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ADVANCED ENERGY TECHNOLOGIES

Budget Trends and Challenges for DOE's Energy R&D Program

Statement of Mark E. Gaffigan, Acting Director
Natural Resources and Environment

March 5, 2008

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Highlights

Highlights of GAO-08-556T, a testimony before the Subcommittee on Energy and Environment, Committee on Science and Technology, House of Representatives

Why GAO Did This Study

For decades, the nation has benefited from relatively inexpensive energy, in the process growing heavily reliant on conventional fossil fuels—oil, natural gas, and coal. However, in the current wake of higher energy costs and environmental concerns about fossil fuel emissions, renewed attention is turning to the development of advanced energy technologies as alternatives. In the United States, the Department of Energy (DOE) has long conducted research, development, and demonstration (R&D) on advanced renewable, fossil, and nuclear energy technologies. DOE's Office of Science has also funded basic energy-related research.

This testimony addresses (1) funding trends for DOE's renewable, fossil, and nuclear energy R&D programs and its Office of Science and (2) key challenges in developing and deploying advanced energy technologies. It is based on GAO's December 2006 report entitled *Department of Energy: Key Challenges Remain for Developing and Deploying Advanced Energy Technologies to Meet Future Needs* (GAO-07-106). In doing that work, GAO reviewed DOE's R&D budget data and strategic plans and obtained the views of experts in DOE, industry, and academia, as well as state and foreign government officials.

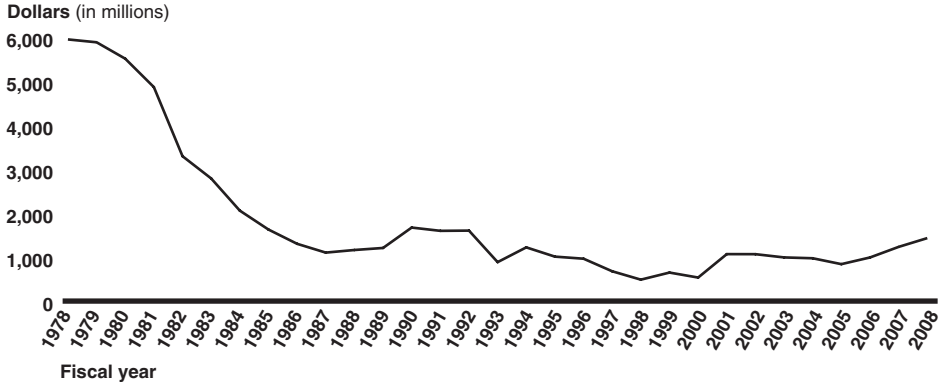
To view the full product, including the scope and methodology, click on GAO-08-556T. For more information, contact Mark E. Gaffigan, at 202-512-3841 or gaffiganm@gao.gov.

What GAO Found

Between fiscal years 1978 and 1998, DOE's budget authority for renewable, fossil, and nuclear energy R&D fell 92 percent when adjusted for inflation (from its $6 billion peak in fiscal year 1978 to $505 million in fiscal year 1998). It has since rebounded to $1.4 billion in fiscal year 2008 (see figure). Energy R&D funding in the late 1970s was robust in response to the 1973 energy crisis caused by constricted oil supplies. However, R&D funding plunged in the 1980s as oil prices returned to their historic levels. DOE's fiscal year 2009 budget, as compared with 2008, requests slightly less budget authority for renewable energy R&D, while seeking increases of 34 percent for fossil energy R&D and 44 percent for nuclear energy R&D. In addition, DOE is requesting $4.7 billion for basic research under its Office of Science.

The development and deployment of advanced energy technologies present key technical, cost, and environmental challenges. DOE's energy R&D program has focused on reducing high up-front capital costs; improving the operating efficiency of advanced energy technologies to enable them to better compete with conventional energy technologies; and reducing emissions of carbon dioxide, a greenhouse gas linked to global warming, and pollutants that adversely affect public health and the environment. However, while DOE has spent $57.5 billion over the past 30 years for R&D on these technologies, the nation's energy portfolio has not dramatically changed—fossil energy today provides 85 percent of the nation's energy compared to 93 percent in 1973. Because DOE's energy R&D funding alone will not be sufficient to deploy advanced energy technologies, coordinating energy R&D with other federal energy-related programs and policies will be important. In addition, other governments and the private sector will play a key role in developing and deploying advanced energy technologies that can change the nation's energy portfolio.

Budget Authority for Renewable, Fossil, and Nuclear Energy R&D, Fiscal Years 1978-2008



