3. Federal Energy Research and Development

The Federal Government's role in financing large-scale civilian R&D dates from the early 1950s. The principal landmarks were President Eisenhower's decision to commercialize nuclear energy in the wake of his "Atoms for Peace" speech in 1953 and the furor following the launch of the Soviet Sputnik satellite in 1956. Figure 2 shows trends in U.S. Government R&D outlays since 1950, in constant 1999 dollars. Current expenditures exceed $70 billion, 57 percent of which is defense-related. In the 1980s, total Government R&D spending rose by about 40 percent. The increase resulted primarily from increased emphasis on defense R&D. In the late 1980s, spending on health research also increased in relative importance. In the fiscal year 1999 budget, health R&D exceeds all other categories of R&D except national defense. Since the 1980s, energy R&D expenditures have declined. Current appropriations for energy R&D total about $1.6 billion, about 5 percent of all civilian Government-funded R&D.

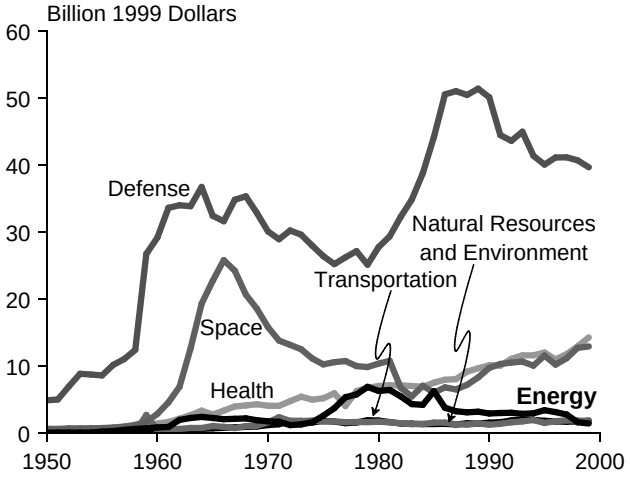
Overview of Federal Energy Research and Development

Research and Development Defined

Federal energy-related R&D can be described as falling into three classes: basic research, research that seeks to develop new energy technologies, and research that seeks to improve existing technologies.

- **Basic Research.** The potential beneficiaries of basic research could be considered to be the population of the United States or the world as a whole. Basic research includes research projects designed to pursue the advancement of scientific knowledge and the understanding of phenomena rather than specific applications.
- **Research To Develop New Technologies.** The efforts in this context involve attempts to discover new scientific knowledge that can have commercial application. Although the end objective of the research is known, the research task is difficult and uncertain.
- **Research To Improve Existing Technologies.** These efforts emphasize the use of scientific knowledge to design and test new processes that may have substantial technical and cost uncertainties. The immediate beneficiaries are generally well defined: current producers and consumers of particular fuels or operators, and customers of the technology being improved.

Figure 2. Federal Research and Development Outlays by Program, Fiscal Years 1950-1999



Note: Budget figures for Transportation, Natural Resources and Environment, and Agriculture are similar and thus difficult to distinguish graphically. Agriculture data are not shown in this graph.

Source: Office of Management and Budget, *Budget of the United States Government, Fiscal Year 2000* (Washington, DC, February 1999), Historical Tables, pp. 160-165.

Energy Research and Development as a Subsidy

It is easier to measure energy R&D spending than to it characterize from a subsidy perspective. R&D spending is intended to create useful knowledge that benefits society. Thus, all Federal R&D spending could, in a general way, be considered a subsidy to knowledge; however, the extent to which specific R&D programs actually affect energy markets is more difficult to ascertain.

The results of research are inherently uncertain. Many programs will advance knowledge across a range of energy and non-energy applications, rather than in the context of a particular fuel or form of consumption. Further, the knowledge obtained may be negative, in the sense that the research may only reveal technical or economic dead ends to be avoided in the future.[42] Thus, only a portion of Federal energy R&D is likely to achieve results (in the form of changes in energy costs or consumption) that can be attributed specifically to a particular R&D program. Moreover, to the extent that there are attributable results, they are likely to be measurable only years after the funded research effort is initiated.

