3. Federal Energy Research and Development

The Federal government's role in financing large-scale civilian research and development (R&D) dates back to the late 1940s. The principal landmarks were President Eisenhower's decision to commercialize nuclear energy articulated in his 1953 "Atoms for Peace" speech and the public concern raised by the launch of the Soviet Sputnik satellite in 1957. Since 1949, the largest R&D outlays have been for defense and, to a lesser extent, space and health programs.[64] In the 1980s, total Federal R&D spending rose by more than 100 percent. The growth was primarily associated with defense-related R&D. In the late 1980s, spending on health research also increased in relative importance. During the 1990s, the growth in R&D expenditures was less than in the past. After 2000, R&D outlays have grown rapidly, particularly for defense and health care. According to the Office of Management and Budget (OMB), the FY 2007 appropriations for energy-related R&D (basic and applied research) amounted to about 5 percent of all Federally-funded R&D. Total Federal R&D for fiscal year (FY) 2007 exceeded $125 billion, 60 percent of which was defense-related.

The scale and focus of energy-related R&D expenditures have changed over time (Table 12). In the late 1970s, funding was influenced strongly by the decade's two oil crises. As oil prices abated through much of the 1980s, Federal R&D funding levels fell considerably. Funding levels fell from $6.5 billion in 1978 to $1.2 billion in 1987. Funding levels have picked up since, averaging $1.9 billion to $2.5 billion over the last decade. Since the last EIA subsidy report was released in the year 2000, energy-related R&D expenditures for biofuels, advanced nuclear, and advanced coal technologies have substantially increased. Like the growth in tax expenditures, EPACT2005 has had a significant impact on energy-related R&D expenditures. Due in part to EPACT2005, funding for hydrogen-related R&D grew from zero to $230 million between 1999 and 2007. Title VIII of EPACT2005 authorizes $3.3 billion in hydrogen-and-fuel-cell-related R&D for the period 2006 through 2010. Title IX of EPACT2005 authorized R&D funding for energy efficiency, distributed generation, nuclear energy, and renewable energy. For example, EPACT2005 authorized funding for nuclear-related R&D totaling $2.4 billion over the years 2007 through 2009. Due in part to widespread power outages in the eastern United States during the summer of 2003, EPACT2005 contained provisions directed at improving transmission and distribution system reliability.

Since 1978, funding for energy-related R&D has totaled $75 billion, of which $30 billion has been devoted to nuclear, $20 billion to coal, $13 billion to renewable energy, $4 billion to other fossil fuels, and $8 billion to end-use technologies.

Defining Federal Research and Development

For purposes of this report Federal energy-related R&D is divided into three categories: basic research, research that seeks to develop new energy technologies, and research that enhances existing technologies.

[64] See http:/www.whitehouse.gov/omb/budget/fy2008/pdf/hist.pdf.

Table 12. Summary of U.S. DOE R&D Expenditures, 1978 to 2007 (million 2007 dollars)

Fiscal Year	Renewable Energy	Coal	Other Fossil	Nuclear	End Use	Clean Coal Technology	Total
1978	1,046	1,709	275	2,938	561	0	6,529
1979	1,302	1,685	322	2,614	541	0	6,464
1980	1,367	1,657	203	2,373	413	0	6,011
1981	1,196	1,464	184	2,018	377	0	5,239
1982	588	975	97	1,954	155	0	3,769
1983	454	497	68	1,313	99	0	2,432
1984	346	500	80	1,110	106	0	2,142
1985	328	523	71	702	81	0	1,705
1986	270	504	63	586	61	0	1,484
1987	224	430	55	450	55	0	1,213
1988	253	502	63	422	55	309	1,603
1989	159	383	75	492	64	284	1,457
1990	155	435	78	494	47	796	2,004
1991	223	439	105	463	60	543	1,833
1992	277	513	95	500	54	563	2,002
1993	282	331	122	419	61	0	1,216
1994	355	231	222	441	64	291	1,604
1995	416	224	238	471	61	47	1,456
1996	314	335	208	289	45	185	1,377
1997	289	258	202	980	42	(3)	1,768
1998	300	182	192	1,218	398	(124)	2,166
1999	344	174	218	900	438	(49)	2,024
2000	326	172	244	742	595	(173)	1,905
2001	468	400	150	643	634	120	2,415
2002	317	486	144	570	632	48	2,197
2003	319	482	123	570	603	(52)	2,045
2004	298	535	105	754	498	(106)	2,083
2005	376	511	81	1,124	502	(168)	2,424
2006	356	530	64	1,062	470	(20)	2,462
2007	444	470	0	946	414	0	2,273
Total	13,392	17,537	4,147	29,558	8,186	2,491	75,302

Source: U.S. Department of Energy, Budget Authority History Table by Organization.

Research to Develop New Technologies. R&D expenditures in this category attempt to discover new scientific knowledge for which there is potential for commercial application. Although reaching the point of technology transfer to the private sector for commercialization is the objective this type of R&D, the probability of success is uncertain.