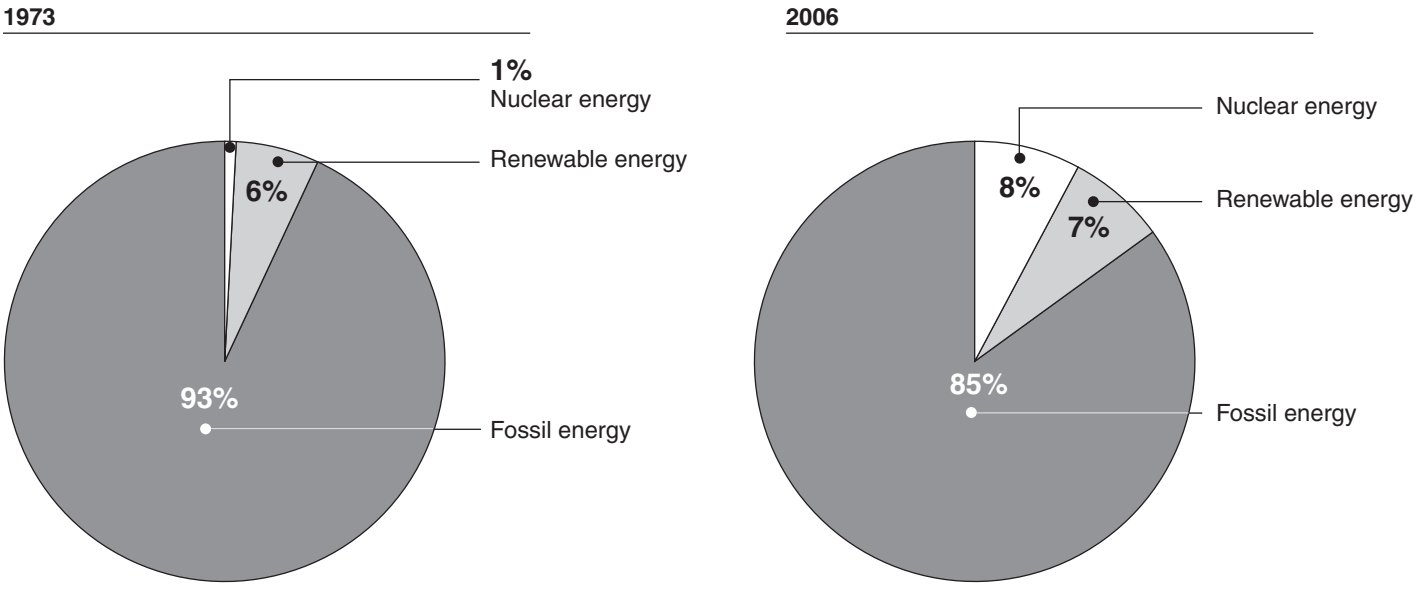
Source: GAO analysis of DOE data.

Note: Budget authority is in real terms, adjusted to fiscal year 2008 dollars to account for inflation.

Mr. Chairman and Members of the Subcommittee:

I am pleased to be here today to discuss the challenges that our nation faces in meeting its future energy needs. The United States has primarily relied on market forces to determine its energy portfolio. The market has generally succeeded in providing us with plentiful, reliable, and inexpensive conventional fossil fuels—oil, natural gas, and coal—to power our vehicles and run our homes and businesses. However, as shown in figure 1, the nation's energy portfolio today has not dramatically changed since 1973. In 2006, fossil fuels accounted for 85 percent of the nation's energy supply as compared with 93 percent in 1973—the primary difference in the portfolio was the growth of nuclear power in the 1970s and 1980s. Oil continues to account for 97 percent of the energy consumed for transportation and fossil fuels continue to generate 71 percent of the nation's electricity; renewable energy grew slightly during this period to 7 percent of U.S. energy consumption.

Figure 1: Comparison of the U.S. Energy Portfolio in 1973 and 2006



Source: GAO analysis of EIA data.

While conventional fossil fuels have provided us with relatively inexpensive and plentiful energy, they present economic and national security risks and have adverse health and environmental impacts. For

example, about two-thirds of the oil we consume is imported, and supply constrictions have contributed to major energy price shocks several times since 1973. More recently, decreased domestic production and increased world consumption of oil have pushed prices upward, nearly doubling the amount American consumers have paid for oil in just the past 3 years. In addition, DOE projects that U.S. transportation demand will increase by 31 percent and U.S. electricity demand will increase by 35 percent by 2030. Furthermore, emissions from the conventional burning of fossil fuels have contributed to health problems—about 50 percent of Americans live in areas where levels of one or more air pollutants are high enough to affect public health. Also, the combustion of fossil fuels account for most of the greenhouse gas emissions—particularly carbon dioxide—that have been linked to global warming.

Since its inception in 1977, the Department of Energy (DOE) has had leadership responsibility for energy research, development, and demonstration (R&D) to deploy advanced renewable, fossil, and nuclear technologies. DOE's energy R&D goal is to develop technologies for meeting future energy demands, addressing health and environmental issues, and diversifying the nation's energy portfolio.[1] During the past 30 years, DOE has spent about $57.5 billion for R&D in renewable, fossil, and nuclear technologies. In addition, DOE's Office of Science has spent about $34.3 billion from fiscal year 2000 through fiscal year 2008 on related basic energy research in such areas as high energy and nuclear physics, basic energy sciences, and fusion energy.

DOE's fiscal year 2009 budget requests $1.8 billion for renewable, fossil, and nuclear energy R&D and $4.7 billion for the Office of Science. In addition, several other federal agencies perform R&D to develop advanced energy technologies. For example, the Department of Agriculture funds R&D on ethanol and biodiesel production and energy crops that maximize ethanol production. The Department of Defense is the nation's largest consumer of transportation fuels, spending $13.6 billion on energy in fiscal year 2006. The Department of Defense is conducting R&D—some of it in collaboration with DOE—to develop alternative fuels to displace oil. One Air Force program has already certified a new fuel for the B-52 bomber, a 50/50 blend of the standard oil-based JP-8 jet fuel and a new synthetic fuel

[1]DOE is also responsible for energy efficiency programs, which are integral to addressing future energy challenges by reducing demand.

currently derived from natural gas that may be derived from biomass in the future.

