June 10-14, 2007
- Basic Research Needs for Catalysis for Energy
  BES Workshop, August 5-10, 2007

Basic Research Needs for the Hydrogen Economy

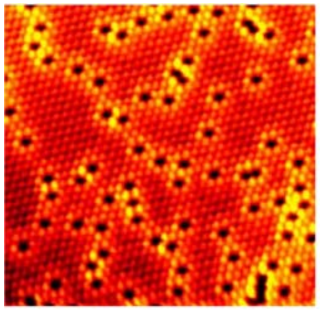


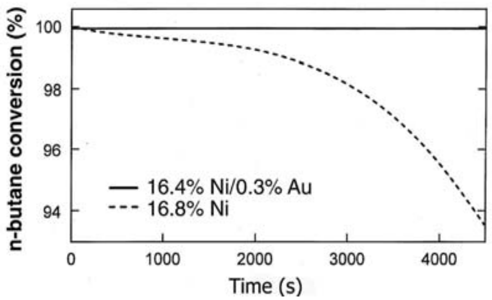
"Bridging the gaps that separate the hydrogen- and fossil-fuel based economies in cost, performance, and reliability goes far beyond incremental advances in the present state of the art. Rather, fundamental breakthroughs are needed in the understanding and control of chemical and physical processes involved in the production, storage, and use of hydrogen. Of particular importance is the need to understand the atomic and molecular processes that occur at the interface of hydrogen with materials in order to develop new materials suitable for use in a hydrogen economy. New materials are needed for membranes, catalysts, and fuel cell assemblies that perform at much higher levels, at much lower cost, and with much longer lifetimes. Such breakthroughs will require revolutionary, not evolutionary, advances. Discovery of new materials, new chemical processes, and new synthesis techniques that leapfrog technical barriers is required. This kind of progress can be achieved only with highly innovative, basic research."

Priority Research Areas in Hydrogen Production

Fossil Fuel Reforming

Catalysis; membranes; theory and modeling; nanoscience

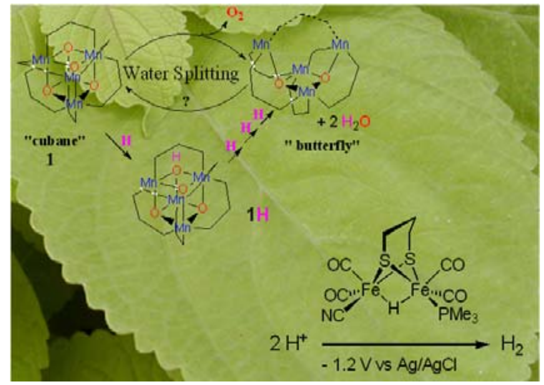




Ni surface-alloyed with Au to reduce carbon poisoning

Bio- and Bio-inspired H_2 Production

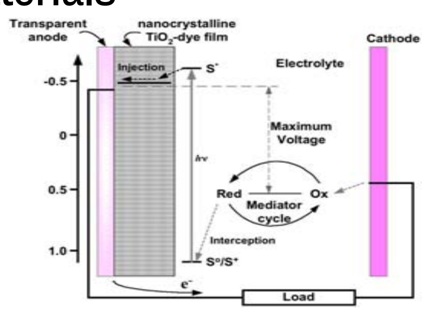
Biological enzyme catalysis; nanoassemblies; bio-inspired materials and processes

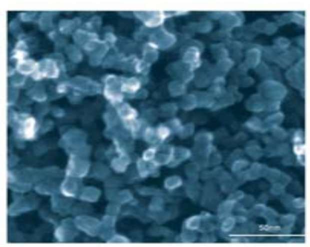


Synthetic catalysts for water oxidation and hydrogen activation

Solar Photoelectrochemistry/Photocatalysis

Understanding physical mechanisms; novel materials; theory and modeling; stability of materials



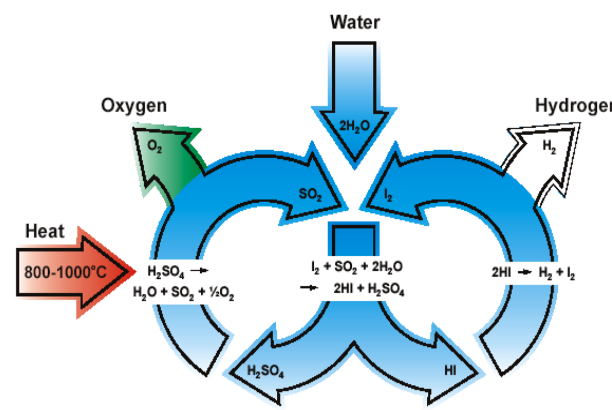


Dye-Sensitized solar cells

Nuclear and Solar Thermal Hydrogen

Thermodynamic data and modeling; novel materials; membranes and catalysts

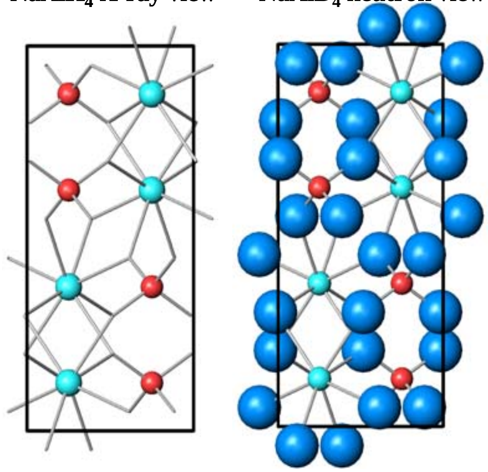
High T operation places severe demands on reactor design and on materials



