APPENDIX D

INTRODUCTORY PRESENTATIONS --
OCTOBER WORKSHOP

U.S. Department of Energy's

Office of Science

Overview of the Office of Science

for the BESAC Workshop on

Basic Research Needs

to Assure a Secure Energy Future

Dr. James F. Decker, Deputy Director

October 21, 2002

DOE's Office of Science (SC)

- Supports basic research that underpins DOE missions.
  - Provides over 40% of federal support to the physical sciences (including more than 90% of high energy and nuclear physics)
  - Provides sole support to select sub-fields (e.g. nuclear medicine, heavy element chemistry, magnetic fusion, etc.)
  - Supports the research of 15,000 PhDs and graduate students
- Constructs and operates large scientific facilities for the U.S. scientific community.
  - Accelerators, synchrotron light sources, neutron sources, etc.
  - Used by about 18,000 researchers every year
- Provides infrastructure support for the ten SC laboratories.

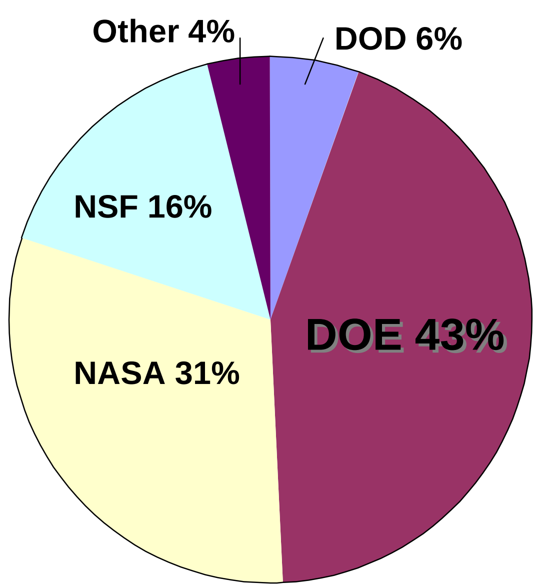
The Department of Energy is a Science Agency

Top Five Government Research Organizations for*:

Physical Sciences	Mathematics & Computing	Life Sciences	Environmental Sciences
1. Energy (1,938)	**1. Energy (862)**	1. HHS (18,216)	1. NASA (1,113)
2. NASA (1,152)	2. DOD (861)	2. USDA (1,342)	2. NSF (515)
3. HHS (794)	3. NSF (515)	3. DOD (616)	3. Interior (353)
4. NSF (593)	4. HHS (181)	4. NSF (500)	4. DOD (301)
5. DOD (364)	5. Commerce (78)	**5. Energy (267)**	**5. Energy (298)**

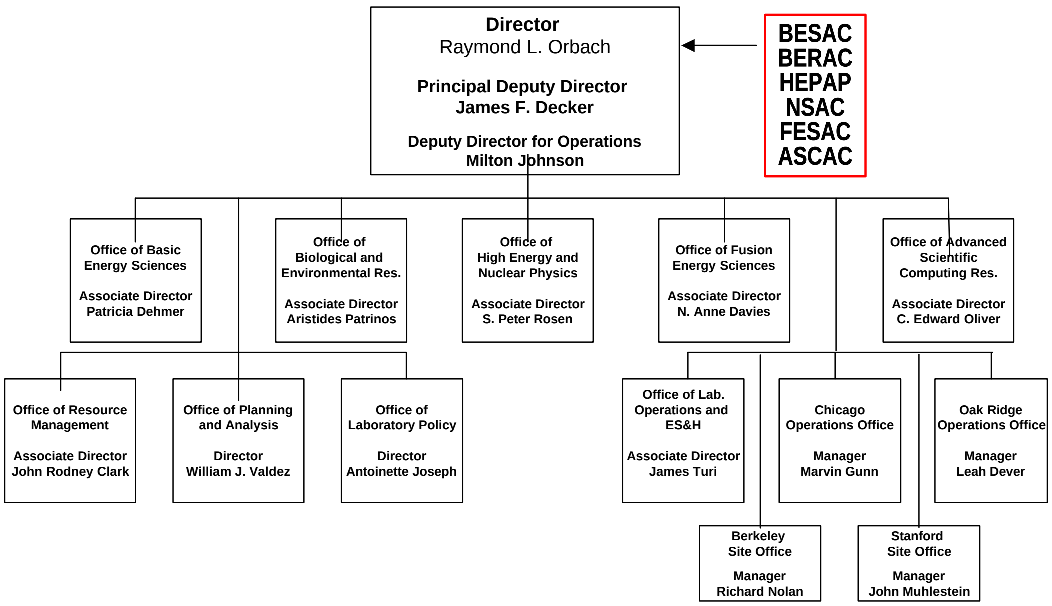
* *Numbers are FY 2002 dollars in millions - Source: NSF -- Preliminary Federal obligations for research, by agency and field of science and engineering: fiscal year 2002*

DOE Provides 43% of Federal Support to the Physical Sciences



Source: NSF - Division of Statistical Research Services

Office of Science Organization

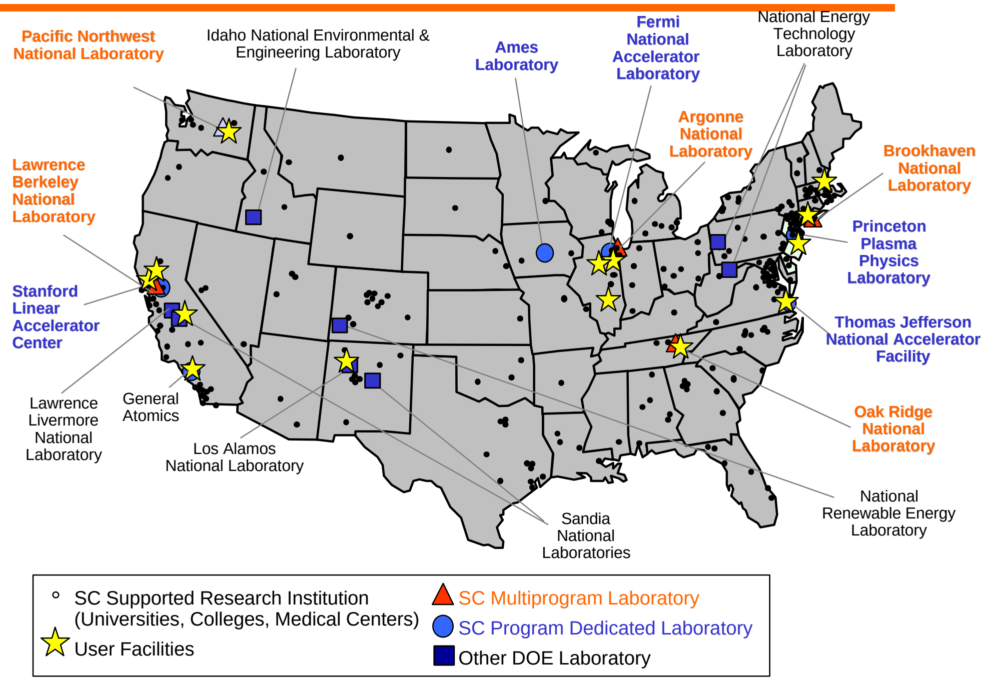


FY2003 Budget Request

OFFICE OF SCIENCE
FY 2003 PRESIDENT'S BUDGET REQUEST
(B/A in thousands)

	FY 2001 Comparable Approp.	FY 2002 Comparable Approp.	FY 2003 President's Request
SCIENCE			
Basic Energy Sciences	973,768	999,605	1,019,600
Advanced Scientific Computing Research	161,296	157,400	169,625
Biological and Environmental Research	514,064	570,300	504,215
High Energy Physics	695,927	713,170	724,990
Nuclear Physics	351,794	359,035	382,370
Fusion Energy Sciences	241,957	247,480	257,310
Energy Research Analyses	950	995	1,020
Science Laboratories Infrastructure	26,887	37,130	42,735
Science Program Direction	139,861	152,475	139,479
Small Business Inn. Research and Technology Transfer	93,069	-	-
Subtotal	3,199,573	3,237,590	3,241,344
Safeguards and Security	39,081	47,609	48,127
Reimbursable Work	(4,648)	(4,460)	(4,383)
Total Safeguards and Security	34,433	43,149	43,744
Total Science	3,234,006	3,280,739	3,285,088

SC Laboratories, User Facilities, and the Institutions that Use Them



Basic Energy Sciences

Research

Science at the nanoscale: increased research in condensed matter physics and materials synthesis and processing.

- X-ray and neutron scattering: research and new instrumentation at the major user facilities.
- Other core research programs: heavy-element chemistry, separations and analysis, materials chemistry, photochemistry, combustion, and catalysis.

- **Facilities**
  - New and upgraded instrumentation.
  - Continued high level of service at major user facilities.
- **Construction, Engineering & Design**
  - Construction of the Spallation Neutron Source is fully funded.
  - Nanoscale Science Research Centers (NSRC): continue engineering & design at ORNL, LBNL, SNL/LANL.
  - Begin construction of the NSRC at ORNL.
  - The Linac Coherent Light Source at SLAC begins project engineering and design.

Biological and Environmental Research

- Genomes to Life will enable revolutionary advances in energy supply, greenhouse gas mitigation, and environmental cleanup.
    - Bioterrorism detection/defeat.
- The Human Genome Program will provide high quality complete sequence of Chromosomes 5, 16, and 19.
- Climate Change Research underpins the President's initiative. Research and observations will improve climate models and understanding of the global carbon cycle.
- Climate Change Research Initiative.
- The Environmental Management Science Program is transferred from the Office of Environmental Management.
- Boron Neutron Capture Therapy.

Genomes to Life

Genomes to Life builds on advances in sequencing, molecular science and computing to understand and eventually harness microbes and microbial communities to address DOE's energy, environmental and national security missions. In FY 2003 we will:

- Continue joint research that combines capabilities of DOE's advanced biological and computational sciences programs.
- Support DNA sequencing of microbes closely related to potential bio-threat agents.
- Determine the composite DNA sequence and functional capability of microbes in a complex microbial community to address DOE energy, environmental, and national security needs.
- Begin the complex task of characterizing all of the multi-protein molecular machines and their associated regulatory networks in microbes of importance to DOE's energy, environmental, and national security missions.
- $15M increase enables full funding for up to 4 multidisciplinary, multi institutional research teams at universities and national labs needed to address the 4 goals of Genomes to Life.

Fusion Energy Sciences

- **Science and Enabling R&D**
  - Innovation in fusion energy, plasma science and related technologies are part of the Administration's National Energy Policy.
  - Explore innovative approaches to confining, heating, and fueling plasmas.
- **Facilities**
  - Significantly increase operating time on three national fusion facilities to resolve issues in energy transport and plasma stability, using a variety of heating techniques.
- **Fabrication, Engineering & Design**
  - Expand concept innovation with fabrication of a new stellarator, the National Compact Stellarator Experiment (NCSX), at the Princeton Plasma Physics Laboratory

High Energy & Nuclear Physics

Nuclear Physics

Increased facility operating time to:

- Create and study a quark-gluon plasma at the Relativistic Heavy Ion Collider
- Explore how quarks bind together to form protons and neutrons at the Continuous Electron Beam Accelerator Facility

High Energy Physics

Exploit the opportunity to answer two key questions about matter and energy:

- Explore the origin of mass in the search for the Higgs boson at the Tevatron
- Understand the absence of antimatter in the Universe by studying Charge-Parity Violation at the B-Factory

Advanced Scientific Computing Research

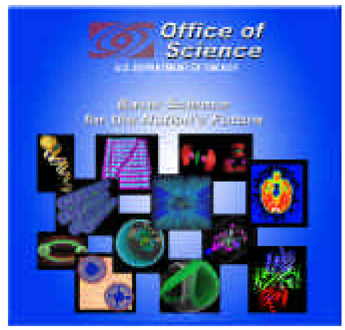
- **Mathematical, Information, & Computational Sciences**
  - **Supports operation of supercomputer and network facilities available to researchers 24-7-365:**
    - National Energy Research Scientific Computing Center (NERSC),
    - Advanced Computing Research Testbeds, and
    - Energy Sciences Network (ESNet).
  - **Scientific Computing Research Investments:**
    - Applied Mathematics,
    - Computer Science, and
    - Advanced Computing Software Tools.
  - **High Performance Networking, Middleware and Collaboratory Research Investments:**
    - Networking,
    - Collaboratory Tools, and
    - National Collaboratory Pilot Projects.
- **Laboratory Technology Research**

Scientific Discovery through Advanced Computation

- SciDAC brings the power of tera-scale computing and information technologies to several scientific areas -- breakthroughs through simulation.
- SciDAC is building community simulation models through collaborations among application scientists, mathematicians and computer scientists -- research tools for plasma physics, climate prediction, combustion, etc.
- State-of-the-art electronic collaboration tools will facilitate the access of these tools to the broader scientific community to bring simulation to a level of parity with theory & observation in the scientific enterprise.
- Topical Computing (TC)
  - FY03 increases will reconfigure some resources at existing facilities around TC concept.
  - These facilities will support applications communities to develop the operational model.
  - Full-scale TC facilities will be proposed in FY-04.

The Future

- Reasserting U.S. Leadership in Scientific Computation
- The Beauty of Nanoscale Science
- Building a 21st Century Workforce
- Dark Energy—the Mystery that Dominates the Universe
- Fusion: Bringing a Star to Earth
- Scientific Foundations for Countering Terrorism
- Using Nature's Own Tool Kit to Clean Up the Environment
- Biotechnology for Energy Security



Occasional Papers
Spring 2002

Basic Research Needs to Assure a Secure Energy Future

A BESAC Workshop

Patricia M. Dehmer
Director, Office of Basic Energy Sciences
21 October 2002

Remarks by Secretary Abraham

Brookhaven National Laboratory – June 14, 2002

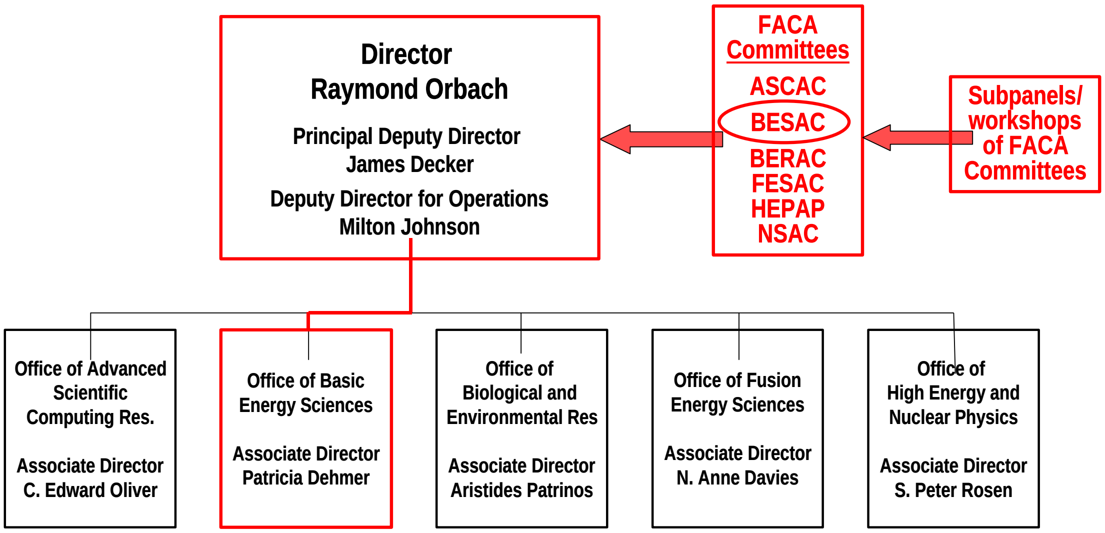
DOE and American Leadership in Science

The Department of Energy could well have been called the Department of Science and Energy given our contribution to American science. And the reason we are so deeply involved in science is simple. Our mission here at DOE … as I have stressed since becoming Secretary … is national security.

And in my view, a serious commitment to national security demands a serious commitment to science, including basic research. This commitment strengthens our energy security, international competitiveness, economic growth, and intellectual leadership. Moreover, if we ever hope to leapfrog today's energy challenges we must look to basic research.

I think it's clear. A nation that embraces basic research embraces a brighter future.

What Does "A BESAC Workshop" Mean?



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Conversations with BESAC on the Workshop

"The basic research community has focused on many of the known problems in energy technologies for many years – the workshop should not rehash these areas."

"Rather, the workshop should focus on new, revolutionary basic research opportunities."

4

The Basic Energy Sciences Program Mission

"... to foster and support fundamental research to expand the scientific foundations for new and improved, environmentally conscientious energy technologies"

"... to plan, construct, and operate major scientific user facilities for the Nation"

5

The Basic Energy Sciences Program ...

- ☑ *... is one of the Nation's largest sponsors of basic research.*
- ☑ *... supports research in more than 150 academic institutions and 13 DOE laboratories.*
- ☑ *... supports world-class scientific user facilities, providing outstanding capabilities for characterizing materials of all kinds.*
- ☑ *... is uniquely responsible in the Federal government for supporting research in materials sciences, chemistry, geosciences, and aspects of biosciences related to energy resources, production, conversion, efficiency, and use – all in an environmentally conscientious manner.*

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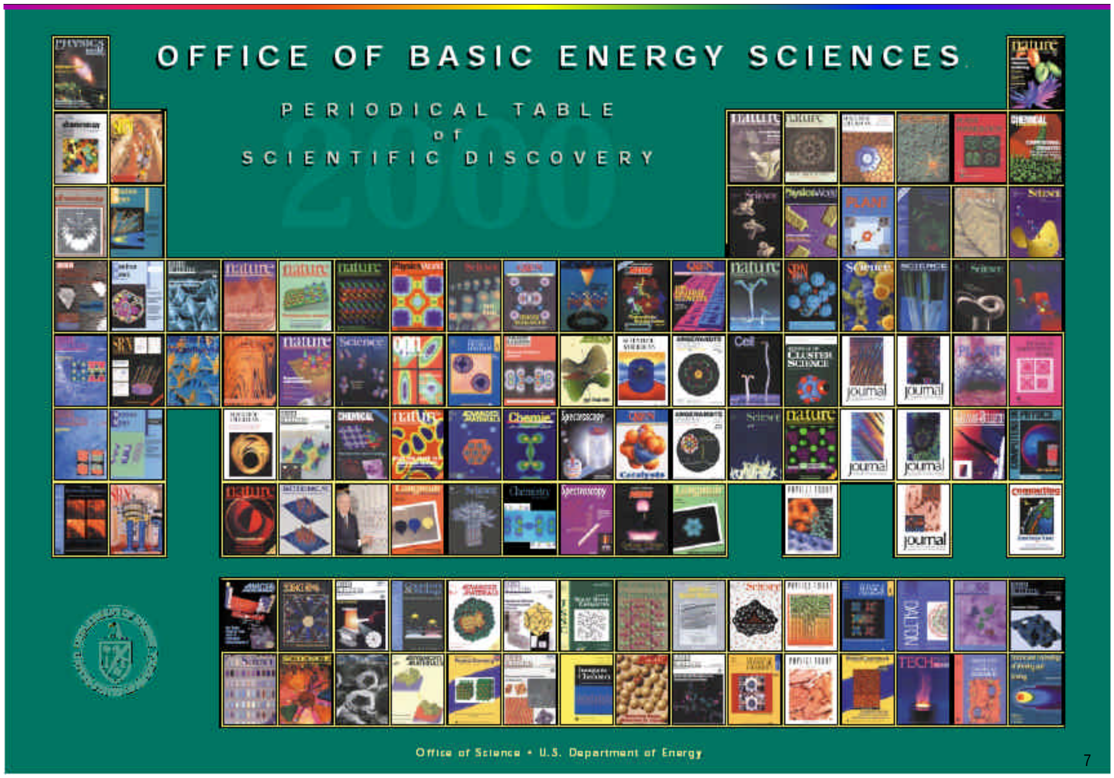
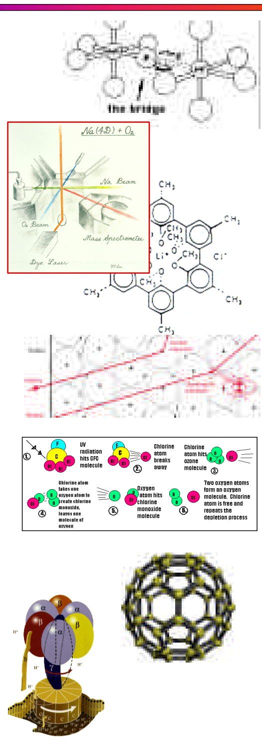
Past Accomplishments