Federal R&D is intended to support research that the private sector would not undertake. It is not supposed to substitute for private-sector R&D. However, the creation of a Government-funded R&D program could, under some circumstances, displace private-sector R&D. In that case, the Federal program would not produce any net new knowledge but simply reduce private costs. It is impossible, however, to know with certainty what private-sector firms would have done in the (hypothetical) absence of a Federal program. In general, the less "basic" the R&D program and the more focused on near-term commercialization, the greater the risk that the program will be a substitute for private-sector R&D.

There are no means to determine conclusively whether or not particular Federal energy R&D projects are substitutes or complements for private-sector activities. Moreover, because research is risky, with failure an inherent part of the process, the effectiveness of Federal R&D cannot easily be assessed. This report makes no judgments on either of these issues. Rather, it surveys the current composition of Federal R&D spending and provides a degree of historical perspective on the changing composition of Federal energy R&D efforts.

There is another issue that is specific to U.S. energy R&D programs: much U.S. energy R&D is aimed not at producing fuels *per se* but at developing fuel-consuming capital equipment (particularly power generation technologies). Such projects may be more properly viewed as a subsidy to capital equipment manufacturers than to fuel producers or consumers. Although, in principle, all successful power generation R&D benefits electricity consumers, the effects on fuel producers are more ambiguous. Because they are energy-saving technologies, the new technologies will only benefit producers if they help to expand the market for their fuel. Thus, if one seeks to understand the effects, rather than the intent, of R&D spending, the success of the programs must be evaluated, noting that expenditures will necessarily occur long before technology adoption, and considering the competitive consequences of any new technologies introduced.

Finally, much of the expenditure that is formally defined as "energy research and development" in the U.S. Government's budget accounts is not directly expended on energy research or development. Some of the funds are expended for environmental restoration and waste management for energy (particularly nuclear) research facilities,

[42]Several studies suggest that the return on Federal R&D investment is much lower than the return on private-sector R&D, implying relatively high failure rates. See N. Terlecyyj, *Effects of R&D on the Productivity Growth of Industries: An Exploratory Study* (Washington, DC: National Planning Association, 1974), and Z. Griliches, "Returns to R&D in the Private Sector," in J. Kendrick and B. Vaccara (eds.), *New Developments in Productivity Measurement and Analysis*, NBER Studies in Income and Wealth No. 44 (Chicago, IL: University of Chicago Press, 1980), pp. 419-454. This result need not be surprising, as the Federal Government's research portfolio may be much riskier than that chosen by the private sector.

or on R&D on environmental restoration and waste management, or on overhead or difficult-to-allocate functions. Such spending may not have a material impact on current or future energy markets.

Energy Research and Development Trends

Table 8 allocates Federal energy R&D by energy type and function. Currently, nearly two-thirds of Federal energy R&D ($2.8 billion) is allocated to basic research. DOE's largest single basic research program is the General Science Program, funded at $1.6 billion in fiscal year 1999. Basic research is difficult to characterize as an energy subsidy, however, because it cannot be allocated between energy and non-energy benefits, or among forms of energy. Therefore, the balance of this chapter focuses on applied energy R&D.

Table 8 lists both "estimated" and "actual" research and development appropriations for fiscal year 1992. The estimated appropriations are drawn from the Department of Energy's fiscal year 1993 budget proposal, prepared in early 1992, which showed appropriations by budget account for the previous fiscal year.[43] The estimated appropriations were used in EIA's 1992 subsidy report. The actual appropriations are drawn from the Office of the Chief Financial Officer's Appropriation History Tables, prepared in early 1997, which show final appropriations by budget account.

The differences between the two columns have multiple causes. The Department transfers (with the approval of Congress) unspent monies from one account to another. This may take place well after the end of a fiscal year if the Department has multi-year spending authority for a particular account. The largest difference between the two columns is due to a large reprogramming of funds for fusion research. There have also been several changes of classification. For example, the account "Biological and Environmental Research" has been transferred from "Environment, Safety, and Health" to "General Science." In addition, minor errors in the original 1992 report have been corrected in the final appropriations column. For example, some of the expenditures on wind in the "Wind, Photovoltaic, and Other Solar" category were interchanged with biomass expenditures in the 1992 report.