In addition to R&D funding, the federal government can attempt to tap the vast resources of the private sector through tax incentives, such as tax credits to companies that make certain types of energy investments. These tax preferences—which are legally known as tax expenditures—result in forgone revenue for the federal government. The revenue losses can be viewed as spending channeled through the tax system. The federal government provides the energy industry and consumers with 20 tax expenditures affecting energy supply, totaling $6.3 billion in fiscal year 2007 and $4.9 billion in fiscal year 2008.[2] While the tax subsidies were historically directed toward the conventional energy sector, they have also been directed toward stimulating the deployment of advanced energy technologies.[3] For example, the Energy Policy Act of 2005 provided a (1) 2-year extension of the production tax credit for renewable technologies, (2) new investment tax credit of up to $1.3 billion for constructing new clean-coal power plants, and (3) new production tax credit of 1.8 cents per kilowatt-hour for up to 6,000 megawatts of new nuclear power capacity lasting 8 years after each qualifying nuclear reactor begins service. The Energy Policy Act of 2005 also authorized DOE to implement a new loan guarantee program for energy projects that decrease air pollutants or greenhouse gases, employ new or significantly improved technologies, and have a reasonable prospect of repayment. In February 2007, the Congress authorized DOE to guarantee loans of up to $4 billion.[4] In December 2007, the Congress directed DOE to make loan guarantees of up to $38.5 billion in fiscal years 2008 and 2009.[5]

Moreover, the federal government can enact standards and mandates that could impact the nation's energy portfolio. For example, the federal government has recently revised the renewable fuels standards to require

[2]Summing of tax expenditure estimates does not take into account interactions between individual provisions.

[3]The alternative fuels production credit, the largest energy-related tax credit, is a tax credit of $3 per oil equivalent barrel (in 1979 dollars) for gas produced from biomass or synthetic fuels produced from coal.

[4]See Pub. L. No. 110-5 (2007).

[5]This direction appears in an explanatory statement to Pub. L. No. 110-161 (2007), published by the House of Representatives.

the use of 36 billion gallons of biofuels by 2022.[6] For electricity, the Congress has considered renewable portfolio standards that require a percentage of electricity be generated from renewable sources. Consideration has also been given to either a carbon tax or a carbon cap and trade program to reduce the environmental impact of carbon emissions and to better enable the market to compare total costs of conventional fossil energy sources with advanced energy technologies. Many states and foreign governments have enacted energy portfolio standards, mandates, and financial incentives to stimulate the deployment of renewable energy technologies that address their growing energy needs and environmental concerns. In particular, 29 states have established renewable portfolio standards requiring or encouraging that a fixed percentage of the state's electricity be generated from renewable sources. For example, in response to the Texas renewable portfolio standard's requirement that 5,880 megawatts of renewable capacity be installed by 2015, electric power companies had installed over 1,900 megawatts of new renewable capacity by September 2006—about 3 percent of Texas' total electricity consumption. Similarly, to develop a sustainable energy supply and protect the environment, Germany established a goal to increase the share of renewable energy consumption to at least 4.2 percent of its total energy requirements by 2010 and 10 percent by 2020.

Within this broader context, I will discuss today (1) funding trends for DOE's renewable, fossil, and nuclear energy R&D programs and its Office of Science and (2) key challenges in developing and deploying advanced energy technologies. My remarks are primarily based on our December 2006 report on key challenges to developing and deploying advanced technologies for using renewable, fossil, and nuclear energy.[7] I will also highlight findings from our recent reports on DOE's R&D for oil and natural gas and the Hydrogen Fuel Initiative.[8] We conducted our work for these reports from October 2005 through December 2007 in accordance with generally accepted government auditing standards. Those standards

[6]Pub. L. No. 110-140 (2007).

[7]GAO, *Department of Energy: Key Challenges Remain for Developing and Deploying Advanced Energy Technologies to Meet Future Needs*, GAO-07-106, (Washington, D.C.: Dec. 20, 2006).

[8]GAO, *Department of Energy: Oil and Natural Gas Research and Development Activities*, GAO-08-190R, (Washington, D.C.,: Nov. 6, 2007) and GAO, *Hydrogen Fuel Initiative: DOE Has Made Important Progress and Involved Stakeholders but Needs to Update What It Expects to Achieve by Its 2015 Target*, GAO-08-305, (Washington, D.C.: Jan. 11, 2008).