Nobel Prize Research Supported During the 1980s and 1990s



1983 Chemistry — Henry Taube, Stanford University, for "his work on the mechanisms of electron transfer reactions, especially in metal complexes"

1986 Chemistry — Yuan Tseh Lee, UC Berkeley, for "dynamics of chemical elementary processes"

1987 Chemistry — Donald J. Cram, UC Los Angeles, for "development of molecules with structurally specific interaction of high specificity"

1994 Physics — Clifford G. Shull (MIT) for "pioneering contributions to the development of neutron scattering techniques for studies of condensed matter"

1995 Chemistry — Frank Sherwood Rowland (UC, Irvine) for "work in atmospheric chemistry, particularly concerning the formation and decomposition of ozone"

1996 Chemistry — Richard E. Smalley and Robert Curl (Rice U) for "collaborative discovery that carbon could occur in a uniquely beautiful and satisfying structure that engendered an entirely new branch of chemistry"

1997 Chemistry — Paul D. Boyer (UC, Los Angeles) for "elucidation of the enzymatic mechanism underlying the synthesis of adenosine triphosophate (ATP)"

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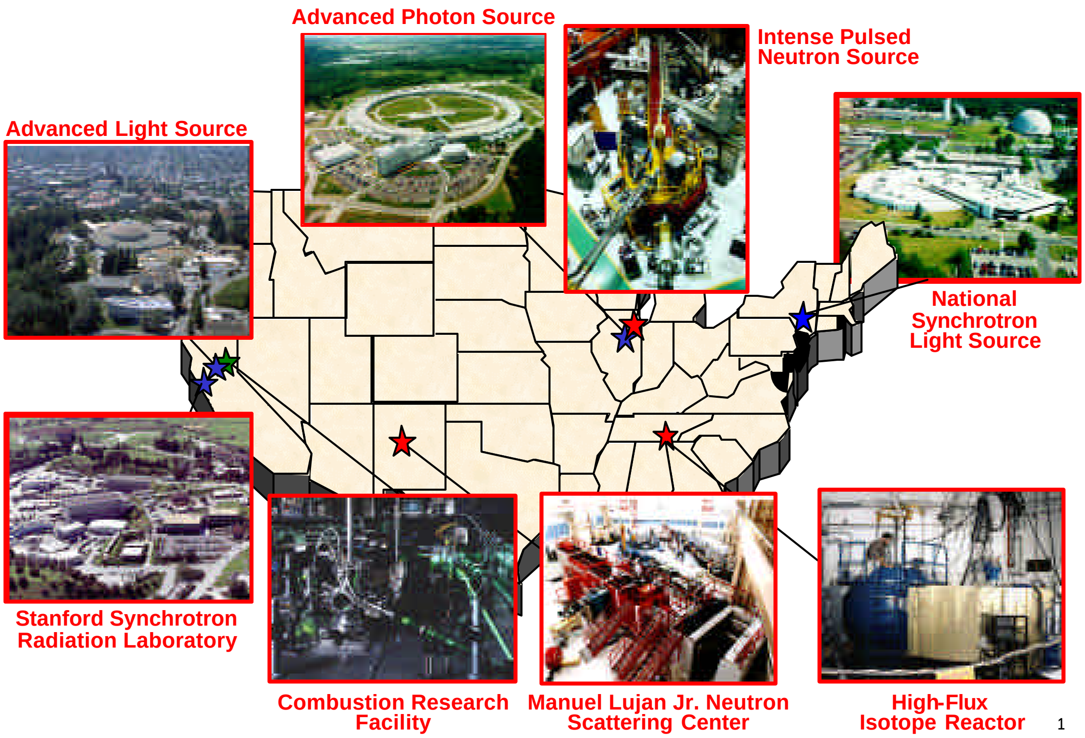
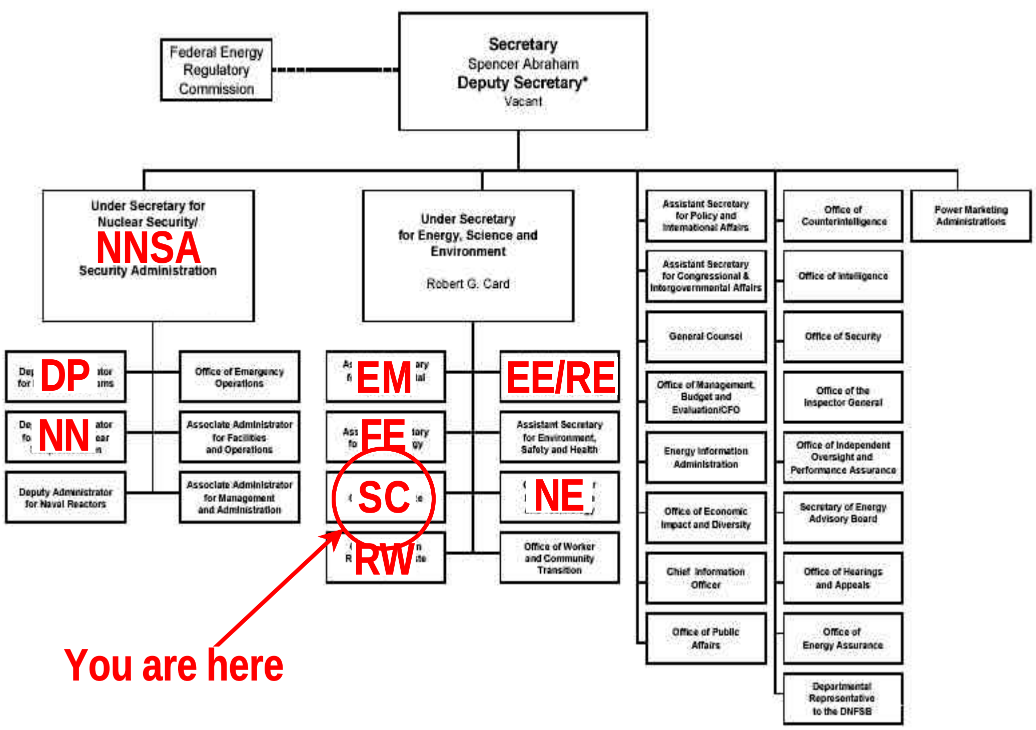
The BES Major Scientific User Facilities



The Spallation Neutron Source

DEPARTMENT OF ENERGY



BES Research for National and Energy Security

Renewable Energy Resources (RE)

Nuclear Energy (NE)

Fossil Energy (FE)

Energy Conservation (EE)

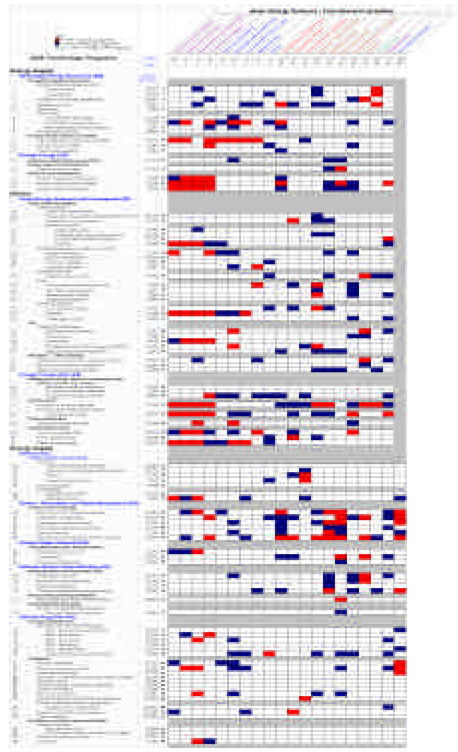
Fusion Energy Sciences (SC)

Environmental Management (EM)

Nuclear Waste Disposal (RW)

Defense Nuclear Nonproliferation (NN)

Defense Programs (DP)



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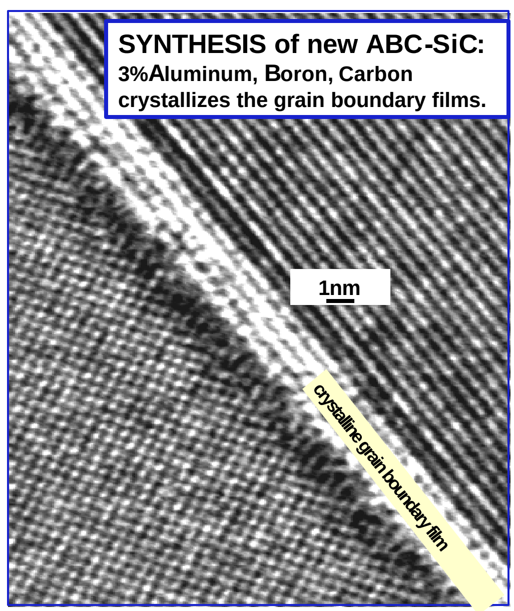
Strong, Tough, and Creep-Resistant Ceramics

ceramic turbine (Honeywell)
silicon nitride or silicon carbide

Grain boundary films, as thin as 1 nm, affect mechanical properties of ceramics

- **Doubled fracture resistance**
- **Resistant to high-temp deformation**
- **High strength**



Lutgard De Jonghe, Robert O. Ritchie
Materials Sciences Division
LBNL

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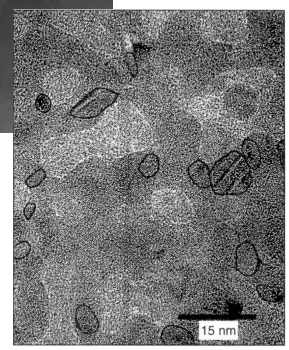
Bulk Metallic Glasses

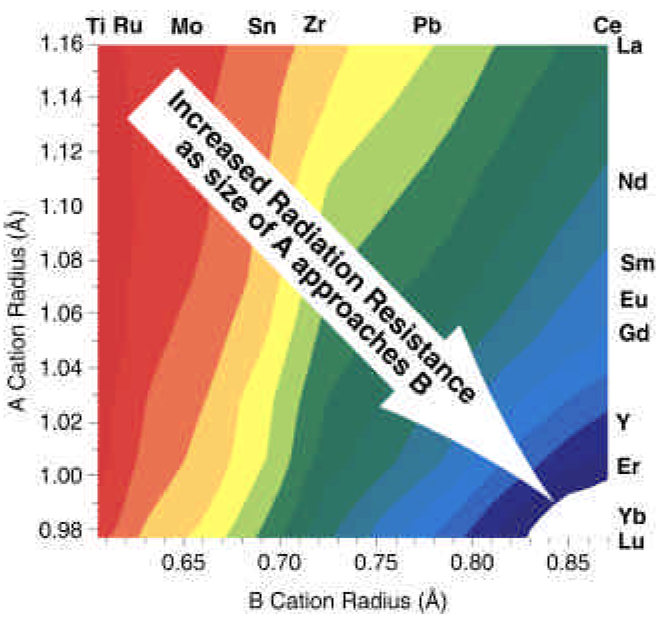
New alloys that form bulk metallic glasses at low cooling rates have led to significant advances in the study of undercooled liquid metals and the glass transition in metallic systems. These materials do not have crystalline structure, but rather the atoms are randomly positioned like in a liquid. This structure leads to improved toughness and large plastic strain to failure because of the lack of grain boundaries which in crystalline materials are points of weakness.

Some of the first bulk metallic glass material



TEM showing amorphous structure and Cu-rich and Cu-poor regions

Nuclear-Friendly Materials

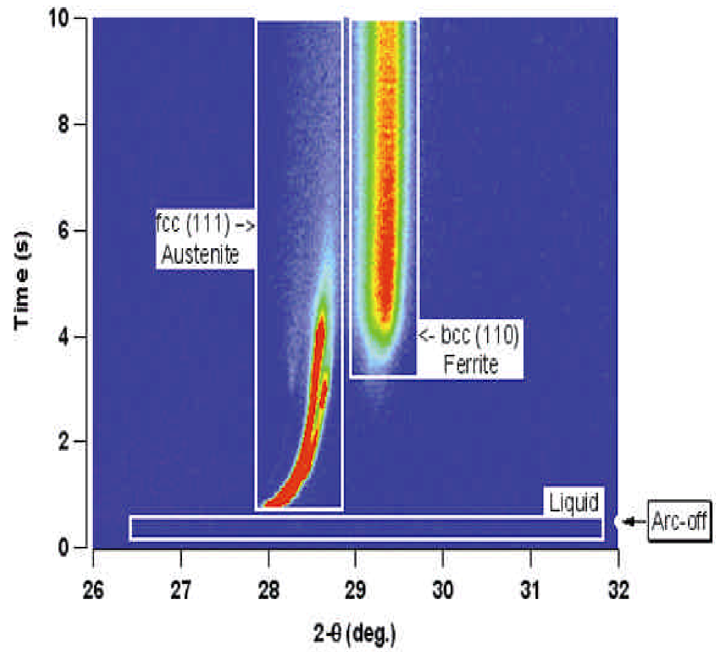


Changing the constituent A and B elements in $A_2B_2O_7$ compounds profoundly affects radiation performance.

Dramatic improvements in radiation tolerance were found as the metallic elements A and B become more similar in size.

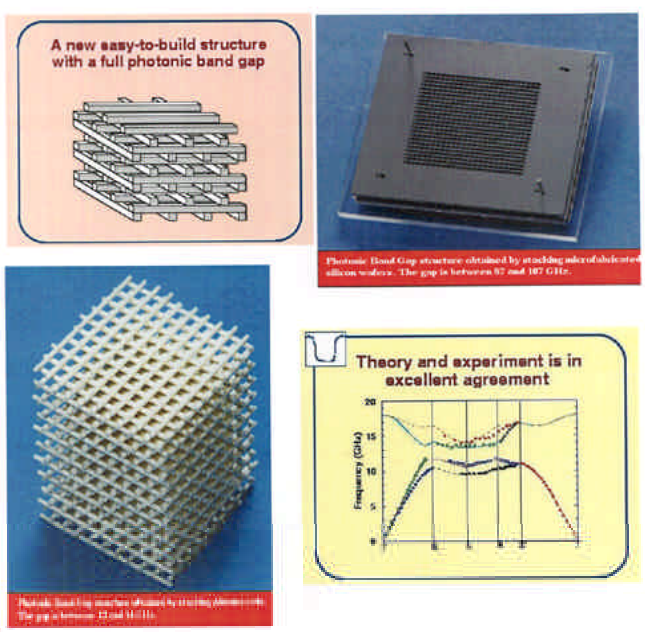
X-rays Diffraction to Understand Welds

In-situ synchrotron investigations of welding, combined with computer modeling and microstructural characterization, help understand the solidification process and the resultant materials properties.



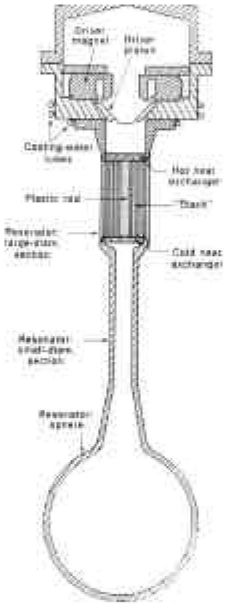
Time resolved X-ray diffraction shows non-equilibrium weld solidification

Photonic Band Gap Structures



By designing materials where certain wavelengths do not propagate, one can build very high Q cavities, highly directional antennas, and enhanced low loss propagation.

Thermoacoustic Refrigeration



Oscillating temperature and heat flux accompany the oscillating pressure in sound waves. Combining oscillating temperature, pressure, heat, and motion, we create "thermoacoustic" heat engines, refrigerators, and mixture separators, with efficiency now close to that of mature technologies.

Los Alamos National Laboratory, G. Swift, et al.

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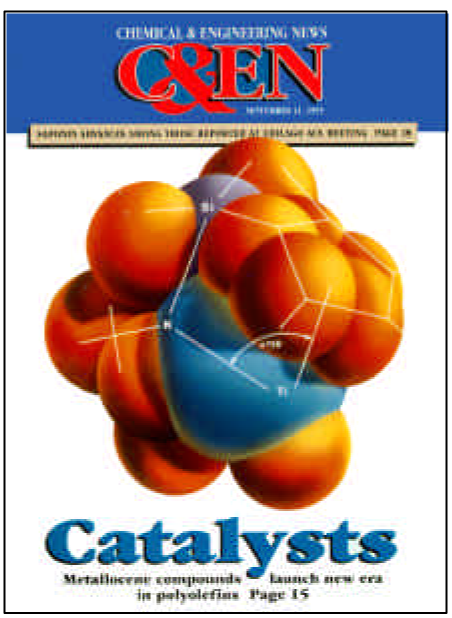
Organometallic Catalysts



The study of weakly bound ligands in organometallic compounds led to industrial polymerization catalysis.

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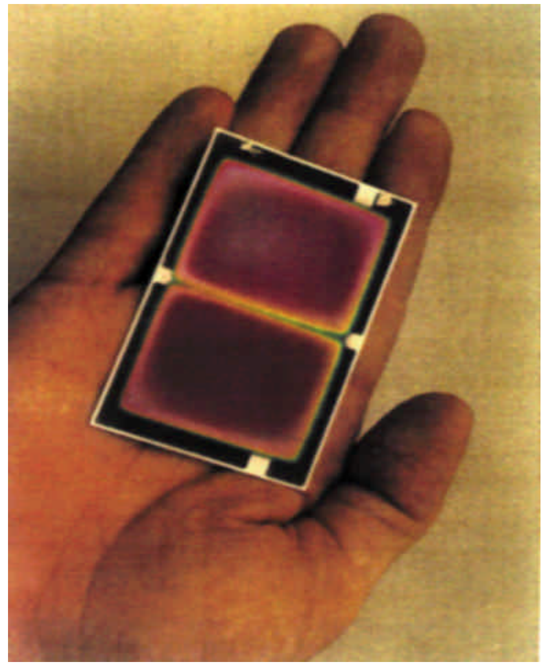
Rechargeable Thin-Film Lithium Batteries

- Revolutionary solid electrolyte
  - (lithium phosphorus oxynitride)
  - stable in contact with lithium metal
  - enables highest energy density
- Rechargeable battery
  - 1/2 the thickness of plastic wrap
  - can be fabricated on silicon
  - resulted in 4 CRADAs and 1 license
  - used in medical and consumer devices, smart credit cards, miniature hazardous materials monitors, memory backup power reservoir



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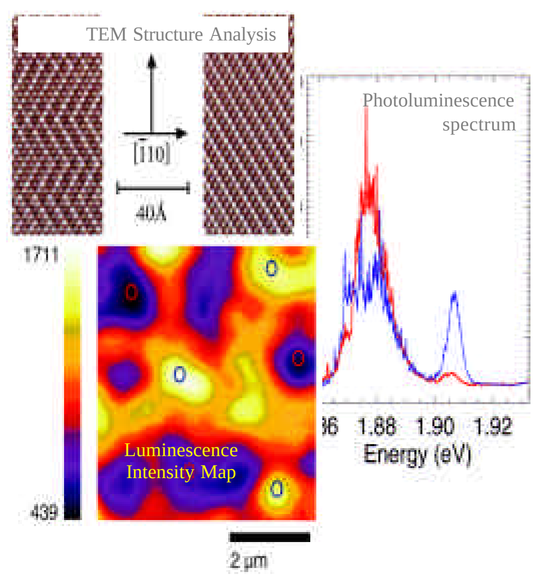
Semiconductor Alloys Lead to Record Solar Cell

Studies relate spontaneous ordering in a semiconductor alloy to optoelectronic properties

- Superstructure ordering modifies energy band structure.
- Allows tailoring optical properties to optimize solar cell performance.
- Resulted in a record-performance "triple junction" photovoltaic device (32.4% efficiency!)
- These devices are being applied in space-based applications and terrestrial light concentrator devices.



