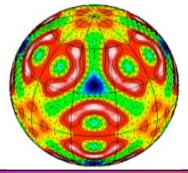


BASIC ENERGY SCIENCES
Serving the Present, Shaping the Future

Our Energy Challenges in a New Era of Science

The Collision of Today's Energy Reality, Society, Politics, and Science

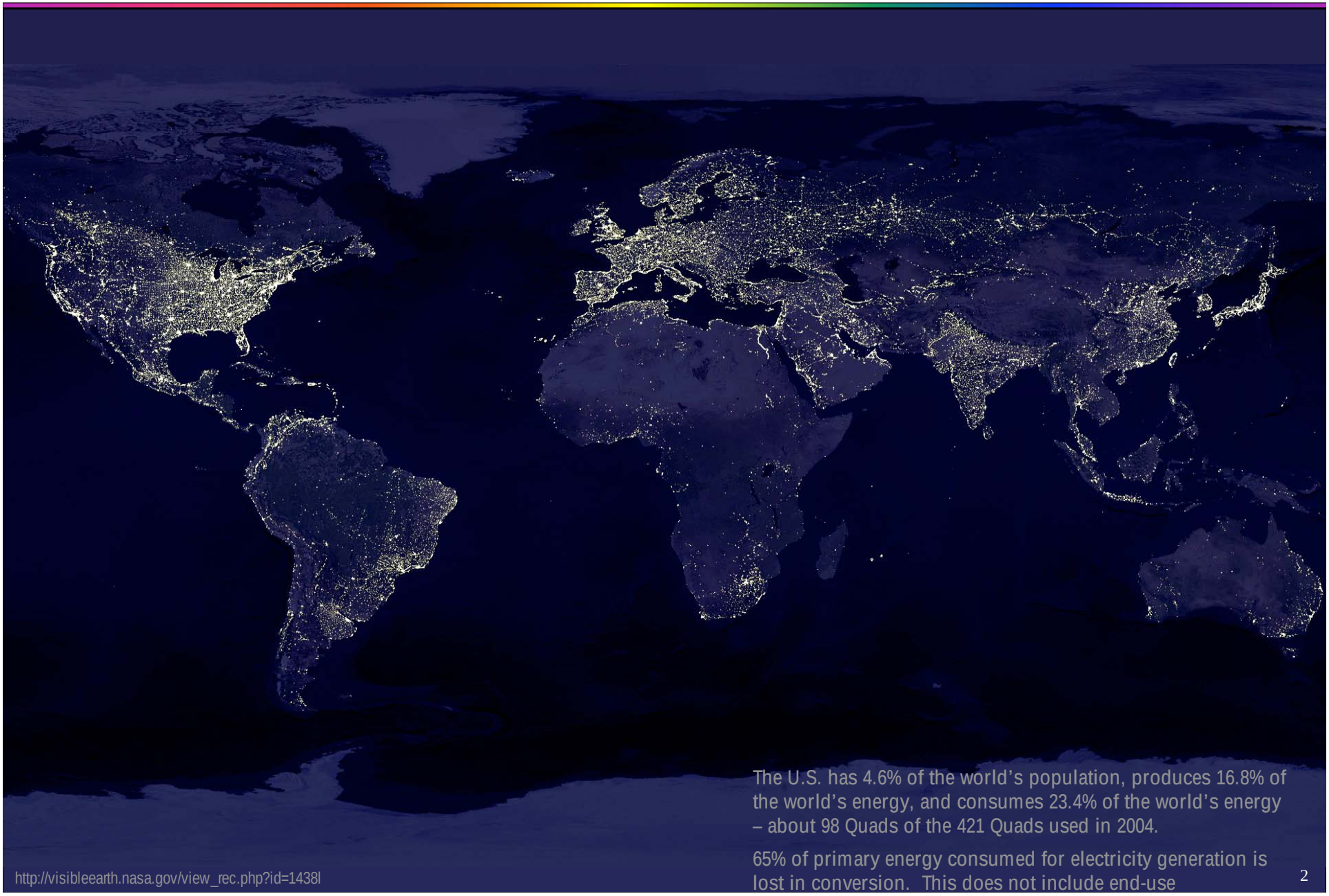
Patricia M. Dehmer
Director, Office of Basic Energy Sciences
Office of Science, U.S. Department of Energy
http://www.science.doe.gov/bes/

Today's Talk: http://www.science.doe.gov/bes/presentations/index.html

March Meeting of the American Physical Society
March 15, 2006

A Snapshot of Global Electric Power Usage

Artificial night sky brightness from the Defense Meteorological Satellite Program (DMSP)



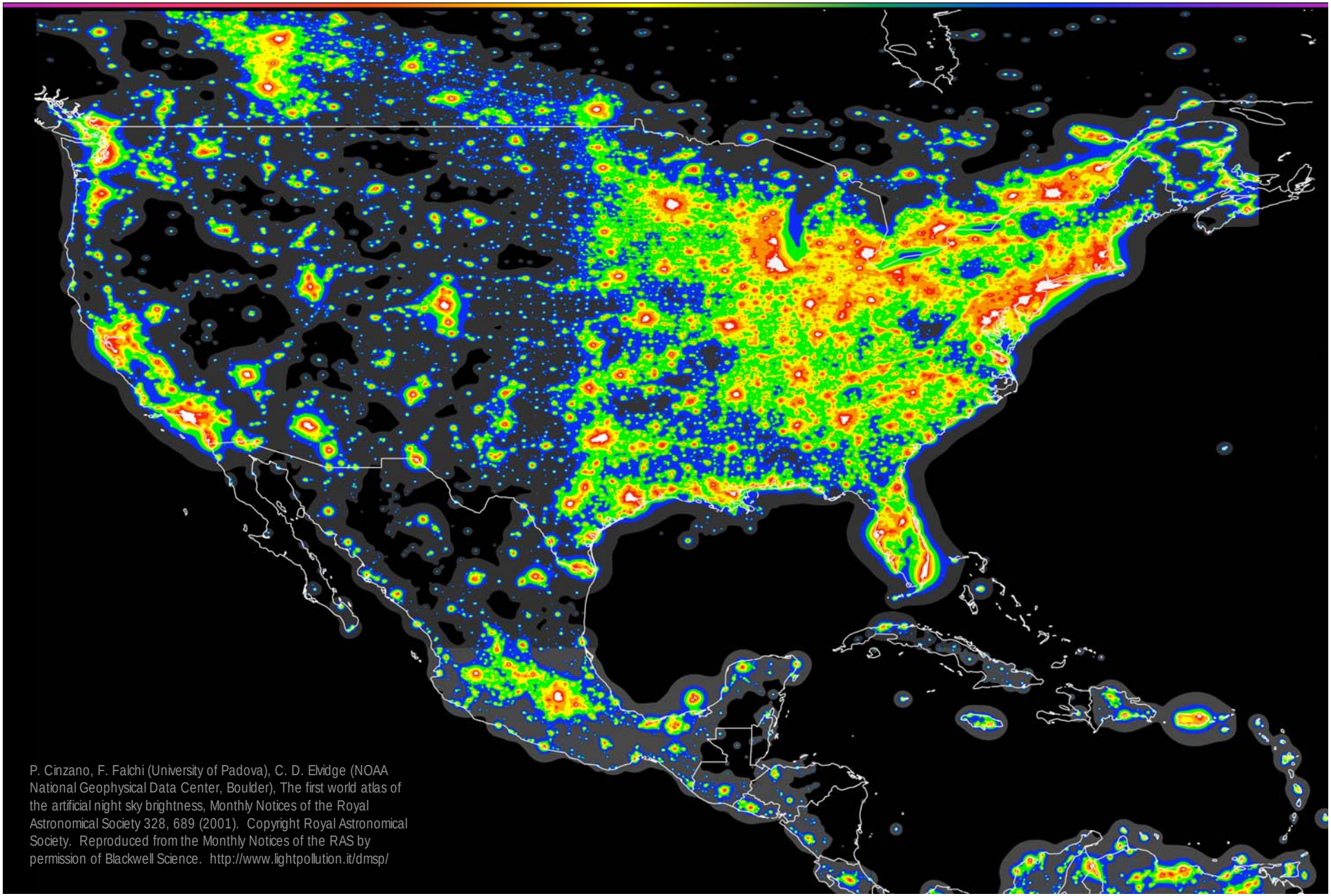
The U.S. has 4.6% of the world's population, produces 16.8% of the world's energy, and consumes 23.4% of the world's energy – about 98 Quads of the 421 Quads used in 2004.

65% of primary energy consumed for electricity generation is lost in conversion. This does not include end-use

http://visibleearth.nasa.gov/view_rec.php?id=1438l

Radiance-calibrated Artificial Night Sky Brightness for the U.S.