require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

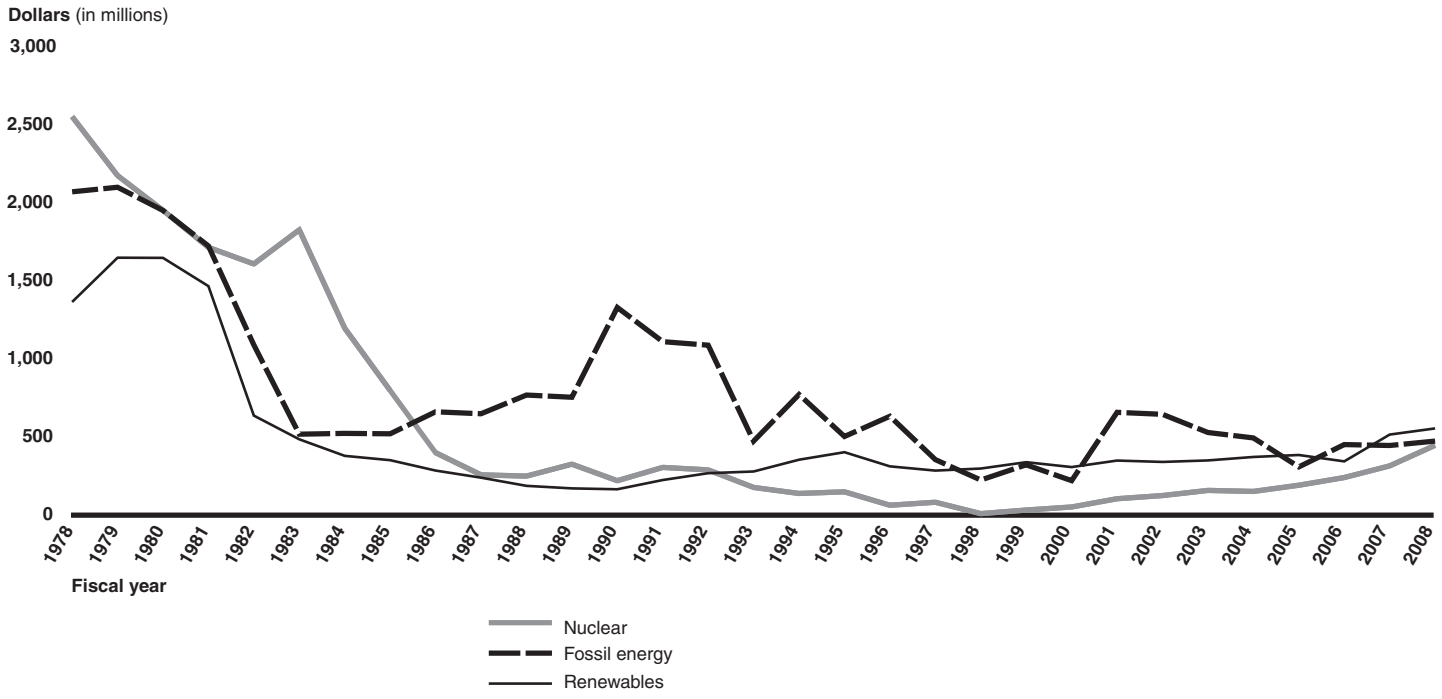
In summary, DOE's budget authority for renewable, fossil, and nuclear energy R&D dropped by 92 percent (in inflation-adjusted terms) between fiscal years 1978 and 1998 before bouncing back in part during the past 10 years. Specifically, DOE's budget authority for renewable, fossil, and nuclear energy R&D of about $6 billion was near its high point in fiscal year 1978, when the nation faced severe energy crises. DOE's budget authority subsequently declined in the 1980s and 1990s as energy prices returned to historical levels reaching its lowest level in fiscal year 1998 at $505 million (in inflation-adjusted terms). Since then, DOE's budget authority for renewable, fossil, and nuclear energy R&D has increased to $1.4 billion in fiscal year 2008. The Office of Science's budget authority also grew by 16 percent from fiscal year 2000 through fiscal year 2008.

Further development and deployment of advanced renewable, fossil and nuclear energy technologies faces three key challenges. First, there are technology-specific challenges. For example, high-wind sites have generally been developed using current wind turbine technology. To further expand the use of wind energy, DOE is working with industry to develop new wind turbine designs and materials that exploit low-wind and offshore sites. Second, there are cost challenges. These advanced energy technologies often face high up-front capital costs and the need to improve operating efficiency so they can better compete with conventional energy technologies. The nuclear industry, for example, projects that new nuclear power plants will likely cost between $4 billion and $6 billion each, about twice the cost of comparable conventional coal power plants. Finally, these technologies face challenges in addressing emerging concerns related to public health and the environment. For example, DOE is working with electric power companies to demonstrate coal gasification and carbon sequestration technologies designed to enable coal plants to reduce carbon dioxide and mercury emissions.

DOE's Budget Authority for Renewable, Fossil, and Nuclear Energy R&D Has Substantially Declined in Real Terms Since 1978

DOE's budget authority for renewable, fossil, and nuclear energy R&D dropped by 92 percent from $6 billion in fiscal year 1978 to $505 million in fiscal year 1998 (in inflation-adjusted terms) before bouncing back to $1.4 billion in fiscal year 2008. As shown in figure 2, R&D budget authority in renewable, fossil, and nuclear energy peaked in the late 1970s and fell sharply in the 1980s. Since fiscal year 1998, R&D budget authority for renewable and nuclear energy R&D have grown, while fossil energy R&D funding has fluctuated in response to coal program initiatives.

Figure 2: DOE's Budget Authority for Renewable, Fossil, and Nuclear R&D, Fiscal Years 1978-2008



Source: GAO analysis of DOE data.

