ANALYSIS OF ENERGY R&D PROGRAMS

As noted earlier in this report, US federal investments in energy R&D have been in decline throughout the 1990s. This decline in federal energy R&D actually began in 1979 when US federal investments in energy R&D peaked at $6.7 billion dollars. US private sector investments in energy R&D peaked one year later in 1980 when they reached $5.2 billion. US national (i.e., public and private) investments in energy R&D currently stand at a 23-year low of $4.4 billion in 1996 (see Figure 1). The peak year for energy R&D investments was 1980, when investments in energy R&D reached $11.6 billion.[1]

A recently published analysis noted that underlying this reduction in the support of energy R&D in the United States is a pronounced shift away from the funding of long term "public good" or public benefit energy R&D in the United States. This shift is particularly marked with respect to the private sector's support for energy R&D. This analysis also showed that the push for energy market deregulation in the United States and lower energy prices was severely dampening the private sector's investments in energy R&D. There also seems to be little prospect that the federal government will be able to significantly increase its funding for energy R&D. The analysis concluded by pointing out that these trends of disinvestment and a focus on less risky near-term research would likely have a pronounced negative impact on US efforts to develop "cleaner, environmentally-preferred advanced energy supply" technologies.[i]

Reacting to trends such as those outlined above, President Clinton asked his Council of Advisors on Science and Technology (PCAST) to perform an assessment of the US energy R&D effort. That assessment, *Federal Energy Research and Development for the Challenges of the Twenty-first Century*, concluded that the United States is not currently investing enough nor investing in the right energy technologies to meet the opportunities and the challenges of the next century.[ii] The report, the most comprehensive study of federal energy R&D carried out in recent years, urged that funding for energy R&D be increased and recommended significant changes in emphasis in certain programs.

In this section of the report, trends within the US federal energy R&D program will be discussed and an analysis of major energy R&D programs supported by the federal government along with trends within these program elements will be presented.

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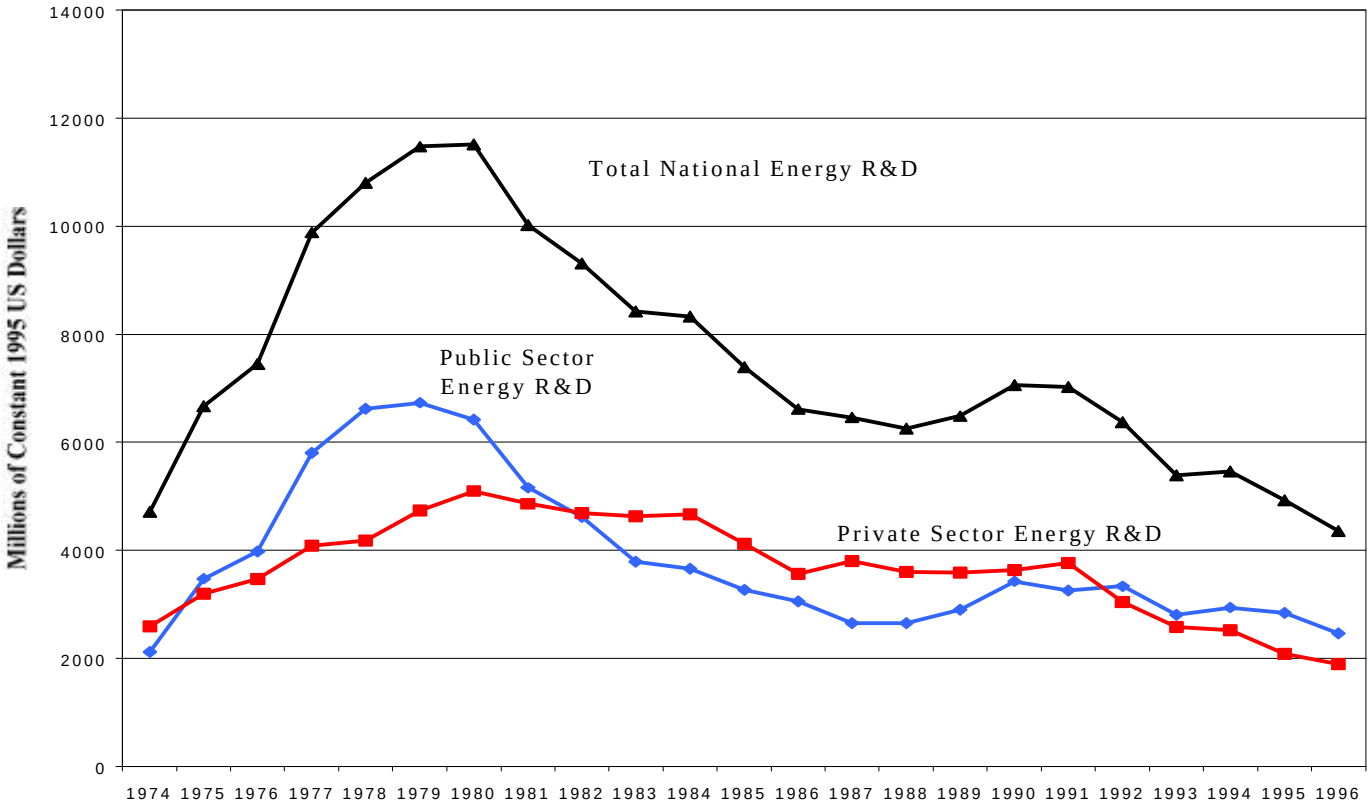
[1] J.J. Dooley, *US National Investments in Energy R&D: 1974-1996* (PNNL-11788, Washington, DC: Pacific Northwest National Laboratory, December 1997). This research was requested by the White House Council of Economic Advisors and is published in Council of Economic Advisors, *Economic Report of the President: 1998* (Washington, DC: February 1998).