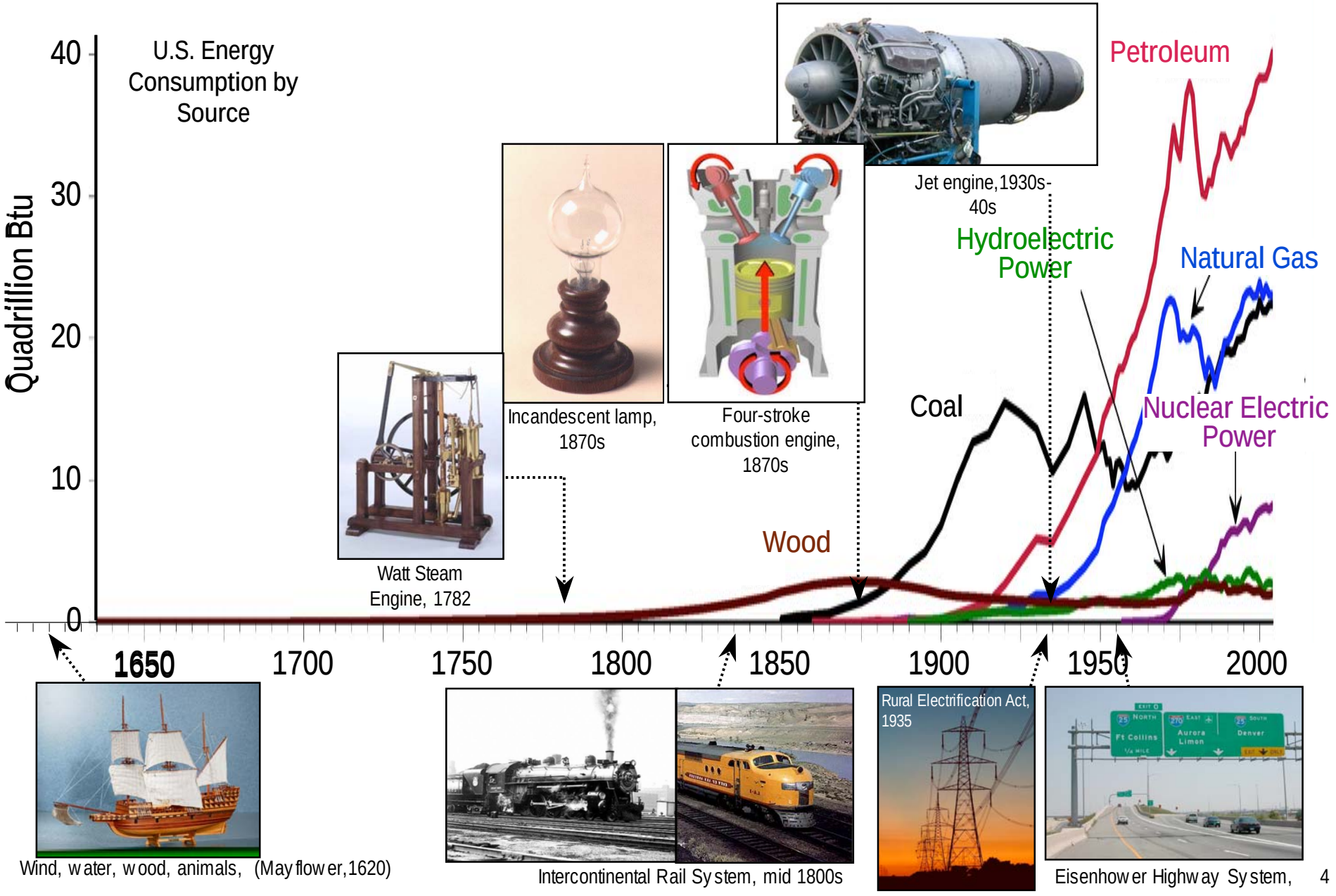
>2/3 of the U.S. population has lost naked-eye visibility of the Milky Way



P. Cinzano, F. Falchi (University of Padova), C. D. Elvidge (NOAA National Geophysical Data Center, Boulder), The first world atlas of the artificial night sky brightness, Monthly Notices of the Royal Astronomical Society 328, 689 (2001). Copyright Royal Astronomical Society. Reproduced from the Monthly Notices of the RAS by permission of Blackwell Science. http://www.lightpollution.it/dmsp/

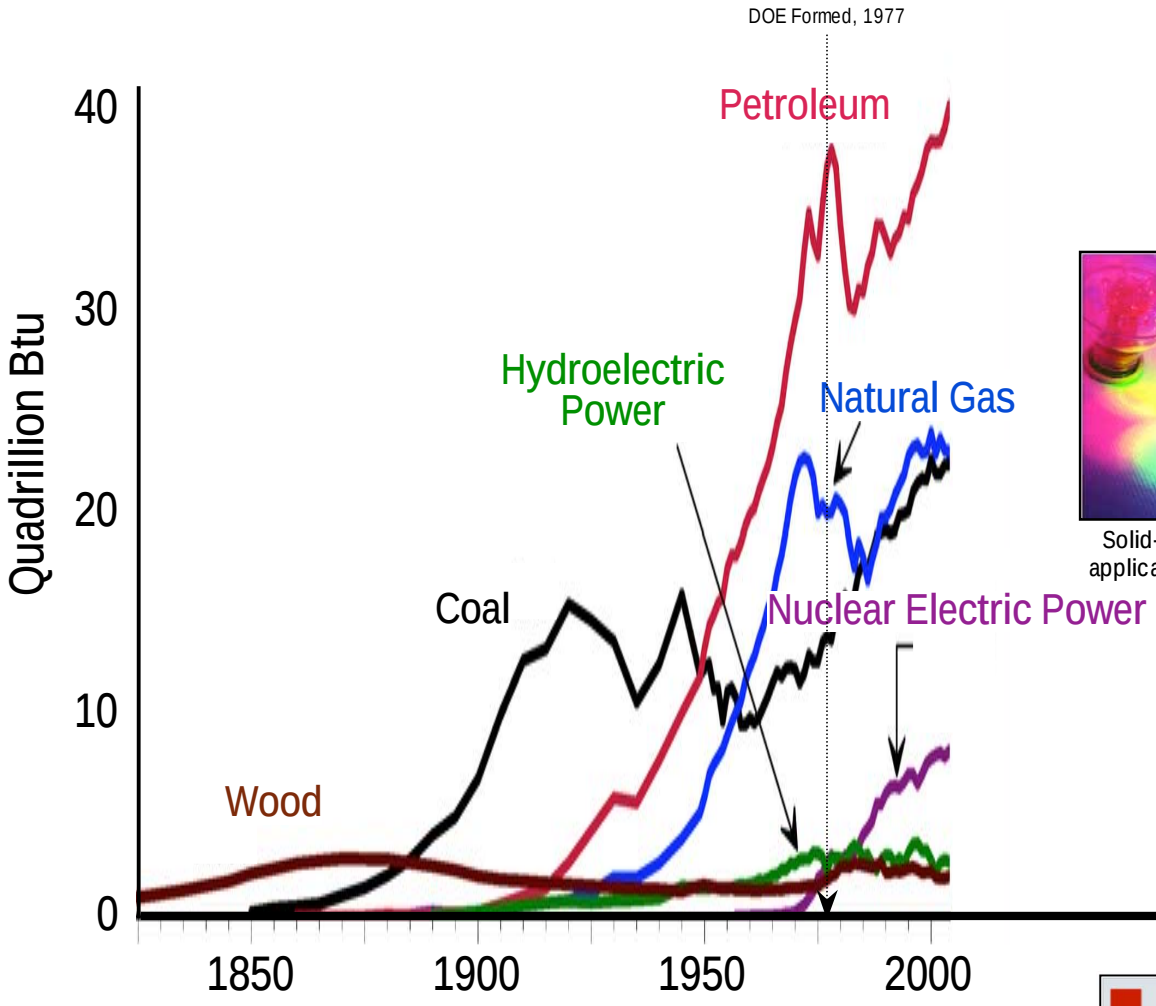
Technology, Energy, and Society are Inextricably Intertwined

Today's Energy Technologies and Infrastructures are Firmly Rooted in the 20th Century

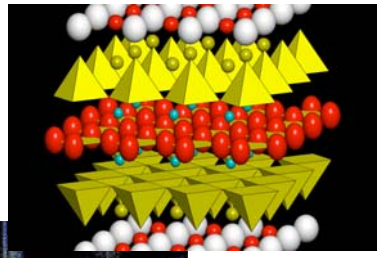


What Will the 21st Century Bring?