Research to Improve Existing Technologies. These expenditures use scientific knowledge to design and test new processes that may have substantial technical and cost uncertainties. The immediate beneficiaries are generally well defined, i.e., current producers and consumers of particular fuels, or operators and customers of the technology being improved.

Energy Research and Development as a Subsidy

It is easier to measure energy R&D spending than to characterize it as a subsidy. R&D spending is intended to create useful knowledge and develop technologies that have potential

commercial benefits to society. Thus, all Federal R&D spending could, in a general way, be considered a subsidy to knowledge and technology. However, the extent to which specific R&D programs actually affect energy markets is more difficult to ascertain.

The results of R&D are inherently uncertain. Many programs are intended to advance knowledge across a range of energy and non-energy applications, rather than in the context of a particular fuel or form of consumption. Furthermore, the knowledge obtained may not be of value, in the sense that the research may only reveal technical or economic dead ends to be avoided in the future.[65] Thus, only a portion of Federal energy R&D is likely to achieve results in the form of changes in energy production costs or consumption that can be attributed to a specific R&D program. Moreover, to the extent that R&D yields commercial technologies, 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 will not undertake. It is not supposed to substitute for private sector R&D. However, the creation of a Federally-funded R&D program could, under some circumstances, displace private-sector R&D. In that case, the Federal program would not produce new knowledge that could not be developed by the private sector, but would simply reduce private R&D costs. It is impossible to know with certainty what R&D private-sector firms would have performed 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. As R&D projects approach commercial viability, the justification for government participation lessens.[66]

Federal government energy-related R&D spending often represents a first stage of Federal intervention in energy markets. The rationale for government intervention in technology development lessens as products approach commercialization, because private investors at later stages of product development face fewer barriers towards successful commercialization. Other forms of Federal interventions in energy markets may complement the preliminary work done at the R&D stage.

For example, in promoting planned construction of advanced nuclear power, recent Federal intervention has involved new programs and changes to programs already in place. While this chapter describes Federal interventions supporting nuclear-related R&D, other chapters and the appendix to this report describe nuclear-related Federal energy interventions as they relate to tax expenditures, such as EPACT 2005's nuclear production tax credit, or loan guarantees, construction insurance, enhanced accident insurance, and regulatory changes. The combination of these programs suggests that the nuclear industry, in order to expand, faces several difficult hurdles, technological advancement being only one. For instance, preapproved technologies may reduce some of the regulatory risk associated with the

[65] Several studies suggest that the return on overall Federal R&D investment is much lower than the return on private-sector R&D, implying relatively high failure rates. See, Terlecyyj, N., "Effects of R&D on the Productivity Growth of Industries: An Exploratory Study (Washington, DC: National Planning Association, 1974), and Griliches, Z., "Returns to R&D in the Private Sector," in Kendrick, J. and Vaccara, B. (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 the private sector's.

[66] One recent study, "Energy Research at DOE: Was It Worth It? Energy and Fossil Energy Research 1978 to 2000," concluded that: "DOE's R&D programs in fossil energy and energy efficiency have yielded significant benefits (economic, environmental, and national security-related), important technological options for potential applications in a different (but possible) economic, political and/or environmental setting, and important additions to the stock of engineering and scientific knowledge in a number of fields." The committee also found that DOE has not employed a consistent methodology for estimating and evaluating the benefits from its R&D programs in these and presumably other areas." National Research Council Committee on the Benefits of DOE R&D on Energy Efficiency and Fossil Energy, Washington, DC: National Academy Press (2001), p. 5.

construction of new nuclear power plants. Potential investors in new nuclear power units may also need assurances that sufficient economies of scale will be undertaken so as to make new builds financially viable and that any construction delays will not result in financial losses and abandoned projects. However, most Federal government programs directed at reviving nuclear power have sunset provisions which are intended to become effective as advanced nuclear power becomes a commercially viable investment.

Therefore, tax expenditures directed toward developers, manufacturers, and end-use consumers of emerging technologies may act as a substitute for Federal R&D programs, allowing manufacturers (and others) to gather useful information and introduce modifications to improve performance and reliability, and lower costs. In the end, 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 the prospects of 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 an historical perspective on changes in the composition of Federal energy R&D efforts in response to changes in national priorities. Because Federal energy R&D programs may sponsor both fuel-consuming capital equipment, particularly power generation technologies, and fuel production technologies, e.g., biofuels, Federal R&D may produce conflicting benefits. Such projects may be more properly viewed as a subsidy to capital equipment manufacturers, rather than to fuel producers or consumers. Because generation technologies aided by Federal R&D may become more energy efficient, they 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 with the understanding that considerable time and resources may be expended as a new technology moves from the R&D stage through demonstration to commercialization. Only then can the full consequences of any new technologies be ascertained.

Finally, much of what is defined as energy R&D in the Federal government's budget accounts is not directly expended on energy research or development. Rather, a portion of the funds are expended on environmental restoration and waste management associated with the byproducts of energy-related research facilities, e.g., nuclear waste disposal.