Applied R&D is aimed primarily at improving existing technology. Appropriations for applied energy R&D were about $1.5 billion in fiscal year 1999. Of that amount, more than half is allocated to nuclear activities. Within the range of nuclear projects, most of the money is spent on environmental management rather than R&D *per se*. For coal, the bulk of spending supports development of clean coal technologies. Solar, photovoltaic, and wind energy absorb the major share of renewable energy research funds ($134 million out of a total of $327 million). Expenditures shown as "unallocated" in Table 8 are administrative and miscellaneous programs associated with R&D. For example, unallocated expenditures for nuclear R&D ($143 million) in fiscal year 1999 include program termination costs and program direction. For renewable energy programs, they include program direction and funding for the National Renewable Energy Laboratory ($22 million in fiscal year 1999). The unallocated appropriation for basic energy research ($49.8 million in fiscal year 1999) funds personnel in a variety of research centers and provides support services and other related expenses.

[43]U.S. Department of Energy, *United States Department of Energy Posture Statement and Fiscal Year 1993 Budget Overview* (Washington, DC, February 1992).

Table 8. Federal Funding for Energy-Related Research and Development by Program, Fiscal Years 1992 and 1999
(Million 1999 Dollars)

Category	Fiscal Year 1992 Appropriation (Estimated)[a]	Fiscal Year 1992 Appropriation (Final)	Fiscal Year 1999 Appropriation
Basic Research			
Basic Energy Research			
General Science	1,672.8	2,059.3	1,624.2
General Energy Science	1,004.1	999.4	821.8
Environment, Safety, and Health	585.3	161.6	47.4
Unallocated	47.4	68.8	49.8
Fusion Energy Sciences	872.5	379.1	222.6
Total Basic Research Appropriations	**4,182.1**	**3,668.1**	**2,765.9**
Applied Research and Development			
Nuclear Power			
New Nuclear Plants (Nuclear Energy Research Initiative)	139.2	221.2	30.0
Waste/Fuel/Safety (Environmental Management)	707.1	754.6	466.6
Unallocated (Termination Costs)	168.6	155.9	143.0
Total	*1,014.9*	*1,131.7*	*639.6*
Coal			
Advanced Clean Efficient Power Systems	168.3	166.4	87.7
Advanced Clean Fuels	57.8	57.1	15.5
Advanced Research and Technology Development	92.8	91.8	19.9
Interagency National Acid Precipitation Assessment Program[b]	35.4	35.4	([c])
Unallocated	90.0	121.1	97.1
Total	*444.3*	*471.7*	*220.2*
Other Fossil Energy			
Oil	58.6	57.8	48.6
Shale Oil	6.5	6.7	0.0
Natural Gas	14.4	14.2	115.2
U.S. Geological Survey Energy Research and Development[b]	29.7	29.7	([c])
Total	*109.2*	*108.3*	*163.8*
Renewable Energy			
Wind, Photovoltaic, and Other Solar	156.3	135.9	133.9
Biofuels and Biomass	24.4	44.5	95.5
Geothermal	31.0	30.7	28.5
Hydroelectric	1.2	1.2	3.3
Electricity Technologies	43.4	42.9	44.1
Unallocated	21.6	20.6	22.0
Total	*277.9*	*275.8*	*327.2*
Electric Utility (Advanced Turbine Systems)[d]	5.4	5.4	33.0
Total Applied Research and Development Appropriations	**1,851.7**	**1,992.9**	**1,383.8**
Clean Coal Outlays	184.8	151.7	183.0
Total Applied Research and Development, Including Clean Coal	**2,036.5**	**2,144.6**	**1,566.8**

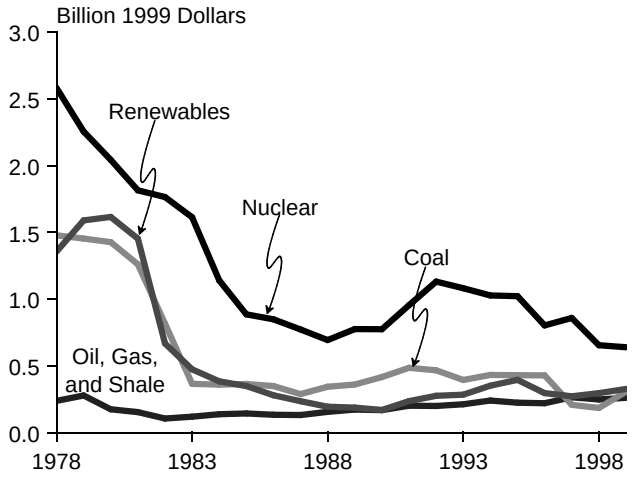
[a]As published in the 1992 EIA report.
[b]Assumed no change between estimated and actual fiscal year 1992 appropriations.
[c]Program terminated.
[d]Included in "end use" in the 1992 EIA report.