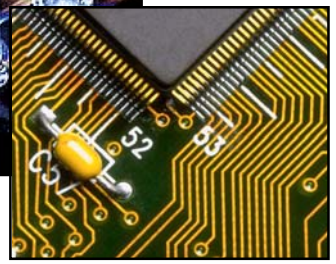
21st Century Science and Technology Will Exert Control at the Atomic, Molecular, and Nanoscale Levels



High Tc super-conductors

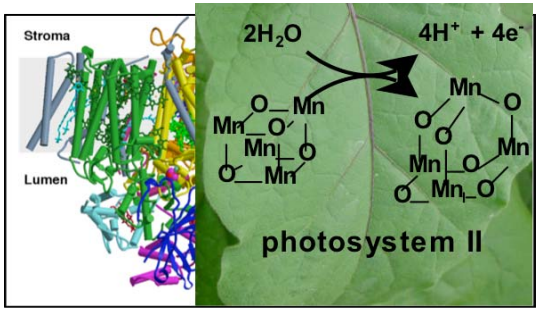


Solid-state lighting and many other applications of quantum confinement



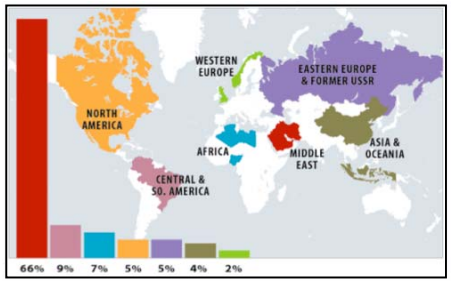
Peta-scale computing

Bio-inspired nanoscale assemblies – self-repairing and defect-tolerant systems.

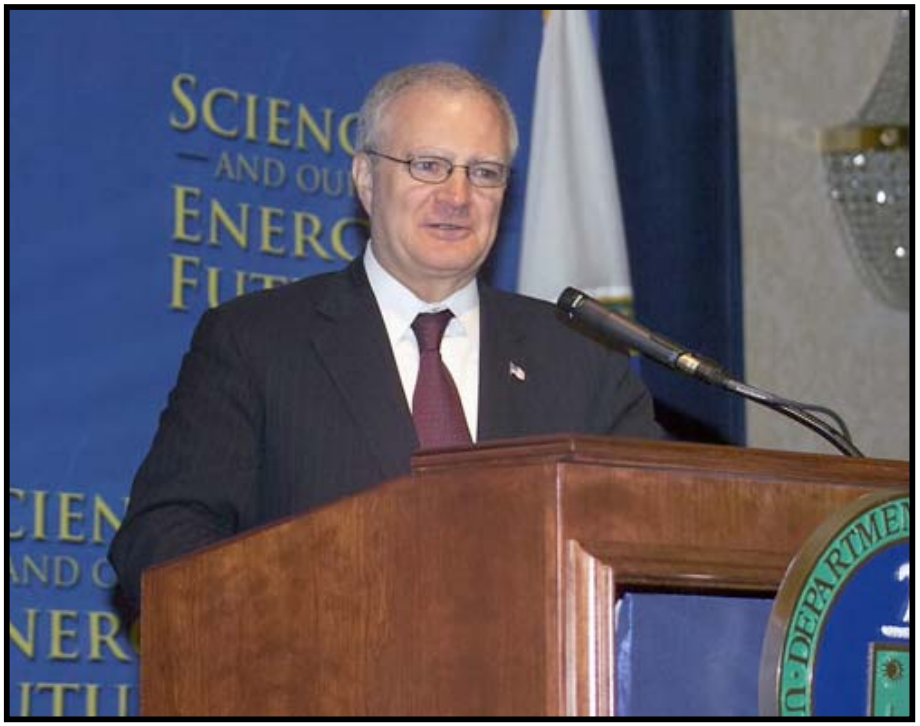


Why change?

- World-wide supply and distribution of petroleum reserves
- Environmental impacts of fossil fuels



Meeting Our Energy Challenges in a Revolutionary Era of Science



John Marburger, Director, Office of Science and Technology Policy, Executive Office of the President

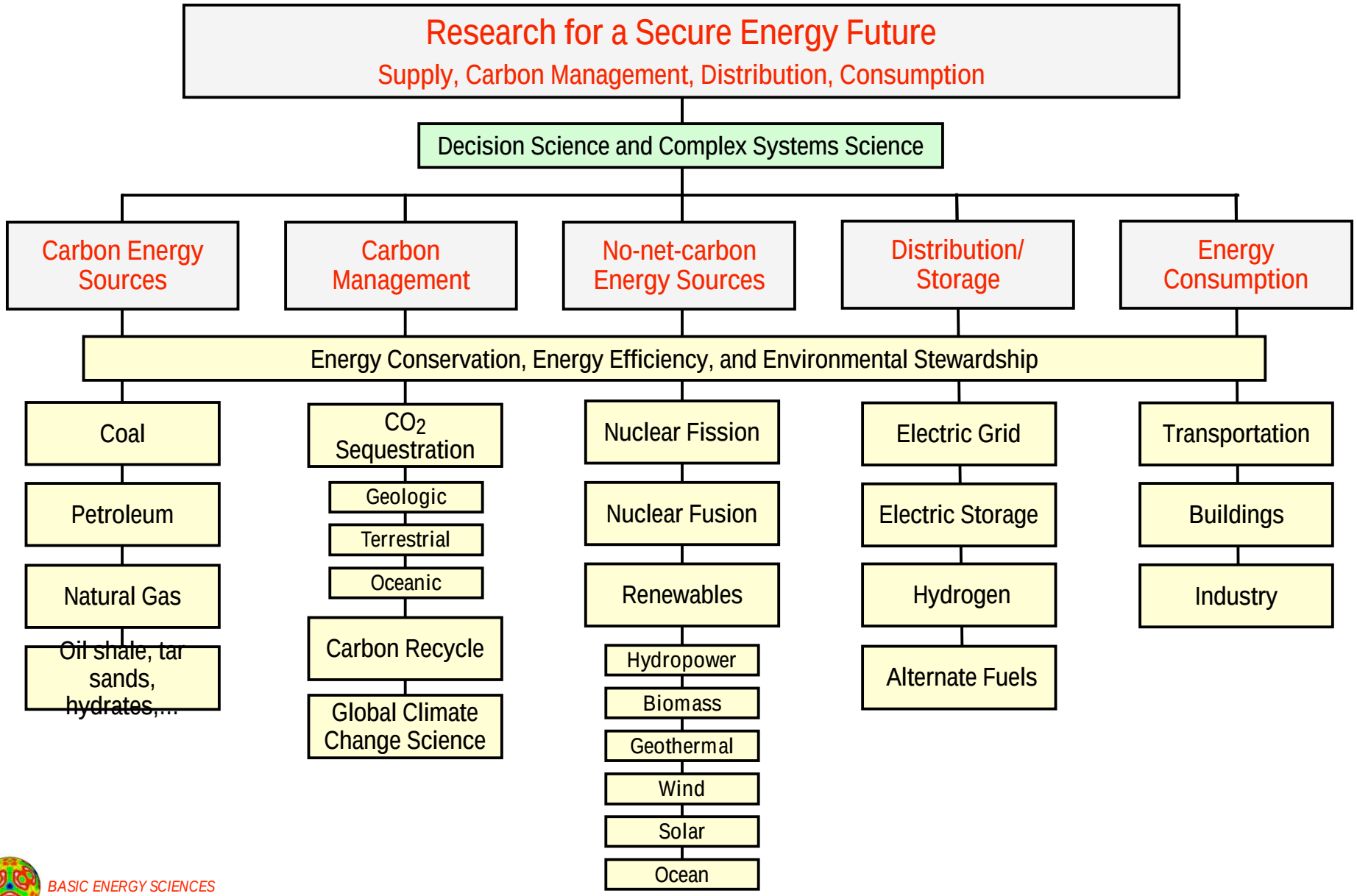
Transforming Our Energy Future: Advancing the Role of Science and the Critical Connections with Applied Energy Programs, Oak Ridge National Laboratory, November 15, 2005

http://www.science.doe.gov/sc-5/AHGSET/presentations/Tuesday%20Nov15/J.Marburgerspeech.doc

"… all these examples depend on improvements in various materials – catalysts, photovoltaics, batteries, fuel cells, solid state light sources, even hydrogen storage media – in each case the relevant materials have desirable functional properties that originate in their small scale structure. And it is here that our current revolutionary science capabilities can have significant impact. In our industrially developed nations, no single application will have the revolutionary effect of the steam engine, but at multiple points in the existing complex energy infrastructure the materials advances we can expect from science will profoundly influence the cost and environmental impact of many end uses.

As we contemplate how we will meet our energy challenges, we need to keep the entire system in mind, from primary fuels to social behavior."