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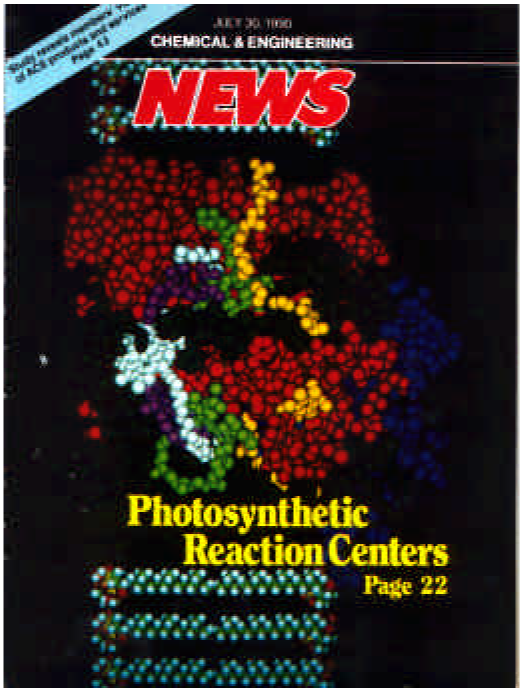
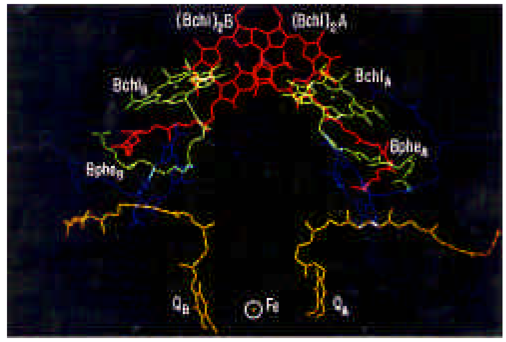
Photosynthetic Reaction Center





The fundamental process by which plants and bacteria convert and store solar energy as chemical free energy occurs in the photosynthetic reaction center. One electron is pumped by the action of light from the primary donor, bacteriochlorophyll dimer $(BChl)_2A$, to a quinone acceptor, Q_A. The charge separation process is studied as the prototype for simpler model systems.

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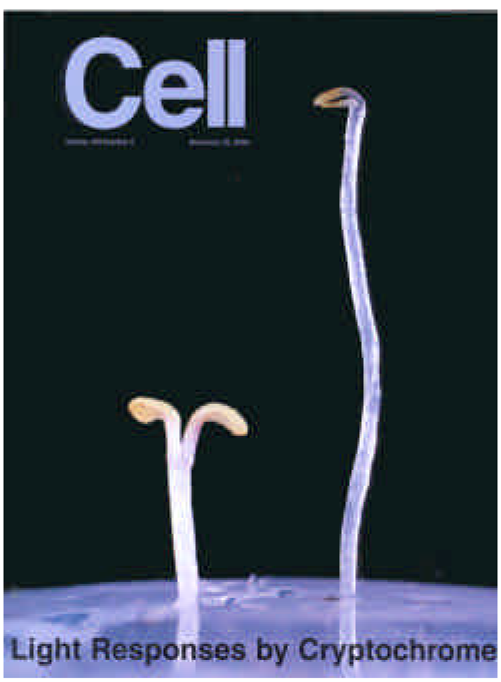
Plant Response to Blue Light



Plants use different photoreceptors to sense the quality and quantity of light in the surrounding environment; this information is conveyed by molecular-level signaling mechanisms to allow plants to adjust their growth and development accordingly. Potential developmental responses to cryptochrome action include seed germination, stem elongation, and flowering.

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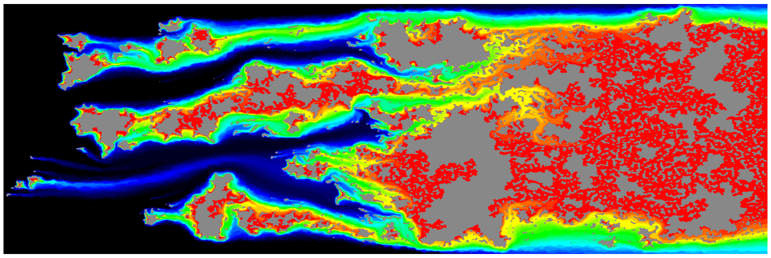
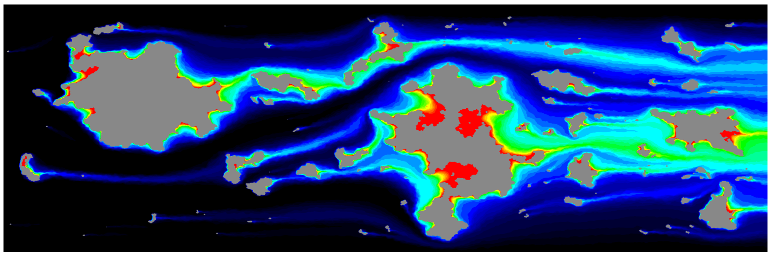
Patterns and Predictions of Subsurface Flow



C=0.2



C=0.4

Recovery of subsurface fluids, whether oil and gas or contaminants, requires understanding the ways fluids flow within porous and fractured rocks and soil.

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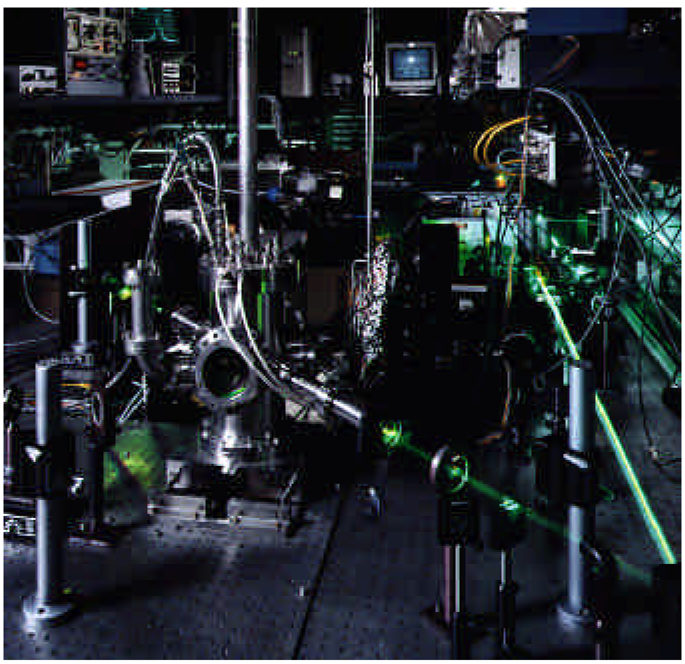
The Combustion Research Facility



- **Research addresses**
  - **Energy sciences**
  - **Energy efficiency**
  - **Environmental impact**
  - **Fuel flexibility**
- **Core programs provide**
  - **Basic to applied research**
  - **Unique laser facilities**
  - **Partnerships with academia and industry**

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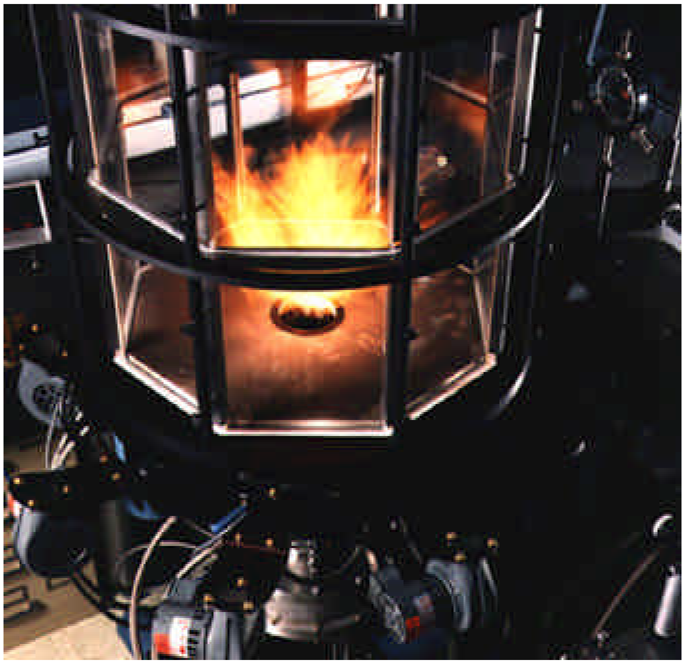
Basic Research and Applied Programs at the CRF



- Basic
  - Combustion chemistry
  - Optical diagnostics
  - Reacting fluid flows
- Applied
  - Engine combustion and emissions
  - Industrial furnaces and boilers
  - Manufacturing processes
  - Alternative fuels
  - Field measurements
  - Remote sensing

27

"Generic" Scientific Opportunities

- **Realizing the nanoscale revolution**
  Tailoring materials one atom at a time for desired properties and functions
- **Complex systems**
  Understanding collective, cooperative, and adaptive phenomena and emergent behavior
- **Harnessing the power of advanced computing**
  Investigating condensed matter and materials physics, chemistry, and biosciences

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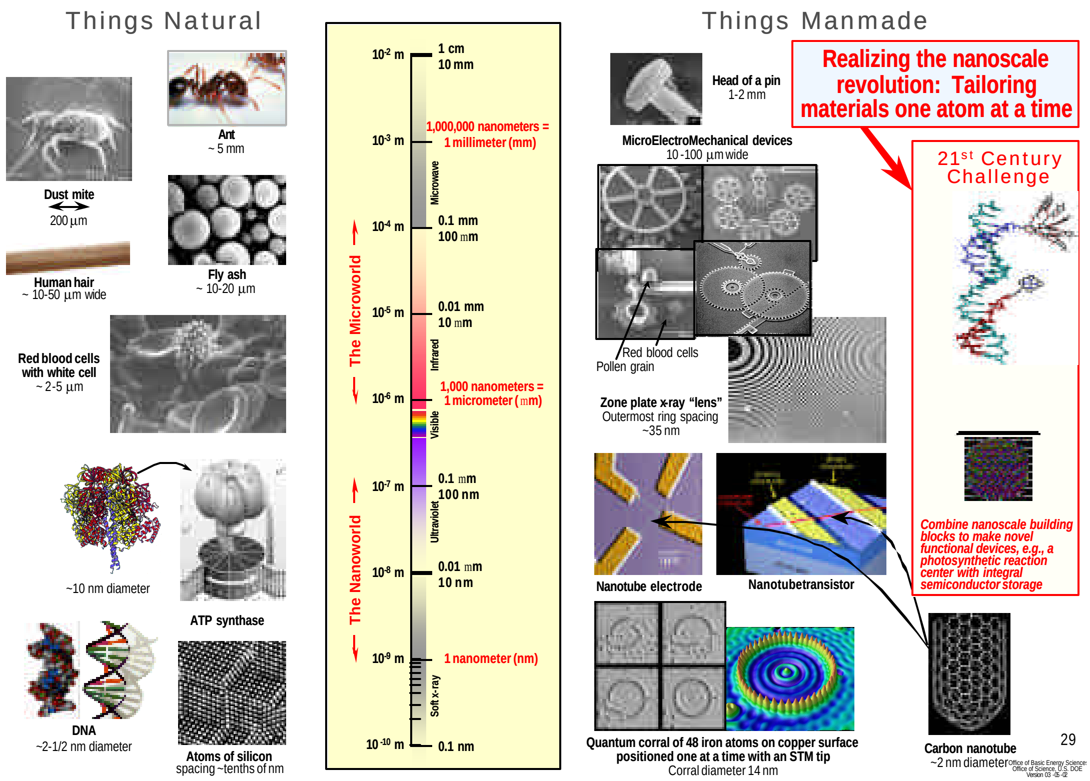
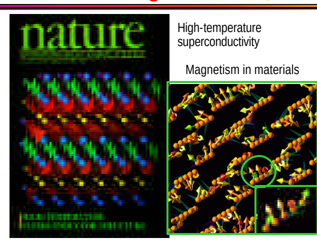
The Scale of Things -- Nanometers and More



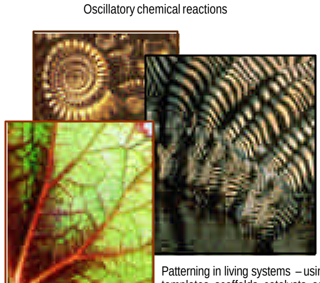
Complex systems:

Understanding collective, cooperative, and adaptive phenomena and emergent behavior



Collective effects and emergent behavior in inorganic systems

Oscillatory chemical reactions



Patterning in living systems – using templates, scaffolds, catalysts, oscillatory chemical reactions, and more – and emergent functionality

Interactions among individual components can lead to coherent behavior that can be described only at higher levels than those of the individual units. This can produce remarkably complex and yet organized behavior.

- **Electrons interacting with each other and the host lattice in solids give rise to magnetism and superconductivity.**
- **Chemical constituents interacting in solution give rise to complex pattern formation and growth.**
- **Living systems self assemble their own components, self repair them as necessary, and reproduce; they sense and respond to even subtle changes in their environments.**

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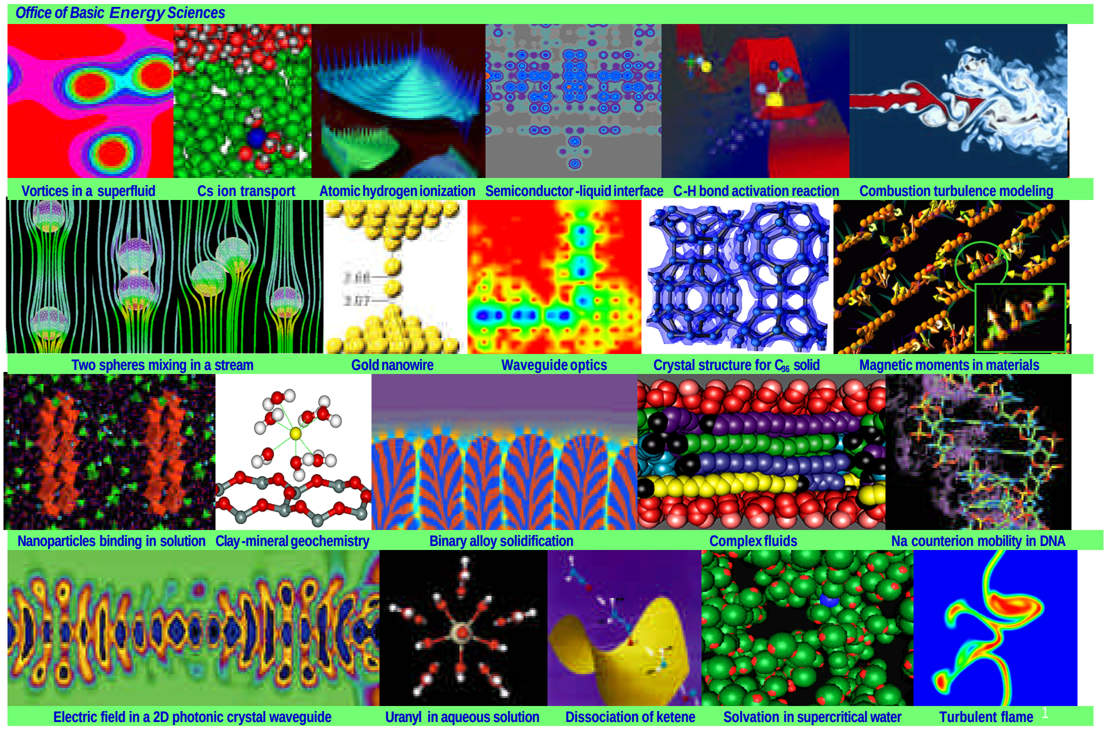
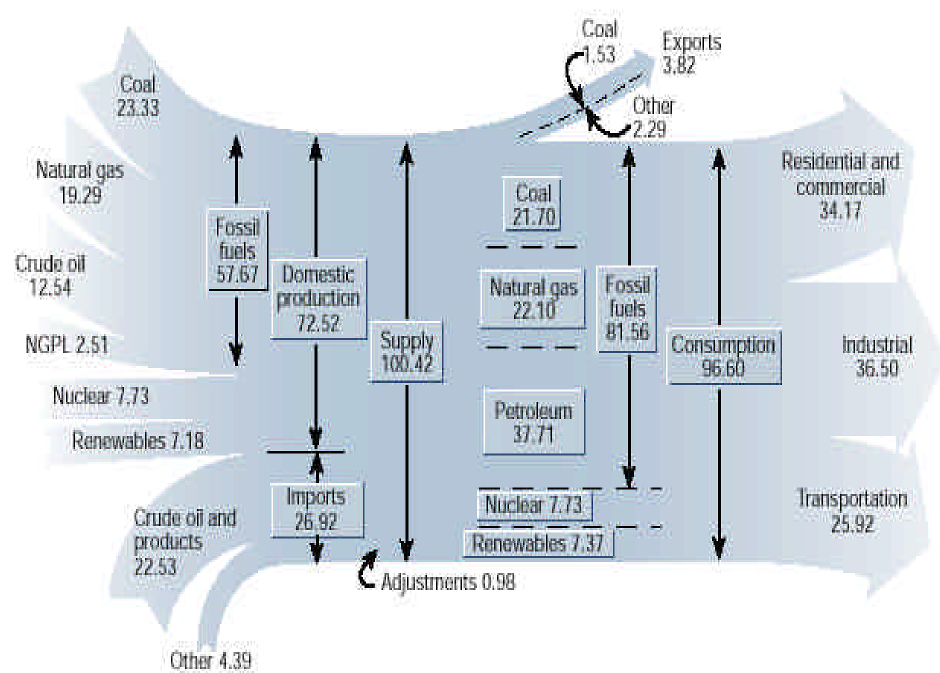
Harnessing the Power of Advanced Computing for Condensed Matter and Materials Physics, Chemistry, and Biosciences

Office of Basic Energy Sciences



Fundamental Research for Energy Security



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Conversations with BESAC

"The basic research community has focused on many of the known problems in energy technologies for many years – the workshop should not rehash these areas."

"Rather, the workshop should focus on new revolutionary basic research opportunities."

