

GAO

Report to the Chairman, Subcommittee
on Energy and Water Development,
Committee on Appropriations, U.S.
Senate

December 2008

RESEARCH AND DEVELOPMENT

DOE Could Enhance the Project Selection Process for Government Oil and Natural Gas Research





Highlights of [GAO-09-186](#), a report to the Chairman, Subcommittee on Energy and Water Development, Committee on Appropriations, U.S. Senate

Why GAO Did This Study

Although competitive oil and natural gas markets generally provide incentives for companies to invest in research and development (R&D), some industry experts believe these companies may underinvest in certain areas. A recent GAO report noted important criteria for the Department of Energy (DOE) to consider in evaluating its oil and natural gas R&D efforts—including the likelihood that industry would perform the research without federal funding. The Office of Management and Budget has raised similar concerns. In this context, GAO was asked to review (1) how much U.S. industry has invested in oil and natural gas R&D over the last 10 years, and the current focus of these activities; (2) how DOE's oil and natural gas R&D funding and activities compare with industry's; and (3) to what extent DOE ensures that its oil and natural gas R&D would not occur without federal funding. GAO reviewed DOE and U.S. industry data for oil and natural gas R&D spending, and interviewed DOE officials and representatives from various segments of the industry.

What GAO Recommends

To better ensure that DOE selects oil and gas R&D projects that industry is unlikely to pursue, GAO recommends DOE's project selection process include a formal assessment of the likelihood that the R&D would not have occurred without federal funding. DOE provided only technical comments which we incorporated as appropriate.

To view the full product, including the scope and methodology, click on [GAO-09-186](#). For more information, contact Mark E. Gaffigan (202) 512-3841 or gaffiganm@gao.gov.

RESEARCH AND DEVELOPMENT

DOE Could Enhance the Project Selection Process for Government Oil and Natural Gas Research

What GAO Found

From 1997 through 2006, the U.S. oil and natural gas industry spent at least \$20 billion on R&D, and currently focuses mostly on near-term (within about the next 2 years) production challenges. The nature of R&D varies by type of company. For example, major oil companies tend to have in-house R&D facilities, and though most of their projects are designed to meet near-term needs, they also conduct some longer-term research. Similarly, service companies, which specialize in providing technologies to facilitate exploration and production, focus their R&D primarily on their clients' immediate needs, but also conduct some longer-term research. In contrast, larger independent companies generally do not conduct in-house R&D; instead, they may buy new technologies from other companies and adapt them to meet their needs, and also may participate in research partnerships. Smaller independent companies do not generally conduct R&D, but some obtain or become aware of technology from other companies, trade publications, or professional associations.

From 1997 through 2006, DOE's total funding for oil and natural gas R&D totaled significantly less than industry's—about \$1 billion versus at least \$20 billion—and, in contrast to industry's focus on near-term challenges, DOE's R&D focuses on both near- and longer-term challenges. Some examples of DOE's projects that have had a near-term focus include projects that develop more advanced drilling and imaging tools, and enhance oil recovery. An example of a DOE project that has had a longer-term, high-risk focus is evaluating the potential use of methane hydrates, which are molecules of methane trapped inside a lattice of ice, as a future energy source—an area that industry officials said was generally beyond their time horizon for R&D.

DOE keeps abreast of industry R&D activities and uses a project selection process to ensure that its efforts support industry R&D; however, DOE does not formally assess whether industry would undertake this R&D without federal funding. Based on its awareness of industry needs gathered from its interactions with industry, DOE develops research priorities that drive its project solicitations. Individual oil and natural gas projects are screened to ensure that the applicant (1) explains the significance of the problem the proposal addresses, (2) demonstrates understanding of the current technology and information gaps, and (3) considers the likelihood that the project will advance the current state of technology. While these efforts help to ensure that DOE is informed about industry activities, DOE does not formally assess the likelihood that industry would have conducted the R&D without federal funding, nor does it explicitly include such an evaluation in its screening criteria. For instance, GAO found that several of DOE's projects addressing challenges in advanced drilling and improved recovery of oil and natural gas were similar to activities conducted by industry. In this regard, in its review of DOE's oil and natural gas R&D budget, the Office of Management and Budget has challenged DOE to better justify the need for certain government research. By making a more formal evaluation in its screening process, DOE could better demonstrate that it selects projects that industry is unlikely to pursue.