Energy Research and Development Trends

Currently, about 57 percent ($3.8 billion) of total Federal energy R&D is allocated to basic research. DOE's largest basic research outlay is the General Science Program, funded at $1.9 billion in FY 2007. This program supports research and operates facilities to provide the foundation for new and improved energy technologies. This program also provides funding for understanding environmental impact of these technologies. Basic Research also includes the Fusion Energy Sciences Program which is funded at $319 million in FY 2007. It is the National research effort to advance plasma science, fusion science, and technology needed for a fusion energy source in the future. Basic research is difficult to characterize as an energy subsidy because it cannot be allocated between energy and non-energy benefits or among forms of energy. Therefore, these programs, including Fusion Energy Sciences, are not included as subsidies in this analysis.

The balance of this chapter focuses on applied energy R&D. Federal energy R&D that is unrelated to basic research, or Applied R&D, accounts for $2.8 billion (Table 13). This includes

energy programs in the FY 2007 DOE Operating Plan, as well as energy programs in other Federal agencies.

Table 13. Federal Energy R&D by Type and Function (million 2007 dollars)

R&D Program Category	FY 1999 Appropriation	FY 2007 Operating Plan
Basic R&D		
General Science	1,968	1,942
General Energy Science	996	1,292
Environment, Safety, and Health	57	28
Other Allocated	60	250
Fusion Energy Sciences	270	319
Basic R&D Sub Total	3,352	3,831
Applied R&D		
Coal	489	574
Natural Gas and Petroleum Liquids	198	39
Nuclear Power	740	922
Renewable and Other Electric Technologies	587	867
End Use	487	418
Applied R&D Sub Total	2,500	2,819
Total	5,853	6,650

NOTE: Total may not equal sum of components due to independent rounding.

Sources: U.S. Department of Energy FY 2007 Operating Plan by Appropriation; Energy Information Administration, *Federal Financial Interventions and Subsidies in Energy Markets 1999: Primary Energy*, SR/OIAF/99-03 (Washington, DC, September 1999); *Federal Financial Interventions and Subsidies in Energy Markets 1999: Energy Transformation and End Use*, SR/OIAF/2000-02, (Washington, DC, May 2000).

Applied R&D focuses on turning knowledge and concepts into useful products. Applied energy R&D expenditures are about $2.8 billion in FY 2007. The largest programs are the renewable technologies ($905 million)[67] and nuclear power ($922 million). Funding for coal is $574 million. Natural gas and petroleum liquids are funded at about $39 million for geologic assessments and expenses incurred in connection with the phase-out of existing programs.

The largest funding category for renewables technologies is for biofuels and biomass ($246 million) followed by hydrogen technologies (Table 14). The hydrogen technologies program, which did not exist when EIA prepared its report in 1999, is funded at $230 million in FY 2007.[68] Solar programs are funded at $187 million. These renewable programs, unlike others, such as wind, are not yet considered commercially viable because of cost and performance issues. Technologies receiving smaller funding levels include wind ($58 million) and geothermal ($6 million). There are no R&D funds allocated to hydropower for FY 2007. Geothermal R&D funding was $35 million in FY 1999, compared to $6 million in FY 2007. The Electricity Delivery and Energy Reliability programs have increased from $54 million in FY 1999 to $140 million in FY 2007. The Nuclear Power program includes new nuclear plants ($319 million), Waste/Fuel and Safety ($350 million), and Program Direction and Termination Costs ($253 million). These programs are discussed in more detail in the balance of this chapter.

[67] Technical system reliability R&D totaling $137 million is included in this portion of Applied R&D. It is classified as "Electricity" in the Executive Summary and Chapter 5.

[68] Although hydrogen R&D programs are not renewables, they are included here because they are administered by the DOE Office of Energy Efficiency and Renewable Energy.

Table 14. Renewables and Other R&D Expenditures (million 2007 dollars)

R&D Program	FY 1999 Appropriation	FY 2007 Operating Plan
Wind	42	58
Solar	120	187
Hydrogen Technology	-	230
Biofuels and Biomass	116	246
Geothermal	35	6
Hydroelectric	4	-
Other Allocated	95	-
Total Renewables	412	727
Electricity Deliverability and Energy Reliability	54	140
Total	466	867

NOTE: Totals may not equal sum of components due to independent rounding.

Sources: U.S. Department of Energy FY 2007 Operating Plan by Appropriation, U S Department of Agriculture, *FY 2007 Budget Summary and Annual Performance Plan*, pp. 32 and 78; Defense Logistics Agency, The Defense Logistics Agency Hydrogen and Fuel Cell Program, September 12, 2007, leo.plonsky@dla.mil; http://www.rita.dot.gov/agencies_and_offices/research/hydrogen_portal/. Energy Information Administration, *Federal Financial Interventions and Subsidies in Energy Markets 1999: Primary Energy*, SR/OIAF/99-03 (Washington, DC, September 1999); *Federal Financial Interventions and Subsidies in Energy Markets 1999: Energy Transformation and End Use*, SR/OIAF/2000-02, (Washington, DC, May 2000),

Federal Energy R&D Subsidies to Renewable and Other Technologies

Renewable R&D

The Office of Energy Efficiency and Renewable Energy (EERE) conducts research, development, and deployment activities in partnership with industry to advance a diverse supply of reliable and affordable, efficient and clean power technologies.[69] The FY 2007 budget emphasizes research on alternatives that are intended to reduce the Nation's dependence on foreign oil and accelerate development of clean electricity supply options.