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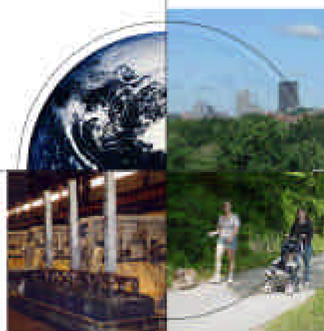
Overview
DOE's Office of Fossil Energy Programs



Basic Energy Sciences Advisory Committee-Sponsored Workshop

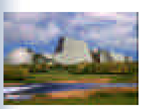
October 21, 2002
Rita A. Bajura
Director
NETL

Fossil Energy

FE Responsible for RD&D Program in Fossil Energy Supply, Delivery, and Use Technologies

Electric Power Using Coal

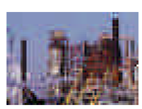

Environmental Control

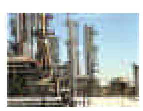

V21 Next Generation


Carbon Sequestration

Clean Liquid Fuels


Exploration & Production

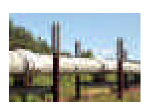

Refining & Delivery

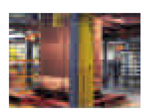

Alternative Fuels


Future Fuels

Natural Gas


Exploration & Production


Pipelines & Storage


Fuel Cells

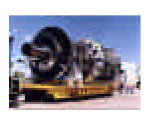

Combustion Turbines

Photo of hydrogen fueled car: Warren Gretz, NREL

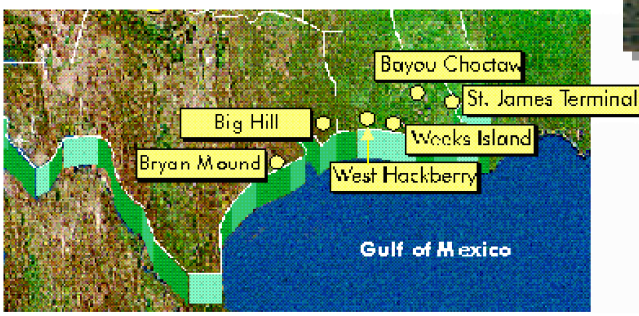
RAB-Science 10/21/02

Fossil Energy

FE Responsible for the Strategic Petroleum Reserve

Maintain readiness of nation’s emergency:

- Crude oil stockpile
- Northeast heating oil reserve



West Hackberry Louisiana

Fossil Energy

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Energy Profoundly Impacts Our Quality of Life

Comfort
Fuel warms our homes and provides electricity to wash our clothes and power our televisions

Food
Energy needed to produce food and to deliver clean water to our homes

Reliability
Reliable power for air traffic control, banking, and telecommunications

Mobility
Fuel provides mobility

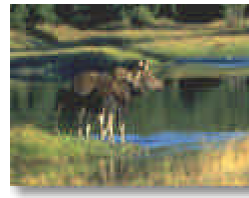
Fossil Energy

RAB-Science 10/21/02

Energy Impacts the Environment

Production and Use

Air Emissions
Emissions down but continuing pressure to reduce further



Land Use
Energy is a major land user

Water
Energy production and use can impact water quality

EIA Report #EIA/DOE-0573 (98) "Emissions of Greenhouse Gases in the U.S.: 1998 Executive Summary" (Nov. 99)

Fossil Energy

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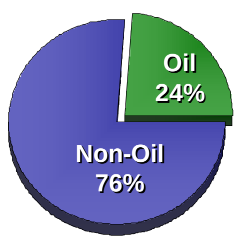
Energy Impacts the Economy

Production and Use

Individual Economics
$2,000 per person per year spent on energy



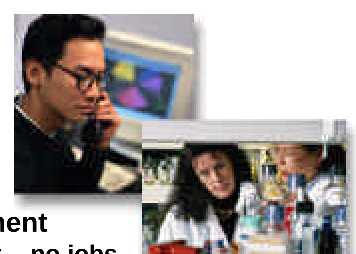
International Trade
Petroleum imports account for one-fourth of U.S. trade deficit in goods*

Burgers ~~$1.99~~ $2.09

Prices
Energy prices impact all economic sectors

While energy accounts for 6% of GDP, it underlies all economic activity

* Data for 2000 on Balance of Payments basis



Employment
No energy - no jobs

Fossil Energy

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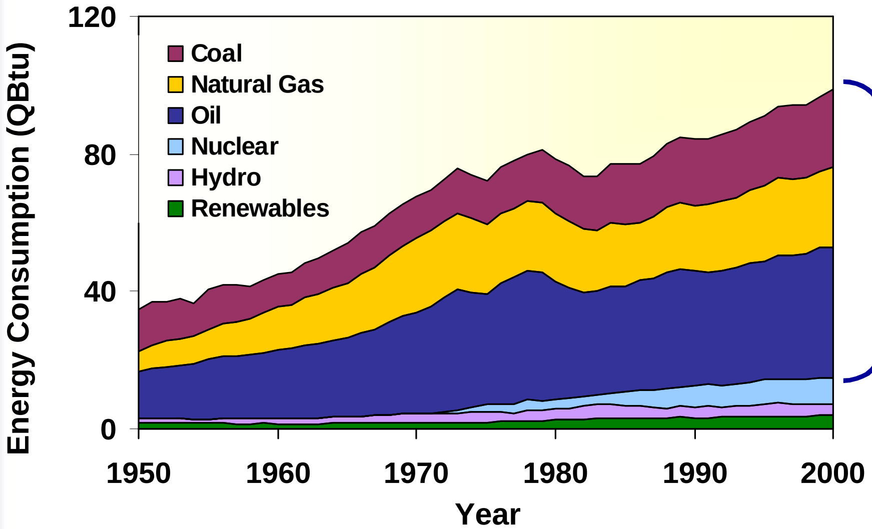
U.S. Energy Today



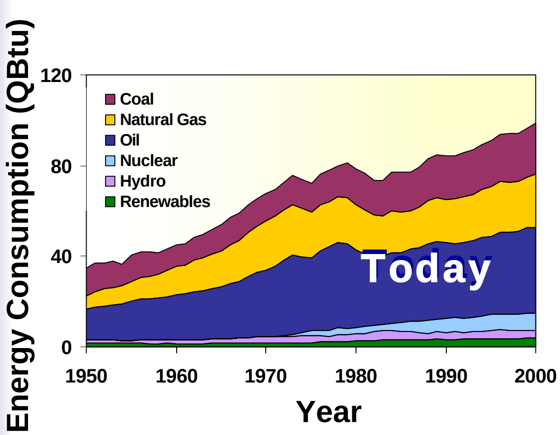
Fossil Fuels Provide 85% Energy Supply

EIA, AER Interactive Data Query System

Fossil Energy

RAB-Science 10/21/02

The Challenge:
Defining a Pathway for U.S. Energy Future



Sustainable
Secure
Affordable
Future

DOE/EIA

Fossil Energy

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Issues Facing Energy

- **Local/regional environmental**
- Energy security
- Global supply/environmental

Fossil Energy

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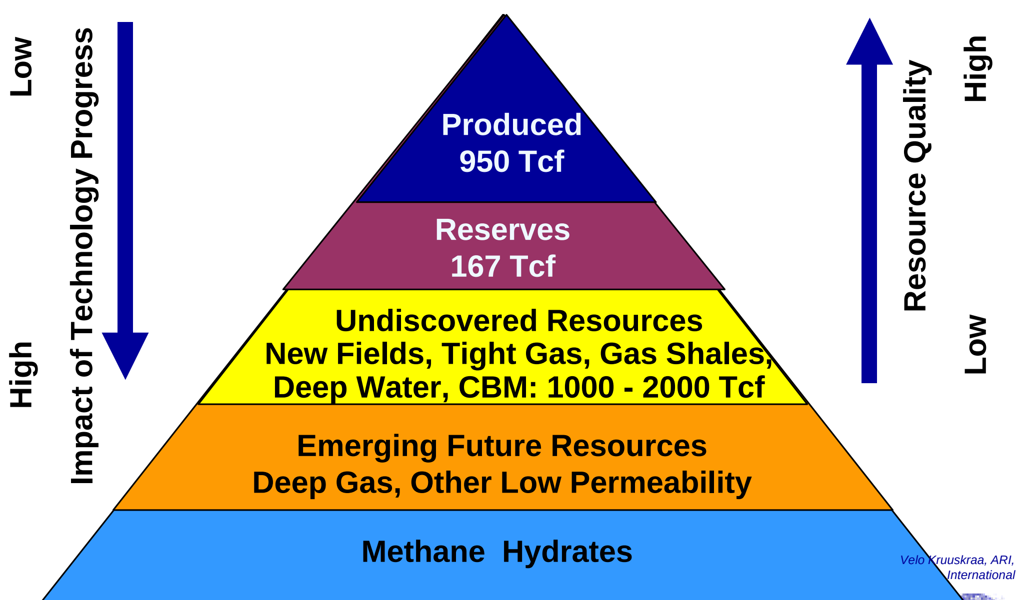
Resource Base Depends on Economics of Production

Natural Gas Resource Pyramid As of Year 2000



Fossil Energy

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Fossil Fuel Resources Abundant

Proved Recoverable World Reserves

Estimated World Resource

Natural Gas
More Than
5,000 Tcf

Coal
984 Billion Tons

Oil
Just Over 1
Trillion Barrels

Methane Hydrates
Up to 270 Million Tcf

Proved recoverable reserves should last most of 21st century

World Energy Council
1998 Survey of Energy Resources

Fossil Energy

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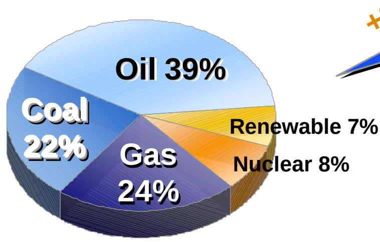
Fossil Energy Will Continue to Dominate

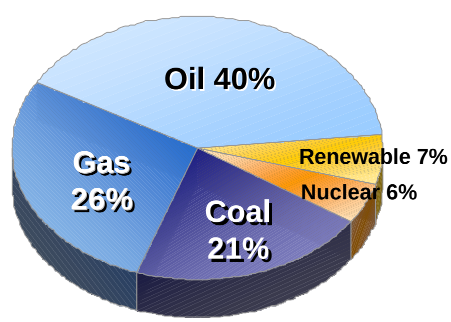
Need to Address Environmental Issues

2000

99 Quads

Fossil fuels provide 85% of US energy
(67% of electricity)





2020

131 Quads

Reliance on fossil fuels projected to grow to 87%

Fossil Energy

DOE/EIA Annual Energy Outlook 2002, 12/2001, Reference Case for 2020

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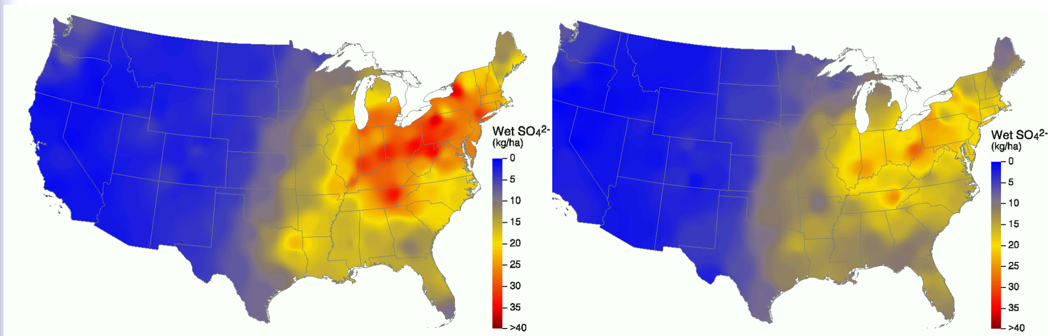
Success: Cleaner Air

Monitored Reduction in Wet Sulfate Deposition Due to Acid Rain Program

1989 - 1991 **1998-2000**



Acid rain reduced as much as 30% in acid-sensitive ecosystems

Source: National Acid Deposition Program

Fossil Energy

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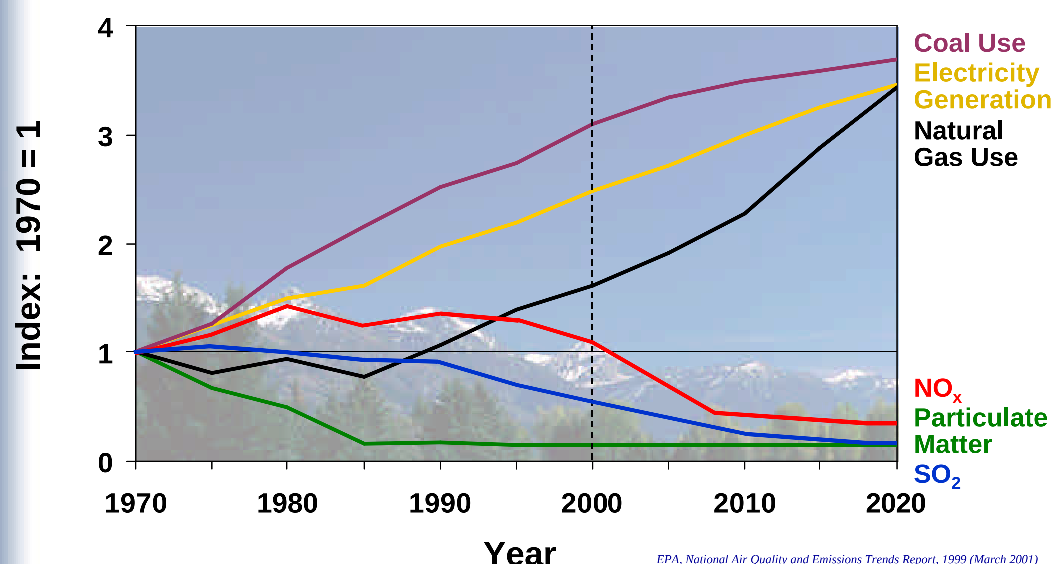
"Clear Skies" Initiative Would Sharply Reduce Criteria Pollutant Emissions

U.S. Power Plants



EPA, National Air Quality and Emissions Trends Report, 1999 (March 2001)
DOE, EIA Annual Energy Review

Fossil Energy

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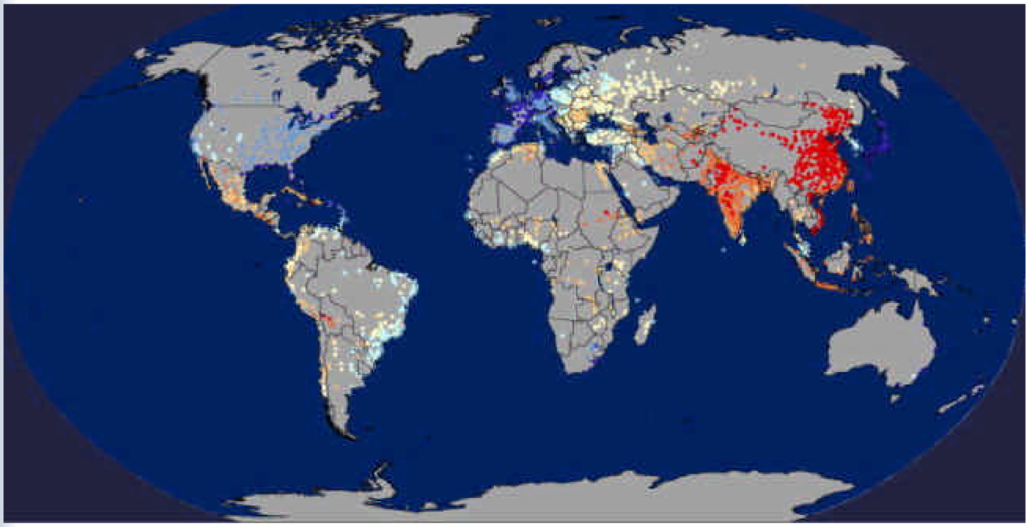
Concentration of Particulate Matter in Urban Areas



Low — **High**

Fossil Energy

World Bank Atlas - 2001, Technology: Stationary Sources and Demand-Side Management, Terry Surles, California Energy Commission , May 1, 2002

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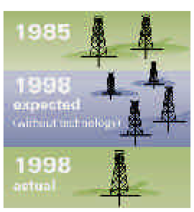
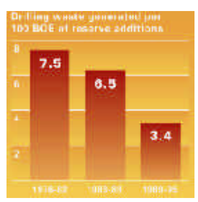
Natural Gas & Oil Exploration & Production

Technology Reducing Environmental Impact



Fewer wells to add same level of reserves



Lower drilling waste volume

Lower produced water volumes

Smaller footprints

Greater protection of unique and sensitive environments

Fossil Energy

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Mining is Critical to Quality of Life

Every American Born Will Need...

- 11.7 Tons Clays
- 1,925 lbs. Copper
- 1.8 Troy oz. Gold
- 295 Tons Coal
- 13.9 Tons Phosphate
- 3 Tons Aluminum
- 1,078 lbs. Lead
- 21.3 Tons Iron Ore
- 15.2 Tons Salt
- 1,001 lbs. Zinc
- 850 Tons Stone, Sand, Gravel
- 83,890 Gallons Petroleum
- 34.4 Tons Cement
- 34.5 Tons Other Minerals and Metals
- 6 million cu. ft. of Natural Gas

1,875 tons of minerals, metals, and fuels in a lifetime

2000 Mineral Information Institute, Golden, Colorado

Fossil Energy

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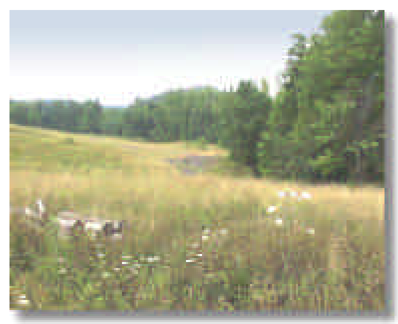
Coal Mining

Technology Reducing Environmental Impact

Made progress through improved

- Planning
- Permitting
- Groundwater management
- Utilization of coal mine methane
- Reclamation

Legacy programs exist



Reclaimed Surface Mine in Western PA

Contaminated Mine Drainage

Fossil Energy

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Issues Facing Energy

- Local/regional environmental
- **Energy security**
- Global supply/environmental

Fossil Energy

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Threats to Energy Security

- **Increased**
  - Terrorist threats
  - Oil and gas imports
  - Interdependencies
- **Aging infrastructure**
- **Less reserve capacity**

Fossil Energy

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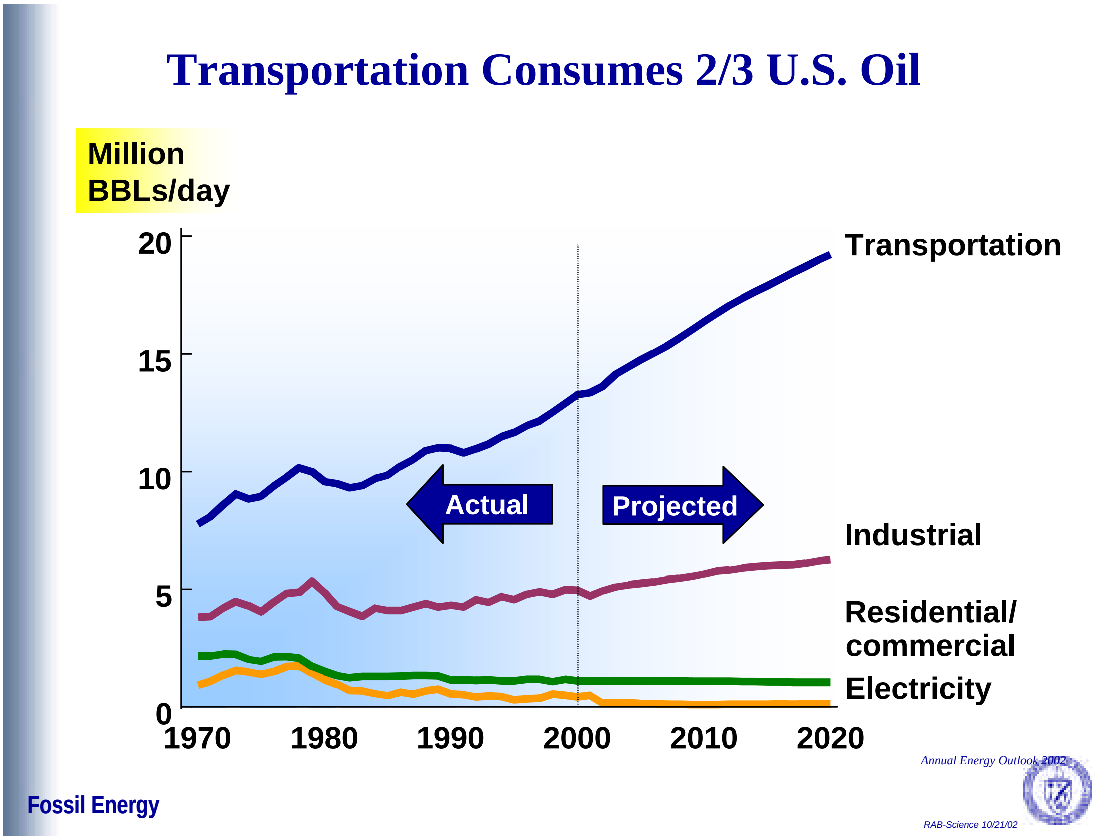
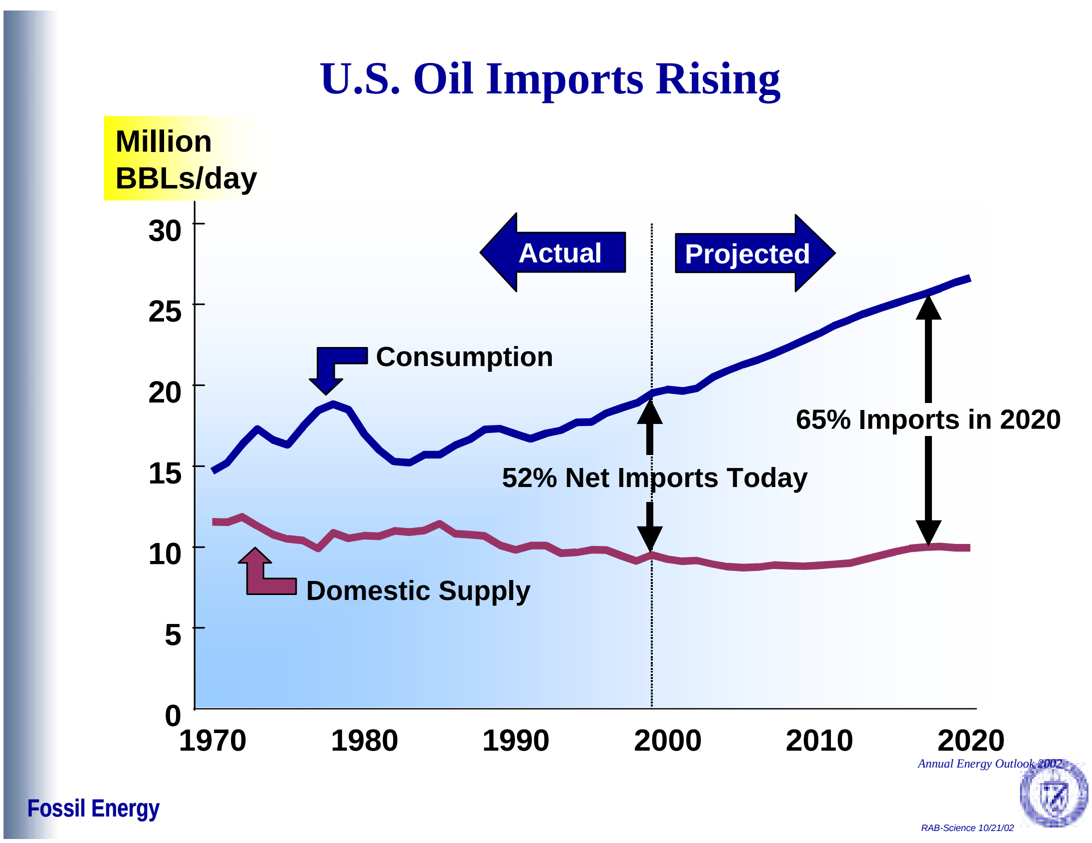
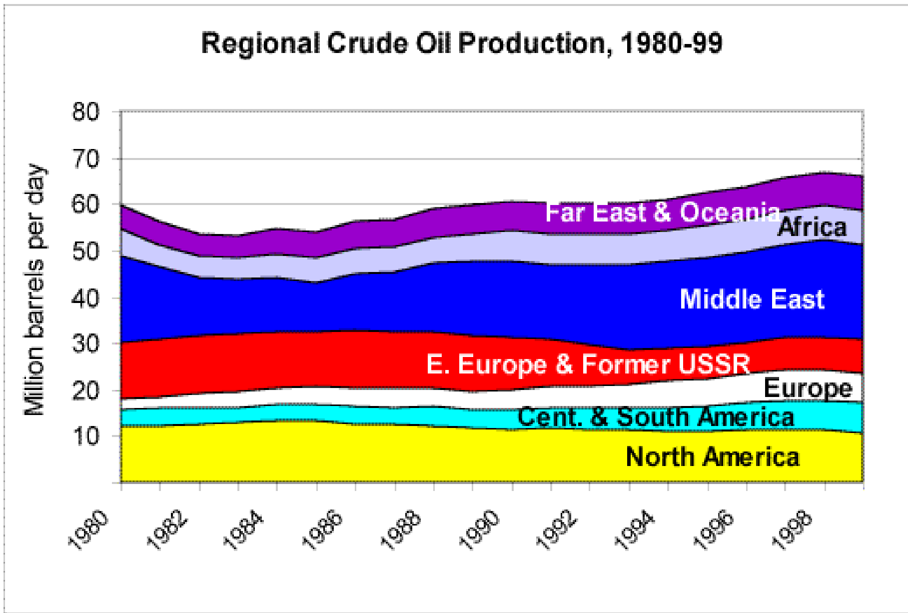