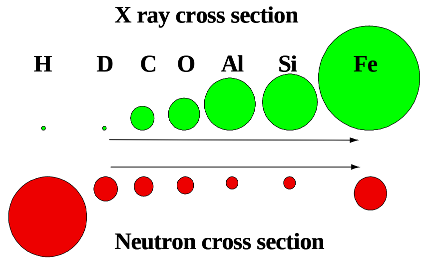
Source: BES Hydrogen Workshop Report

Priority Research Areas in Hydrogen Storage

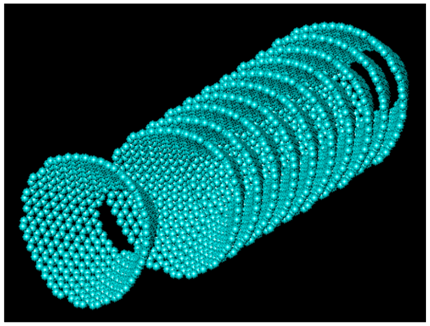
Novel and Nanoscale Materials



Complex metal hydrides can be recharged on board the vehicles

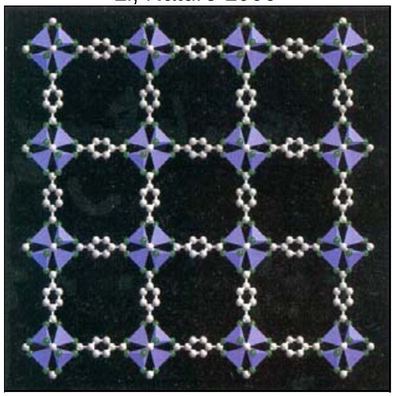


Neutron imaging of hydrogen

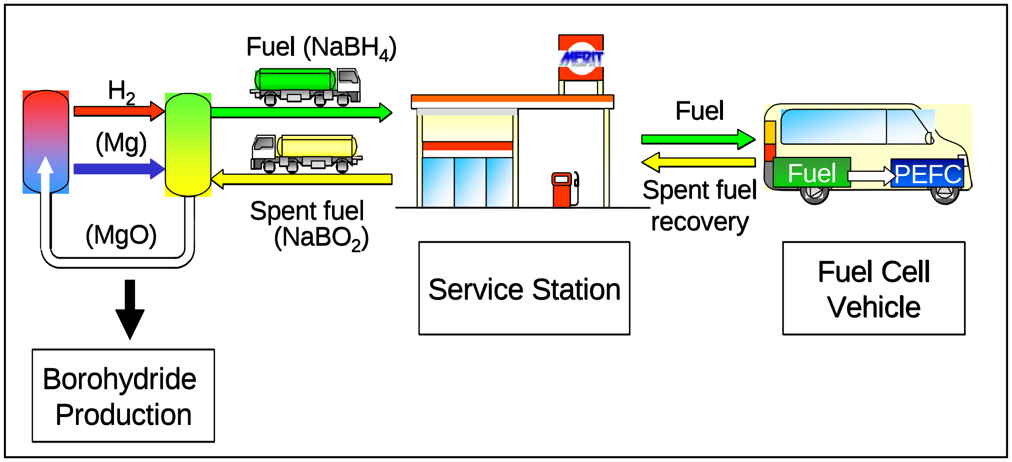


Cup-stacked carbon Nanofiber

Li, Nature 1999



Nanoporous inorganic-organic compounds

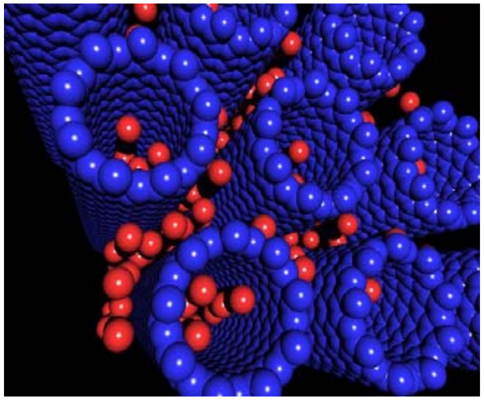


Chemical hydrides will need off-board regeneration

Theory and Modeling

To Understand Mechanisms, Predict Property Trends, Guide Discovery of New Materials

H Adsorption in nanotube array

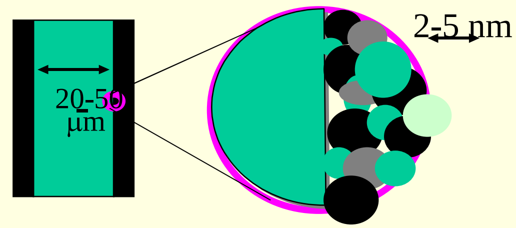


Source: BES Hydrogen Workshop Report

Priority Research Areas in Fuel Cells

Electrocatalysts and Membranes

Non-noble metal catalysts; designed triple-percolation electrodes

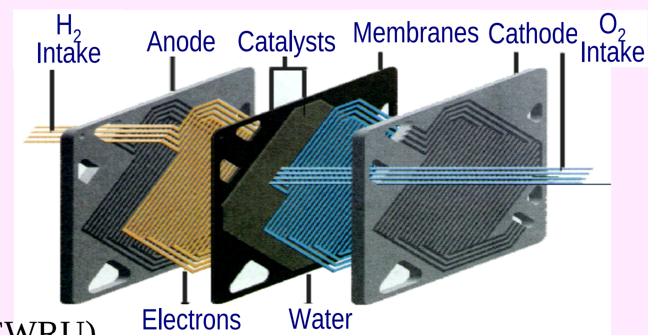


Controlled design of triple percolation nanoscale networks: ions, electrons, and porosity for gases