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Abbreviations

DOE	Department of Energy
EIA	Energy Information Administration
EPAct 2005	Energy Policy Act of 2005
FOA	Funding Opportunity Announcement
FRS	Financial Reporting System
IEA	International Energy Agency
NETL	National Energy Technology Laboratory
OMB	Office of Management and Budget
R&D	research and development
RPSEA	Research Partnership to Secure Energy for America
SEC	Security and Exchange Commission

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United States Government Accountability Office
Washington, DC 20548

December 29, 2008

The Honorable Byron L. Dorgan
Chairman
Subcommittee on Energy and Water Development
Committee on Appropriations
United States Senate

Dear Mr. Chairman:

The United States is the world's largest consumer of oil and natural gas, as well as the world's largest importer of these resources, importing about one-fifth of the natural gas used and about two-thirds of the oil.¹ Although domestic resources are substantial, they are increasingly concentrated in geologically challenging settings that require innovative exploration and production technologies. The U.S. oil and gas industry invests in research and development (R&D) to develop new oil and gas technologies to explore for and produce these resources, and its innovations make the United States more competitive.

The U.S. oil and gas industry comprises a variety of companies. The largest oil and gas companies, referred to as "majors," are integrated companies; they explore, develop, and produce oil and gas resources, and refine them into products such as gasoline before selling them through retail outlets. Service companies, which specialize in providing equipment and delivering services to their clients that facilitate oil and gas exploration and production, also expend resources on R&D. Other oil and gas companies, both large and small, referred to as "independents," typically concentrate only on exploration and production activities.

Competition provides an incentive for these companies to invest in R&D for new oil and gas technologies that can improve profitability. However, companies may not undertake research in instances where they incur all of the R&D costs but cannot capture most of the benefits. For example, a successful innovator of a new technology may capture some rewards, but because patent protection is inherently imperfect, those rewards typically would be a fraction of the overall benefits to society as other companies begin to use the same technology. As such, some industry experts argue

¹For purposes of this report, we will refer to natural gas as "gas."

that the federal government is needed to fill the gaps where industry may underinvest in R&D.

Since its inception in 1977, the Department of Energy (DOE) has had primary leadership responsibility for the federal government's energy R&D. From 1997 through 2006, DOE spent over \$8 billion on energy R&D. DOE directs the National Energy Technology Laboratory (NETL) to facilitate the development of new oil and gas technologies that can help industry increase domestic supply, improve its efficiency, and protect the environment as resources are explored for and developed. NETL has received funding for these activities through annual oil and gas R&D appropriations. More recently, NETL has received additional funding through the Energy Policy Act of 2005 (EPA 2005), section 999. To carry out its mission, NETL collaborates with industry, universities, other national laboratories, foreign governments, and other domestic government agencies. In doing so, NETL attempts to leverage government R&D resources and complement industry efforts.

Over the years, we have completed a number of reviews related to government energy R&D activities.² Our most recent report highlighted the importance of DOE considering certain criteria in evaluating its R&D efforts, including the likelihood that industry would perform the research without federal funding.³ In recent years, similar questions have been raised by the Office of Management and Budget (OMB), the executive office that assists the President in evaluating the effectiveness of agency programs and assessing competing agency funding demands, among other things.

In this context, you asked us to review industry and DOE R&D activities for oil and gas, specifically: (1) how much U.S. industry has invested in oil and natural gas R&D over the last 10 years, and the current focus of these

²GAO, *Department of Energy: Oil and Natural Gas Research and Development Activities*, [GAO-08-190R](#) (Washington, D.C.: Nov. 6, 2007); *Advanced Energy Technologies: Budget Trends and Challenges for DOE's Energy R&D Program*, [GAO-08-556T](#) (Washington, D.C.: Mar. 5, 2008); *Cooperative Research: Results of U.S.-Industry Partnership to Develop a New Generation of Vehicles*, [GAO/RCED-00-81](#) (Washington, D.C.: Mar. 30, 2000); *Renewable Energy: DOE's Funding and Markets for Wind Energy and Solar Cell Technologies*, [GAO/RCED-99-130](#) (Washington, D.C.: May 14, 1999); and *Department of Energy: Fossil Energy Programs*, [GAO/RCED-98-63](#) (Washington, D.C.: Jan. 30, 1998).

³[GAO-08-190R](#) also described other key criteria, namely, whether the benefits exceed the costs, and whether cost-sharing opportunities with companies exist. Determining whether DOE's current projects meet these criteria was beyond the scope of this report.

activities; (2) how DOE's oil and natural gas R&D funding and activities compare with industry's; and (3) to what extent DOE ensures that its oil and natural gas R&D would not occur without federal funding. You also asked us to provide descriptive information about the oil and gas R&D activities that other nations' governments are conducting. We provide information on selected countries in appendix II.