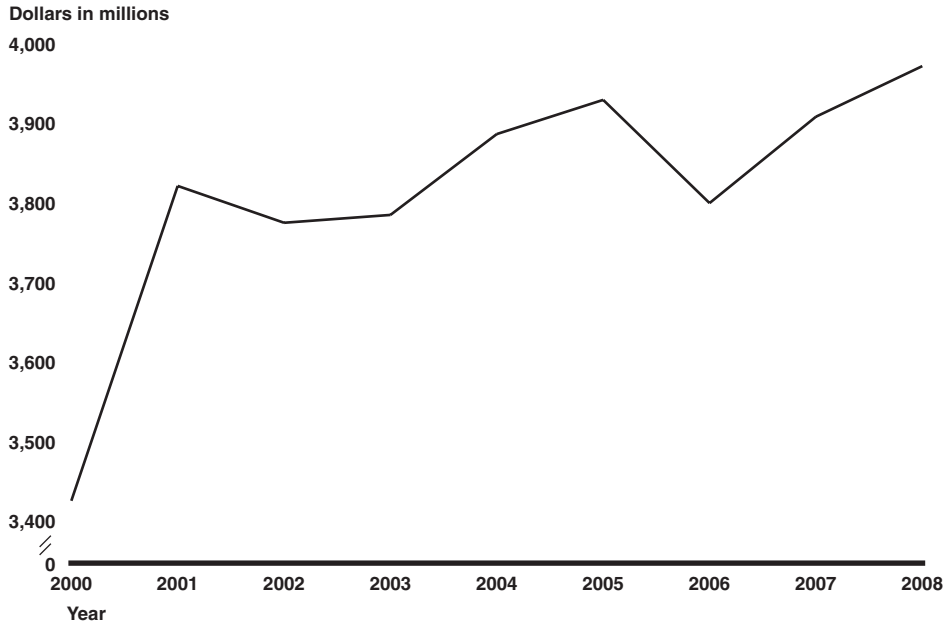
Note: Budget authority is in real terms, adjusted to fiscal year 2008 dollars to account for inflation. The budget data focuses on development of advanced energy technologies and excludes such R&D areas as Vehicle Technologies because its focus is improving the energy efficiency of vehicles.

Nuclear energy R&D, which received no funding in fiscal year 1998, experienced the largest increase, rising to $438 million in fiscal year 2008.

During this period, budget authority for renewable energy increased by 89 percent and fossil energy increased by 116 percent. A comparison of DOE's fiscal year 2009 budget request with the fiscal year 2008 appropriation shows that renewable energy R&D would decline slightly, while fossil energy R&D and nuclear energy R&D would increase by 34 percent and 44 percent, respectively (see app. I).

As shown in figure 3, budget authority for the Office of Science increased by 16 percent from $3.4 billion in fiscal year 2000 to $4 billion in fiscal year 2008. The budget request for the Office of Science for fiscal year 2009 is $4.7 billion, a 19-percent increase over the fiscal year 2008 appropriation. Because the Office of Science funds basic research in materials sciences, for example, many of its R&D programs may have useful applications for energy R&D. In fiscal year 2009, the Office of Science has requested $69.1 million for research related to the solar energy R&D program, $42.9 million related to biomass R&D, and $60.4 million for the Hydrogen Fuel Initiative. The Office of Science also funds fundamental research in such areas as high energy physics, nuclear physics, and fusion energy.

Figure 3: DOE's Budget Authority for Office of Science, Fiscal Years 2000-2008



Source: GAO.

Note: Budget authority is in real terms, adjusted to fiscal year 2008 dollars to account for inflation.

DOE Faces Key Challenges in Developing Advanced Energy Technologies for Deployment

There are key technical, cost, and environmental challenges in developing advanced renewable, fossil, and nuclear energy technologies to address future energy challenges.

DOE's R&D Challenges for Advanced Renewable Energy Technologies

DOE's recent R&D focus in renewable energy has been in (1) biomass-derived ethanol, (2) hydrogen-powered fuel cells, (3) wind technologies, and (4) solar technologies. The primary focus of ethanol and hydrogen R&D is to displace oil in the transportation sector. The primary focus of wind and solar technologies is to generate electricity. DOE also conducts R&D on geothermal and hydropower to generate electricity, but they have reflected a small proportion of the R&D budget in prior years and are not discussed here.

Biomass-derived ethanol. DOE's short-term R&D goal is to help meet the administration's "20 in 10" goal of substituting 20 percent of gasoline consumption in 10 years with alternative fuels, primarily biomass-derived ethanol. DOE's longer-term R&D goal is to develop new technologies to allow the ethanol industry to expand enough to displace 30 percent of gasoline requirements—about 60 billion gallons—by 2030. In 2007, industry produced over 7 billion gallons of ethanol, displacing about 3 percent of the nation's oil consumption.[9] Ethanol, however, faces high production and infrastructure costs, creating challenges in competing with gasoline nationally.[10] Ethanol refiners in the United States rely mostly on corn as a feedstock, the use of which has contributed to price increases for some food products, and ethanol's corrosive properties create challenges in developing an infrastructure for delivering and dispensing it. DOE's R&D focuses on (1) developing a more sustainable and competitive feedstock than corn, primarily by exploring technologies to use cellulosic biomass from, for example, agricultural residues or fast-growing grasses

[9]Biodiesel, electricity from batteries, and other technologies also contribute to the displacement of oil. DOE's R&D efforts also include, among other things, liquid fuels from biomass and plug-in hybrid vehicles.