Low temperature fuel cells

'Higher' temperature membranes; degradation mechanisms; tailored nanostructures

Internal view of a PEM fuel cell

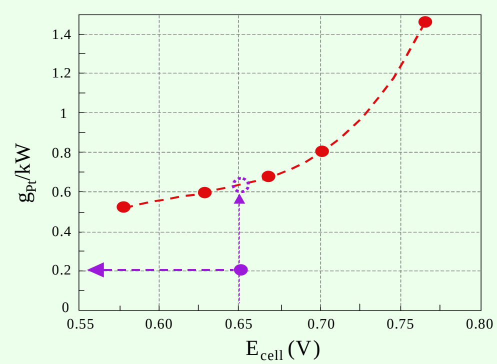


Source: T. Zawadzinski (CWRU)

Solid Oxide Fuel Cells

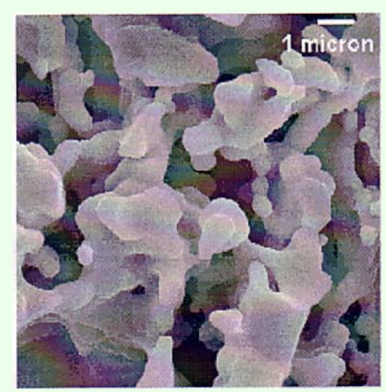
Theory, modeling, and simulation; new materials; novel synthesis; in-situ diagnostics

Mass of Pt Used in the PEMFCs — a Critical Cost Issue



Source: H. Gasteiger (General Motors)

YSZ Electrolyte for SOFCs



Tailored Porosity

Source: R. Gorte (U. Penn)

Source: BES Hydrogen Workshop Report

Potentials of Renewable Energy Sources

Solar

120,000 TW
at Earth surface
600 TW practical

Wind

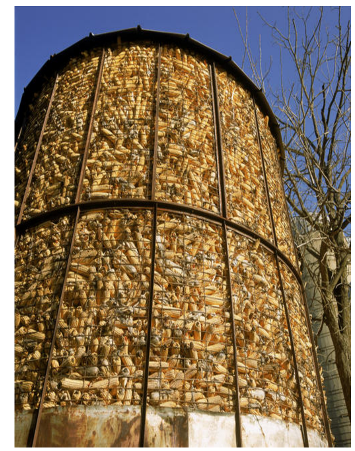
2-4 TW extractable

Tide Ocean Currents

2 TW gross

Biomass

5-7 TW gross
all cultivatable
land not used
for food



Hydroelectric

4.6 TW gross
1.6 TW technically feasible
0.6 TW installed capacity

Geothermal

12 TW gross
over land
small fraction
recoverable

Data Source: Nate Lewis, 2005

Basic Research Needs for Solar Energy Utilization

- ***The Sun is a singular solution to our future energy needs***
  - capacity dwarfs fossil, nuclear, wind . . .
  - sunlight delivers more energy in one hour than the earth uses in one year
  - free of greenhouse gases and pollutants
  - secure from geo-political constraints

- ***Enormous gap between our tiny use of solar energy and its immense potential***
  - Incremental advances in today's technology will not bridge the gap
  - Conceptual breakthroughs are needed that come only from high risk-high payoff basic research

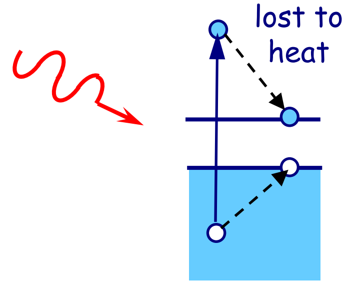
- ***Interdisciplinary research is required***
  physics, chemistry, biology, materials, nanoscience

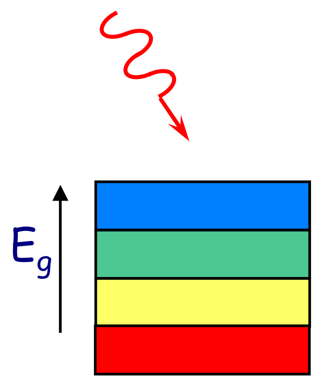
- ***Basic and applied science should couple seamlessly***

http://www.sc.doe.gov/bes/reports/abstracts.html#SEU

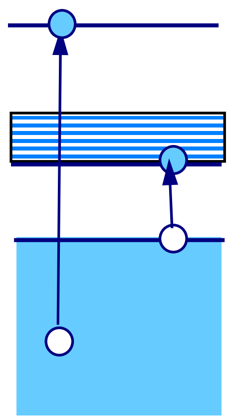
Revolutionary Photovoltaics: 50% Efficient Solar Cells

Present Technology: 32% limit for
- single junction
- one exciton per photon
- relaxation to band edge