Transportation Consumes 2/3 U.S. Oil
Million BBLs/day
20
15
10
5
0
1970
1980
1990
2000
2010
2020
Actual
Projected
Transportation
Industrial
Residential/ commercial
Electricity
Annual Energy Outlook 2002
Fossil Energy
RAB-Science 10/21/02


U.S. Oil Imports Rising
Million BBLs/day
30
25
20
15
10
5
0
1970
1980
1990
2000
2010
2020
Actual
Projected
Consumption
52% Net Imports Today
65% Imports in 2020
Domestic Supply
Annual Energy Outlook 2002
Fossil Energy
RAB-Science 10/21/02

Much of World's Oil Comes from Unstable Regions



Fossil Energy

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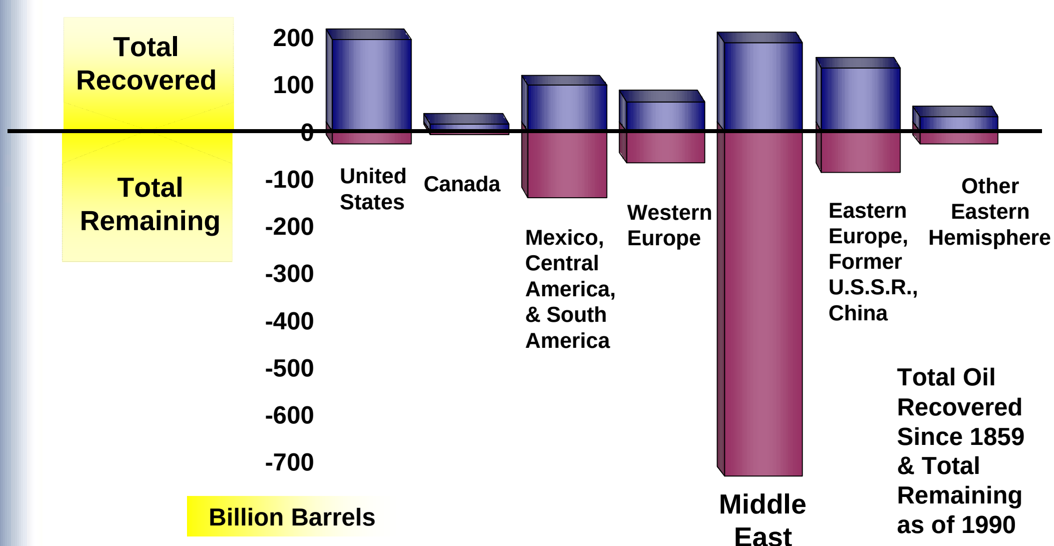
Bulk of World's Reserves in Middle East



Fossil Energy

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Demographics of Middle East

- Population is young, growing rapidly, poor
- Nations are young
- Rich/poor gap
- Rising internal energy use

Based on Matt Simmons

Fossil Energy

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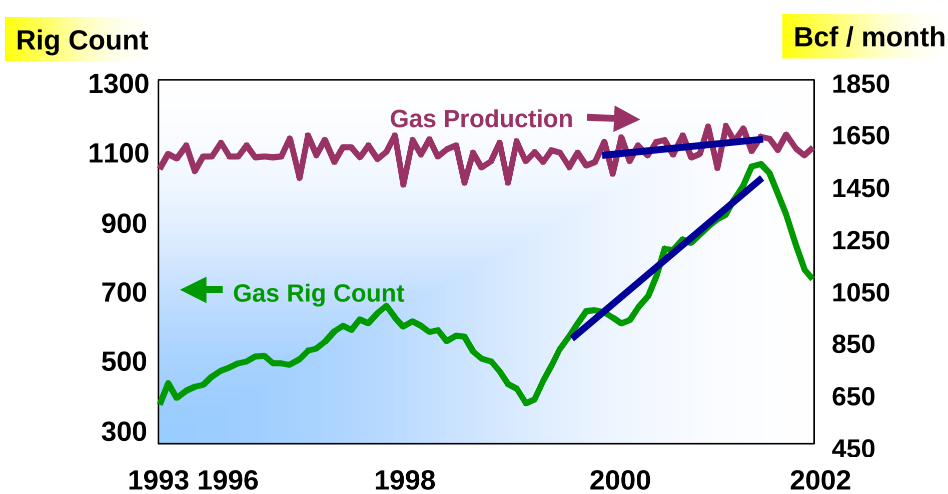
Production Lag Suggests Shrinking U.S. Gas Surplus

U.S. Drilling Rig Count vs. Gas Production



Source: Matt Simmons
EIA History - Natural Gas Monthly - January 2002,
Oil & Gas Split Rig Count - Baker Hughes

Fossil Energy

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Issues Facing Energy

- Local/regional environmental
- Energy security
- **Global supply/environmental**

Fossil Energy

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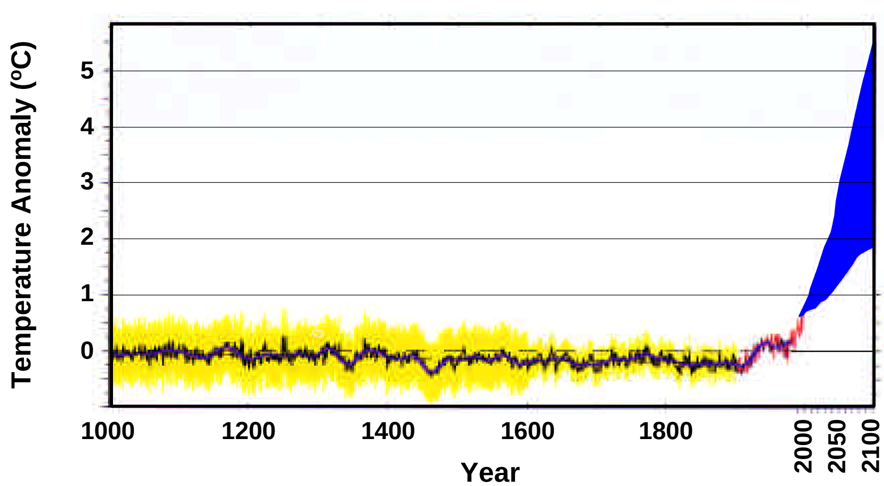
Mean Annual Temperature Variations
Northern Hemisphere



B. Eliasson, First National Conference on Carbon Sequestration, May 15-17, 2001

Fossil Energy

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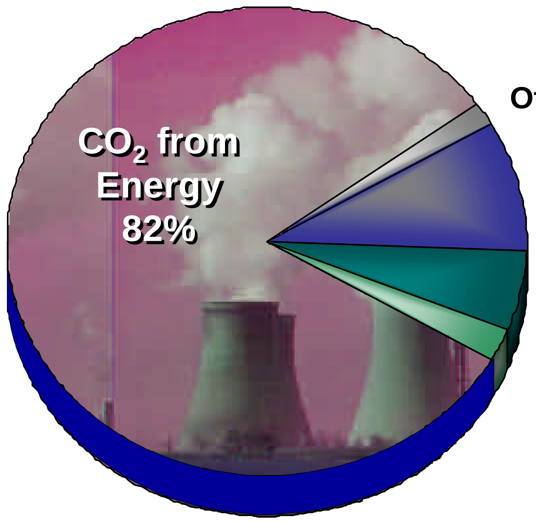
CO_2 From Energy Is Major Contributor

U.S. GHG Emissions Weighted by Global Warming Potential



EIA Report #EIA/DOE-0573
"Emissions of Greenhouse Gases in the U.S. 1999," Executive Summary (Oct. 2000)

Global Climate Change

Fact or Fiction?

- **Science unlikely to provide unequivocal causality answer**
- **Governments and markets likely to act on their perception of the science**
  - Interpreted with a slant towards their self-interest
- **Corporate boards increasingly expected to evaluate potential risks / benefits of climate change**
  - Enron effect

Portions based on Executive Action Brief No. 23, June 2002, The Conference Board

Technological Carbon Management Options

Reduce Carbon Intensity

- Renewables
- Nuclear
- Fuel Switching

Improve Efficiency

- Demand Side
- Supply Side

Sequester Carbon

- Capture & Store
- Enhance Natural Processes

All options needed to:

- **Supply energy demand**
- **Address environmental objectives**

Vision 21

Ultra-Clean Energy Plant of Future

Energy Plants for Post-2015

- Coal and other fuels
- Electricity and possible co-products

Goal

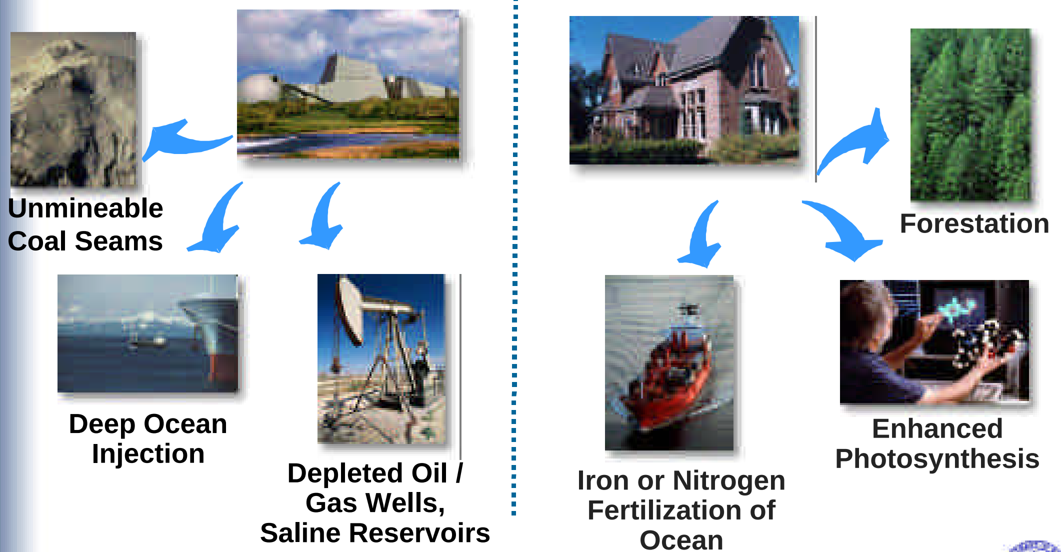
Eliminate Environmental Concerns from Use of Fossil Energy

Approach

- **Maximize efficiency**
- **Near-zero emissions**

Approaches to Sequester Carbon

Capture and Storage | ***Enhance Natural Processes***



Fossil Energy

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Hydrogen

A Proposed Solution for Energy Issues . . .

- Energy security
- Local environmental degradation
- Global environmental degradation

→ **Hydrogen Economy**

Ability for consumers to use hydrogen energy devices for transportation, electric power generation, and portable power

Fossil Energy

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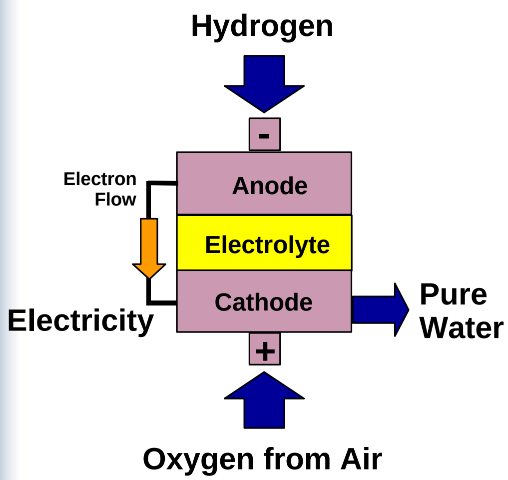
Fuel Cells Are One Enabling Technology for Hydrogen Economy

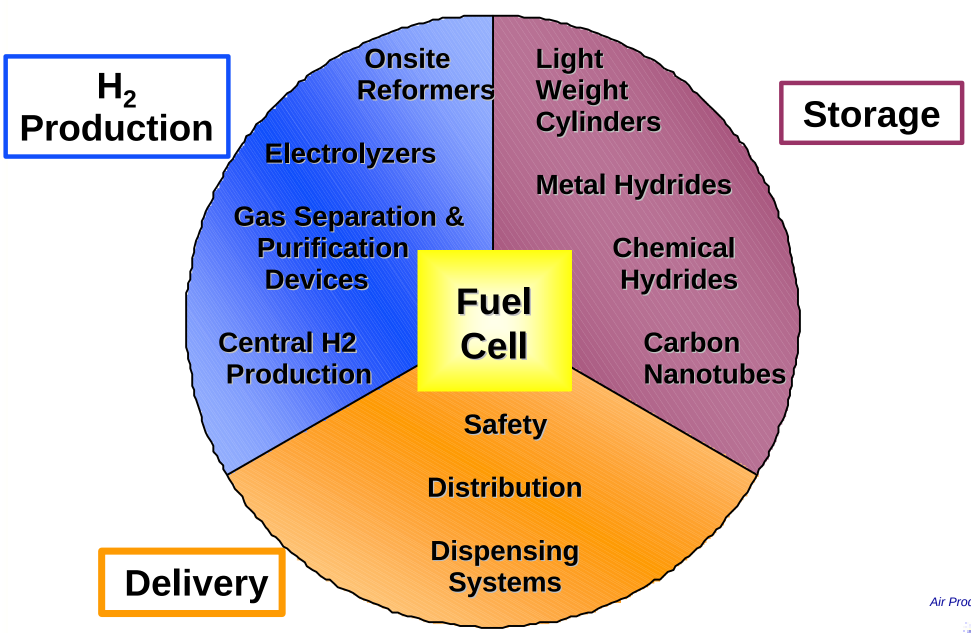


Basically a battery with an external supply of fuel and oxidant

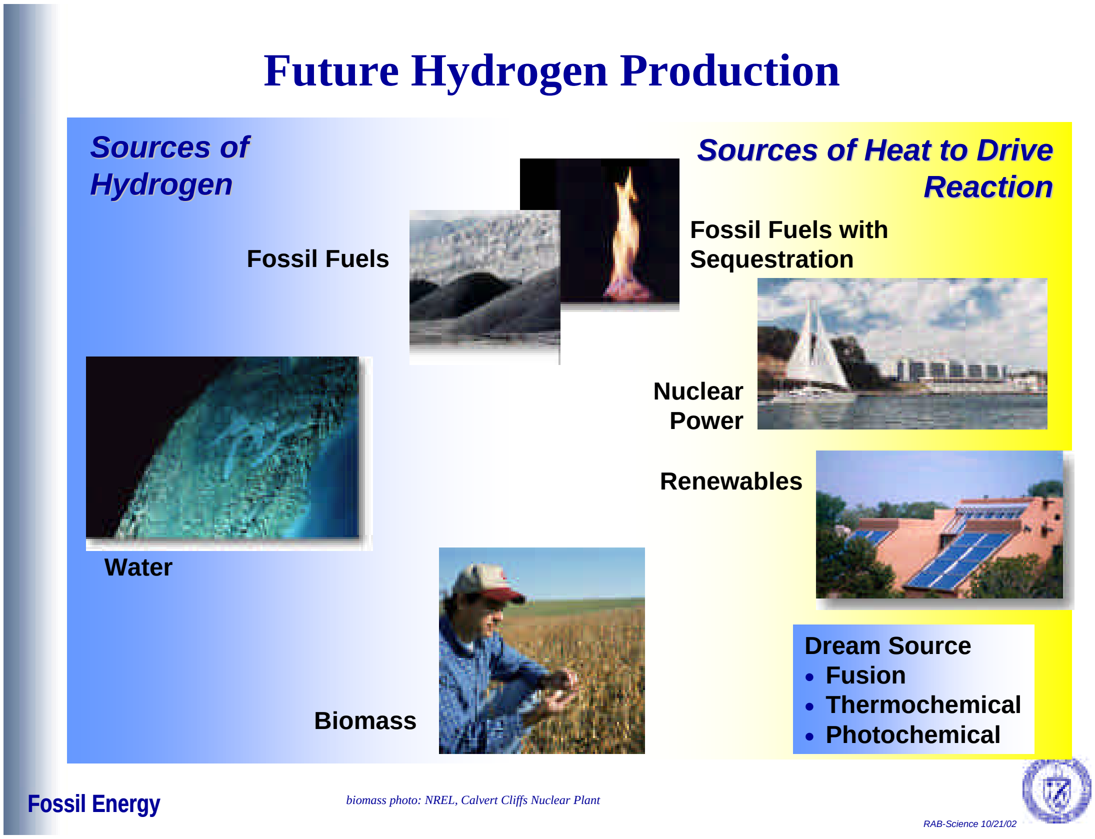
Cells stacked together for desired power