Science for Comprehensive Decades-to-Century Energy Plan



Science for Comprehensive Decades-to-Century Energy Plan

Research for a Secure Energy Future

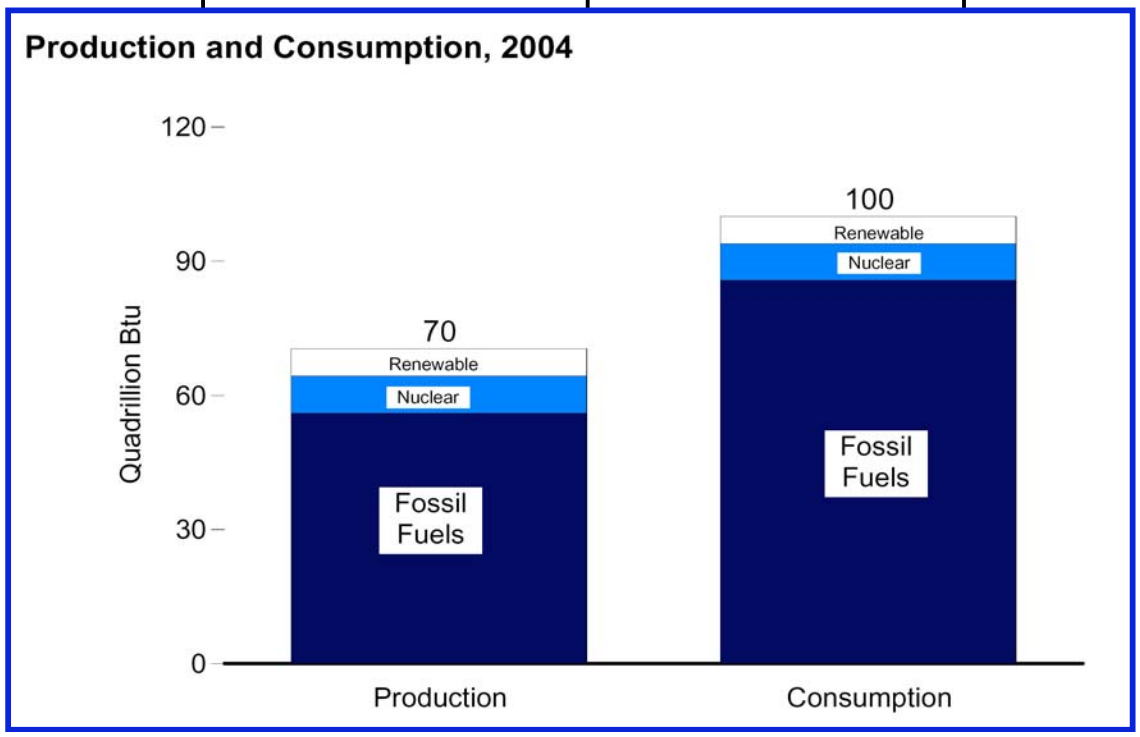
Supply, Carbon Management, Distribution, Consumption

Decision Science and Complex Systems Science

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

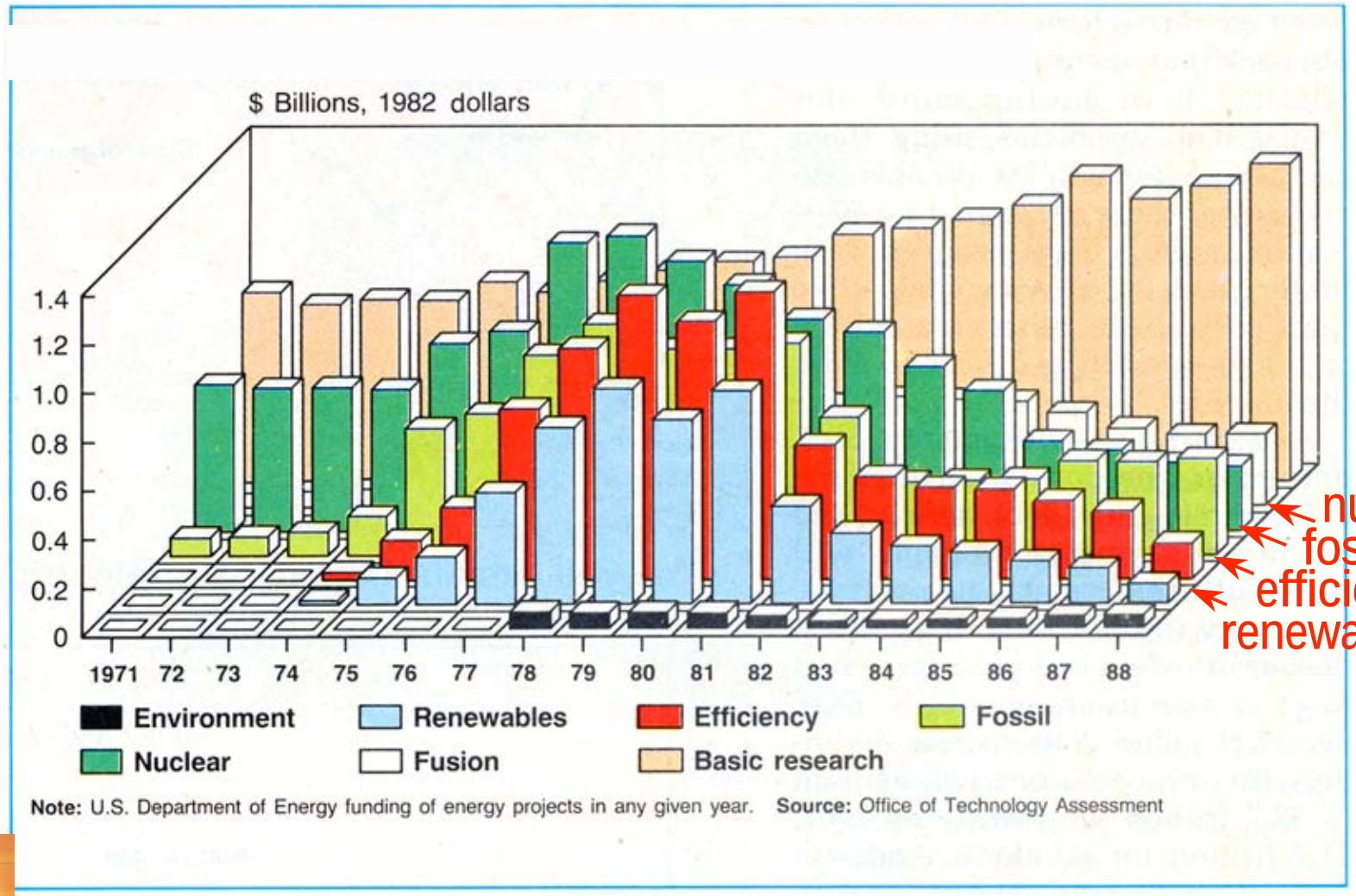
Energy Conservation, Energy Efficiency, and Environmental Stewardship

- Electric Grid
  - Electric Storage
    - Hydrogen
      - Alternate Fuels
- Transportation
  - Buildings
    - Industry

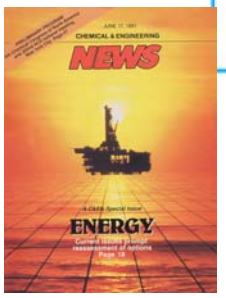


A Decades-to-Century Energy Plan Must Have a Consistent Long-term Vision

Applied energy research increased rapidly following the 1973 oil embargo and then fell sharply