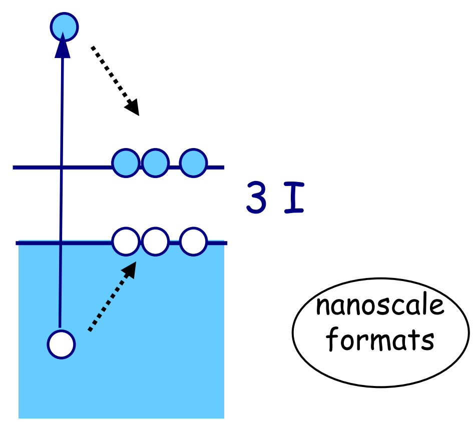




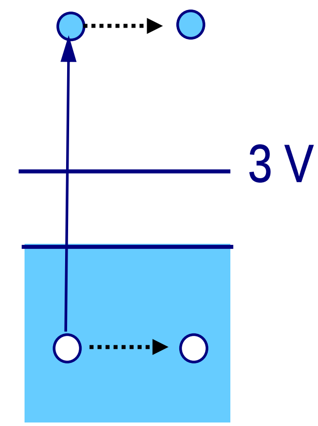
multiple junctions



multiple gaps



multiple excitons per photon



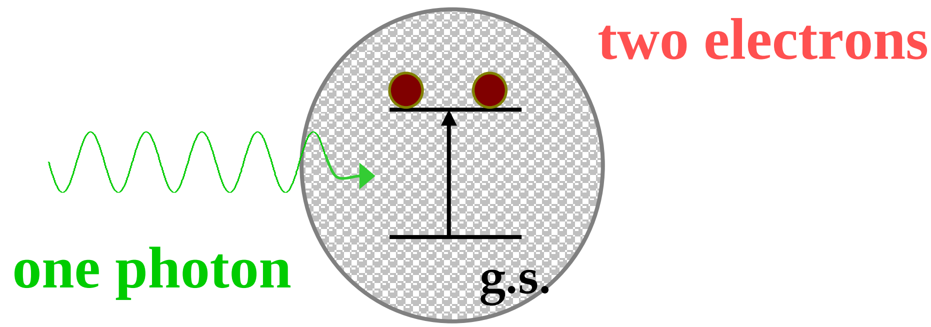
hot carriers

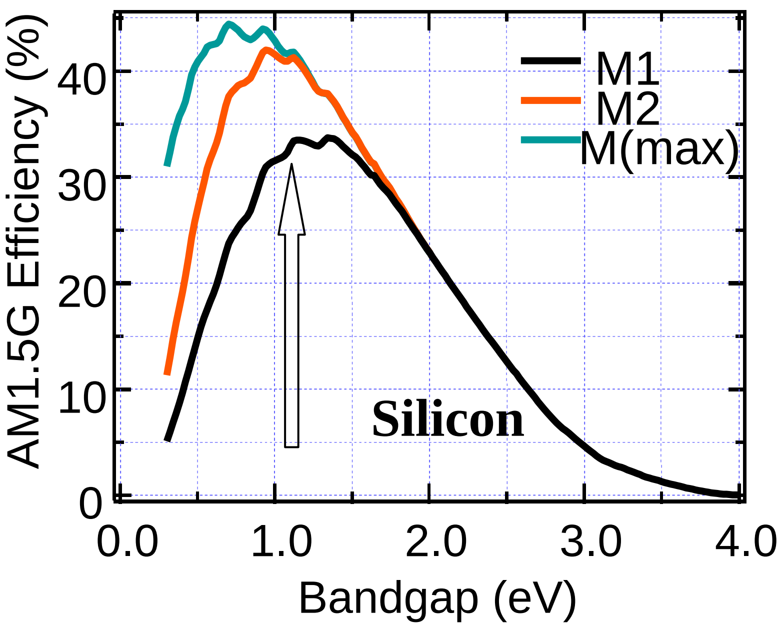
Rich Variety of New Physical Phenomena
Challenge: Understand and Implement

Next Generation Photovoltaic Cells:

Exceeding Today's Thermodynamic Limits through Multi-Exciton Generation (MEG)

MEG in Si, PbSe quantum dots multiplies one photon into two, three, four, or more electrons.





A multiplier M of only 2 increases efficiency of silicon solar cell from 32% to 42%

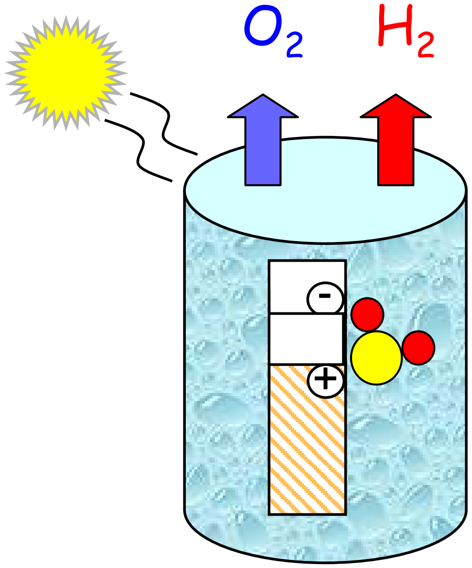
BES research continues into:

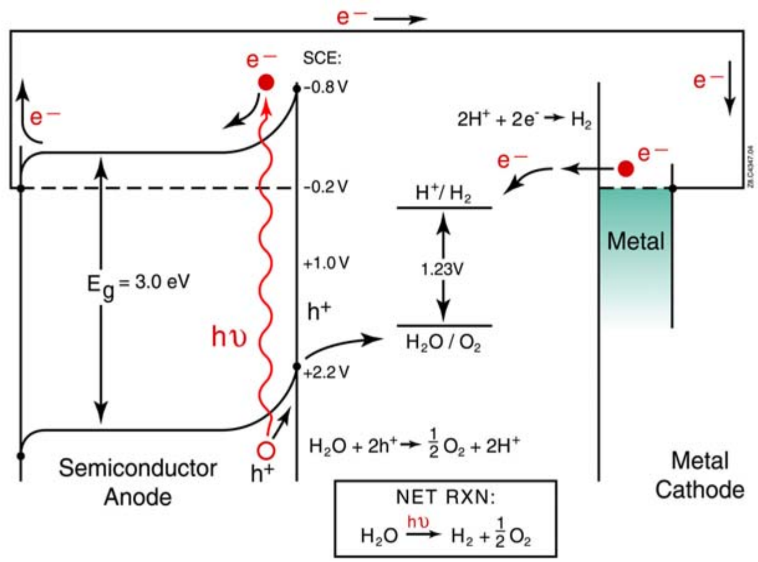
- -mechanism of multiplication
- -materials that exhibit effect
- -method of electron extraction

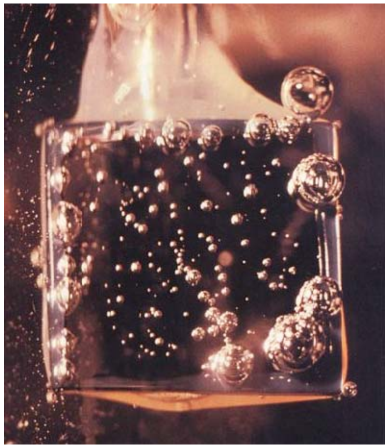
A. Nozik, NREL anozik@nrel.gov

V. Klimov, LANL, klimov@lanl.gov

Efficient Solar Water Splitting







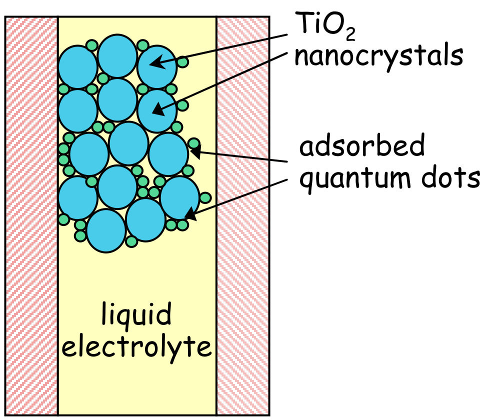
Demonstrated 10% Efficiencies in Laboratory

Scientific Challenges

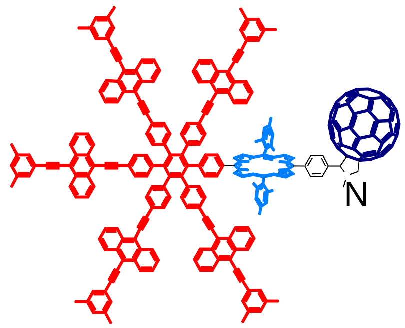
- Cheap materials that are robust in water
- Catalysts for the redox reactions at each electrode
- Nanoscale architecture for electron excitation ⇒ transfer ⇒ reaction

Nanoscience as a Cross-cutting Theme

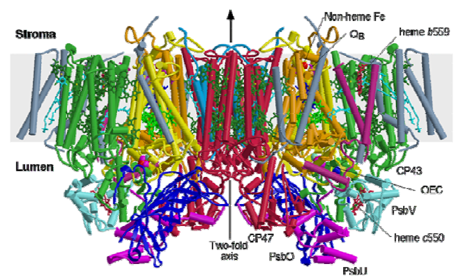
Manipulation of Photons, Electrons, and Molecules



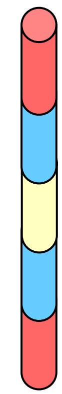
quantum dot solar cells



artificial photosynthesis



natural photosynthesis



nanostructured thermoelectrics

Nanoscale Architectures
top-down lithography
bottom-up self-assembly
multi-scale integration

Characterization
scanning probes
electrons, neutrons, x-rays
smaller length and time scales

Theory and Modeling
multi-node computer clusters
density functional theory
10 000 atom assemblies

Interdisciplinary research is required to enable transformational breakthroughs in solar energy utilization

Basic Research Needs for Solid State Lighting Workshop
May 22-24, 2006

Workshop Chairs: Julia Phillips (Sandia National Labs)
Paul Burrows (Pacific Northwest National Lab)

Panels and Leads:

LED Science: Jerry Simmons (SNL); Bob Davis (Carnegie Mellon)

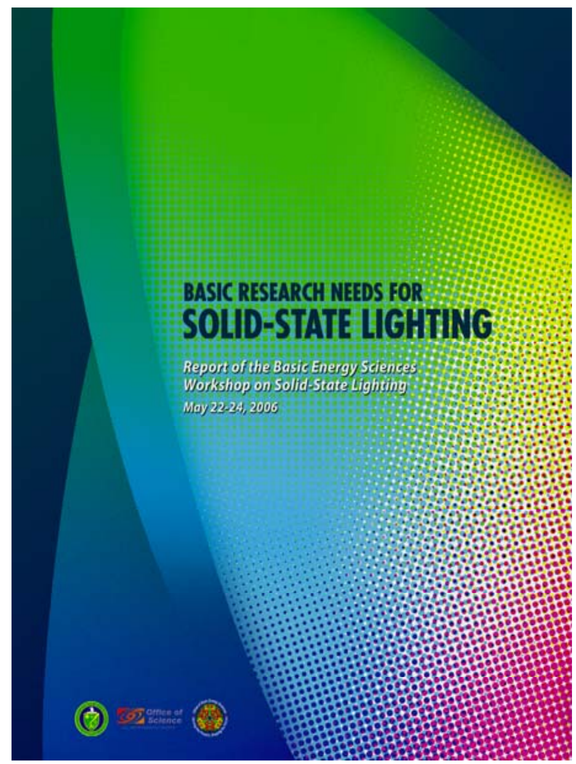
OLED Science: Franky So (U of Florida); George Malliaras (Cornell)