[10]See GAO, *Biofuels: DOE Lacks a Strategic Approach to Coordinate Increasing Production with Infrastructure Development and Vehicle Needs*, GAO-07-713, (Washington, D.C.: June 8, 2007).

and trees; (2) reducing the cost of producing cellulosic ethanol to $1.33 per gallon by 2012 and $1.20 per gallon by 2017; (3) converting biomass to biofuels through both biochemical and thermochemical processes to help the industry expand; (4) contributing to a strategy to develop a national biofuels infrastructure, including demonstration projects for integrated biorefineries to develop multiple biomass-related products; and (5) promoting market-oriented activities to accelerate the deployment of biomass technologies. Although DOE has made progress in reducing ethanol production costs, cellulosic ethanol in 2007—based on current corn prices—still cost about 50 percent more to produce than corn ethanol.

Hydrogen-powered fuel cells. The long-term R&D goal of DOE's Hydrogen Fuel Initiative is to provide hydrogen fuel cell technologies to industry by 2015 to enable industry to commercialize them by 2020. To be commercialized, hydrogen fuel cell technologies must be competitive with gasoline vehicles in terms of price, convenience, safety, and durability. Hydrogen is the preferred fuel for vehicle fuel cells because of the ease with which it can be converted to electricity and its ability to combine with oxygen to emit only water and heat as byproducts. Let me clarify, however, that hydrogen is not an energy source, but, like electricity, is an energy carrier. Furthermore, because hydrogen is lighter than air, it does not exist on earth and must be extracted from common compounds. Producing hydrogen through the extraction process requires energy from renewable, fossil, or nuclear sources, adding to the challenge of developing hydrogen technologies. Our January 2008 report concluded that DOE has made important progress in developing hydrogen fuel cells, but the program has set very ambitious targets and some of the most difficult technical challenges—those that require significant scientific advances—lie ahead. Specifically, R&D for vehicles includes reducing the cost of commercial-scale manufacturing of fuel cells by nearly fourfold, storing enough hydrogen on board a fuel-cell vehicle to enable a 300-mile driving range, and increasing the durability of fuel cells by more than threefold to match the 150,000 mile life-span of gasoline vehicles. DOE also conducts R&D on stationary and portable fuel cells which could be used, for example, to replace batteries on fork lifts and diesel generators used for back-up power. We recommended that DOE update its overarching R&D plan to reflect the technologies it reasonably expects to provide to industry by 2015 to accurately reflect progress made by the Hydrogen Fuel Initiative, the challenges it faces, and its anticipated R&D funding needs. I would also note that developing the supporting infrastructure to deploy the technologies nationally will likely take

decades, tens of billions of dollars in investments, and continued R&D well beyond the 2015 target date.

DOE's fiscal year 2009 budget request would reduce funding for the Hydrogen Fuel Initiative by 17 percent from $283.5 million in fiscal year 2008 to $236 million in fiscal year 2009. The budget also proposes to increase the proportion of longer-term R&D by increasing the funding for basic research. Although the Hydrogen Program Manager told us that funding is sufficient to meet target dates for critical technologies, other target dates for supporting technologies—such as hydrogen production from renewable sources—would be pushed back.

Wind technologies. DOE is assessing its long-term vision of generating 20 percent of the nation's electricity using wind energy by 2030. Its current R&D efforts, however, are focused on more immediate expansion of the wind industry, particularly on utility-scale wind turbines. More specifically, DOE has focused its R&D efforts on improving the cost, performance, and reliability of large scale, land-based wind turbines, including both high- and low-wind technologies; developing small and mid-size turbines for distributed energy applications, such as for residential or remote agricultural uses; and gathering information on more efficient uses of the electricity grid and on barriers to deploying wind technology and providing that information to key national, state, and local decision-makers to assist with market expansion of wind technologies.[11] For example, one of DOE's targets is to increase the number of distributed wind turbines deployed in the United States from 2,400 in 2007 to 12,000 in 2015. Although wind energy has grown in recent years, from about 1,800 megawatts in 1996 to over 16,800 megawatts in 2007, the wind industry still faces investors' concerns about high up-front capital costs, including connecting the wind farms to the power transmission grid.

Solar technologies. DOE's R&D goal is for solar power to be unsubsidized and cost competitive with conventional technologies by 2015 by, for example, developing new thin-film photovoltaic technologies using less expensive semiconductor material than crystalline-silicon to reduce the manufacturing cost of solar cells. Specifically, DOE is working to reduce the costs of photovoltaic systems from about 18-23 cents per kilowatt hour in 2005 to about 5-10 cents per kilowatt hour in 2015. DOE is also conducting R&D to reduce the cost and improve the reliability of

[11]DOE continues to perform R&D on off-shore wind technologies as well.

concentrating solar power technologies, which use various mirror configurations to convert the sun's energy to heat to generate electricity. In addition, DOE has expanded R&D to address low-cost thermal storage to allow solar thermal systems to be more valuable to utility grid power markets. Along these lines, both the photovoltaic and concentrated solar power activities have ramped up efforts in the areas of grid integration and reliability to facilitate the transition to larger scale, centralized solar electric power plants. Investors' concerns about high up-front capital costs are among the most significant challenges in deploying photovoltaic or concentrating solar energy technologies. This requires both technologies to have lower costs for installation and operations and maintenance, better efficiency of converting solar power to electricity, and longer-term (20 to 30 years) durability.