The Hydrogen Technology program, created by EPACT2005, focuses on hydrogen production, delivery, storage, and fuel cell technologies. This program supports the Bush Administration's 5-year, $1.2-billion Hydrogen Fuel Initiative intended to reverse America's growing dependence on foreign oil by accelerating the development of hydrogen fuel cell vehicles and infrastructure technologies. The program is intended to enable a commercialization decision by industry on fuel cell vehicles and hydrogen infrastructure by 2015. A positive commercialization decision in 2015 could lead to the introduction of hydrogen fuel cell vehicles in the market by 2020. The responsibility for implementing the Hydrogen Fuel Initiative rests with a number of organizations. Basic hydrogen research is managed by the Office of Science. The Office of Fossil Energy oversees coal-based hydrogen production research. Nuclear-based hydrogen production research resides with the Office of Nuclear Energy, Science and Technology. The Department of Transportation manages activities related to hydrogen safety. The fuel cell program is under the direction of the Defense Logistics Agency of the Department of Defense.

[69] The text in this section is extracted from the Department of Energy FY 2007 Congressional Budget Request Budget Highlights DOE/CF-009.

The Biomass and Biorefinery Systems R&D program includes a new Departmental Initiative that is funded at $234.2 million and a program at the United States Department of Agriculture (USDA) funded at $12 million in FY 2007. The DOE Biofuels Initiative is intended to accelerate research, development, and deployment of industrial-scale biorefinery operations. The program focuses on three areas: (1) Platforms R&D, to reduce the cost of outputs and byproducts from biochemical and thermochemical processes; (2) Utilization of Platform Outputs, to develop technologies and processes that co-produce liquid and gaseous fuels, chemicals and materials, and/or heat and power, and integrate those technologies and processes into biorefinery configurations; and, (3) Feedstock Infrastructure, to develop cost-effective biomass harvesting, storage and delivery systems, and to develop energy crops suitable for diverse regions and climates.

There is also funding for Biomass Research and Development within the USDA Natural Resources Conservation Service that is coordinated with the DOE Biofuels Initiative.[70] The funding level for FY 2007 is $12 million. The total funding for the DOE and USDA programs is $246.2 million in FY 2007. Biofuels and bioenergy research performed by USDA, including the Agricultural Research Service, are included in Renewable R&D expenditures. Biofuels and bioenergy R&D within the USDA Research, Education and Extension Mission Area excluding the $12 million are reported in Table 14. This additional funding totaled $29 million in FY 2007 (see Table 17).

The Solar Energy program is funded at $186.9 million in FY 2007. It focuses on R&D to enable cost-effective development of solar power that will reduce the demand for natural gas during peaking hours and promote a cleaner environment. Through DOE's new Solar America Initiative (SAI), the Solar Program is intended to help accelerate the competitiveness of solar electricity from photovoltaic (PV) systems. Under the SAI, industry-led teams will compete to deliver future PV systems that are less expensive, more efficient, and highly reliable. By focusing on PV technology manufacturing issues while advancing systems integration, SAI intends to promote deployment of 5 to10 gigawatts (GW) of new grid-connected solar electricity generating capacity by 2015. The Solar Energy programs also focus on lowering the cost of solar power through larger-scale centralized generation.

The Wind Energy program is funded at $57.8 million in FY 2007. This program develops and promotes the use of advanced technologies to harness kinetic wind energy. The program is developing low wind speed utility scale technology through leveraged partnerships with industry to substantially increase the economically viable wind resource base across the country. The program explores innovative applications that will open new markets for wind technology, including offshore development.

Since 1974, the Geothermal Technology program has worked in partnership with U.S. industry to establish geothermal energy as an economically-competitive contributor to the U.S. energy supply. DOE planned to conclude the Geothermal Technology program in FY 2007 and transfer program R&D results to industry and State and local governments. The program is funded at $5.9 million in FY 2007. However, the program was funded in DOE's FY 2008 budget at $20 million, with an additional request for $30 million in FY 2009. In 2006, the Massachusetts Institute of Technology (MIT) issued a DOE-sponsored study in which MIT researchers concluded that enhanced geothermal systems could provide 100 gigawatts (GW) or more of

[70] U.S. Department of Agriculture, Fiscal Year 2007 Budget Summary and Annual Performance Plan, p. 78.

cost-competitive geothermal generating capacity over the next 50 years with a reasonable amount of R&D investment.[71]

Electricity Delivery and Energy Reliability R&D

The Office of Electricity Delivery and Energy Reliability (OE) leads the national effort to modernize and expand the U.S. electricity delivery system to ensure a reliable and robust electricity supply. In addition to its policy and regulatory functions, OE is engaged in a variety of R&D initiatives related to transmission and distribution reliability, technology, and system control. FY 2007 funding totals $140 million for the following programs (Table 14).

The High Temperature Superconductivity R&D program is intended to pursue improvements in the efficiency and reliability of the Nation's electric delivery system. The goal of this research is to develop by 2016 operational wire and power prototypes that are physically smaller than current infrastructure and deliver energy with half of the losses of conventional equipment with the same power rating.