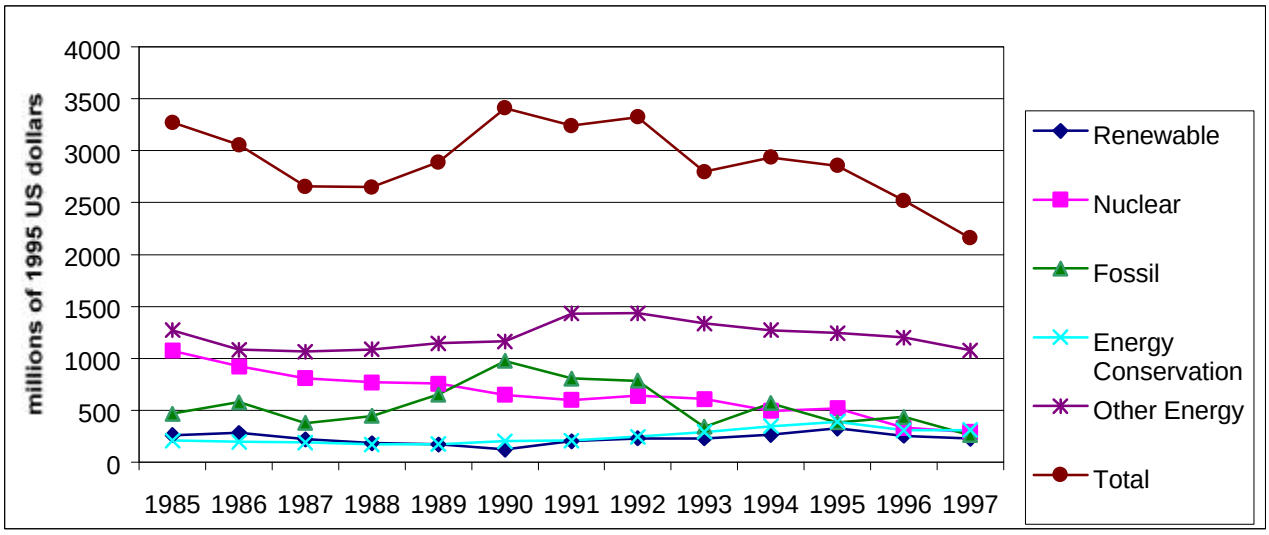
Figure 4: US National Investment in Energy R&D 1974-1996[2]