DOE's R&D Challenges for Advanced Fossil Energy Technologies

Since fiscal year 2006, DOE has proposed eliminating its R&D in oil and natural gas and, in January 2008, announced a restructuring of its coal R&D program.

Increased oil production. Since fiscal year 2006, DOE has proposed to terminate its oil R&D. In November 2007, we reported that DOE has focused its R&D on increasing domestic production primarily by improving exploration technologies, extending the life of current oil reservoirs, developing drilling technology to tap into deep oil deposits, and addressing environmental protection. DOE officials stated that if the oil R&D program continues, it would focus on such areas as enhanced oil recovery technologies and expanding production from independent producers. Independent producers account for about 68 percent of domestic oil production.

Natural gas technologies. Since fiscal year 2006, DOE has proposed to terminate its natural gas R&D.[12] Our November 2007 report noted that DOE's R&D focuses on improving exploration technologies, reducing the environmental impact of natural gas operations, developing drilling technology to tap into deep gas reservoirs, and developing the technology for tapping into natural gas in naturally occurring methane hydrate found in permafrost regions on land and beneath the ocean floor.

[12]In addition, the Energy Policy Act of 2005 provided for commercialization of exploration and production technologies for ultra-deepwater and unconventional natural gas and other petroleum through fiscal year 2014 and authorized the use of $50 million per year from federal oil and gas lease income for 11 years.

Clean coal technologies. DOE's R&D goal is to reduce harmful power plant emissions to "near-zero" levels by 2020. For new power plant applications, DOE is developing and demonstrating advanced integrated gasification combined cycle (IGCC) technologies. In 2003, DOE announced plans to construct a near-zero emissions commercial scale R&D facility called FutureGen with an alliance of coal mining and coal-based electric generating companies. DOE had originally pledged about three-quarters of the estimated $1 billion cost of the FutureGen project (in constant fiscal year 2004 dollars). With escalation costs and rising price of materials and labor, the estimated project costs rose to nearly $1.8 billion. As a result, DOE announced in January 2008 that it is restructuring FutureGen to focus on multiple, competitively selected projects that demonstrate carbon capture and sequestration at commercially viable power plant project sites. The impact of DOE's restructuring on FutureGen at this time is not known, but an industry official from the FutureGen Alliance noted that the project cannot go forward without federal government assistance. Separate from the FutureGen project, DOE also conducts R&D on near-zero emission power plants—including carbon capture and sequestration—through its fuels and power systems programs and its Clean Coal Power Initiative.

DOE's R&D Challenges for Advanced Nuclear Energy Technologies

DOE has focused nuclear energy R&D in the following three areas:

- The Nuclear Power 2010 program focuses on reducing regulatory and technical barriers to deploying advanced "Generation III" nuclear power reactors, which are designed to be more efficient than currently operating reactors. Because over the past 30 years, no electric power company had applied to the Nuclear Regulatory Commission for a license to construct a new nuclear reactor, Nuclear Power 2010 shares the costs with industry of preparing early site permits and or construction and operating license applications for submission to the Nuclear Regulatory Commission. Nuclear Power 2010 also regulates the risk insurance authorized by the Energy Policy Act of 2005 that protects industry from certain regulatory delays during licensing and construction.

- The Global Nuclear Energy Partnership program—an extension of the Advanced Fuel Cycle Initiative—develops proliferation-resistant nuclear fuel cycles that maximizes energy output and minimizes waste. Specifically, the program is designed to reduce the threat of global nuclear proliferation by developing advanced technologies for reprocessing spent nuclear fuel in the 2030 time frame. One of the critical elements of this effort is to develop a sodium-cooled fast reactor designed to burn a wide

variety of nuclear fuels to reduce the total amount, temperature, and radiotoxicity of the spent fuel that might otherwise have to be stored for thousands of years in a repository.

- Beginning in fiscal year 2008, the Generation IV Program is focusing solely on the Next Generation Nuclear Plant (NGNP), designed as a versatile, efficient, high-temperature reactor capable of generating electricity and producing hydrogen. DOE collaborates with 12 other international partners on R&D related to fuels, materials, and design methodologies as part of the Generation IV International Forum.

Concluding Observations

In the current wake of higher energy costs and the growing recognition that fossil energy consumption is contributing to global climate change, the nation is once again assessing how best to stimulate the deployment of advanced energy technologies. While still considerably below its peak in the late 1970s, DOE's budget authority for renewable, fossil, and nuclear energy R&D has rebounded to $1.4 billion during the past 10 years after hitting a low point in fiscal year 1998. However, despite DOE's energy R&D funding of $57.5 billion over the last 30 years, the nation's energy portfolio remains heavily reliant on fossil fuels. Many technical, cost and environmental challenges must be overcome in developing and demonstrating advanced technologies before they can be deployed in the U.S. market. Our December 2006 report suggested that the Congress consider further stimulating the development and deployment of a diversified energy portfolio by focusing R&D funding on advanced energy technologies. However, because it is unlikely that DOE's energy R&D funding alone will be sufficient to significantly diversify the nation's energy portfolio, coordinating energy R&D with other federal programs, policies, incentives, standards, and mandates that can impact the nation's energy portfolio will be important for targeting any desired goals to change the nation's energy portfolio. In addition, state and local governments and other nations, along with a worldwide private sector, will play a role in developing and deploying advanced energy technologies both here and throughout the global energy market. A key factor to any sustainable deployment of advanced energy technologies will be to make them cost competitive, while addressing technical and environmental challenges, so that the market can support a more diversified portfolio. Otherwise, without sustained higher energy prices for our current portfolio, or concerted, high-profile federal government leadership, U.S. consumers are unlikely to change their energy-use patterns, and the U.S. energy portfolio will not significantly change.