The Visualization and Controls R&D program is intended to develop communication and control systems that support adaptive, intelligent grid operations, which integrate distributed energy devices. These advances will improve electric delivery system reliability and maximize efficiency by increasing the use of transmission and distribution assets.

The Energy Storage and Power Electronics R&D program pursues advancements that reduce the adverse effects of electricity disturbances.

The Distributed Energy R&D program aims to develop a diverse array of cost-competitive, integrated distributed-generation and thermal energy technologies. It also supports the use of these technologies in residential, business, and industrial applications to improve electricity reliability and reduced negative environmental impacts. The FY 2007 program consists of three activities: Research and Development Permitting, Siting and Analysis, and Infrastructure Security and Energy Restoration.

The Permitting, Siting and Analysis subprogram supports Federal initiatives authorized in EPACT2005, including a national analysis of electric transmission congestion, the designation of national interest electric transmission corridors, and the designation of multi-purpose energy corridors on Federal lands.

Direct Thermal to Electric Conversion program is conducted by the Defense Advanced Research Projects Agency (DARPA). The program focuses on research to significantly reduce the gap between practically-achievable thermal to electric conversion efficiencies and theoretically-achievable thermodynamic efficiencies. The program is funded at $2.5 million in FY 2007. Table 14 includes the aggregate of funding for Electricity Deliverability and Energy Reliability among OE's R&D programs. FY 2007 funding is nearly three times the FY 1999 funding level.

Federal Energy R&D Subsidies to Nuclear Energy

DOE's Office of Nuclear Energy, Science and Technology (NE) mission is to develop new nuclear energy generation technologies to meet energy and climate goals; develop advanced, proliferation-resistant nuclear fuel technologies that maximize energy from nuclear fuel; and

[71] Massachusetts Institute of Technology, prepared under Idaho National Laboratory Subcontract No. 6300019 for the U.S. Department of Energy, Assistant Secretary for Energy Efficiency and Renewable Energy, Office of Geothermal Technologies, ISBN: 0-615-13438-6, 2006.

maintain and enhance the national nuclear infrastructure. DOE's nuclear energy R&D program collaborates with international research communities in planning and conducting applied research to further the course of nuclear technology advancement.

Through the Advanced Fuel Cycle Initiative, DOE seeks to develop advanced, proliferation resistant nuclear fuel technologies that maximize the energy produced from nuclear fuel while minimizing resulting wastes. Associated with this program, the Global Nuclear Energy Partnership (GNEP) aims to further provide for the expansion of nuclear power plants in the United States and around the world, in addition to promoting nuclear nonproliferation goals and helping resolve nuclear waste disposal issues.

NE is funded in two accounts within the Energy and Water Development Appropriations: Energy Supply and Conservation and Other Defense Activities. All funding for R&D and landlord activities for the Idaho National Laboratory (INL) is included in the Energy Supply and Conservation account. Funding for Safeguards and Security is within the Other Defense Activities account. DOE received an appropriation of $922 million for civilian nuclear R&D in FY 2007 (Table 15). Nearly 40 percent of the appropriation ($350 million) is allocated to the cleanup of contaminated nuclear energy and research sites.[72]

Table 15. Nuclear Power R&D Expenditures (million 2007 dollars)

R&D Program	FY 1999 Appropriation	FY 2007 Operating Plan
New Nuclear Plants (Nuclear Energy Research Initiative)	36	319
Waste/Fuel/Safety (Environmental Management)	530	350
Other Allocated (Termination Costs and Program Direction)	173	253
Total	740	922

NOTE: Totals may not equal sum of components due to independent rounding. Space and defense infrastructure and medical isotopes infrastructure programs are not included in this table.

Source: U.S. Department of Energy FY 2007 Operating Plan by Appropriation.

Improving Existing Power Plants and Enhancing Nuclear Power

DOE created the Nuclear Energy Research Initiative (NERI) to address and help overcome the technical and scientific obstacles to the future use of nuclear energy in the United States. NERI is also expected to help preserve the nuclear science and engineering infrastructure within the Nation's universities, laboratories, and industry to advance the state of nuclear energy technology and to maintain a competitive position worldwide.

The FY 2007 allocation of $319 million supports innovative applications of nuclear technology to develop new nuclear generation technologies and advanced energy products. It is also supporting the development of advanced proliferation-resistant nuclear fuel technologies that maximize energy output, and maintain and enhance national nuclear capabilities (Table 15). The Advanced Fuel Cycle Initiative (AFCI), which is integral to the Generation IV Nuclear Energy Systems effort, aims to develop a better, more efficient and proliferation-resistant nuclear fuel cycle. This R&D program is focusing on methods to reduce the volume and long-term toxicity of high-level waste from spent nuclear fuel, reduce the long-term proliferation threat posed by civilian inventories of plutonium in spent fuel, and provide for proliferation-

[72] U.S. Department of Energy Fiscal Year 2007 Operating Plan by Appropriation.