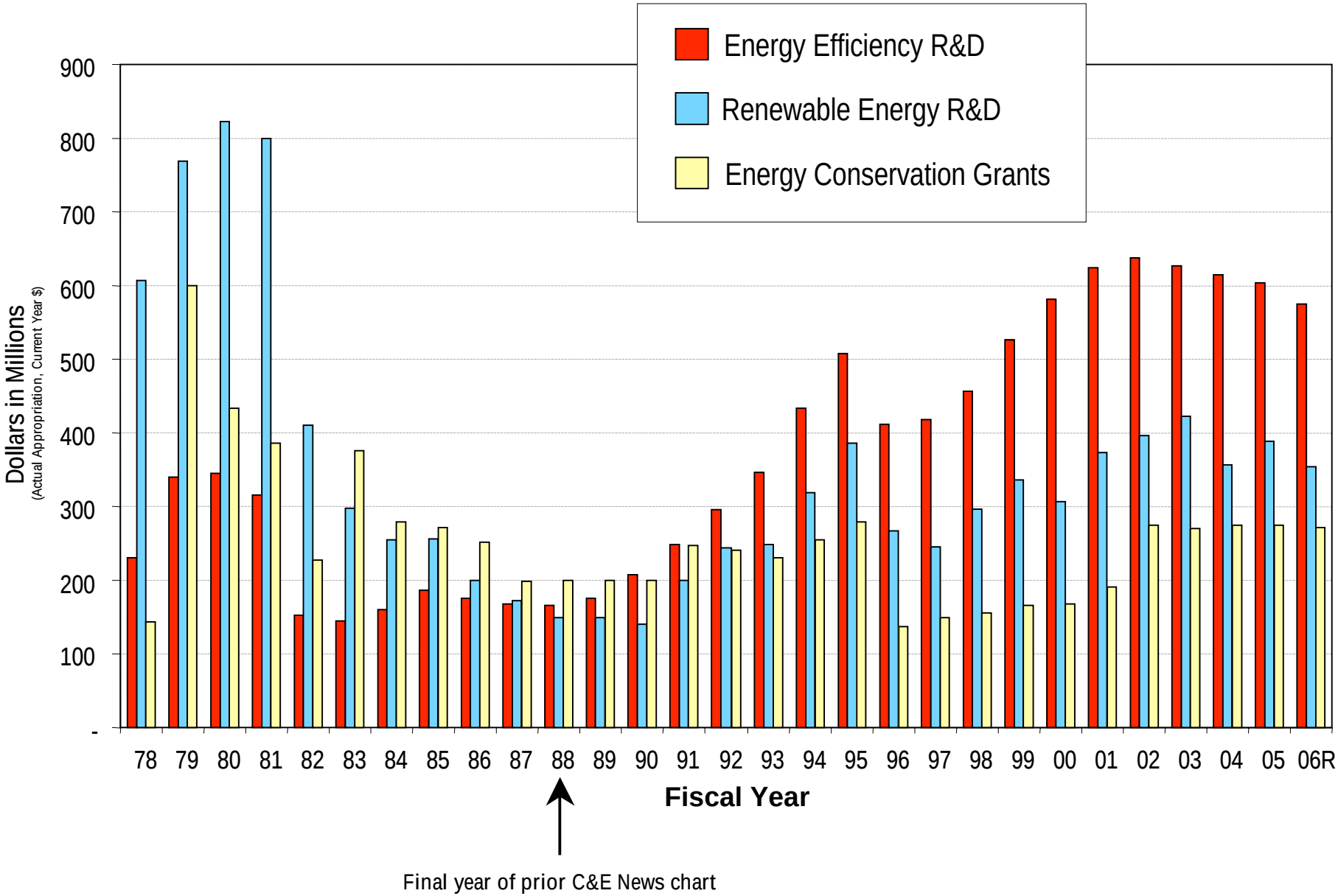


nuclear
fossil
efficiency
renewables

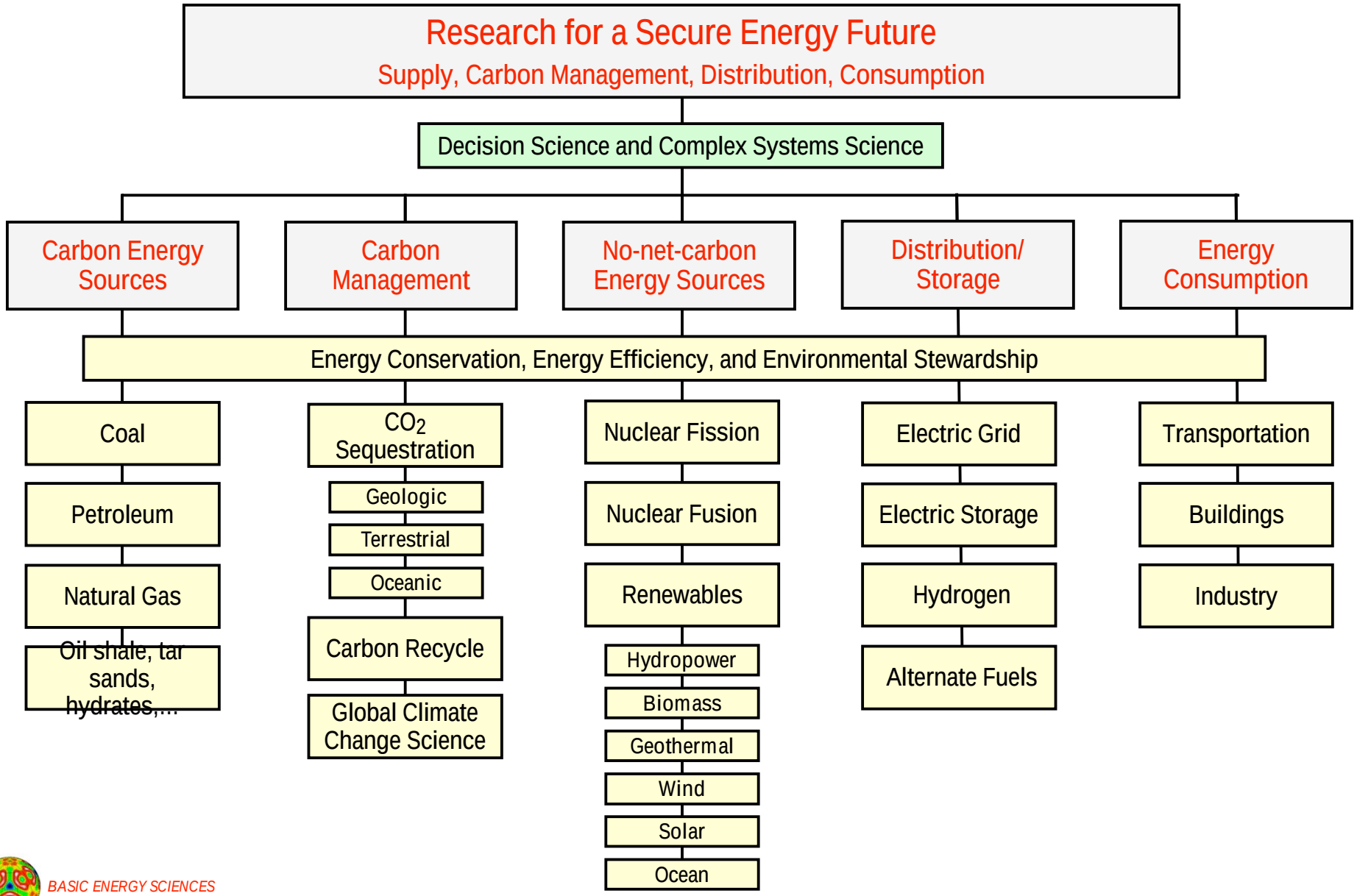


Source: *Chemical & Engineering News*,
" Energy Policy," p.29, June 17, 1991

EE & RE Budget Trends Show Significant Fluctuations for the Past 30 years



Science for Comprehensive Decades-to-Century Energy Plan



The BES "Basic Research Needs for ..." Series of Studies

RECOMMENDATION: 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.