Sources: U.S. Department of Energy, *U.S. Department of Energy Fiscal Year 2000 Congressional Budget Request*, DOE/CR-0059 (Washington, DC, May 21, 1999); and Energy Information Administration, *Federal Energy Subsidies: Direct and Indirect Interventions in Energy Markets*, SR/EMEU/92-02 (Washington, DC, November 1992), p. 43.

Figure 3 illustrates trends in Federal applied energy R&D appropriations from fiscal year 1978 through fiscal year 1998. There were sharp reductions in energy R&D appropriations during the early 1980s, followed by modest growth after 1992. R&D spending by fuel type is dominated by nuclear power R&D, although coal R&D appropriations were boosted in the late 1980s by the advent of the Clean Coal Technology Program, and renewable energy appropriations have risen somewhat since 1990. Federal R&D spending related to oil and gas is budgeted at $164 million in fiscal year 1999.

Another recent trend in Federal R&D is a tendency for Congress to mandate research on particular projects. Title XIII of the Energy Policy Act of 1992 wrote much of DOE's coal R&D program into law and added some new areas of research, mandating R&D on coal-fired diesel engines, nonfuel coal use, coalbed methane, metallurgical coal development, coal gasification, coal liquefaction, low-rank coal use, and magnetohydrodynamic power generation. There are similar detailed provisions throughout the law for research on other energy sources, including nuclear power, end use, and renewable energy.

Figure 3. Federal Energy Research and Development Appropriations by Program, Fiscal Years 1978-1999



Note: GDP deflator used to convert nominal dollars to constant dollars.

Sources: U.S. Department of Energy, Office of the Chief Financial Officer, "Budget Authority History Table by Appropriation" (Washington, DC, 1998); *U.S. Department of Energy Fiscal Year 1999 Budget Request*, DOE/CR-0050 (Washington, DC, February 1998); and *U.S. Department of Energy Fiscal Year 2000 Budget Request*, DOE/CR-0059 (Washington, DC, May 21, 1999).

Energy Research and Development Programs

Nuclear Power

Figure 4 illustrates trends in DOE's nuclear power R&D programs. DOE received an appropriation of $640 million for nuclear R&D in fiscal year 1999, but the majority of the funds ($466.6 million) are allocated to the cleanup of contaminated nuclear energy and research sites. About two-thirds of the cleanup funds are being used for site closures, and the balance is slated for site and project completion.

Non-Defense Environmental Safety and Health

A substantial portion of Government-funded nuclear R&D is for managing and addressing the environmental legacy resulting from nuclear energy and research activities. The goal is to clean up as many contaminated sites as possible by 2006. For fiscal year 1999, more than one-half of non-defense environmental, safety, and health funds are allocated for site closures.

Nuclear Safety Research

In addition to DOE's nuclear R&D program, the U.S. Nuclear Regulatory Commission (NRC) will also spend $53 million (about 11 percent of its budget) on nuclear safety R&D in fiscal year 1999. NRC responsibilities include regulation of commercial nuclear power reactors; non-power research, test, and training reactors; fuel cycle facilities; medical, academic, and industrial uses of nuclear materials; and the transport, storage and disposal of nuclear materials and waste. The NRC's operations (including R&D) are fully funded by a fee levied on the operation of nuclear power plants. Hence, NRC safety research cannot be considered as a subsidy to the nuclear power industry.

Improving Existing Power Plants and Enhancing Nuclear Power

The Nuclear Energy Research Initiative provides funds for R&D at universities, national laboratories, and industry to advance nuclear power technology. It includes proliferation-resistant reactor and fuel technologies, high-performance, high-efficiency reactor technology, advanced nuclear fuels, and new technologies for the minimization and management of nuclear waste. The fiscal year 1999 appropriation for this program is $19 million, out of the $30 million for new or improved nuclear power plants.