Sources: The data used here to describe private-sector energy R&D investments is built upon a combination of three primary data sets. The first of these is the only official, broad-based US government survey of industrial R&D expenditures (23,400 firms surveyed annually), which is carried out by the National Science Foundation in cooperation with the Department of Commerce's Bureau of the Census (NSF/Census). Biennially, this survey collects data on private sector funding of energy R&D performed by industrial firms with annual R&D budgets of over $1 million. The other two data sets used here to describe private sector energy R&D funding are historical funding data from the Electric Power Research Institute (EPRI) and the Gas Research Institute (GRI), two large nonprofit energy research organizations in the United States. It proved necessary to add in the energy R&D carried out through EPRI and GRI, since the NSF/Census survey did not include work funded by or carried out by nonprofit entities, e.g., R&D funded by an investor-owned electric utility but coordinated through EPRI would not be counted in the NSF/Census data set. See J.J. Dooley, *US National Investment in Energy R&D: 1974-1996* (PNNL-11788, Washington, DC: Pacific Northwest National Laboratory, December 1997).

[2] JJ Dooley. *US National Investments in Energy R&D: 1974-1996.* Pacific Northwest National Laboratory. PNNL-11788. Washington, D.C. December 1997. This research was request by the White House Council of Economic Advisors and is published in the *Economic Report of the President: 1998*. Council of Economic Advisors. Washington, D.C. February 1998.

Figure 5: US Federal Investments in Energy R&D: 1985-1997



Sources: Ronald Meeks, *Federal R&D Funding by Budget Function: Fiscal Years 1996-98* (Special Report, NSF 98-301, Arlington, VA: National Science Foundation, Division of Science Resources Studies, 1997); National Science Foundation, *Federal R&D Funding by Budget Function: Fiscal Years 1994-96* (NSF 95-342, Arlington, VA: National Science Foundation, 1995); J.J. Dooley. "Unintended Consequences: Energy R&D in Deregulated Market," *Energy Policy* (June 1998): 547-555.

Fossil Energy **FY1998 $362.4 million**

The US Department of Energy's Fossil Energy R&D program is in the midst of a profound change in emphasis and direction. Since 1990, the program has seen its R&D effort fall by more than 55% in real terms. The 20-year $2.4 billion industrially cost-shared Clean Coal Program has largely been terminated.[iii] In its place, the Office of Fossil Energy is seeking to expand its fuel cell program and is attempting to initiate long-term and more research-oriented programs in methane hydrate production and carbon dioxide capture and storage. While relatively new programs such as these represent a rather modest proportion of the overall research effort funded by this office, they do represent a new direction that the office has been urged to adopt so that its programs are more directly oriented to addressing the issue of climate change.[iv]

The Fossil Energy Research program can be subdivided into four major program areas: coal R&D, oil R&D, gas R&D, and an "other" category. The budget for the other category in FY1998 stood at $95.2 million with the majority of these funds going towards program management and lesser amounts directed at environmental restoration R&D, some advanced metallurgical process R&D, and other cross-cutting research areas.[v] A fuller explanation of the coal, oil and natural gas R&D programs is presented below.

Coal R&D *FY1998 $107.4 million*

The majority ($74 million) of the funds in this program area allocated to the Advanced Power Systems program and are directed at research programs designed to develop higher efficiency coal combustion systems such as advanced pulverized coal technologies, indirectly fired cycles, gasification-combined cycles, and advanced pressurized fluidized bed reactors. The coal program also focuses ($15.8 million) on advanced "clean fuel technologies" needed for coal-to-liquids programs (i.e., direct and indirect liquefaction) as well as physical and chemical processes for

cleaning coal prior to combustion. The last component of this coal program ($17.6 million) is a series of crosscutting research efforts to develop new materials, instrumentation and controls, and coal transport systems needed for a wide variety of coal consuming processes. Within the advanced power system program in FY1998 was the start of what is hoped to be a significant program in carbon dioxide capture and disposal. In FY1998, the Office of Fossil Energy funded the first 12 projects (each at approximately $50,000) to develop innovative concepts for the carbon dioxide capture and disposal programs. The Office of Fossil Energy hopes to rapidly expand this program to point where its annual budget is at the tens of million dollars a year level. The ultimate goal of this program is to develop technologies through the proof-of-concept stage by 2005 and subsequently demonstrated at full scale by 2010 that could economically capture and sequester carbon dioxide.[vi]