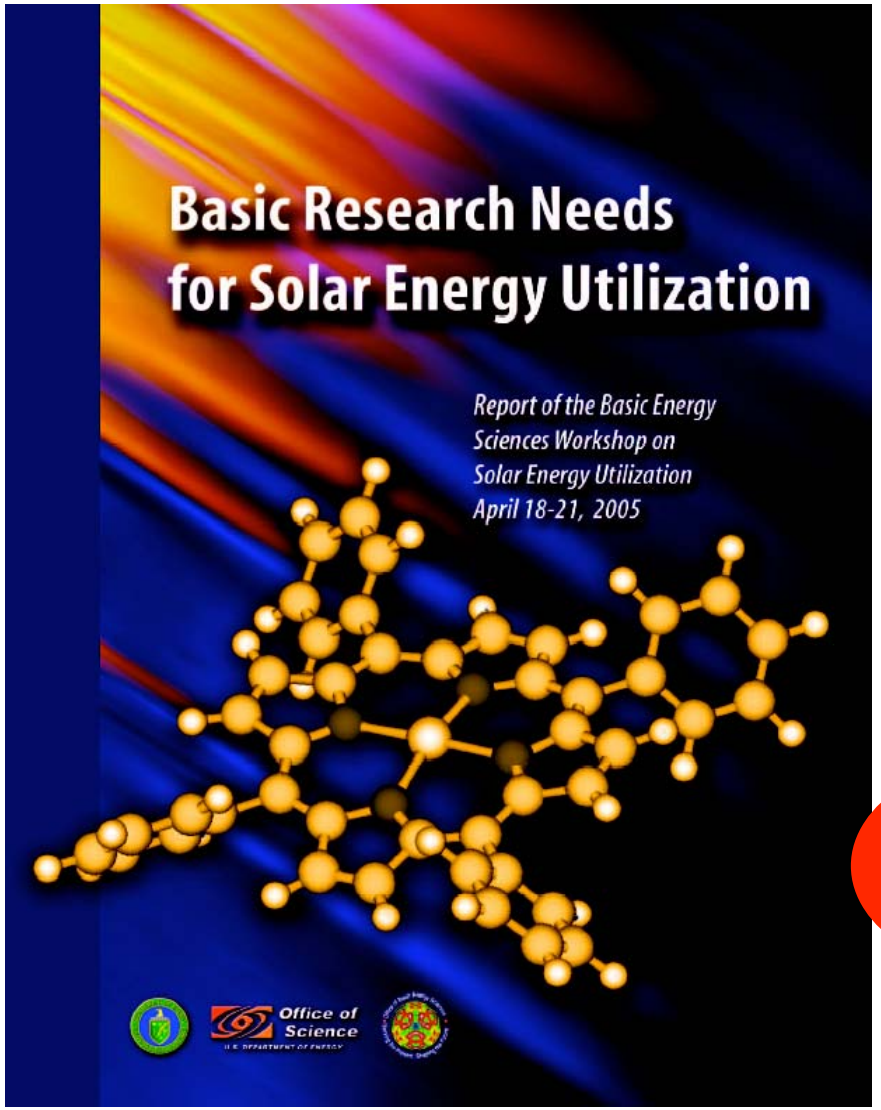
February 2003

"Basic Research Needs …" and Other Workshops

Help Define Research Directions and Provide the Links to Societal Needs

- **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 Advanced Nuclear Energy Systems**
  BES Workshop, July 31-August 3, 2006
- **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 Combustion of Alternate Fuels**
  BES Workshop, October 30-November 1, 2006 (tentative)
- **Basic Research Needs for Energy Storage**
  BES Workshop, mid FY 2007

The "Basic Research Needs for ..." Format



CONTENTS

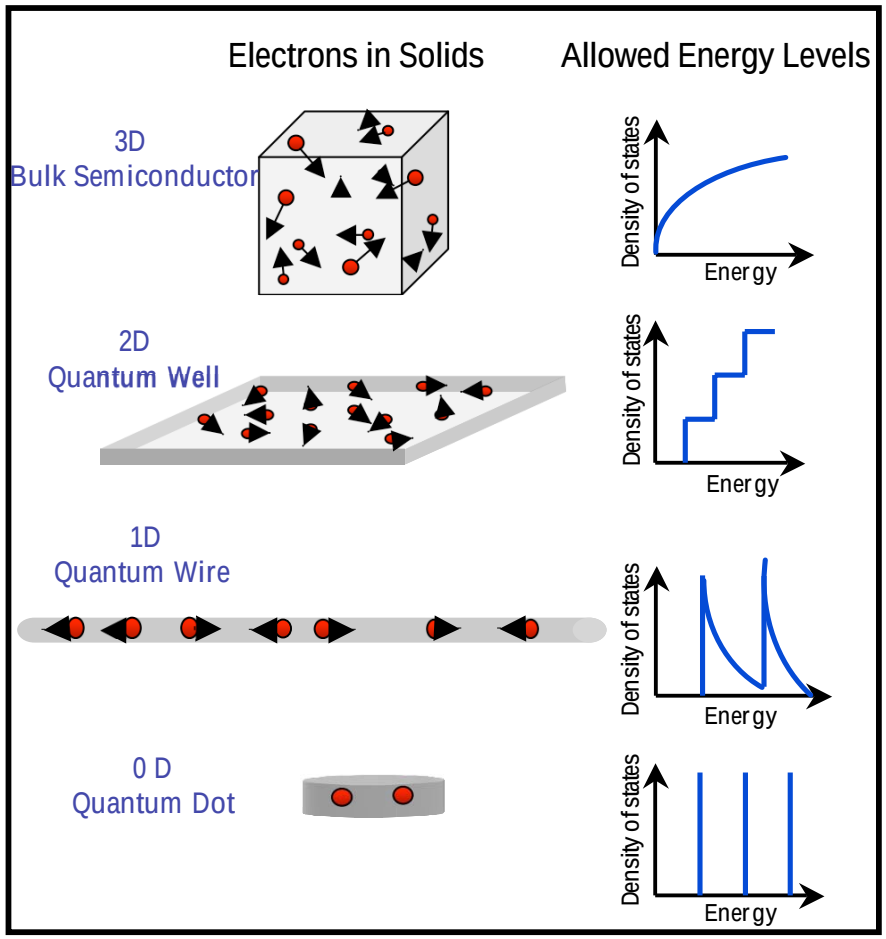
New Section for Future Workshops:
Crosscutting Science and Grand Challenges

Many Crosscutting Science 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 in both chemistry and materials sciences
- Bio-materials and bio-chemical 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

Quantum Confinement

Fundamental new states of matter in low-dimensional electron systems suggest paths for new materials



- In 3D systems, the interaction between electrons is very small. The electrons can be viewed as individual particles without correlations and their kinetic energy dominates the behavior- as described in the Fermi liquid theory.
- In lower dimensions, the electrons are forced into much stronger interactions with each other and surprising physical behavior emerges.
- The electronic properties are drastically modified in low dimensional systems. Examples range from gold nano catalyst to quantum dots with different spectroscopic properties.
- To exploit the fundamentally new states in low dimensional systems requires a many-body approach to characterize, manipulate and predict the strong correlations among the huge number of electrons (i.e. the response of each electron strongly influences the behavior of all other electrons in the system).

As the system dimension reduces, electron collisions become inevitable. The strong electron interactions and correlations result in new physical phenomena.

Tackling the Parts of a Decades-to-Century Energy Plan

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

Superconductivity

Solid-state lighting

Energy Efficiency, and Environmental Stewardship

Coal

Petroleum

Natural Gas

Oil shale, tar sands, hydrates,...

CO_2 Sequestrat

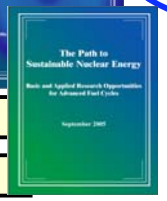
Geologi

Terrestrial

Oceanic

Carbon Recycle

Global Climate Change Science



Nuclear Fission

Nuclear Fusion

Renewables

Hydropower

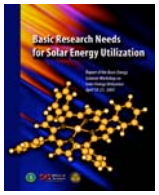
Biomass

Geothermal

Wind

Solar

Ocean



Electric Grid

Electric Storage

Hydrogen

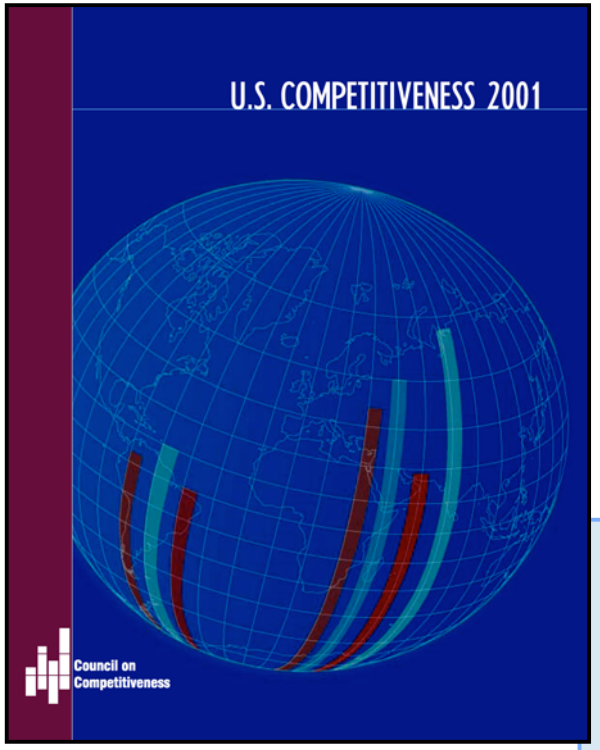
Alternate Fuels

Transportation

Buildings

Industry

U.S. Competitiveness – A Theme that Runs Deep



U.S. Competitiveness 2001: Strengths, Vulnerabilities and Long Term Priorities, Council on Competitiveness

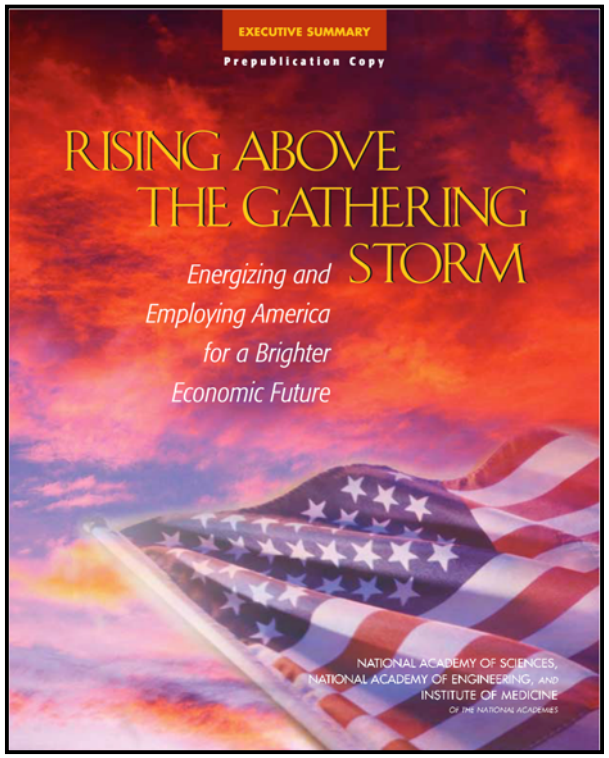
http://www.compete.org/pdf/Highlights.pdf

"Given the rising bar for competitiveness, the United States needs to be in the lead or among the leaders in every major field of research to sustain its innovation capabilities."