resistant technologies to recover the energy content in spent nuclear fuel. The focus of this initiative will be Global GNEP, which consists of 16 member nations which promote the expansion of peaceful applications of nuclear power.[73]

GNEP is intended to accelerate the work being done under the AFCI program. Advanced recycling technologies can extract highly radioactive elements of commercial spent nuclear fuel and use that material as fuel in fast spectrum reactors to generate additional electricity. The extracted material, which includes all transuranic elements (e.g., plutonium, neptunium, americium and curium), would be consumed by fast breeder reactors to significantly reduce the quantity of material requiring disposal in a repository. The plutonium would remain bound with other highly radioactive isotopes, thereby improving its proliferation resistance and reducing security concerns. With the transuranic materials separated and used for fuel, the volume of waste that would require disposal in a repository whose size would be reduced by 80 percent.

The Nuclear Power 2010 program operating plan is funded at $80.3 million in FY 2007 for purposes of obtaining three early site permits by the NRC. In addition, the program will complete the industry cost-shared project initiated in FY 2003 to develop generic guidance for the Construction and Operating License (COL) application preparation, to resolve generic COL regulatory issues, and to continue the implementation phase of the two New Nuclear Plant Licensing Demonstration Projects awarded in FY 2005.

The goal of the Generation IV Nuclear Energy Systems Initiative (Gen IV) is to address the fundamental R&D issues necessary to establish the viability of next-generation nuclear energy system concepts. The 2007 budget provides $35.6 million for the Gen IV initiative to expand R&D that could help achieve the desired goals of sustainability, economic feasibility, and proliferation resistance. The Nuclear Hydrogen Initiative (NHI), with funding of $19.3 million, intends to conduct R&D on enabling technologies, and develop technologies that will apply heat from Generation IV nuclear energy systems to produce hydrogen through electrolysis. The budget level for nuclear R&D in FY 2007 is 25 percent greater than it was in FY 1999. A substantial part of the increase is for the Nuclear Energy Research Initiative which increased by $283 million compared with FY 1999.

Environmental Management

A substantial portion of Federally-funded nuclear R&D is used for managing and addressing the environmental legacy resulting from past nuclear energy and research activities. Thousands of contaminated areas and buildings exist throughout the United States. The goal of the program is to decommission. Upon completing the clean up of these facilities, DOE's presence and associated costs will be limited to long-term surveillance and maintenance.

Other Allocated Expenditures

Other allocated expenditures amount to $253 million in FY 2007 (Table 15). The largest portion of this amount is for Idaho facilities management and safeguards and security ($190 million). The Idaho Facilities Management program provides site-wide infrastructure needed to support R&D while the Safeguards and Security Program protects DOE interests. The remaining $62.6 million is allocated to nuclear energy program direction, which provides Federal staffing resources and associated funding required to execute DOE's nuclear energy program.

[73] GNEP member countries include the United States, Australia, Bulgaria, China, France, Ghana, Hungary, Japan, Jordan, Kazakhstan, Lithuania, Poland, Romania, Russia, Slovenia, and the Ukraine.

Federal Energy R&D Subsidies to Coal

The Fossil Energy Research and Development program started in the late 1980s. The program goal is to ensure that economic benefits of moderately-priced coal-fired generation are compatible with public expectations for environmental quality with the intent of achieving energy security derived from reliance on abundant domestic coal-resources. The program pursues these goals by: (1) managing and performing energy-related research that reduces market barriers to the reliable, efficient, and environmentally sound use of fossil fuels for power generation and conversion to other fuels such as hydrogen; (2) partnering with industry and others to advance the commercialization of clean and efficient fossil energy technologies; and, (3) supporting the development of information and policy options that benefit the public by ensuring access to adequate supplies of affordable and clean energy.[74]

EPACT2005 Section 962 directs DOE to conduct a coal and power systems research, development and demonstration program to facilitate the production and generation of coal-based power. Cost and performance goals are to be established to insure the continued competitiveness for electricity generation, transportation fuel, and chemical feed stocks. Section 963 establishes a program for carbon capture technologies to be used in conjunction with combustion based systems with the intent of reducing future greenhouse gas emissions. Table 16 compares FY 1999 and FY 2007 expenditures for DOE's Office of Fossil Energy coal R&D program.

Table 16. Coal R&D Expenditures (million 2007 dollars)

R&D Program	FY 1999 Appropriation	FY 2007 Operating Plan
Clean Coal Power Initiative	106	61
Advanced Clean Fuels	19	-
Future Gen Advanced Clean Fuels	-	54
Fuel and Power Systems	24	311
Clean Coal Technology Adjustment	222	-
Other Allocated	118	148
Total	489	574

NOTES: Totals may not equal sum of components due to independent rounding.
The Clean Power Initiative was previously referred to as Advanced Clean Efficient Power Systems. Advance Clean Fuel funding now falls under Fuel and Power Systems. Source: U.S. Department of Energy FY 2007 Operating Plan by Appropriation.

The program focuses on near-zero atmospheric emissions coal-based electricity and hydrogen production. The President's Coal Research Initiative is aimed at meeting these objectives. The programs included in this initiative are the Clean Coal Power Initiative (CCPI), FutureGen, and Fuel and Power Systems. The total FY 2007 appropriation for the R&D program is $574 million.