Natural Gas R&D *FY1998 $111.2 million*

The bulk of the natural gas R&D program is directed at developing clean, high-efficiency electricity generation technologies fueled by natural gas. The two major focuses of this aspect of the program are the advanced gas turbines research program ($45.0 million) and the fuel cell program ($40.2 million). The natural gas R&D program also funds some research ($15 million) directed at natural gas supply, storage, and processing technologies designed to ensure the long-term availability of the US gas supply. The program also funds ($7.8 million) a natural gas to liquids program designed to easily transform natural gas into more transportable liquid forms to serve as alternatives to oil-based transportation fuels.[vii] Starting with the FY1999 budget, the Office of Fossil Energy hopes to formally restart its methane hydrate research program. (DOE had a methane hydrate program that ran from 1982-1992.) The budget for this program will likely be quite modest in the first few years (less than a million dollars), but the Office of Fossil Energy hopes the program will rapidly grow to the tens of millions of dollar level to begin fulfilling the methane hydrate program's goal of "commercial production of methane from hydrates by 2015."[viii]

Oil R&D *FY1998 $48.6 million*

The Oil Technology Program focuses on developing technologies needed to keep US marginal oil fields in continuing production, advanced exploration (e.g., seismic imaging) technologies needed to identify new resources, and advanced production technologies (e.g., advanced drilling, completion, and stimulation technologies). The program also supports some research related to environmental protection and crosscutting oil production R&D.[ix]

Nuclear (Fission and Fusion) R&D **FY1998 $273.6 million**

Even though the United States has the largest number of operating nuclear reactors (109) delivering the largest capacity (100,000 MW) in the world, the research and development underpinning the continued development of this energy source has been in serious decline for over a decade.[x] Deep reductions have been felt by both of the major aspects of this program, fusion R&D and fission R&D.

Fission R&D *FY1998 $ 66.9 million*

Cumulative investments between 1979 and 1997 in fission reactor research sponsored by the US Department of Energy totaled $11.3 billion (in constant 1997 dollars).[xi] However, since 1985, US federal investments in nuclear fission R&D have declined by 73% in real terms. The small US fission program funds the University Nuclear Science and Reactor program ($7 million), which supports the needed maintenance for an ever-decreasing number of university-based nuclear research reactors and associated educational activities. According to one estimate, undergraduate enrollment in nuclear engineering programs has fallen by 10% per year throughout the 1990s.[xii]

This has resulted in there being only 30 operating university-based research reactors in 1999, less than half the number that were in operation in the late 1970s.[xiii] The program also supports ($12 million) research needed to extend the operating lifetimes of the current stock of US nuclear reactors ensuring their continued safe operation. The federal fission program also funds ($40.5 million) research on advanced radioisotope reactors for spacecraft.[xiv]

In FY1999, the Department of Energy was able to win Congressional support to begin a modest program ($19 million) to start a program to begin exploring the design of the next generation of nuclear power plants.[xv] Although a modest program to begin with, DOE hopes that this program will be the start to reverse the trend of the past years where there was no funding for research related to new reactor designs.