Appendix I: Comparison of DOE's Fiscal Year 2008 Appropriations with Its Fiscal Year 2009 Budget Request

(Millions of dollars)

Program	Fiscal year 2008 appropriation	Fiscal year 2009 budget request	Percentage change
Energy Efficiency and Renewable Energy[a]			
Biomass and Biorefinery Systems	$198.2	$225.0	14
Solar	168.5	156.1	(7)
Wind	49.5	52.5	6
Geothermal	19.8	30.0	51
Water Power	9.9	3.0	(70)
Hydrogen Technology (Hydrogen Fuel Initiative)[b]	94.5	66.9	(29)
Subtotal	**$540.4**	**$533.5**	**(1)**
Fossil Energy			
Oil	5.0	0.0	(100)
Natural gas	19.8	0.0	(100)
Coal			
Clean Coal Power Initiative	69.4	85.0	22
FutureGen	74.3	156.0	110
Fuels and Power Systems	324.9	372.7	15
Fuels (Hydrogen Fuel Initiative)[b]	24.8	10.0	(60)
Clean Coal Technology	(58.0)	0	(100)
Cooperative R&D	5.0	0	(100)
Subtotal	**$465.2**	**$623.7**	**34**
Nuclear energy[c]			
Nuclear Power 2010	133.8	241.6	81
Generation IV[d]	114.9	70.0	(39)
Advanced Fuel Cycle Initiative/ Global Nuclear Energy Partnership[d]	179.4	301.5	68
Nuclear Hydrogen Initiative (Hydrogen Fuel Initiative)[b]	9.9	16.6	68
Subtotal	**$438.0**	**$629.7**	**44**
Office of Science			
High energy physics	689.3	805.0	17
Nuclear physics	432.7	510.1	18
Biological and environmental research	544.4	568.5	4
Basic energy sciences	1,269.9	1,568.2	23

(Millions of dollars)

Program	Fiscal year 2008 appropriation	Fiscal year 2009 budget request	Percentage change
Advanced scientific computing research	351.2	368.8	5
Fusion energy sciences program	286.5	493.1	72
Science laboratories infrastructure	66.9	110.3	65
Safeguards and security	75.9	80.6	6
Science program direction	177.8	203.9	15
Workforce development for teachers and scientists	8.0	13.6	70
Congressionally directed projects	123.6	0	(100)
Small business innovation research	0	0	0
Use of prior year balances and other adjustments	(53.2)	0	
Subtotal	**$3,973.0**	**$4,722.1**	**19**
Total	**$5,416.6**	**$6,509.0**	**20**

Source: DOE.

Note: Dollar amounts for the fiscal year 2009 budget request are not adjusted for inflation. Differences may exist due to rounding.

[a]Excludes budget authority for Vehicle Technologies, which includes the FreedomCAR and Fuel Partnership and the 21st Century Truck Partnership. The Vehicle Technologies R&D program focuses on improving the energy efficiency of vehicles by developing lightweight materials, advanced batteries, power electronics, and electric motors for hybrid and plug-in hybrid vehicles, and advanced combustion engines and fuels.

[b]The Hydrogen Fuel Initiative is funded separately through DOE's Offices of Energy Efficiency and Renewable Energy, Fossil Energy, Nuclear Energy, and Science and the Department of Transportation. In addition to Hydrogen Technology R&D, Energy Efficiency and Renewable Energy funds Fuel Cell Technology R&D, which historically has been an energy efficiency program. The fiscal year 2008 appropriation for Fuel Cell Technology R&D is $116.6 million, and DOE's request for fiscal year 2009 is $79.3 million The Hydrogen Fuel Initiative received a total of $283.5 million in budget authority in fiscal year 2008; the administration is requesting $236 million for the initiative in fiscal year 2009. During fiscal year 2008, Energy Efficiency and Renewable Energy transferred some of the Hydrogen Fuel Initiative activities to its Vehicle Technologies R&D program.

[c]Excludes the Mixed Oxide Fuel Fabrication Facility, which received $278.8 million in fiscal year 2008. DOE is requesting $487 million for fiscal year 2009.

[d]During fiscal year 2008, R&D on the sodium-cooled fast reactor was transferred from the Generation IV program to the Accelerated Fuel Cycle Initiative/Global Nuclear Energy Partnership Program.

Contacts and Acknowledgments

For further information about this testimony, please contact me at (202) 512-3841 or gaffiganm@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. Richard Cheston, Robert Sanchez, Kerry Lipsitz, MaryLynn Sergent, and Anne Stevens made key contributions to this statement.

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