The CCPI is a cooperative, cost-sharing program between the Federal government and industry intended to demonstrate emerging technologies in coal-based power generation. The objective of CCPI is to collaborate with the Nation's power generators, equipment manufacturers, and coal producers to help identify the most critical barriers to using coal in the power sector. Technologies will be selected with the goal of accelerating development and commercial deployment of coal technologies that will economically meet environmental standards.

[74] The Department of Energy Fiscal Year 2007 Congressional Budget Request Budget Highlights, DOE/CF-009.

FutureGen aimed to establish the capability and feasibility of co-producing electricity and hydrogen from coal with near-zero atmospheric emissions. Carbon sequestration is an integral component of the project.[75] FutureGen is intended to employ a public/private partnership aiming to demonstrate technology with the goal of developing near-zero atmospheric emission plants that are fuel-flexible and capable of multi-product output with electrical efficiencies of over 60 percent. The cost of the electricity produced is to amount to no more than a 10-percent increase over comparable plants, without carbon sequestration, that use coal, biomass, or petroleum coke. The project is intended to retain the strategic value of coal.

The Fuel and Power Systems program provides funding for research in connection with FutureGen. The Fuel and Power System program focuses on how to reduce coal power plant emissions, especially mercury, and significantly improve efficiency in terms of carbon emissions per unit of electricity produced, leading to a viable near-zero atmospheric emissions coal energy system.

The Innovations for Existing Plants (IEP) program focuses on the near-to-mid-term task of retrofitting existing power plants to improve overall power plant efficiency and develop advanced cost-effective environmental control technologies. It focuses on reducing mercury emission and other coal technologies, including those developed in the FutureGen project that can be deployed when retrofitting existing power plants.

The Integrated Gasification Combined Cycle (IGCC) program continues the development of technologies for gas stream purification to meet quality requirements for use with fuel cells and conversion processes. The program also focuses on impurity tolerant hydrogen separation technology, enhanced process efficiency, and reductions in costs, including energy required to produce oxygen for gasification.

The Advanced Turbines program focuses on creating the technology base for turbines that will permit the design of near-zero atmospheric emission IGCC plants and a class of FutureGen plants with carbon capture and sequestration. The Advanced Turbine program research focuses on developing technology for high-efficiency hydrogen and syngas turbines for advanced gasification systems to be incorporated in FutureGen plants.

The Carbon Sequestration program is developing a portfolio of technologies with potential to reduce greenhouse gas emissions. The program focuses on developing capture and separation technologies that may dramatically lower the costs and energy requirements for reducing carbon dioxide emissions from fossil-based (especially coal) power plants. The program goal is to research and develop a portfolio of safe and cost-effective greenhouse gas capture, storage, and mitigation technologies by 2012.

The mission of the Advanced Clean Fuels program is to conduct the research necessary to promote the transition to a hydrogen economy. Research will target cost reduction and increased efficiency of hydrogen production from coal feedstocks.

[75] The prospects of the FutureGen grew uncertain when, in January 2008, the U.S. Department of Energy announced that it intended to restructure FutureGen. The DOE's new FutureGen vision called for "Federal-funding to demonstrate cutting edge CCS (Carbon Capture and Storage) at multiple commercial-scale integrated gasification combined-cycle (IGCC) demonstration plants…Under this new approach multiple plants would produce at least 3000 megawatts of electricity and jointly these projects will capture and safely sequester at least double the amount of carbon dioxide annually compared to the concept announced in 2003." Source: DOE, Fact Sheet, "DOE to Demonstrate Cutting-Edge Carbon Capture and Sequestration Technology at Multiple FutureGen Clean Coal Projects." The DOE cited higher than expected costs for the restructuring. The DOE also stated that the program would be revamped so that DOE would only fund the carbon sequestration element of the program. The restructuring cast strong doubts over whether the prototype plant, selected in December 2007 for Mattoon, Illinois, would continue.

Advanced Research projects seek a greater understanding of the physical, chemical, biological, and thermodynamic barriers that limit the use of coal and other fossil fuels. The program funds two types of activities. The first includes applied research programs to develop the technology base needed for the development of super clean, high efficiency coal-based power and coal-based fuel systems. The second is a set of crosscutting studies and assessment activities in environmental, technical and economic analyses, coal technology export, and integrated program support.

The objectives of the Fuel Cells program are to provide for the development of low-cost, scalable fuel flexible fuel cell systems that can operate in central, coal based power systems in distributed or dispensed generation applications.

The Other Allocated funding includes several other expenditures, the largest of which is program direction funded at $125.6 million in FY 2007. Other expenditures include plant and capital equipment, fossil energy environmental restoration, and special recruitment programs. The total funding for this category in FY 2007 is $148 million (Table 16).