Cross-Cutting Science: J. Misewich (BNL); A. Nurmikko (Brown); D. Smith (LANL)

Plenary Speakers:

Fred Schubert (RPI), George Craford (Lumileds); Alan Heeger (UCSB), Eli Yablonovitch (UCLA)

Workshop Charge: *To identify basic research needs and opportunities underlying light emitting diode and related technologies, with a focus on new or emerging science challenges with potential for significant long-term impact on energy-efficient and productivity-enhancing solid state lighting. Highlighted areas will include organic and inorganic materials and nanostructure physics and chemistry, photon manipulation, and cross-cutting science grand challenges.*



Solid State Lighting

Discovery Research

- Rational design of SSL lighting structures
- Control of radiative & non-radiative processes in light-emitting materials
- New functionalities through heterogeneous nanostructures
- Innovative photon management
- Enhanced light-matter interactions
- Precision nanoscale characterization, synthesis, and assembly
- Multi-scale modeling – quantum excitations to light extraction

Use-inspired Basic Research

- Unconventional light-emitting semiconductors
- Photon conversion materials
- Polar materials and heterostructures for SSL
- Luminescence efficiency of InGaN
- Managing and exploiting disorder in OLEDs
- Understanding degradation in OLEDs
- Integrated approach to OLED fundamentals

Applied Research

Technology Milestones:

By 2025, develop advanced solid state lighting technologies with a product system efficiency of 50 percent with lighting that accurately reproduces sunlight spectrum.

- Materials and components for inorganic and organic light-emitting diodes research for improved efficiency and cost reduction
- Strategies for improved device light extraction
- Low-cost fabrication and patterning techniques and tools & manufacturing R&D
- Product degradation and reliability issues

Technology Maturation & Deployment

- Developing national standards and rating systems for new products
- Commercial adoption and support
- Industrial partnership
- Legal, health, market, and safety issues
- Cost reduction
- Prototyping

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Technology Offices
EERE

Basic Research Needs for Electrical Energy Storage
April 2-4, 2007

Chair: John Goodenough (UT-Austin)
Co- Chairs: Hector Abruna (Cornell)
Michelle Buchanan (ORNL)

Breakout Session Panel and Leaders:

Chemical Storage Science
- Stan Whittingham, SUNY-Binghamton
- Steven Visco, LBNL

Capacitive Storage Science
- Bruce Dunn, UCLA
- Yury Gogotsi, Drexel

Cross-Cutting
- Daniel Nocera, MIT
- Andy Gewirth, U Illinois

CHARGE: To identify basic research needs and opportunities underlying batteries, capacitors and related technologies, with a focus on new or emerging science challenges with potential for significant long-term impact on the efficient storage and release of electrical energy. Highlighted areas will include coupled ionic and charge transport, electrolyte physics, theory and modeling, and novel materials and approaches.

Electrical Energy Storage

Discovery Research	Use-inspired Basic Research	Applied Research	Technology Maturation & Deployment
▪ Understand and predict interfacial charge transfer and multi-body effects ▪ Predict and control dynamics of phase transitions ▪ Control of chemistry and its dynamics at electrified interfaces ▪ Determine consequences of dimensionality ▪ Physicochemical consequences of nano-dimensions ▪ Fundamentals of solvation dynamics and ionic transport ▪ Revolutionary tools for ***in situ*** structural and dynamic studies over broad spatial / temporal regimes	▪ Retrosynthetic approaches to high performance new materials ▪ Design of new materials capable of multi-electron storage per redox center ▪ Understand design criteria for electrolytes that enable higher voltages ▪ Tailor nanoscale electrode architectures for optimal transport ▪ Novel chemistries for scavenging impurities and self-healing ▪ Generation of knowledge and computational and experimental tools to predict properties, performance evolution, and lifetime of materials	• Develop and apply material models and computational tools for component and system design and diagnostics • Identify, develop, evaluate materials, electrodes, cells, and advanced electrochemical systems • Develop and apply novel material processing technologies • Design and develop device and system architectures • Assemble/test devices with respect to energy storage system requirements—high power, high energy density, long lifetime, rapid recharge, deep discharge, reliability, safety, low cost.	▪ Demonstrate energy storage systems in advanced vehicle applications. ▪ Support the establishment of domestic manufacturing capabilities for components and systems ▪ Assist development and deployment of high capacity storage systems for centralized and distributed power sources ▪ Develop long-life, low cost, reliable, environmentally friendly, recyclable energy storage for portable and stationary energy storage

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EERE and OE

Past and Future BRN Workshops Address Many Elements Required for a Decades-to-Century Energy Security Strategy

Research for a Secure Energy Future

Supply, Carbon Management, Distribution, Consumption

Decision Science and Complex Systems Science

- **Carbon Energy Sources**
- **Carbon Management**
- **No-net-carbon Energy Sources**
- **Distribution/ Storage**
- **Energy Consumption**