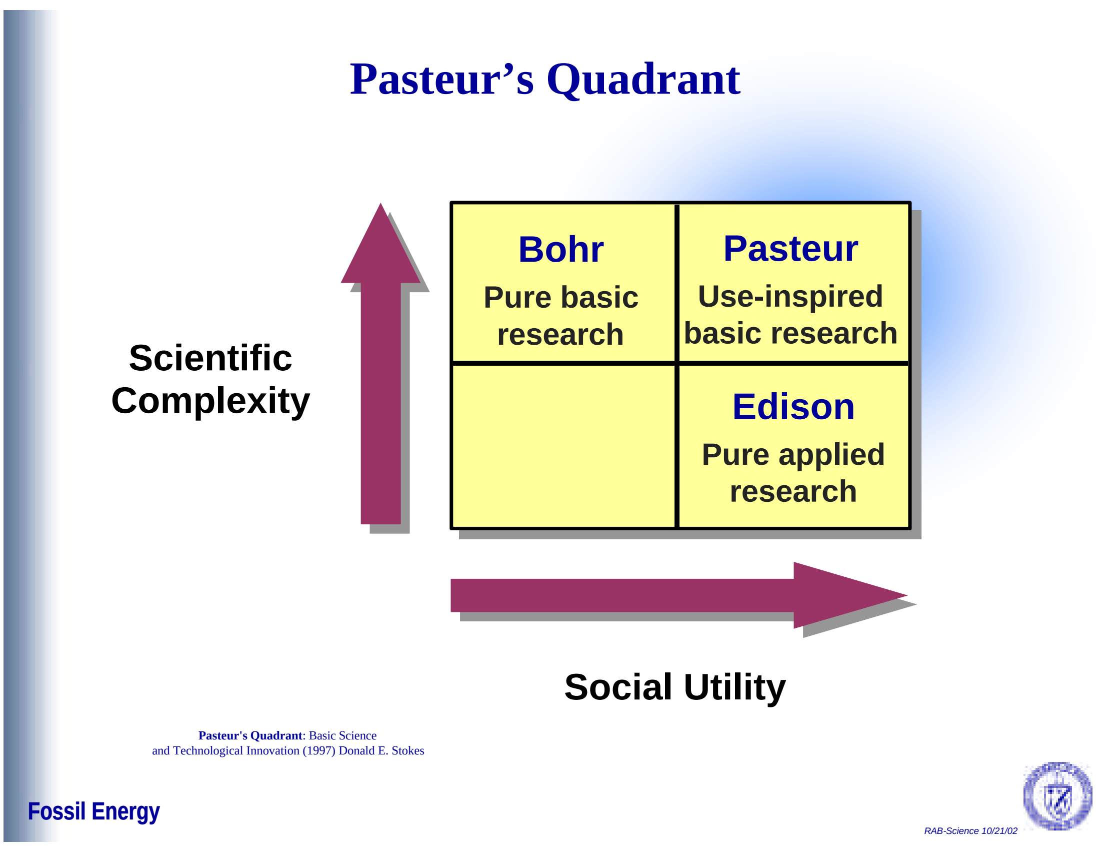
Issue: Cost
- Fuel cells cost $1,600 - $4,500 per kilowatt
- Internal combustion engines cost $\geq$ $35 per kilowatt

Infrastructure R&D Requirements



Air Products


Future Hydrogen Production
Sources of Hydrogen
Fossil Fuels
Water
Biomass
Sources of Heat to Drive Reaction
Fossil Fuels with Sequestration
Nuclear Power
Renewables
Dream Source
• Fusion
• Thermochemical
• Photochemical
Fossil Energy
biomass photo: NREL, Calvert Cliffs Nuclear Plant
RAB-Science 10/21/02


Pasteur's Quadrant
Bohr
Pure basic research
Pasteur
Use-inspired basic research
Edison
Pure applied research
Scientific Complexity
Social Utility
Pasteur's Quadrant: Basic Science and Technological Innovation (1997) Donald E. Stokes
Fossil Energy
RAB-Science 10/21/02

The Short List

Fossil Energy Basic Research Needs

- **Materials**
  - Alloys
  - Ceramics
- **Sensors & controls**
- **Self healing systems**
- **Robotic systems**
- **Computational techniques**
- **Geologic interactions**
  - Water
  - CO_2
  - Gas,oil, coal

Innovative Sequestration Approaches

Issue

- **Scarcity of innovative concepts in program**
- **Traditional FE R&D performers more engineering oriented**

Approach

- **Engage best minds in nation!**
- **National Academy of Science to assist in proposal preparation**
  - NAS roll-out meeting Feb. 03
- **National Lab involvement encouraged**

Seek Out of the Box Solutions!

Advanced Technologies Can Resolve the Environmental, Supply, and Reliability Constraints of Producing and Using Fossil Fuels

Fossil Energy

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Office of Nuclear Energy, Science and Technology

Basic Research Needs in Support of Advanced Nuclear Reactor and Fuel Cycle Technologies

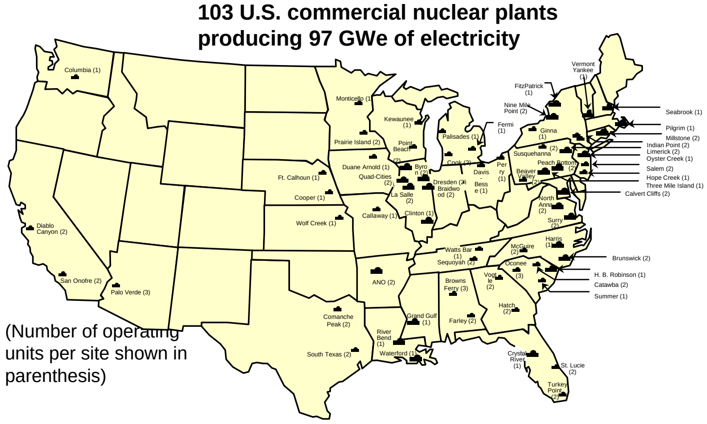
Basic Energy Sciences Advisory Committee Workshop on "Basic Research Needs to Assure a Secure Energy Future"
Gaithersburg, MD,
October 21, 2002

R. Shane Johnson
Associate Director for Advanced Nuclear Research
Office of Nuclear Energy, Science and Technology

Office of Nuclear Energy, Science and Technology

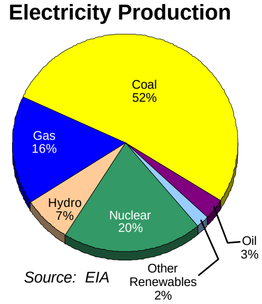
Yearend 2001 United States Commercial Nuclear Power Statistics

103 U.S. commercial nuclear plants producing 97 GWe of electricity



(Number of operating units per site shown in parenthesis)

Electricity Production



Source: EIA

U.S. Energy Security Challenges

- Assure long-term, reliable energy supplies
- Balance energy production with environmental protection
- Reduce the carbon intensity of the U.S. economy

RSJohnson/Oct21_02 to BESAC WS.ppt 2

Office of Nuclear Energy, Science and Technology

Nuclear Energy -- Practical, Achievable Solutions to Difficult Issues of the Future

Benefits of Nuclear

- Clean – no CO_2, NO_x, SO_x emissions
- Low Generating Cost
- Compact, manageable waste stream
- Stable and secure fuel supply
- Sustainable – could be a thousand-year energy resource
- Potential for hydrogen production as a transportation fuel

Challenges for New Nuclear

- Innovative nuclear concepts push technological boundaries
- Higher temperatures, new coolants, new materials, new fuel cycle technologies
- U.S. nuclear R&D infrastructure weakened
- Bringing new, advanced nuclear technologies to reality will require government leadership

RSJohnson/Oct21_02 to BESAC WS.ppt 3

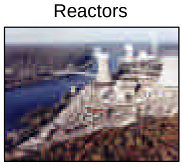
Office of Nuclear Energy, Science and Technology

Three Generations of Nuclear Energy - Thoroughly Demonstrated

The Evolution of Nuclear Power

Generation I

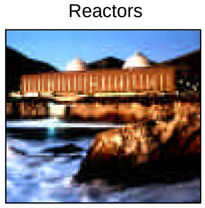
Early Prototype Reactors



- Shippingport
- Dresden, Fermi I
- Magnox

Generation II

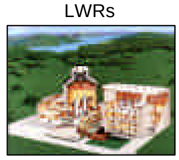
Commercial Power Reactors



- LWR-PWR, BWR
- CANDU
- VVER/RBMK

Generation III

Advanced LWRs



- ABWR
- System 80+
- AP600
- EPR

Generation III+

Generation III Evolutionary Designs Offering Improved Economics

Generation IV

- Highly Economical
- Enhanced Safety
- Minimize Wastes
- Proliferation Resistant

Gen I | Gen II | Gen III | Gen III+ | Gen IV

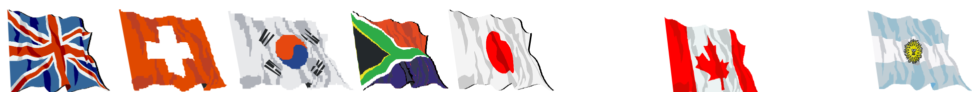
1950 1960 1970 1980 1990 2000 2010 2020 2030

RSJohnson/Oct21_02 to BESAC WS.ppt 4

Generation IV Technology Roadmap

- **Identifies systems deployable by 2030 or earlier**
- **Specifies six systems that offer significant advances towards:**
  - Sustainability
  - Safety and reliability
  - Proliferation resistance and physical protection
  - Economics
- **Summarizes R&D activities and priorities**
- **Provides foundation for Generation IV R&D program plans**

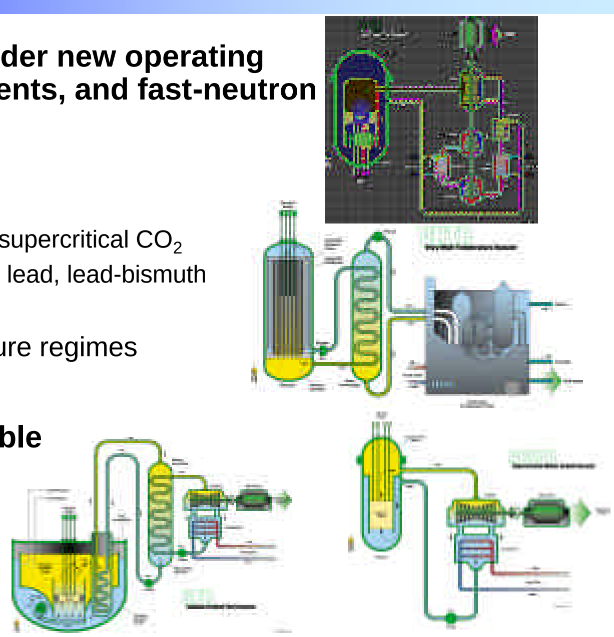
Generation IV Candidate Systems:
- Very-high-temperature gas-cooled reactor
- Gas-cooled fast reactor
- Supercritical-water-cooled reactor
- Lead-cooled fast reactor
- Sodium-cooled fast reactor
- Molten-salt reactor



U.S.A. United Kingdom Switzerland South Korea South Africa Japan France Canada Brazil Argentina

Generation IV Systems R&D Challenges

- **New materials bearing up under new operating regimes, chemical environments, and fast-neutron irradiation**
  - Alternative coolants
    - Supercritical water
    - Gas coolants such as helium, supercritical CO_2
    - Liquid metals such as sodium, lead, lead-bismuth
    - Molten salt
  - Higher pressure and temperature regimes
  - Greater fast-neutron damage
- **New nuclear fuel forms capable of surviving power and temperature excursions**
- **New spent-fuel separation and recycling processes**

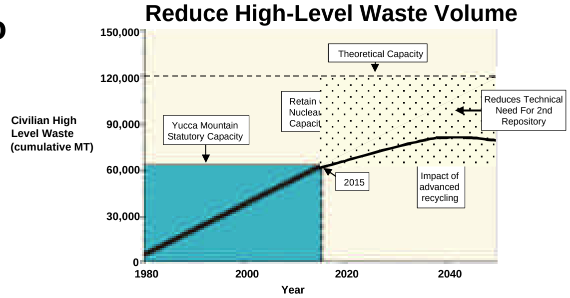


Office of Nuclear Energy, Science and Technology

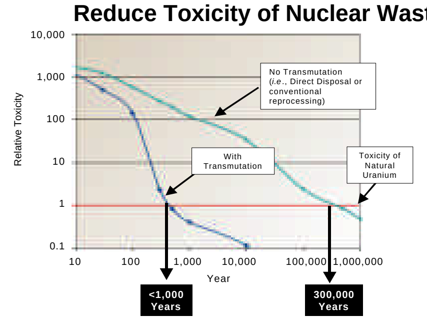
Advanced Fuel Cycle Research - Maximizing Energy From Nuclear Fuel

- **Develop the technologies to**
  - reduce commercial high-level waste by a factor of four by 2015
  - reduce long-term radiotoxicity and heat load of spent fuel by 2030
- **Reduce proliferation risk through destruction of plutonium in existing and future reactors**
- **Enable a decision to forgo a second repository while still supporting expanded nuclear power in the United States**

Reduce High-Level Waste Volume



Reduce Toxicity of Nuclear Waste



Office of Nuclear Energy, Science and Technology

Advanced Fuel Cycle R&D Challenges

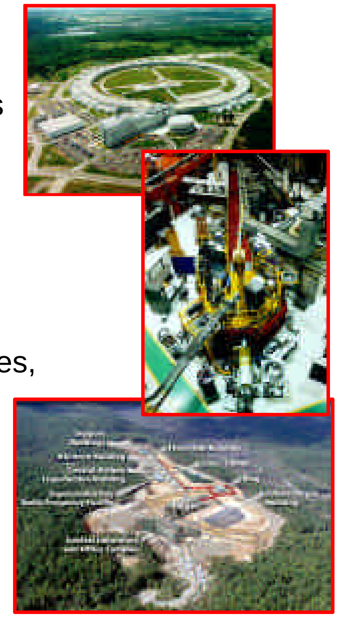
- **Advanced separation chemistry and processes that:**
  - minimize waste volume
  - minimize losses
  - are proliferation resistant
  - minimize dose to workers
- **Advanced fuels for transmutation systems**
  - ceramic fuel in inert metal matrix (cermet)
  - dispersion fuel in inert matrix
  - ceramic, metal and particle fuels
- **Subcritical multiplier for accelerator transmutation**
  - demonstrate safety of configuration
  - materials and coolant for spallation target

Spallation Neutron Source

Basic Science Support

Foundations for Support

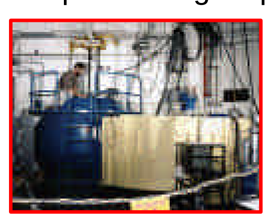
- Provide the fundamental understanding of materials and chemistry that support the development of next-generation reactor and fuel cycle systems
- Provide projects at the university level that engage students in R&D that showcase a relevance to advanced reactor development
- Maintain critical infrastructure for fundamental studies, including the ability to work on radioactive materials
- Encourage the development and application of advanced computational tools (e.g. multi-scale material modeling) toward advanced nuclear application



Basic Science Support

Specific Areas

- Radiation-stable materials for high temperature application (ferritic-martensitc alloys, ceramics and ceramic composites, refractory metals, coatings) to include welding and joining.
- Complex microstructural evolution in engineering materials (complex alloys) under irradiation
- Corrosion of structural materials in supercritical water undergoing radiolysis
- Corrosion of structural materials in lead and lead-bismuth.
- Advanced actinide chemistry that simplifies the number of processing steps (*e.g.,* group extraction using designer molecules)
- Materials for minimizing loss in the recycle process
- Fundamental understanding of the processing and physical properties of nitride fuel



Science Issues in the Office of Energy Efficiency and Renewable Energy

Sam Baldwin

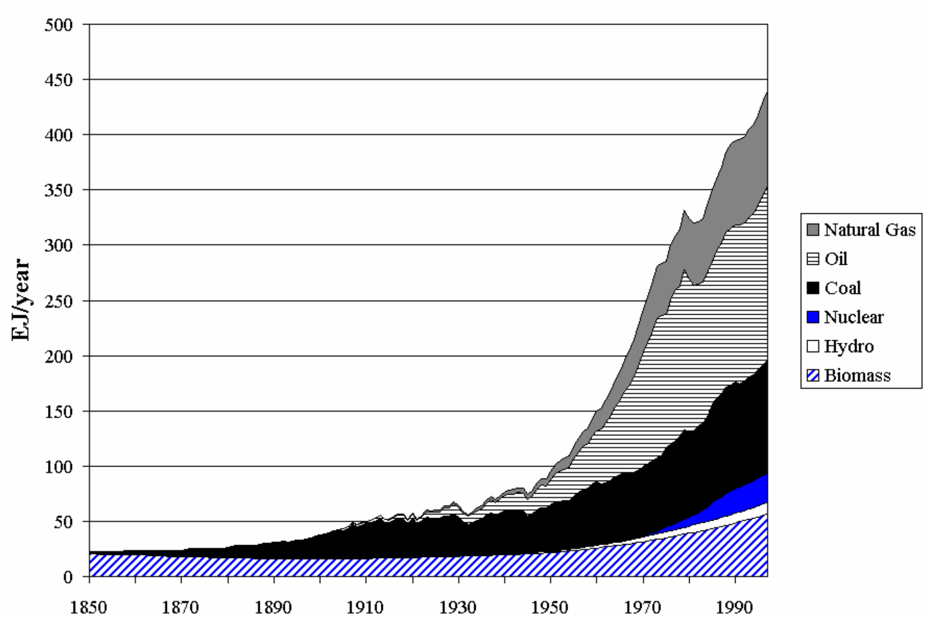
Chief Technology Officer and Member, Board of Directors

Office of Energy Efficiency and Renewable Energy

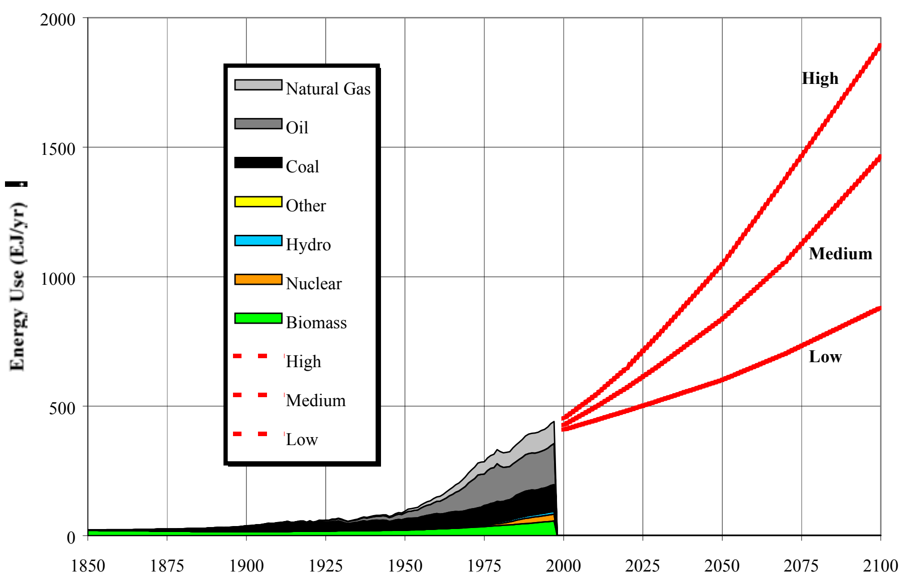
U.S. Department of Energy

October 21, 2002

World Primary Energy Supply by Source, 1850-1997

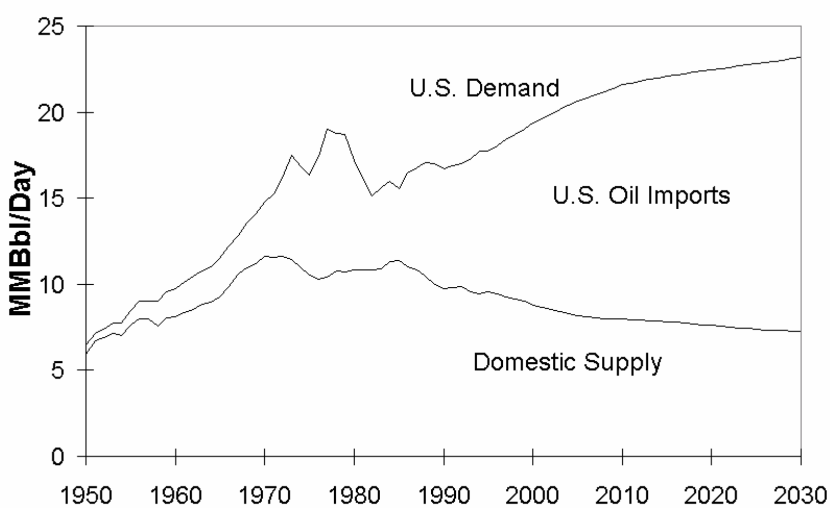


Projections of Energy Use



The Oil Gap

(Business-as-usual)

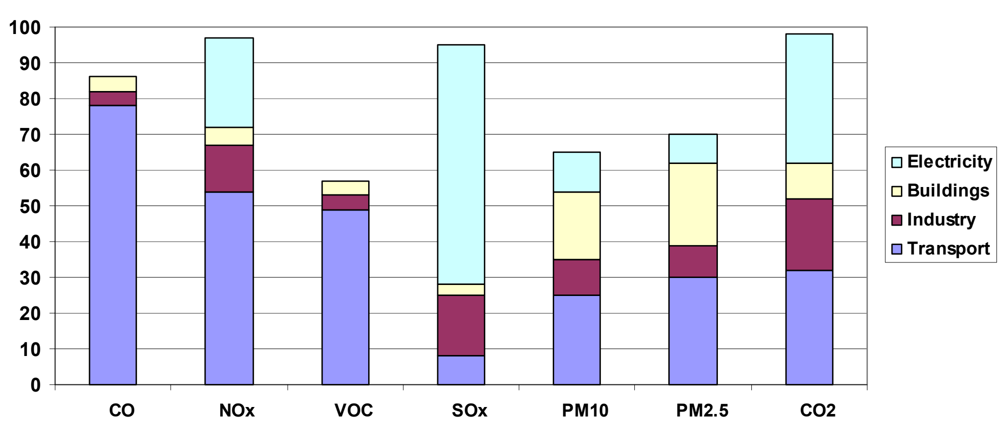


The Oil Problem

Nations that HAVE oil (% of Global Reserves)		Nations that NEED oil (% of Global Consumption)	
Saudi Arabia	26%	U.S.	26%
Iraq	11%	Japan	7%
Kuwait	10%	China	6%
Iran	9%	Germany	4%
UAE	8%	Russia	3%
Venezuela	6%	S. Korea	3%
Russia	5%	France	3%
Mexico	3%	Italy	3%
Libya	3%	Mexico	3%
China	3%	Brazil	3%
Nigeria	2%	Canada	3%
U.S.	2%	India	3%

Source: EIA International Energy Annual 1999

U.S. 1998 Energy-Linked Emissions as Percentage of Total Emissions



EERE Vision, Mission, and Goals

Vision: A prosperous future where energy is clean, abundant, reliable, and affordable.