Unallocated Expenditures

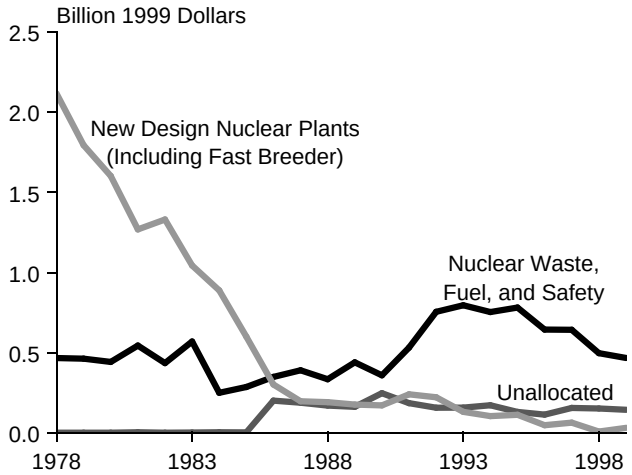
Unallocated expenditures cover a range of difficult-to-categorize nuclear R&D accounts totaling $143 million in fiscal year 1999 appropriations. The largest single item in this category is termination costs for the Fast Flux Test Facility, a 400-megawatt sodium-cooled research reactor that was shut down in 1992, and the deactivation of an experimental breeder reactor. Termination costs ($95 million out of the $143 million in this category) cover removal of spent fuel and maintenance of the safeguards and security infrastructure for the facilities.

Coal

Coal-related programs in DOE's Office of Fossil Energy include R&D on coal power systems, coal-derived fuels, and advanced R&D, as well as a Clean Coal Technology Demonstration Program. Total fiscal year 1999 appropriations for the R&D program were $220.2 million (Figure 5). The coal R&D program is focused on three goals: higher efficiency and cleaner power generation; improved emission control systems; and the development of economically competitive technologies for the production of alternative transportation fuels and chemicals.

Coal R&D is an integrated program consisting of Advanced Clean/Efficient Power Systems, Advanced Clean Fuels Research, and Advanced Research and Technology Development. The program is focused toward the *Vision 21* concept, aimed at doubling the existing power plant efficiency with the flexibility to produce high-value products from coal and other fuels while achieving near-zero pollution and reducing energy costs.

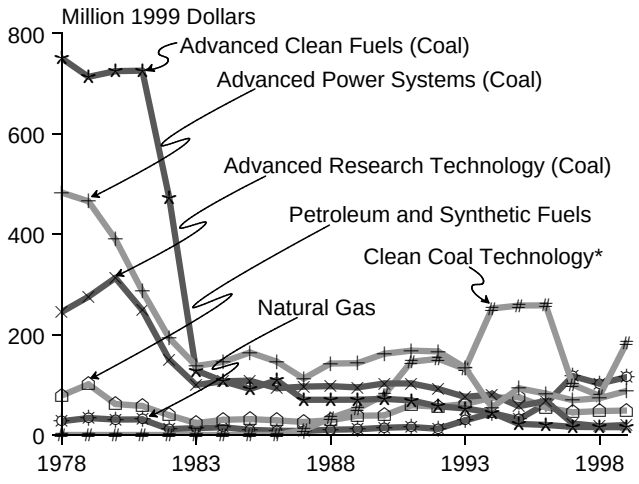
Figure 4. Federal Nuclear-Related Research and Development Appropriations by Program, Fiscal Years 1978-1999



Note: GDP deflator used to convert nominal dollars to constant dollars.

Sources: U.S. Department of Energy, Office of the Chief Financial Officer, "Budget Authority History Table by Appropriation" (Washington, DC, 1998); *U.S. Department of Energy Fiscal Year 1999 Budget Request*, DOE/CR-0050 (Washington, DC, February 1998); and *U.S. Department of Energy Fiscal Year 2000 Budget Request*, DOE/CR-0059 (Washington, DC, May 21, 1999).

Figure 5. Principal Research and Development Appropriations for Fossil Energy, Fiscal Years 1978-1999



*Outlays.

Note: GDP deflator used to convert nominal dollars to constant dollars.