The overall funding for coal R&D in FY 2007 has increased by $85.1 million compared with FY 1999. The largest increase is in Fuel and Power Systems which has increased by $287 million. About one-third of the increase in this program is R&D for carbon sequestration.[76]

Federal Energy R&D Subsidies to Natural Gas and Petroleum Liquids

The United States relies on fossil fuels for approximately 85 percent of the energy it consumes. EIA's *Annual Energy Outlook 2008 (Revised Early Release)* forecast projects that reliance on fossil fuels will modestly decline to 82 percent by 2030.[77] To address this situation, the Natural Gas and Petroleum Liquids program promotes the development of environmentally-sensitive and economically-efficient fossil fuel energy systems for the benefit of current and future energy users. R&D funding for oil and natural gas is $39 million in FY 2007 (Table 13).

The United States Geological Survey (USGS) is funded at $20.1 million in FY 2007 to conduct research to enhance exploration, development, and production of oil, natural gas, coal, and other resources such as geothermal. EPACT2005 calls for a focus on all energy sources with an emphasis on assessment of geothermal resources and alternative energy sources such as gas hydrates and oil shale. Section 351 of EPACT2005 directed USGS to create the Preservation of Geological and Geophysical Data Program to rescue, curate, and preserve materials and data related to energy and minerals. Section 351 also directs USGS to assess the oil and gas underlying Federal lands in the United States.

DOE's FY 2007 oil research efforts are funded at $3.5 million for management costs associated with the closeout of the program. The program addressed new technologies that improve exploration, drilling, reservoir characterization, and extraction. Similarly, the Natural Gas Program received $15.4 million in FY 2007 for the closeout of the program. It focused on natural gas research and fuel cells.

Federal Subsidies to End Use Energy R&D

The End Use Energy program develops technologies, techniques, and tools for making residential and commercial buildings more energy efficient, productive, and affordable. The

[76] Although there is no legislation mandating reductions in carbon dioxide emissions, the carbon sequestration program is included because it meets the definition of a subsidy used in this analysis.
[77] Energy Information Administration, *Annual Energy Outlook 2008 (Revised Early Release)*, DOE/EIA-0383 (2008) (Washington, DC, March 2008), Year-by-Year Reference Case Table 1, http://www.eia.doe.gov/oiaf/aeo/aeoref_tab.html.

portfolio of activities includes: (1) efforts to improve the energy efficiency of building components and equipment; (2) advancement of solid state lighting technologies for general illumination; (3) integration of advanced light systems using whole-building-system-design techniques; (4) development of energy efficient building codes and equipment standards; and (5) integration of clean renewable energy systems into building design and operation.

The Building Technologies Program works in partnership with States, industry, and, particularly, manufacturers, to improve the energy efficiency of buildings. Through new technologies and systems-engineered building practices, the design, construction, and operation of approximately 15 million new buildings projected to be constructed by 2015 is expected to be improved. Funding for this program was $103 million in FY 2007 (Table 17).

Table 17. Federal Funding for End-Use R&D (million 2007 dollars)

R&D Program	FY 1999 Appropriation	FY 2007 Operating Plan
Building Technology, State and Community Programs	117	103
Industrial Sector	201	66
(Less Advanced Turbine Systems)	(121)	-
Industrial Sector Net	80	66
Vehicle Technologies	245	221
Research, Education and Extension Service (USDA)	-	29
Other Allocated (Policy and Management)	46	-
Total	487	418

NOTE: Totals may not equal sum of components due to independent rounding.

Source: U.S. Department of Energy FY 2007 Operating Plan by Appropriation.

The program advances the R&D of energy-efficient building technologies and practices for both new and existing residential and commercial buildings. It works with State and local regulatory groups and others to improve building codes, appliance and equipment standards, and guidelines for efficient energy use and promotes market transformation by educating homeowners, builders, and developers about the returns they can achieve by adopting energy-efficient technologies and practices.

The Industrial Technologies program focuses on reducing the energy intensity of the U.S. industrial sector through a coordinated program of R&D, validation, and dissemination of energy-efficiency technologies and best practices. During FY 2007, activities with specific industries (forest products, glass, metal casting, aluminum, mining, chemicals, and supporting industries) and crosscutting activities (materials and Industrial Assessment Centers) were aimed at focusing on the successful completion of existing projects with the highest potential energy efficiency gains and environmental benefits. New projects were selected that were unlikely to be undertaken without Federal support, and that significantly were expected to reduce energy intensity, consistent with DOE's R&D Investment Criteria.[78] Funding for this program was $66 million in FY 2007.

The Vehicle Technologies program supports the FreedomCAR and Fuel Partnership and the 21st Century Truck Partnership, to enable light- and heavy-duty highway transportation to become more fuel efficient. Technology research includes advanced lightweight materials,

[78] Pursuant to President Bush's Management Agenda, the three primary criteria applicable to all R&D programs are relevance, quality, and performance. See Memorandum for the Heads of Executive Departments and Agencies, Executive Office of the President Office of Management and Budgets, M-05-18, July 8, 2005.

advanced batteries, improved power electronics, electric motors, and advanced combustion engines and fuels. These technologies are intended to contribute to reducing oil consumption. In FY 2007, the program is increasing research on technologies needed for cost-effective plug-in hybrid vehicles. At $221 million, the Vehicle Technologies program accounted for more than half of end-use R&D funding in FY 2007.