Energy Conservation, Energy Efficiency, and Environmental Stewardship

- **Carbon Energy Sources**
  - Coal
  - Petroleum
  - Natural Gas
  - Oil shale, tar sands, hydrates,...
- **Carbon Management**
  - CO_2 Sequestration
    - Geologic
    - Terrestrial
    - Oceanic
  - Carbon Recycle
  - Global Climate Change Science
- **No-net-carbon Energy Sources**
  - Nuclear Fission
  - Nuclear Fusion
  - Renewables
    - Hydropower
    - Biomass
    - Geothermal
    - Wind
    - Solar
    - Ocean
- **Distribution/ Storage**
  - Electricity Production & Grid
  - Electric Storage
  - Hydrogen
  - Alternate Fuels
- **Energy Consumption**
  - Transportation
  - Buildings
  - Industry

Grand Challenge Research Areas Emerged from the Workshops

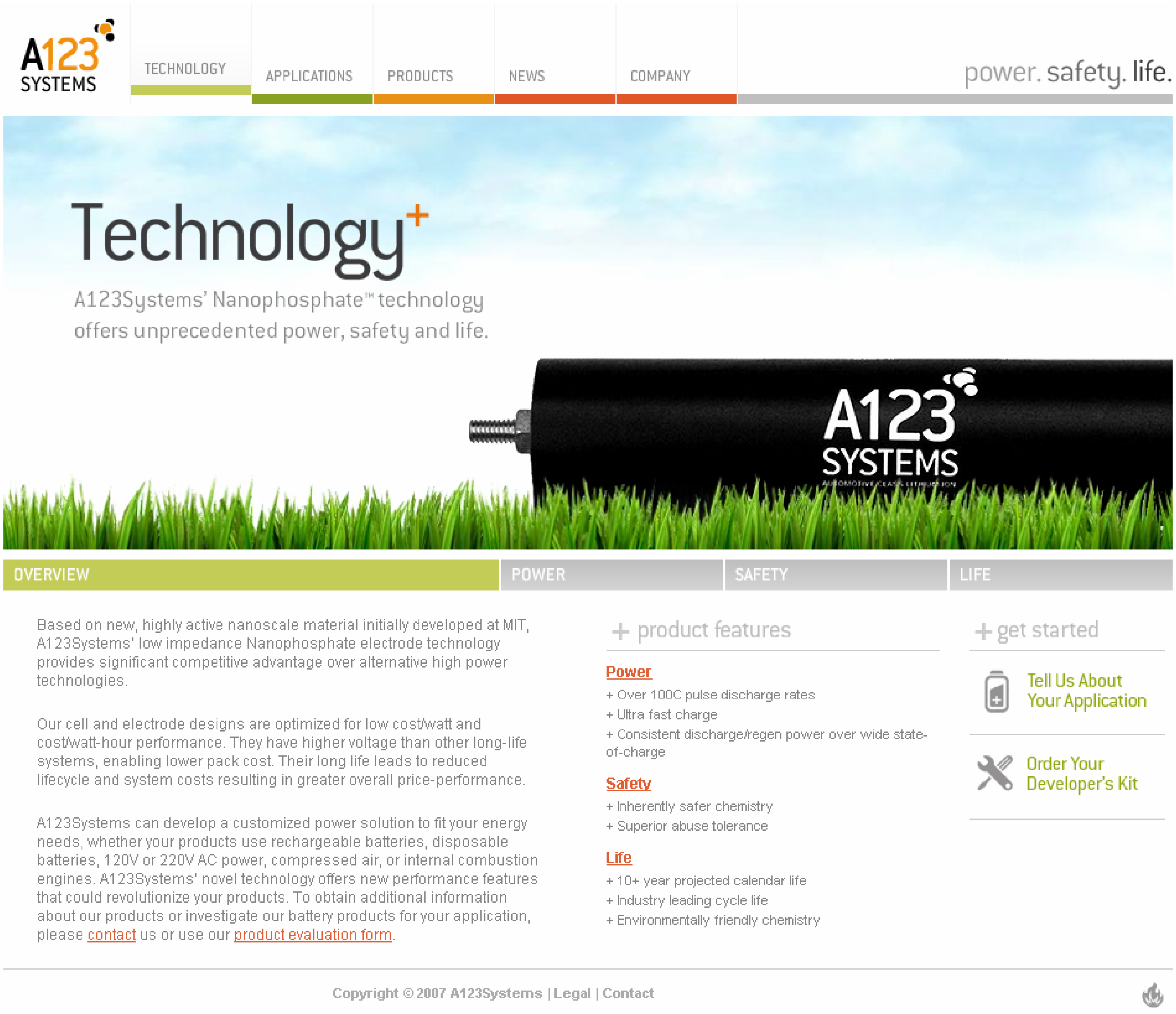
- New materials discovery, design, development, and fabrication, especially materials that perform well under extreme conditions
- Science at the nanoscale, especially low-dimensional systems that promise materials with new and novel properties
- Methods to "control" photon, electron, ion, and phonon transport in materials for next-generation energy technologies
- Structure-function relationships in both living and non-living systems
- Designer catalysts
- Interfacial science and designer membranes
- Bio-materials and bio-interfaces, especially at the nanoscale where soft matter and hard matter can be joined
- New tools for:
  - Spatial characterization, especially at the atomic and nanoscales and especially for in-situ studies
  - Temporal characterization for studying the time evolution of processes
  - Theory and computation

BES Bioscience Research

- $15 million FY06 biomass crosscut (93% at universities)
  - $3 million in microbial biochemistry
    - Ingram at Florida – Multiple substrate fermentation (Celunol)
    - Lynd at Dartmouth – Cellulase Complex (Mascoma)
  - $12 million in plant growth & development/biochemistry (training as well)
    - ~ $1.5 million at Complex Carbohydrate Research Center (CCRC), University of Georgia
    - ~ $4.4 million at Plant Research Laboratory (PRL), Michigan State
    - Somerville at Carnegie – Biocatalyst Fatty Acyl-CoA Reductase (Newco LS9)

A123 Systems

Yet-Ming Chiang, MIT



A123 SYSTEMS

TECHNOLOGY | APPLICATIONS | PRODUCTS | NEWS | COMPANY

power. safety. life.