Sources: U.S. Department of Energy, Office of the Chief Financial Officer, "Budget Authority History Table by Appropriation" (Washington, DC, 1998); *U.S. Department of Energy Fiscal Year 1999 Budget Request*, DOE/CR-0050 (Washington, DC, February 1998); and *U.S. Department of Energy Fiscal Year 2000 Budget Request*, DOE/CR-0059 (Washington, DC, May 21, 1999).

Advanced Clean/Efficient Power Systems Research and Development concentrates on a set of building-block technologies for *Vision 21* that will yield the clean coal power generation systems of the future. The Advanced Clean Fuels Research Program will conduct activities to develop clean methods to produce coal-derived liquid fuels. This research consists of coal preparation, direct and indirect liquefaction, and research on chemical storage agents for hydrogen and molecular modeling of carbon structures. Advanced Research and Technology Development includes both long-range research on coal-related systems and crosscutting R&D on fossil energy, including projects in support of *Vision 21*.

The Clean Coal Technology Program (CCT) occupies an anomalous position in the taxonomy of this report: it has some of the characteristics of R&D but in other respects more closely resembles a direct expenditure program. The program was authorized under the Clean Coal Technology Reserve provision of Public Law 98-473, enacted on October 12, 1984. Initial appropriations were made in Public Law 99-190 enacted on December 19, 1985. Congress has appropriated a Federal budget of $2.3 billion over the duration of the CCT program. For the 40 completed and active projects, industry participants have contributed $3.7 billion. By law, DOE's contribution cannot exceed 50 percent of the total cost of any project. With all projects selected and all the necessary funding appropriated, the outlays for CCT depend largely on the pace of the remaining projects that require final funding allocations for construction and operation. The application categories for the projects are environmental control devices, advanced electric power generation, coal processing for clean fuels, and industrial applications.

Table 9 lists approved Clean Coal projects by application category. The amounts shown in Table 9 are multi-year project costs, including funds that have already been spent and funds not yet obligated. Currently, of the 40 projects in the program, 23 have completed test operations and have either been concluded, moved into commercially funded operations, or are in the final stages of reporting results to DOE; 7 projects are in design, permitting, and other pre-construction activities; 1 project is in construction; and 9 projects are in operation, generating test data.

In fiscal year 2000, only two projects are expected to have outstanding obligation commitments: the Clean Energy Demonstration Project (an integrated gasification combined cycle project now planned for southern Illinois) and the CPICOR combined steelmaking and generation project planned for Geneva, Utah. DOE's current projections are that neither of these two projects will require funding allotments from previous appropriations in fiscal year 2000, and consequently $246 million can be deferred into future years.

The Federal budget treatment of the CCT program is complex. As noted above, the Congress has appropriated some $2.3 billion of multi-year money for the program, with which DOE has been able to make multi-year commitments to private-sector participants. During the early years of the program, however, outlays generally were much lower than appropriations. In recent years, no new money has been appropriated for the program, but DOE has continued to spend the money previously appropriated. Some of the money appropriated in prior years has been deobligated, producing, in effect, negative current appropriations for the program (-$40 million in fiscal year 1999). Outlays are therefore a better measure of the current fiscal consequences of the CCT program than are appropriations. (For most R&D accounts, most of the time, appropriations and expenditures are more or less consistent.) DOE clean coal outlays were $185 million in fiscal year 1992 and $183 million in fiscal year 1999. Termination of the CCT, after completion of projects now underway, is part of the President's realignment plan for the Department of Energy. The Administration's policy calls for limiting the program to existing domestic projects already under contract.

Table 9. DOE Clean Coal Technology Project Costs by Application Category

Application Category	Number of Projects	Total Costs (Million Dollars)	DOE Contribution (Million Dollars)	DOE Share of Costs (Percent)
Advanced Electric Power Generation	19	3,159.9	1,224.1	39
Environmental Control Devices	11	704.9	295.2	42
Coal Processing for Clean Fuels	5	519.2	230.0	44
Industrial Applications	5	1,287.5	192.1	15
Total	**40**	**5,671.5**	**1,941.4**	**34**

Source: U.S. Department of Energy, *Clean Coal Technology Demonstration Program: Program Update 1998* (Washington, DC, March 1999), pp. ES-5 and 3-1.