Fusion R&D *FY1998 $230 million*

The fusion nuclear program's budget has been reduced drastically over the last decade. The most recent of these reductions occurred in 1996 when Congress reduced the programs budget by one-third and directed that the program change its focus from a program designed to make fusion a practical energy source by the end of the twentieth century to one that now is ostensibly focused on developing the science for fusion as a long-term energy source. The fusion program funds basic research to understand the behavior of plasmas, novel fusion energy system concepts, and the US participation in the ITER project.[xvi]

Renewable Energy R&D **FY1998 $341 million**

Although federal support for renewable energy has remained relatively flat during the 1990s (total funding in 1997 is only 9.4% higher in inflation-adjusted terms than it was in 1990), there have recently been many calls for a dramatic expansion of the federal role to support the development of these technologies. The PCAST study suggested doubling federal funding for renewable energy R&D, citing as justification evidence that these flat budgets have prevented the necessary growth in these programs to support needed fundamental research that would dramatically improve the performance of these systems and that utility deregulation in the United States is making it more difficult for private companies to sell these renewable energy systems and support their own internal R&D programs.[xvii] This suggestion to double federal resources for renewable energy R&D seems unlikely given outyear projections for these programs. This will then force further tradeoffs to be made (e.g., funding more near term research at the expense of more fundamental research) and the possibility of terminating less promising research programs (e.g., the US government has already terminated its ocean thermal energy conversion, solar pond, and wave energy R&D projects on these grounds).[xviii]

Solar Energy R&D *FY1998 $70.4 million*

The solar energy R&D program funds a wide variety of research thrusts, including photovoltaic (PV) cells, solar thermal electric power plants, photoconversion processes, passive solar buildings, solar water and space heating systems, and solar resource data. Much of the entire solar energy R&D program is cost shared with industry. The vast majority ($65.4 million) of the solar program's budget is directed towards photovoltaic research. This program focuses on developing various thin film PV systems and R&D on ways to lower the manufacturing costs of these systems. In addition, the Office of Science (formerly the Office of Energy Research) funds basic research on understanding fundamental materials issues with these systems. The Solar Thermal program ($16.5 million) is focused on solar thermal electric systems which make electricity directly from the concentrated solar heat using conventional thermal power cycles.

Biomass Energy R&D *FY1998 $97.4 million*

The biomass program is funded by two separate offices: the Office of Energy Efficiency and Renewable Energy funds the majority ($58.8 million) of the program and concentrates its work on biomass gassification and pyrolysis, and cleanup technologies for high temperature biogas. The program also is analyzing and developing specific crops for use as bioenergy feedstocks. The Office Science's Division of Energy Biosciences supports ($38.6 million) more fundamental basic research needed to provide a better understanding of basic biological processes associated with the capture, transformation, storage and utilization of energy in plants and microorganisms, such as photosynthesis, bioenergetics, primary and secondary metabolism, the synthesis and degradation of biopolymers such as lignin, anaerobic fermentations, genetic regulation of growth and development, thermophily (e.g., bacterial growth under high temperature), and other phenomena with the potential to impact biological energy production and conversion.

Wind Energy R&D *FY1998 $32.8 million*

The wind energy R&D program focuses on fundamental engineering and technological issues associated with wind turbines and associated systems. The program also supports cost-shared research with industry to develop, test and deploy the next generation of wind energy systems.[xix]

Geothermal Energy R&D *FY1998 $29.0 million*

The geothermal program is carried out on a cost-shared basis with US industry. The program focuses on developing and deploying the knowledge and technologies needed to locate and exploit geothermal resources including new drilling and seismic imaging technologies. The program is also developing new large-scale and smaller, distributed geothermal energy conversion systems.[xx]

Hydrogen Energy R&D *FY1998 $19.1 million*

The hydrogen program's overall goal is to improve the economics and reduce the environmental impacts associated with producing hydrogen. The program is working with industry to develop more economical and cleaner ways of producing hydrogen from methane, as well as funding more basic research geared towards producing hydrogen without having to use carbonaceous feedstocks, e.g, producing hydrogen directly from solar-powered electrolysis. The program is also working on technologies and systems needed to store and transport hydrogen as well as developing safe and cost effective fueling systems for hydrogen-powered vehicles.[xxi]