Mission: Strengthen America's energy security, environmental quality, and economic vitality through public-private partnerships that:

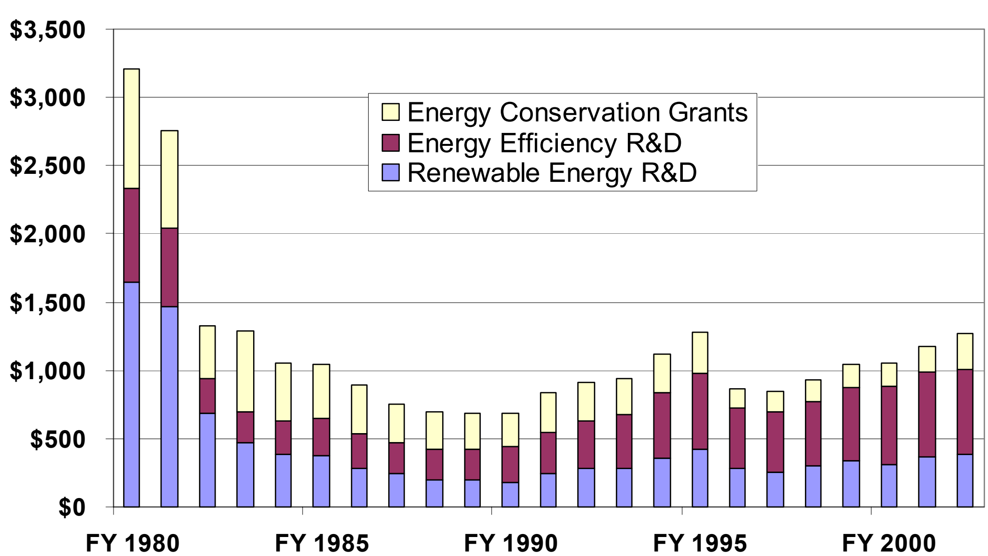
- Promote energy efficiency and productivity;
- Bring clean, reliable, and affordable energy technologies to the marketplace;&
- Make a difference in the everyday lives of Americans by enhancing their energy choices and their quality of life.

Goals:

1. End dependence on foreign oil.
2. Reduce burden of energy prices on disadvantaged.
3. Increase viability and deployment of renewable energy.
4. Increase reliability and efficiency of electricity generation.
5. Increase the efficiency of buildings and appliances.
6. Increase the efficiency/reduce the energy intensity of industry.
7. Create the new domestic bioindustry.
8. Lead by example through Government's own actions.
9. Change the way that EERE does business.

EERE Budgets 1980-2002

Millions of 2000$



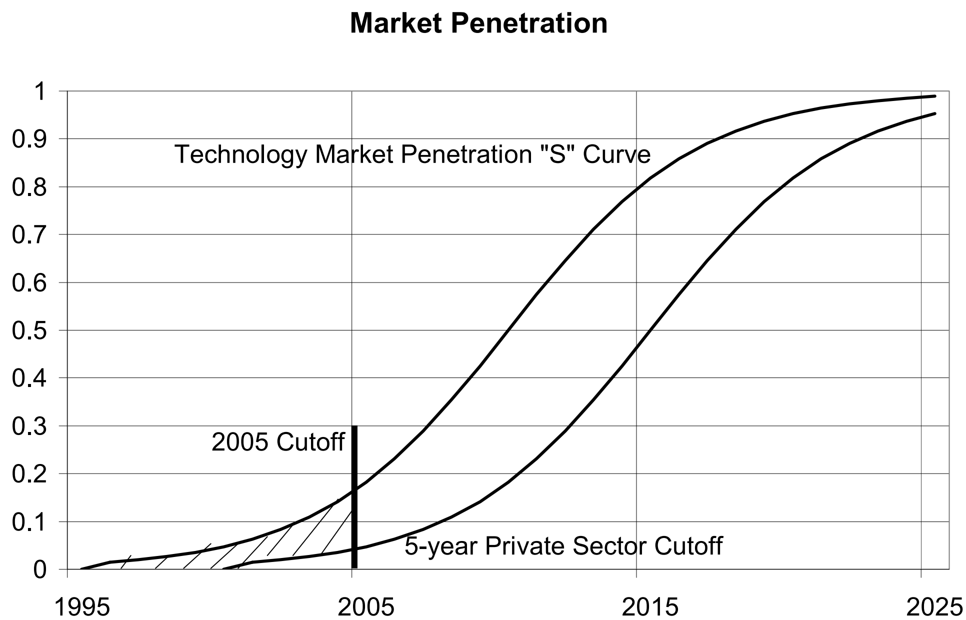
Strategic Program Review of EERE

- **Historic Performance**
  - Patents, Awards, Technical accomplishments
- **Performance-based**
  - Technology push to market pull; components to integrated systems
  - Competitive solicitations; Goals, metrics, milestones; Peer review; Graduations and terminations
- **Public-Private Partnerships**
  - Partnering
  - Contracting
  - Cost-sharing
- **Costs and Benefits**
- **Business Performance**

NRC Benefits/Costs Framework

	Realized Benefits and Costs	Options Benefits and Costs	Knowledge Benefits and Costs
Economic Benefits and Costs			
Environmental Benefits and Costs			
Security Benefits and Costs			

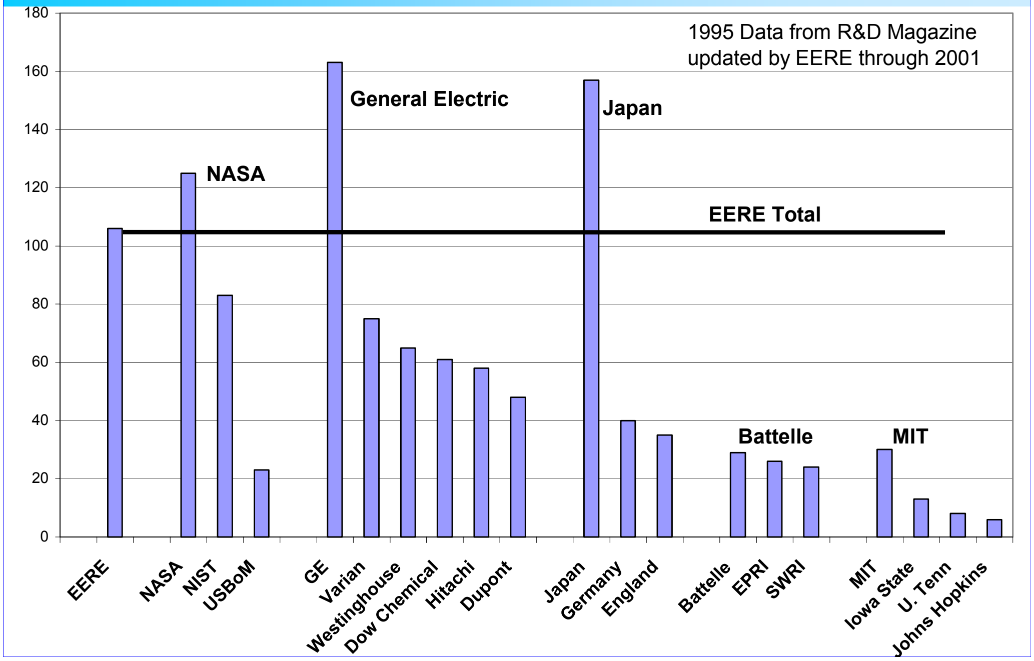
NAS Benefits Analysis Framework



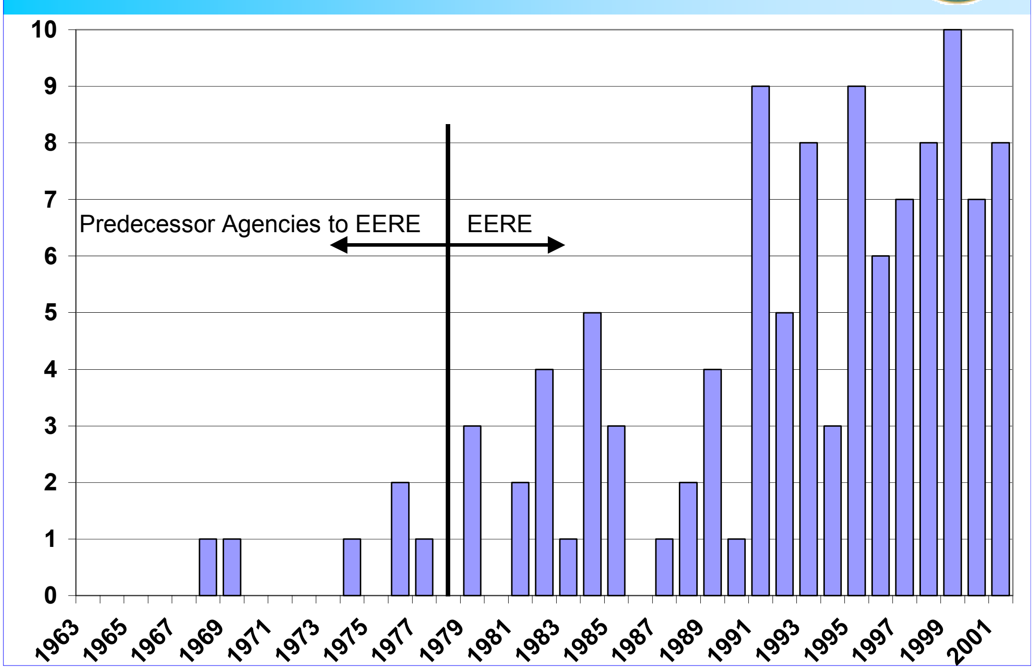
Benefits

- **NAS analysis**
  - $30 B net realized economic benefit on portfolio of $1.6B R&D;
  - NAS estimated additional environmental benefit of $3-$20 billion
- **Technologies to examine**
  - Buildings: Advanced refrigerators/freezers; Spectrally selective windows; Condensing Gas Furnaces; Flame Retention Head Oil Burner; DOE-2; Indoor Air Quality; Energy Star, Low-Income Weatherization; Codes and Standards: refrigerators/freezers, A/C, clothes washers, clothes dryers, dishwashers, water heaters, furnaces, electronic ballasts.
  - FEMP
  - Industry: Direct Steelmaking; Intermetallic Alloys, 140 technologies tracked
  - Transport: Catalytic converters for CIDI, heavy diesels, transportation materials—structural ceramics and lightweight materials; advanced batteries
  - Power: Biopower, Geothermal, Photovoltaics, Wind,

R&D100 Awards by Organization



R&D100 Awards for EERE Sponsored R&D



SPR Recommendations

- **Closures:** activities that should be closed because the work has been successfully completed and no significant further government role is needed (graduations), or does not provide sufficient public benefits (terminations).
- **Redirections:** activities that potentially provide appropriate public benefits but need redirection and/or redefinition to increase the probability of success.
- **Watch List:** activities that need close monitoring to ensure that they advance effectively and expeditiously.
- **Expansions:** activities not currently receiving adequate support in comparison to the benefits they can provide.
- **Best Practices:** actions to improve overall program performance.

Criteria for Judgments

- **Projected Benefits** (economic, environmental, security, options) vs investment
- **Projected potential for commercialization** by industry**.**
- **Whether industry could or would do the RD3 by itself**
- **Program effectiveness (**technical performance, business management, etc.)

http://www.eren.doe.gov/pdfs/strategic_program_review.pd

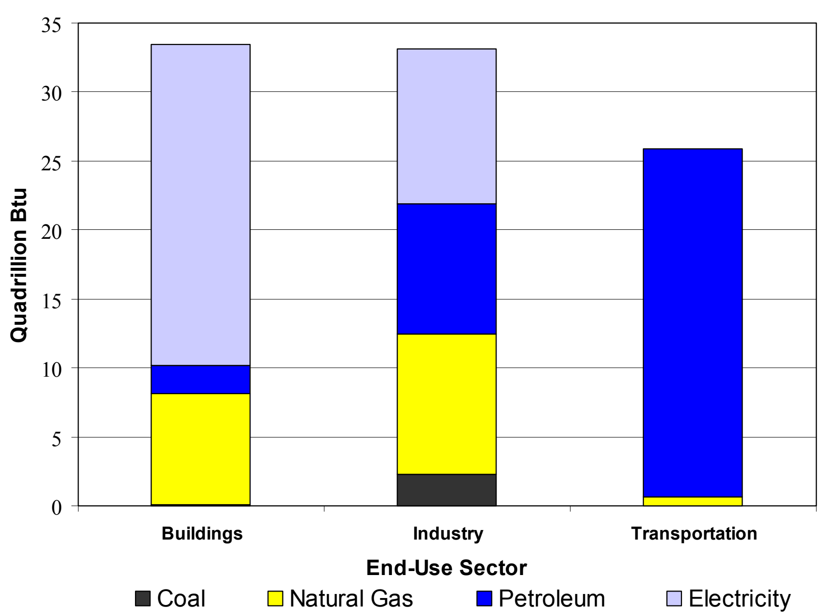
EERE Programs

- Solar
- Wind & Hydropower
- Geothermal
- Distributed Energy, Electricity Infrastructure and Reliability
- Biomass
- Industrial Technologies
- FreedomCAR & Vehicle Technologies
- Hydrogen, Fuel Cells & Infrastructure
- Building Technologies
- Weatherization & Intergovernmental Grants
- FEMP

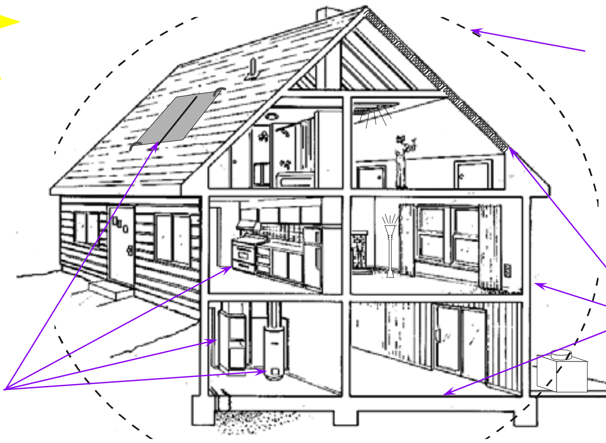
Budget by Program

	FY01	FY02	FY03 Req	FY03 House Floor	FY03 Senate Cmte
Biomass		111,581	108,944	114,944	125,439
Building Technologies		64,449	60,563	68,195	76,563
DEER		131,901	131,290	148,790	136,452
FEMP		20,321	26,425	21,925	26,425
FreedomCAR & Vehicles		181,352	153,563	195,963	181,253
Geothermal		27,098	26,500	26,500	28,300
Hydrogen & Infrastructure		76,317	97,381	96,476	100,500
Industrial Technologies		101,539	92,677	112,677	100,677
Solar		87,107	79,625	79,625	87,000
Weatherization & Intergov.		329,761	374,053	363,655	350,953
Wind & Hydro		38,598	48,986	51,489	56,489
Facilities & Infrastructure		4,870	5,000	5,000	6,800
TOTAL, EERE	1,175,236	1,282,635	1,318,651	1,377,585	1,369,803

Energy Consumption by End-Use Sector & Source - 1999



BUILDINGS



Building Systems
("whole-systems")
Design tools
System Integration

Building Equipment
Space conditioning
Lights
Appliances
BIPV, PEM-FC

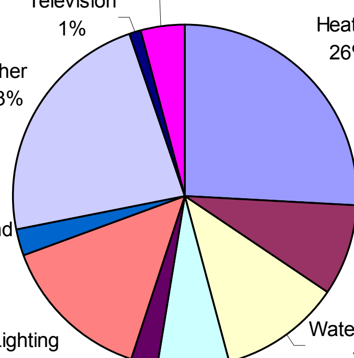
Building Envelope
Windows

Buildings consist of a complex system of interacting components facing variable input conditions

Materials Intensity

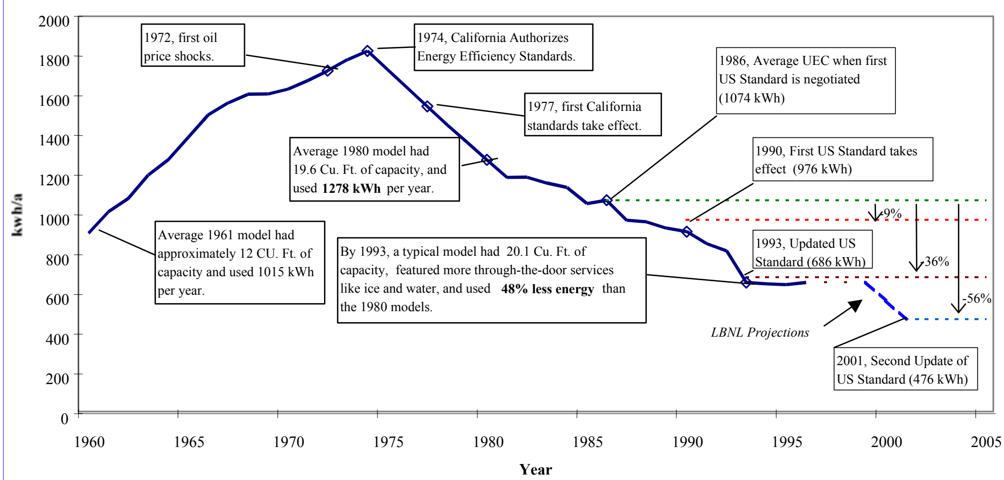
Residential and Commercial Building Energy Use

(34.7 Quads, 1999)



U.S. Refrigerator Energy Consumption

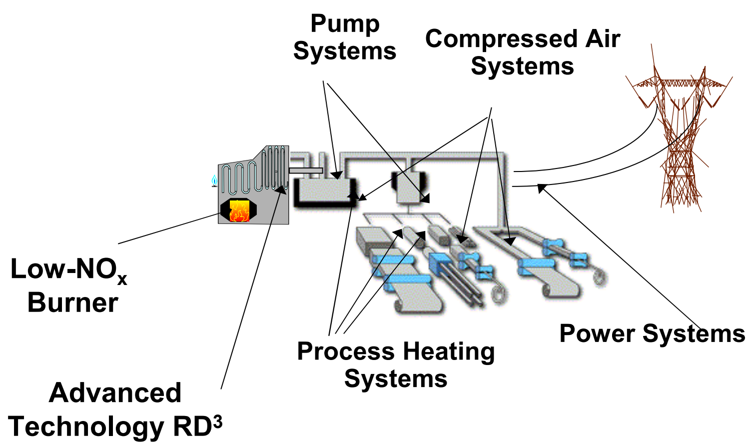
(Average energy consumption of new refrigerators sold in the U.S.)