Technology+

A123Systems' Nanophosphate™ technology offers unprecedented power, safety and life.

A123 SYSTEMS

OVERVIEW | POWER | SAFETY | LIFE

Based on new, highly active nanoscale material initially developed at MIT, A123Systems' low impedance Nanophosphate electrode technology provides significant competitive advantage over alternative high power technologies.

Our cell and electrode designs are optimized for low cost/watt and cost/watt-hour performance. They have higher voltage than other long-life systems, enabling lower pack cost. Their long life leads to reduced lifecycle and system costs resulting in greater overall price-performance.

A123Systems can develop a customized power solution to fit your energy needs, whether your products use rechargeable batteries, disposable batteries, 120V or 220V AC power, compressed air, or internal combustion engines. A123Systems' novel technology offers new performance features that could revolutionize your products. To obtain additional information about our products or investigate our battery products for your application, please contact us or use our product evaluation form.

+ product features

Power

+ Over 100C pulse discharge rates
+ Ultra fast charge
+ Consistent discharge/regen power over wide state-of-charge

Safety

+ Inherently safer chemistry
+ Superior abuse tolerance

Life

+ 10+ year projected calendar life
+ Industry leading cycle life
+ Environmentally friendly chemistry

+ get started

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Peter Schultz, LBNL (now at Scripps Research Institute)

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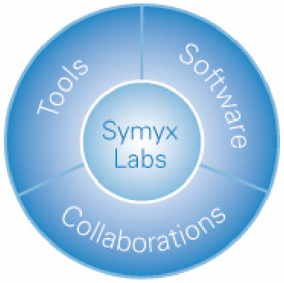
Symyx: Delivering Breakthrough R&D Performance

Symyx is a global leader in helping companies maximize the effectiveness and success of their R&D programs. Our unique approach integrates electronic lab notebook and execution and analysis software, lab automation and breakthrough materials technology. Symyx develops and applies informatics and high-throughput research technologies for the entire R&D process, from early discovery through development to commercialization. By partnering with us, purchasing our hardware or licensing our software, companies can leverage our industry-level investments in Symyx Labs, Software and Tools to improve their R&D execution.



Collaborations
In Symyx Labs, our scientists, engineers, and software programmers work on behalf of customers to discover and optimize materials. Employing our proprietary technology methods, high-throughput workflows that automate complete lab processes, and software, they are creating new breakthroughs in laboratory performance and materials discovery.

Symyx Software
Symyx Software combines experiment design, execution and decision-support to provide a unique solution that saves time for scientists while providing information transparency to the business. Designed by scientists for scientists, Symyx Software is at work in the world's leading R&D organizations, where it is helping to deliver breakthrough results.

Symyx Tools
Symyx Tools provide R&D workflows to automate complete lab processes, increasing testing capacity by 10-100 times. Symyx Tools integrate Symyx materials handling and analytical instrumentation with third-party equipment in order to combine experimental procedures and unify data management. Running up to 384 high-content experiments in parallel across automated instrumentation with integrated control and analytics, Symyx Tools give scientific teams the breakthrough capabilities needed to compete.

Intellectual Property Licensing
Symyx licenses intellectual property to create value by encouraging the widespread use of our innovations in the materials field. We offer selective access to this intellectual property through patent licensing, materials licensing, technology licensing, and OEM software licensing. In patent licensing, we enable customers to implement initial approaches to high-throughput materials research in their laboratories by licensing certain patents, including our broad methodology patents. We also license materials discovered in our collaborative and internal research efforts in return for royalties. Finally, we license certain technologies and software to instrument manufacturers in return for payments and royalties.

Symyx has also launched new companies to independently pursue Symyx-developed technologies. In 2003, Symyx formed Ilypsa, Inc., a pharmaceutical company pursuing non-absorbed, GI-based drugs for renal and metabolic diseases applying proprietary high-throughput technologies originally created and validated at Symyx. In 2006, Symyx formed Visyx Technologies Inc. to develop and pursue commercial applications of proprietary sensor technologies that originally were developed for use within Symyx's internal research programs. Symyx has a minority interest in both Ilypsa and Visyx, both of which also have venture capital investors.

Delivering Breakthrough R&D Results

Hear from our scientists and programmers and see our labs at work in the Symyx 2006 *online* annual review.

LBNL Materials Sciences Spin-Off Companies

BERKELEY LAB

Solexant

POLYPLUS Battery Company

ATI
ARIEL TECHNOLOGIES, INC.

MOMENTA

Symyx®

MMFX TECHNOLOGIES CORP

SEEO

Electric Fuel®

nanomix
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SUPERCONDUCTOR TECHNOLOGIES
Improving the Quality of Wireless℠

Market Capitalization ~$1.5 Billion

Thank You!

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