Oil and Natural Gas

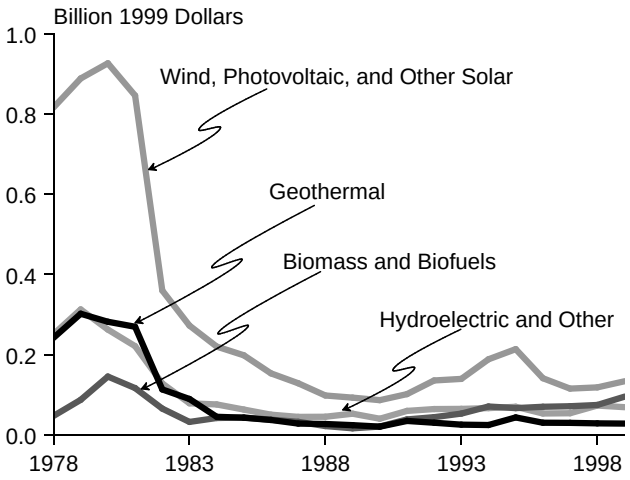
DOE's oil research efforts are funded at $48.6 million in fiscal year 1999, with an emphasis on new technologies that can improve exploration, drilling, reservoir characterization, and extraction. The Natural Gas Program received $115.2 million in fiscal year 1999 for natural gas research and fuel cells. Two new efforts include new diagnostic techniques to locate methane hydrates and engineering assessments to determine the best locations and approaches for revitalizing stripper wells in gas fields.

Renewable Energy

DOE's renewable energy R&D program is large in relationship to the size of the current renewable energy industry, but its purpose is to help expand that industry. Figure 6 illustrates the distribution of R&D expenditures across renewable technologies. The largest single item is the category "Wind / Photovoltaic / Other Solar," funded at $134 million in fiscal year 1999. Within this category, the largest program is for photovoltaics, at $72.2 million in fiscal year 1999. Most of the funds are for fundamental and applied research. The remainder will be used in competitive procurements for cost-shared projects with U.S. utilities and the photovoltaics industry. The research is concentrated on manufacturing process technologies, establishing utility applications of photovoltaic systems, and developing products that can be integrated into buildings.

Solar thermal systems are funded at $17 million per year. The funds are designed to provide technology options for concentrating solar power, including distributed dish / engine systems, on a cost-sharing basis. Research on molten-salt thermal storage technology is also funded through the cost-shared program, with the goal of developing advanced manufacturing techniques and high-temperature components to reduce overall system costs.

Figure 6. Federal Renewable Energy Research and Development Appropriations, Fiscal Years 1978-1999



Note: GDP deflator used to convert nominal dollars to constant dollars.

Sources: U.S. Department of Energy, Office of the Chief Financial Officer, "Budget Authority History Table by Appropriation" (Washington, DC, 1998); *U.S. Department of Energy Fiscal Year 1999 Budget Request*, DOE/CR-0050 (Washington, DC, February 1998); and *U.S. Department of Energy Fiscal Year 2000 Budget Request*, DOE/CR-0059 (Washington, DC, May 21, 1999).

The funding for wind systems is $34.8 million, with a goal of generating electricity at a cost of 2.5 cents per kilowatthour by 2002 at wind speeds averaging 15 miles per hour. The program works directly with industry in technology development and verification projects in order to achieve commercial application.

Funding for geothermal energy R&D is $28.5 million in fiscal year 1999. The focus is on locating geothermal reservoirs, reducing exploration and drilling costs in a hard rock environment, developing production techniques, improving reliability, and reducing operating costs.

Two other renewable energy R&D programs are aimed at improving the efficiency of electricity supply and storage systems. Storage systems include high-temperature superconductivity and energy storage technologies. The majority of the funding is for superconducting wires, with the goal of increasing electric system capacity and improving efficiency in motors and generators.

Advanced Turbine Systems

DOE energy end use, efficiency, and energy conservation R&D programs are excluded from this report by definition. The program that remains is the “electric utility” category, which primarily funds research on advanced turbine systems, fueled primarily by natural gas in the near term, but with hydrogen, alcohol, and petroleum fuels as possible alternatives under some circumstances. This program was included here since the other generation technologies were assigned to their primary fuels. Fiscal year 1999 funding for this program is $33 million.