Science In the Buildings Sector

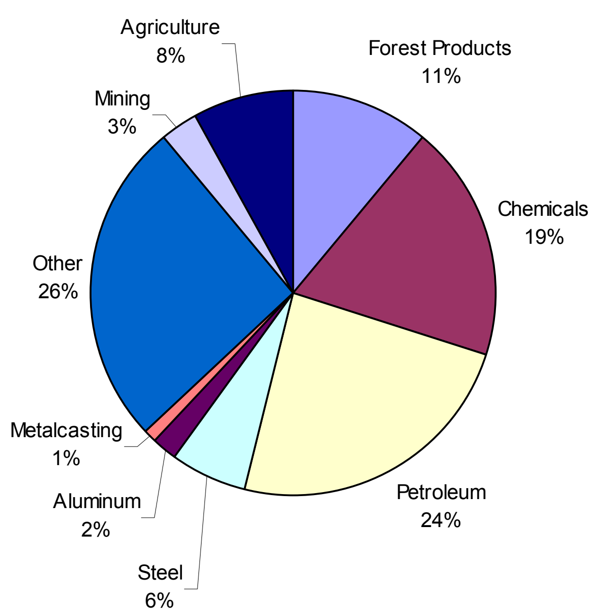
- **Advanced Refrigeration, Air Conditioning (FCVs):** (CFCs=>HFCs)
  - Magnetocaloric effect with Gd-Si-Ge alloys; Nd-Fe-B permanent magnets
- **Advanced Lighting**
  - LEDs, OLEDs, multiphoton phosphors (no Hg), nanostructured filaments
- **Windows**
  - Spectrally selective coatings, electrochromics
- **Power Electronics, Sensors, Controls**
  - Low-loss electronics
- **Water Heaters**
  - UV-, temperature-, and pressure-resistant polymers

Industry

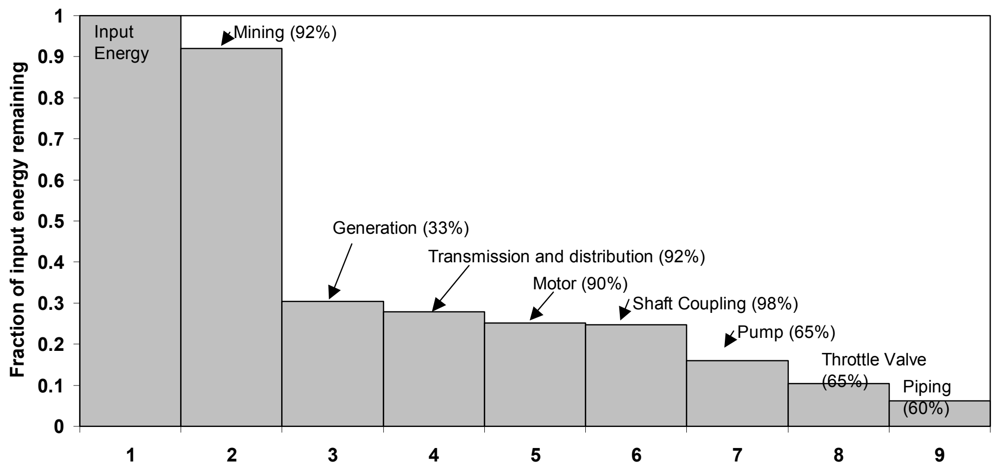


Industrial Energy Use

(35 Quads, 1999)



System Energy Use



Science Needs

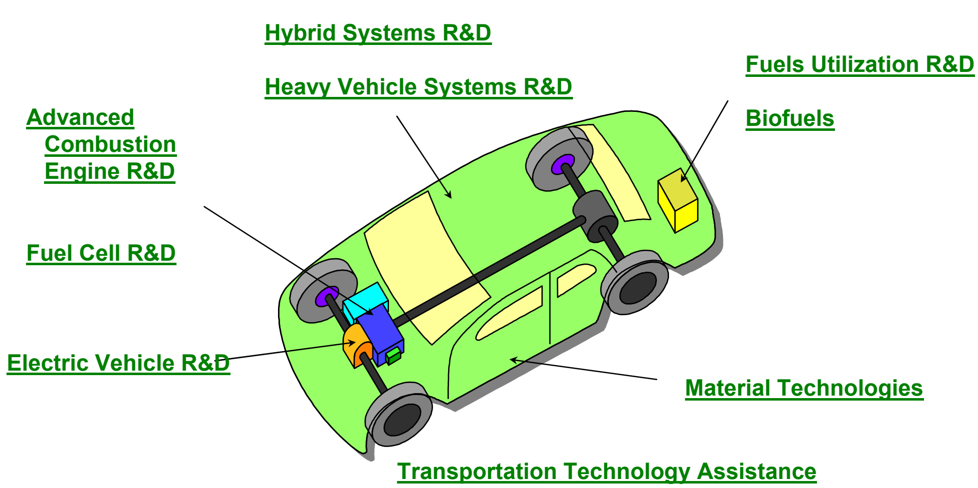
- **Resource extraction:** Remote Sensing (3-D Seismic), Hard materials (PCD drill bits)
- **Generation:** Combustion, Ceramics, Fuel Cells
- **T&D:** Efficient transmission lines; low-loss transformer cores (aSiFe)
- **Motors:** Magnetic materials (NdFeB)
- **ASDs:** Power electronics, sensors, controls
- **Pumps, piping:** Computational fluid dynamics.

Leverage

Science in the Industrial Sector

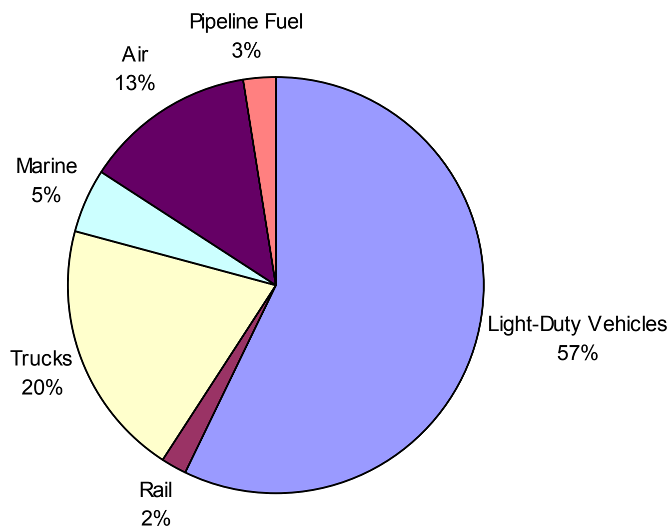
- **Advanced Materials; Advanced Processes**
  - Longer lifetimes, substitutes; advanced processing techniques
- **Efficient, high temperature separations**
  - High temperature membranes, filters; Separation in multicomponent systems
- **Improved process control**
  - Sensors (high operating temperatures, sensitivities)
- **Chemical, petroleum refining operations**
  - Heterogeneous catalysis/surface chemistry; homogeneous catalysis/metalorganic chemistry; separation science; materials properties/synthesis; diagnostics
- **Boilers, furnaces, gasifiers**
  - Efficiency, emissions, gas cleanup: Combustion science; chemistry
- **Industrial process flows, heat transfer, etc.**
  - Multiphase flows, heat transfer, etc.: Computational fluid dynamics.
- **Metal castings**
  - Alloys: alloy chemistries, properties, processing: Materials Science
  - Rapid, non-destructive evaluation of alloy chemistry/properties: Diagnostics

Transportation Technology



Transport Energy Use

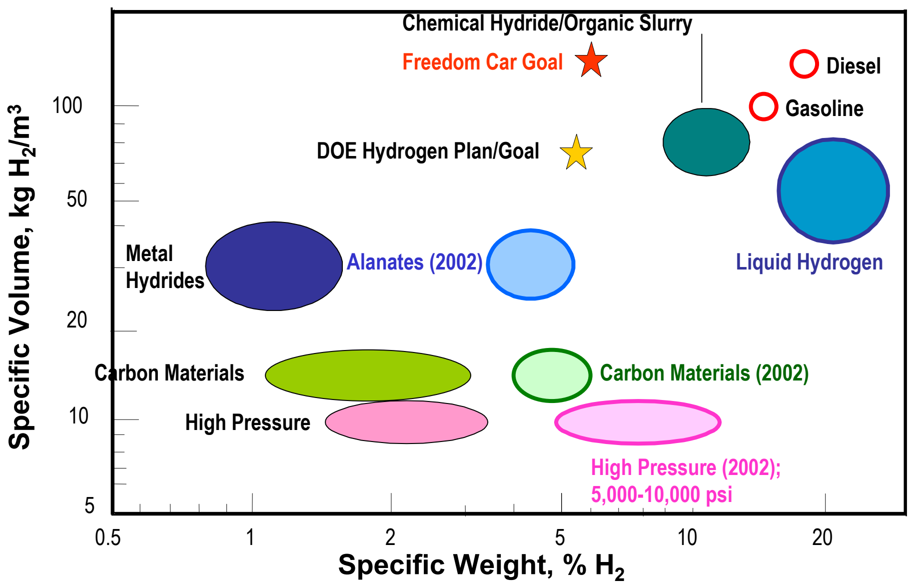
(26 Quads, 1999, 96.7% petroleum)



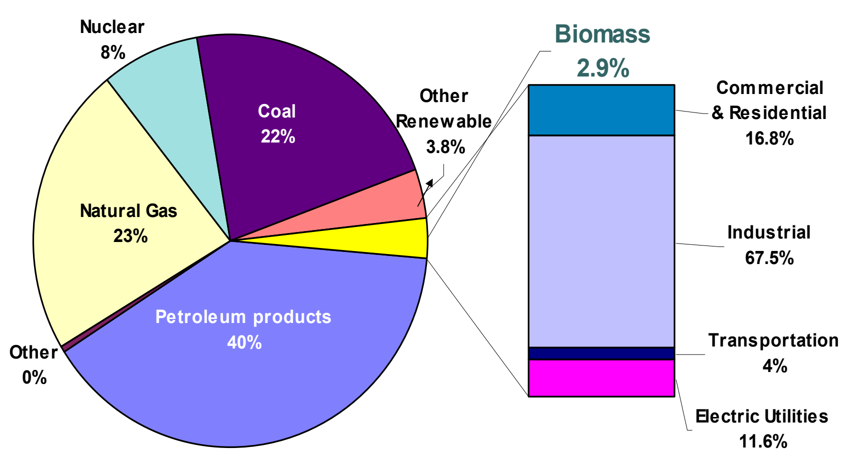
Science in the Transport Sector

- **Advanced Fuels:** petroleum-based, biomass-based
- **Hydrogen production and storage**
  - Fossil fuels; biomass; nuclear; solar; solar thermochemical (S-I, other cycles)
  - Carbon nanostructures, chemical hydrides.
- **Fuel Cells:** Cost, platinum loading, fuel processing/reformers, water/air mgmnt
  - Electrocatalysis, ionic transport in polymer electrolytes, fuel processing catalysis
- **High performance engines**
  - Real-time, high sensitivity multispecies measurements => Diagnostics.
  - Soot formation and evolution => Chemistry
  - Lean NOx catalysts w. high conversion rate over a wider exhaust temp range
  - Low speed flows; turbulence; multiphase flows => CFD
- **Aerodynamic drag**
  - Low speed flow; turbulence => CFD
- **Frames**
  - Composite materials => Materials Science
- **High Power Energy Storage**: Cost ($300), Life (15 yrs), Abuse Tolerance
  - Electrochemistry
- **Advanced Motors/Power Electronics**: Cost ($4/kW, $7/kW), Reliability (15y)

Hydrogen Storage Goals



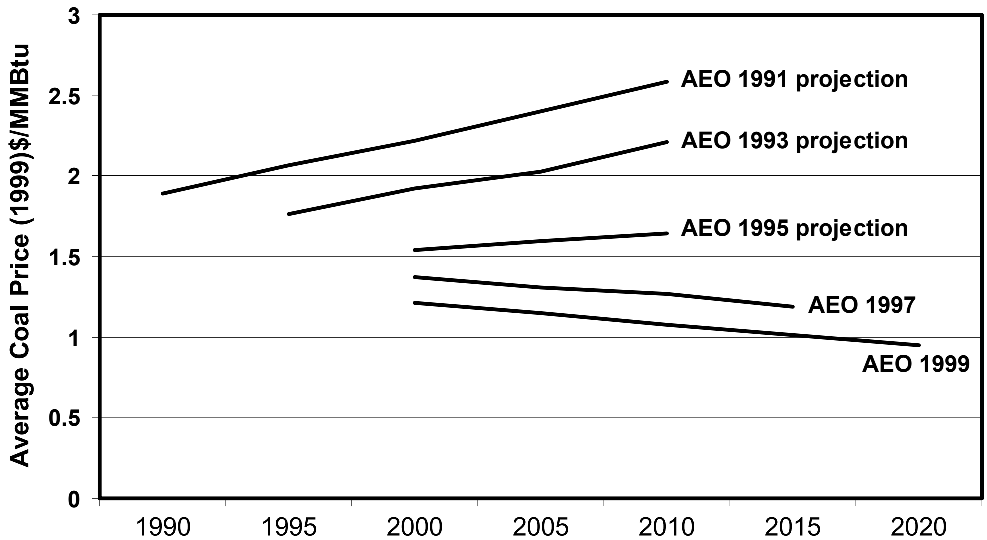
Bioenergy



Total Consumption = 96 Quads
Biomass = 2.9 Quads

Research Design

EIA AEO Coal Price Projections



Biorefinery

Biomass Feedstock

– Trees
– Forest Residues
– Grasses
– Agricultural Crops
– Agricultural Residues
– Animal Wastes
– Municipal Solid Waste

Conversion Processes

- Acid Hydrolysis/Fermentation
- Enzymatic Fermentation
- Gas/liquid Fermentation
- Thermochemical Processes
- Gasification/Pyrolysis
- Combustion
- Co-firing

USES

Fuels:
Ethanol
Renewable Diesel
Methanol
Hydrogen

Electricity

Heat

Products
– Plastics
– Foams
– Solvents
– Coatings
– Chemical Intermediates
– Phenolics
– Adhesives
– Fatty acids
– Acetic Acid
– Carbon black
– Paints
– Dyes, Pigments, and Ink
– Detergents
– Etc.

Science in Bioenergy & Bioproducts

- **Feedstock production**
  - Plant growth and response to stress (and on marginal lands)**;**
  - Higher productivity at lower input (water, fertilizer, etc.)
  - Production of certain components and/or new components

  => Functional genomics; biochemistry; physiology; cellular control mechanisms; respiration; photosynthesis, metabolism, nutrient use, disease response
- **Biochemical pathways**

  => Biocatalysis: enzyme function and regulation; enzyme engineering; catalyst reaction rates and specificity
- **Thermochemical pathways**

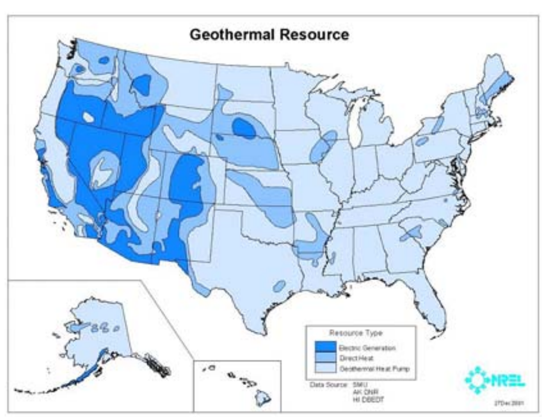
  => Product-selective thermal cracking of biomass; CFD modeling
- **Bioproducts**

  => New and novel monomers and polymers;
  - Biomass composites; => adhesion/surface science
- **Combustion**

  => NOx chemistry; CFD modeling

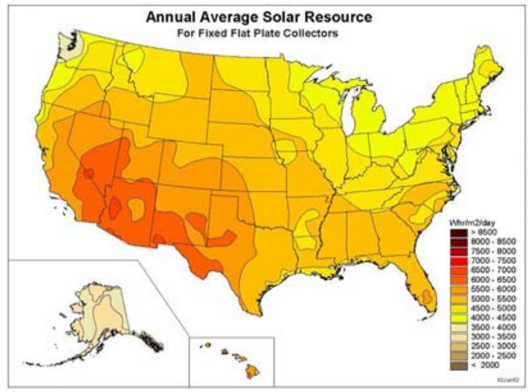
U.S. Geothermal Resource

- **R&D has reduced cost of geothermal power from 15 cents per kilowatt-hour in 1985 to a range of 5-8 cents per kilowatt-hour today.**
- **2007 target: 3-5 cents per kilowatt hour.**

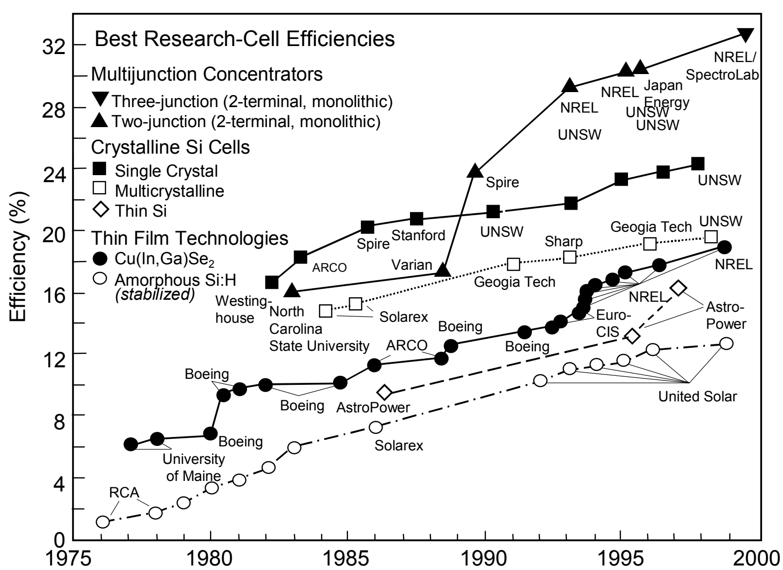


U.S. Solar Resource (PV)

- **R&D has reduced of PV power from $2.00 per kilowatt-hour in 1980 to the current range of 20-38 cents per kilowatt-hour.**
- **2020 target: 5 cents per kilowatt-hour.**

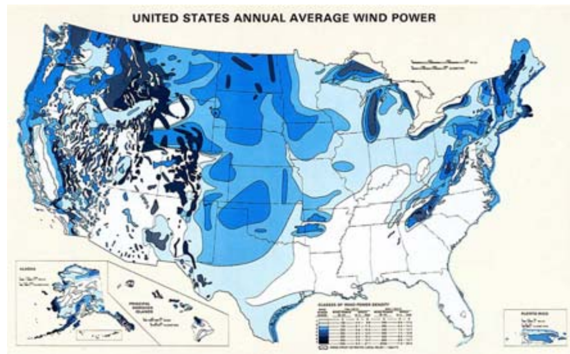


BEST RESEARCH CELL EFFICIENCIES



U.S. Wind Resource

- **R&D has reduced cost of wind power from 80 cents per kilowatt-hour in 1979 to a current range of 4-6 cents per kilowatt-hour (Class 6).**
- **2010 target: 3 cents per kilowatt hour (in Class 4 and above regimes.**
- **New R&D focus: low speed wind tech.; x20 resource; x5 proximity**



Science in the Power Sector

- **Photovoltaics**
  - Materials, growth, characterization,
  - multi-junction thin films—interface chemistry, physics, defects, materials compatibility; Quantum dot cells, multiple quantum well devices, etc.
- **Geothermal**
  - Geoscience: formation/flow of fluids through fractured media; characterizing geology; geochemistry; remote sensing
- **Wind**
  - Computational fluid dynamics to model turbulent flow for wind turbine design
  - Modeling meso-scale atmospheric phenomena for wind forecasting for utilities
  - Composite materials—materials strength, fatigue properties
- **HTS**
  - Materials, cryogenics
- **Remote sensing**
  - algorithms for determining atmospheric and surface properties (aerosol optical depth, surface insolation, surface winds, bioenergy resources)

Time Constants

• **Consensus building**	**~ 2-20+**
• **Science**	**~10+**
• **Technical R&D**	**~10+**
• **Production model**	**~ 4+**
• **Financial**	**~ 2+**
• **Market penetration**	**~10-20+**
• **Capital stock turnover**	**~15-100+**
– Cars	15
– Appliances	10-20
– Industrial equipment/facilities	10-30/40+
– Power plants	40
– Buildings	40-80
– Urban form	100's
• **Lifetime of Greenhouse Gases**	**~100's-1000's**
• **Reversal of Land Use Change**	**~100's**
• **Reversal of Extinctions**	**Never**