- Increase national investment in frontier research
- Strengthen support for fundamental disciplines that have been neglected
- Expand the pool of U.S. scientists and engineers
  - upgrade K-12 math and science education
  - broaden the S&E pipeline to include women and minorities
  - create incentives for higher education institutions to increase the numbers of graduates in scientific, engineering and technical disciplines
- Modernize the nation's research infrastructure

Rising Above the Gathering Storm:

Energizing and Employing America for a Brighter Economic Future



http://newton.nap.edu/books/0309100399/html
http://newton.nap.edu/ex ecsumm_pdf/11463.pdf

- In the spring of 2005, the National Academies were charged by Congress through two letters, one from Senators Lamar Alexander (R, TN) and Jeff Bingaman (D, NM) *[Energy and Natural Resources Committee]* and one from Representatives Sherwood Boehlert (R, NY) and Bart Gordon (D, TN) *[Committee on Science]*, to address the subject of America's competitiveness.
- The National Academies' Committee on Science, Education, and Public Policy (COSEPUP) established the Committee on Prospering in the Global Economy of the 21st Century: An Agenda for American Science and Technology.
- The Committee of 20 was chaired by Norman Augustine, retired Chairman and CEO of Lockheed Martin.
- The committee assembled issue papers and convened focus groups in K-12 education, higher education, research, innovation and workforce issues, and national and homeland security.
- The key thematic issues underlying the discussions were the nation's need to create jobs and the need for affordable, clean, and reliable energy.
- The report was released on October 12, 2005.

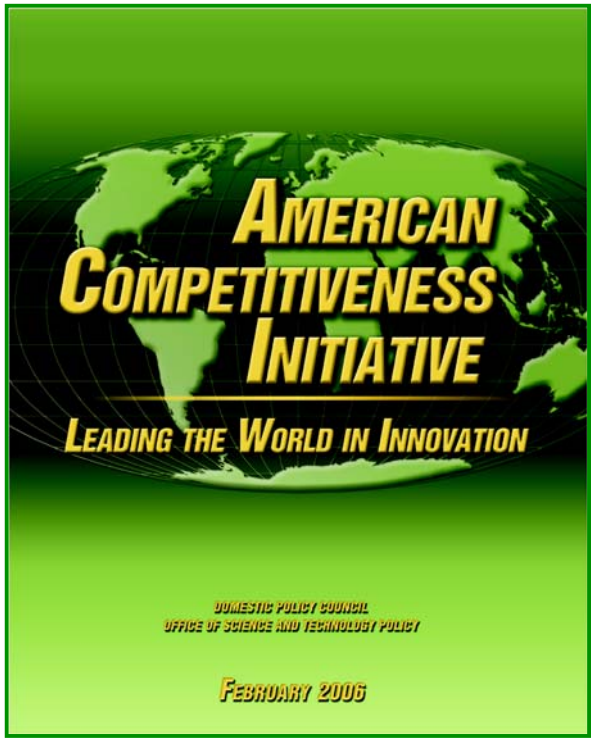
The American Competitiveness Initiative

"Tonight I announce the **American Competitiveness Initiative** to encourage innovation throughout our economy and to give our nation's children a firm grounding in math and science. First, 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."

White House photo by Eric Draper

State of the Union Address
Tuesday, January 31, 2006

The American Competitiveness Initiative



"The centerpiece of the American Competitiveness Initiative is President Bush's strong commitment to double investment over 10 years in key Federal agencies that support basic research programs in the physical sciences and engineering."

"America's economic strength and global leadership depend in large measure on our Nation's ability to generate and harness the latest in scientific and technological developments and to apply these developments to real world applications. These applications are fueled by: scientific research, which produces new ideas and new tools that can become the foundation for tomorrow's products, services, and ways of doing business; …

The 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 National Science Foundation, the Department of Energy's Office of Science, and the National Institute for Standards and Technology within the Department of Commerce.

National Innovation Act of 2005 (S. 2109)

Introduced by Senators Joseph Lieberman (D-CT) and John Ensign (R-NV)

Responds to recommendations contained in the National Innovation Initiative Report of the Council on Competitiveness, focusing on:

Research Investment

- Establishes the Innovation Acceleration Grants Program which encourages federal agencies funding research in science and technology to allocate 3% of their Research and Development (R&D) budgets to grants directed toward high-risk frontier research.
- Increases the national commitment to basic research by nearly doubling research funding for the National Science Foundation (NSF) by FY 2011.
- Makes permanent and modifies the Research and Experimentation (R&E) tax credit.

Science and Technology Talent

- Expands existing educational programs in the physical sciences and engineering by increasing funding for NSF and DOD fellowship programs.
- Authorizes DOD to create a competitive traineeship program for undergraduate and graduate students.
- Authorizes funding for new and existing Professional Science Master's Degree Programs.

Innovation Infrastructure

- Authorizes the DOC to promote the development and implementation of state-of-the art advanced manufacturing systems and to support Pilot Test Beds of Excellence.
- Encourages the development of regional clusters of technology innovation throughout the U.S.
- Empowers DOD to identify and accelerate the transition of advanced manufacturing technologies and processes.

Protecting America's Competitive Edge through Energy (PACE – Energy, S. 2197)

Introduced by Senators Domenici (R-NM), Bingaman (D-NM), Alexander (R-TN), and Mikulski (D-MD)

Section 2. Mathematics, Science and Engineering Education at DOE

Amends the DOE Science Education Enhancement Act to appoint a Director to coordinate activities DOE wide. Establishes the following programs.

Sec. 3171. Specialty Schools for Math and Science – Authorizes the Secretary to help states establish or expand public math and science high schools.

Sec. 3175. Experiential-Based Learning Opportunities – Authorizes the Secretary to establish summer internships for middle and high school students.

Sec. 3181. National Laboratories Centers of Excellence in Mathematics and Science Education – Authorizes the Secretary to establish a program at each of the National Laboratories to support a Center of Excellence in Mathematics and Science at one public secondary school.

Sec. 3185. Future American-Scientist Scholarships – Authorizes the Secretary to award college scholarships up to $20,000 per year for up to four years.

Sec. 3191. Graduate Research Fellowships – Authorizes the Secretary to establish a graduate fellowship program.

Sec. 3195. Summer Institutes – Authorizes the Secretary to establish a program of summer institutes to strengthen the math and science teaching skills of K-12 teachers, with a particular focus on K-8 teachers.

Section 3196. Distinguished Scientists – Authorizes the Secretary to establish a program between universities and national laboratories for 100 distinguished scientists who will hold joint appointments to promote academic and scientific excellence between the two institutions.

Section 3. Department of Energy Early Career Research Grants – Authorizes through fiscal year 2011 an independent research program for scientists and engineers who have completed their professional degrees within 10 years of the date of enactment of the Act.

Section 4. Advanced Research Projects Authority – Energy – Establishes the Advanced Research Projects Authority – Energy as a new office within DOE that will report to the Undersecretary for Science. The Authority is modeled on the Defense Advanced Research Projects Authority (DARPA) and will support ground-breaking energy research.

Section 5. Authorization of Appropriations for the Department of Energy Office of Science. Doubles authorized funding levels for basic research in the physical sciences. The authorization levels for the Office of Science follow the National Academy recommendation of 10 percent annual growth from the current 2006 baseline budget through 2013.

House Legislation (H.R. 4596, 4434, 4435)

Introduced by Representative Bart Gordon (D-TN) and others

Sowing the Seeds Through Science and Engineering Research Act (H.R. 4596)

The bill implements recommendations related to *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*. It authorizes 10% increases per year in funding for basic research in the physical sciences, mathematical sciences, and engineering at the principal Federal agencies supporting such research; provides for up to 200 new awards per year, of $100,000 per year for 5 years, to outstanding early-career researchers; creates a new, portable graduate fellowship program for individuals pursuing studies in areas of national need; establishes a presidential innovation award to stimulate scientific and engineering advances in the national interest; and establishes a national coordination office to identify and prioritize research infrastructure needs at universities and national laboratories and help guide the investments of new infrastructure funds authorized for the National Science Foundation and the Department of Energy

10,000 Teachers, 10 Million Minds Science and Math Scholarship Act (H.R. 4434)

The bill implements most of the K-12 science education recommendations of *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*.