Electric Energy Systems and Storage R&D *FY1998 $42.8 million*

The electric energy systems and storage R&D program has two principal focuses, research on high temperature superconductors (HTS) ($32 million) and the development of advanced energy storage systems ($3.9 million). The high temperature superconductor aspect of this research program is focused on understanding how to manufacture wires and cables made from these typically very brittle HTS compounds and developing electrical motors, generators and transformers that would utilize these HTS components. The energy storage system R&D program is designed to develop advanced components and system concepts (e.g., flywheels, high energy-density batteries, superconducting magnetic energy storage systems) for energy storage that will be needed if there is to be widespread adoption of many kinds of renewable energy systems. The program is also in its last year of funding ($6.9 million) research related to understanding the effects of electric and magnetic fields.

Energy Efficiency **FY1998 $591 million**

US federal investments in energy efficiency are directed at three sectors: buildings (both commercial and residential), industry and transportation. According to a recent review of US

energy R&D policy, cumulative federal investments in energy efficiency R&D from 1978-1996 totaled $8 billion. This federal investment coupled with complementary private sector investments are estimated to have reduced US energy bills by $150-200 billion per year.[xxii] Because of returns like these, federal investments in energy efficiency generally receive bipartisan support and this support has been responsible for the 53% real increase in the federal energy efficiency R&D budgets since 1990.

Transportation Energy Efficiency *FY1998 $193.3 million*

The transportation research program focuses on ways to increase the fuel efficiency of automotive vehicles as well as heavy vehicles (trucks) and research needed to develop alternatively powered vehicles. In addition, the program also supports the development of crosscutting technologies such as lighter materials as well as deployment and testing of new transportation technologies. The Advanced Automotive Technology program ($113.2 million) is developing technologies needed for cleaner and more energy-efficient automobiles such as electric and hybrid technologies, advanced heat engines, fuel cells, alternative fuels, and advanced propulsion materials.[xxiii] The heavy vehicle program ($25.6 million) is working with industry to develop advanced heavy vehicle engines that would be capable of fuel switching as well as research to develop these alternative fuels (e.g., biodiesel fuels). The transportation program also has a significant research effort ($35 million) to develop advanced lightweight transportation materials and advanced high-temperature materials for vehicle applications. Technology deployment and demonstration programs ($11.8 million) are another focus of this program's crosscutting research.

Industrial Energy Efficiency *FY1998 $136.2 million*

The industrial energy efficiency program carries out R&D programs designed to reduce fuel consumption and pollution in the most energy- and waste-intensive industries by applying innovative technologies, such as cogeneration technologies; efficient steam systems; waste-to-energy systems; and electric motors and drives. The Office of Industrial Technologies has organized much of its research ($53.1 million) to focus on developing in collaboration with affected industries the technologies needed to improve energy efficiency in the seven most energy and waste intensive industries in the US. The seven "Industries of the Future" that are the focus of this program are petroleum refining, forest products, chemicals, steel, aluminum, metalcasting, and glass. The industrial energy efficiency program also funds ($49.1 million) more crosscutting research related to cogeneration and advanced materials that could be applicable to any number of industrial applications. Lastly, the program has significant ($26.3 million) efforts to demonstrate and deploy these technologies.

Building Energy Efficiency *FY1998 $77.1 million*

The buildings' energy efficiency program funds research related to (1) energy-efficient lighting and appliances, advanced heating and cooling equipment; designing new insulation and other weatherization retrofit materials; high-performance windows ($27 million); (2) better building design techniques ($23 million) and building and appliance codes and standards ($14.4 million).

Federal Energy Management *FY1998 $19.8 million*

The Federal Energy Management Program carries out research and planning activities designed to advance the deployment of energy efficient, water saving and renewable energy technologies into federal buildings and federal installations.

Other Energy-Related R&D Programs

Basic Energy Sciences *FY1998 $660.3 million*

The Office of Basic Energy Sciences within the Office of Energy Research supports basic scientific research to support and underpin the advanced energy technologies being developed by the Department of Energy's other offices described above. The office also funds basic research geared towards understanding and where possible mitigating the environmental impacts of energy use. The office also constructs and operates major scientific user facilities that are used by thousands of scientists from universities, national laboratories, and industrial laboratories to explore the fundamental behavior of materials. The Office funds a wide array of basic materials research ($391 million), chemical sciences ($200 million), engineering and geosciences ($41.2 million) and energy bioscience research ($27.4 million).