Establishing the Advanced Research Projects Agency - Energy (H.R. 4435)

The bill establishes an Advanced Research Projects Agency - Energy within the U.S. Department of Energy. Modeled after the Department of Defense's Defense Advanced Research Projects Agency, the goal of ARPA-E is to reduce U.S. foreign energy dependence by 20% over a 10-year period. The bill is intended to implement the recommendation from *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*.

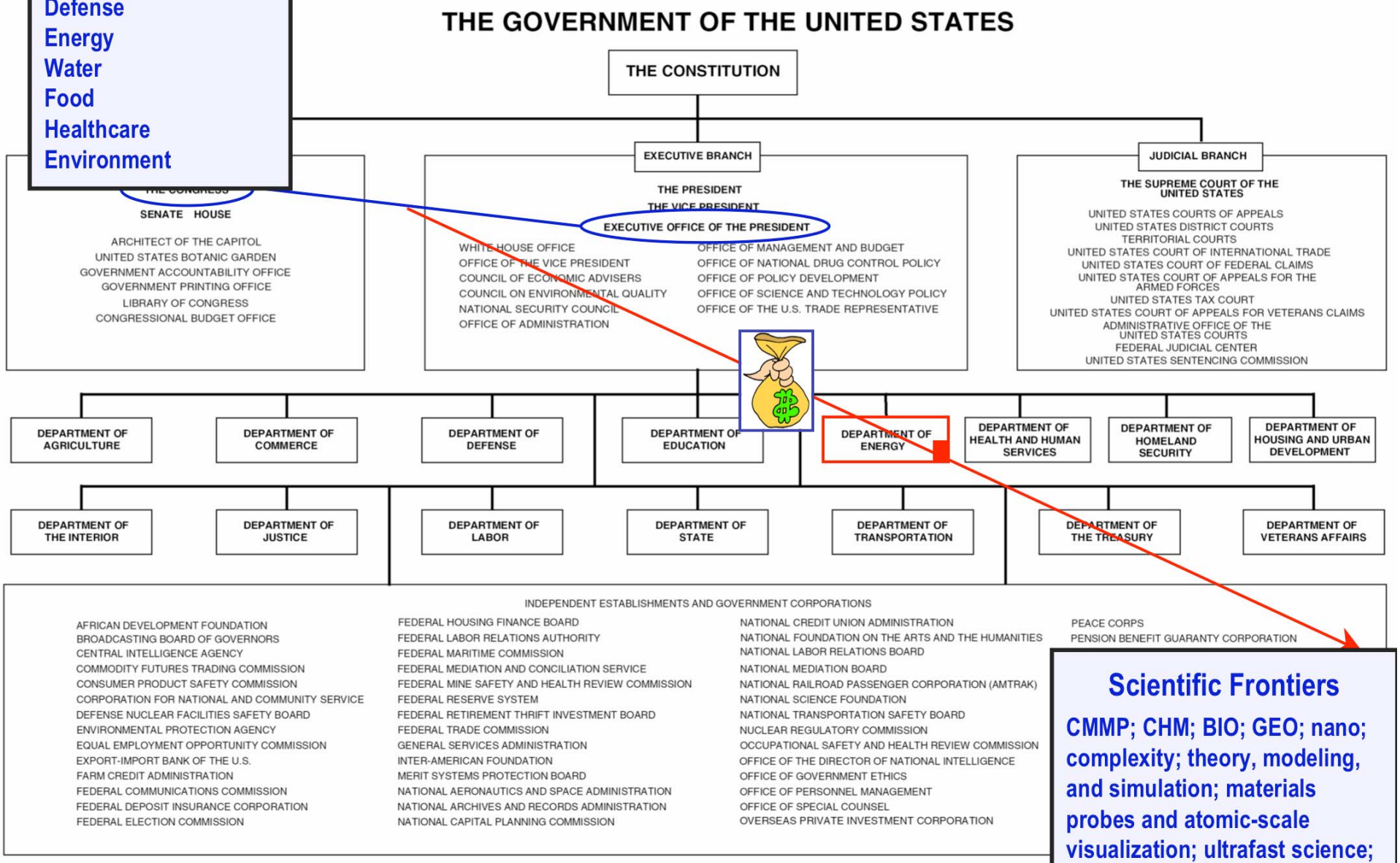
ACI and Administration Investments

Societal Needs

Economic security =

Jobs/Competitiveness

Defense
Energy
Water
Food
Healthcare
Environment



Scientific Frontiers

CMMP; CHM; BIO; GEO; nano; complexity; theory, modeling, and simulation; materials probes and atomic-scale visualization; ultrafast science; facilities for the Nation; ...

The FY 2007 Congressional Budget Request for BES and SC

(dollars in thousands)

	FY 2005 Approp.	FY 2006 Approp.	FY 2007 President's Request	FY 2007 vs. FY 2006
Basic Energy Sciences.....	1,083,616	1,134,557	1,420,980	+286,423
Total, Science.....	**3,635,650**	**3,596,391**	**4,101,710**	**+505,319***

* One half of the $505 million increase is for operations of our scientific facilities, including operations at new facilities: the Spallation Neutron Source and the Center for Nanophase Materials Sciences at Oak Ridge; the Center for Nanoscale Materials at Argonne; the Molecular Foundry at Berkeley; and the Center for Integrated Nanotechnologies at Sandia and Los Alamos National Laboratories. Research is increased by $237 million, 47% of the $505 million increase.

FY 2007 Solicitations and Program Web Announcements

	$ in thousands	FY 2005 Conf. Approp.	FY 2006 Rescission	FY 2007 President's Request	Delta FY06-FY07	% increase
	Research	**477,524**	**433,125**	**536,001**	**102,876**	**23.8%**
BAA*	Core Research	448,341	400,625	409,454	8,829	2.2%
S	Hydrogen	29,183	32,500	50,000	17,500	53.8%
S	Solar Energy Utilization			34,115	34,115	
S	Advanced Nuclear Energy Systems			12,432	12,432	
A	Ultrafast Science			10,000	10,000	
S	Mid-Scale Instrumentation			10,000	10,000	
S in FY05	Chemical Imaging			5,000	5,000	
A	Complex Systems/Emergent Behavior			5,000	5,000	

* BAA = Broad Agency Announcement for research within the core programs. Note that about $10 million for X-ray and neutron scattering instrumentation within the core will be competed with mid-scale instrumentation in the same solicitation.

Draft Timelines for FY 2007 BES Solicitations

Solicitation	Instrumentation	Basic research for the hydrogen fuel initiative	Basic research for solar energy utilization	Basic research for advanced nuclear energy systems
Funding available in FY 2007	approx. $20 million	$17.5 million	$34.1 million	$12.4 million
FY 2007 Congressional Budget released	February 6, 2006	February 6, 2006	February 6, 2006	February 6, 2006
Announcement of intent to issue solicitations	February 16, 2006	February 16, 2006	February 16, 2006	February 16, 2006
Posting on SC website*	Early March 2006	Mid April 2006	Mid March 2006	October 1, 2006
Preapplications deadline*	Mid May 2006	Early July 2006	Early June 2006	Early December 2006
Pis notified of preapplication decisions*	Late June/Early July 2006	Mid September 2006	Mid August 2006	Early January 2007
Full proposal deadline*	Late August/Early Sept 2006	Mid December 2006	Mid November 2006	Late March/Early April 2007
Announce awards*	Early April 2007	Mid May 2007	Mid April 2007	Late June 2007
* All dates are approximate.				

Continuous improvement? Another revolution? The role of science?

In 2027, when DOE is 50 years old:

- What will be the mix of energy sources? Incremental change to today's energy mix? Or greater?
- What will be the trade between energy independence and climate?
- Will regulations drive change? Will stasis drive regulations?
- Will the grid still be largely one-way, from producer to consumer? Or will it be more like the Internet? Will it be "smart" and "self repairing?"
- What other fuel grids will we be contemplating?
- Can we store a day's electricity output from a fossil plant?
- Will we move people to work physically or electronically?
- How will science have changed our energy world? Will we be able to control photon, electron, ion, and phonon transport to very significantly improve, say, solar photoconversion? Will biofuels show significant market impact?

"All the elementary steps of energy conversion (charge transfer, molecular rearrangement, chemical reactions, etc.) take place on the nanoscale. Thus, the development of new nanoscale materials, as well as the methods to characterize, manipulate and assemble them, creates an entirely new paradigm for developing new and revolutionary energy technologies."

"Nanotechnology: Energizing Our Future"

OSTP Series on Hot Topics in Science and Technology, August 10, 2005

End