Civilian High-Level Radioactive Waste *FY1998 $346 million*

The Office of Civilian Radioactive Waste Management primarily focuses its research on the characterization and preparation of the Yucca Mountain site so that it can be ready to open in 2010 as the nation's repository for civilian reactor wastes.[xxiv]

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[i] JJ Dooley. "Unintended Consequences: Energy R&D in Deregulated Market."
[ii] John Holdren et al., *Federal Energy Research and Development for the Challenges of the Twenty-first Century* (Report of the Energy Research and Development Panel of the President's Committee of Advisors on Science and Technology, Washington, DC: September 30, 1997).
[iii] Ibid.
[iv] Ibid.
[vv] US Department of Energy, Office of Fossil Energy, "FY 1999 Budget Request to Congress: Budget Table" (http://www.fe.doe.gov/budget/99table.html).
[vi] US Department of Energy, Office of Fossil Energy, "DOE Selects Potential Breakthrough Approaches For Removing Greenhouse Gases from Ecosystem" (Fossil Energy Techline, April 29, 1998, http://www.fe.doe.gov/techline/tl_novelseq.html).
[vii] US Department of Energy, Office of Fossil Energy, "FY 1999 Budget Request to Congress: Budget Table"; US Department of Energy, Office of Fossil Energy, "Natural Gas Technology: New Options for an Abundant US Resource" (http://www.fe.doe.gov/oil_gas/natgas.html).
[viii] US Department of Energy, Office of Fossil Energy, *A Strategy for Methane Hydrates Research & Development* (DOE/FE-0378, Washington, DC: August 1998).
[ix] US Department of Energy, Office of Fossil Energy, "FY 1999 Budget Request to Congress: Budget Table"; John Holdren et al., *Federal Energy Research and Development for the Challenges of the Twenty-first Century*.
[x] John Holdren et al., *Federal Energy Research and Development for the Challenges of the Twenty-first Century*.
[xi] Ibid.
[xii] David Malakoff, "Nuclear Power: New DOE Research Program to Boost Sagging Industry" *Science* 282 (December 11, 1998) 1980-1981.
[xiii] "Meltdown," *Science* 283 (February 26, 1999) 1237.
[xiv] US Department of Energy, Office on Nuclear Energy, Science and Technology, "FY1998 and FY1999 Budget (Excludes Naval Reactors)" (http://www.ne.doe.gov/org/budget.stm)
[xv] David Malakoff, "Nuclear Power: New DOE Research Program to Boost Sagging Industry."
[xvi] US Department of Energy, Office of Energy Research, "President's FY1999 Budget Request for the Office of Energy Research" (http://www.cfo.doe.gov/budget/99budget/science/execsum.pdf).
[xvii] John Holdren et al., *Federal Energy Research and Development for the Challenges of the Twenty-first Century*.
[xviii] Ibid.

[xix] US Department of Energy, Office of Energy Efficiency and Renewable Energy, "President's FY1999 Budget Request for the Office of Energy Research" (http://www.cfo.doe.gov/budget/99budget/esrd/ee/srrt1.pdf)
[xx] Ibid.
[xxi] Ibid.
[xxii] John Holdren et al., *Federal Energy Research and Development for the Challenges of the Twenty-first Century*.
[xxiii] US Department of Energy, Office of Advanced Automotive Technologies (http://www.ott.doe.gov/oaat/)
[xxiv] US Department of Energy, Office of Civilian Radioactive Waste Management, "Fiscal Year 1999 Budget Request Summary, February 1998" (http://www.rw.doe.gov/pages/budget/execSumBR99.pdf, March 17, 1998); John Holdren et al., *Federal Energy Research and Development for the Challenges of the Twenty-first Century*.