Our report is based on our analysis of prior GAO work, DOE budget data, and discussions with industry and DOE officials.⁴ To gather information about the U.S. oil and gas industry's funding, we used DOE data from its sample of the largest U.S.-based oil and gas companies for 1997 through 2006, the most recent year for which data were available.⁵ Because these data do not capture R&D spending by all U.S. companies, nor international companies that have a presence in the U.S. but are based abroad, the resulting data may underestimate U.S. industry R&D funding.⁶ To gather information about service companies' R&D spending, we obtained data from the Security and Exchange Commission (SEC) for five of the largest service companies.⁷ The DOE data, as well as the data reported by the SEC, reflect R&D as reported by industry. To gather information about U.S. oil and gas industry R&D activities, including those of service companies, we spoke with officials from oil and gas companies of varying types and sizes, including majors, service companies, and large and small independents. To compare DOE funding and activities to industry's, we collected data about DOE's spending and activities for 1997 through 2006

⁴Throughout our report, unless otherwise specified, dollar sums indicate nominal sums that are not adjusted for inflation. When adjusted for inflation, these dollar sums are larger than those we report.

⁵Throughout our report we refer to U.S. industry's funding based on DOE's Financial Reporting System survey, which collects financial data from the largest U.S.-based publicly owned companies or U.S.-based subsidiaries that have at least 1 percent of either production or reserves of oil or gas in the United States, or 1 percent of either refining capacity or petroleum product sales in the United States. The sample for 2006 included 27 companies; however, the number of companies included in the survey may vary from year to year. We found no comprehensive sources of data for oil and gas R&D funding.

⁶In commenting on our report, DOE officials noted that individual industry R&D spending estimates may overstate reported industry spending because individual companies may include activities which DOE would not consider to be R&D. We could not independently corroborate this view.

⁷These companies represent five of the largest service companies—Schlumberger, Halliburton, Baker Hughes, Smith International, and Weatherford International—in terms of total revenue as reported by various industry sources. The data do not reflect total service company R&D.

and met with DOE officials. To determine the extent to which DOE ensures that its oil and gas R&D would not occur without federal funding, we reviewed DOE documents and discussed industry interaction and the project selection process with DOE officials. For purposes of this report, near-term R&D generally refers to funding and activities that occur within about the next 2 years; longer-term R&D refers to funding and activities that would generally occur beyond 2 years. We conducted this performance audit from January 2008 through December 2008 in accordance with generally accepted government auditing standards. Those standards 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.

Results in Brief

From 1997 through 2006, the U.S. oil and gas industry spent at least \$20 billion on R&D, and currently focuses mostly on near-term production challenges. According to DOE data, oil and gas companies spent at least \$9.6 billion on R&D during this period. In addition, service companies spent at least \$10.7 billion during this same period, according to reports filed with the SEC by five of the largest service companies. Industry officials told us that concern for immediate business needs drives industry R&D to primarily address near-term oil and gas production problems or challenges. Such challenges include, for example, development of technologies to extract oil and gas from difficult environments such as the Arctic and very deep waters. The nature of R&D varies by type of company. For example, major oil companies tend to have in-house R&D facilities, and though most of their projects are designed to meet near-term needs, they also conduct some longer-term, high-risk research, such as research into resources that have yet to be developed. Similarly, service companies' R&D primarily focuses on their clients' immediate needs, but they also conduct some longer-term research. In contrast, larger independent companies generally do not conduct in-house R&D; instead, they may buy new oil and gas technologies from other companies and adapt them to meet their immediate needs, and also may participate in research partnerships. Smaller independent companies do not generally conduct their own R&D, but some obtain or become aware of new technologies from other companies, trade publications, or professional and state associations.

From 1997 through 2006, DOE's total funding for oil and gas R&D totaled significantly less than industry's—about \$1 billion versus at least \$20

billion—and, in contrast to industry’s primary focus on near-term challenges, DOE’s R&D focuses on both near- and longer-term challenges. During this period, DOE’s oil and gas R&D appropriations declined by more than 60 percent—from about \$162 million in 1997 to about \$63 million in 2006. More recently, through its 2007 and 2008 oil and gas R&D appropriations, DOE received an additional \$161 million. Overall, this funding has supported hundreds of R&D projects since 1997. While industry’s R&D activities are driven primarily by the need to address near-term problems, DOE’s activities include near-term projects as well as research that is longer term and high risk in nature. Some examples of DOE’s projects that have had a near-term focus include projects associated with developing more advanced drilling and imaging tools and enhancing oil recovery. An example of a DOE project that has had a longer-term, high-risk focus is evaluating the potential use of methane hydrates, which are molecules of methane trapped inside a lattice of ice, as a future energy source—an area of interest that industry officials said was generally beyond their time horizon for R&D.

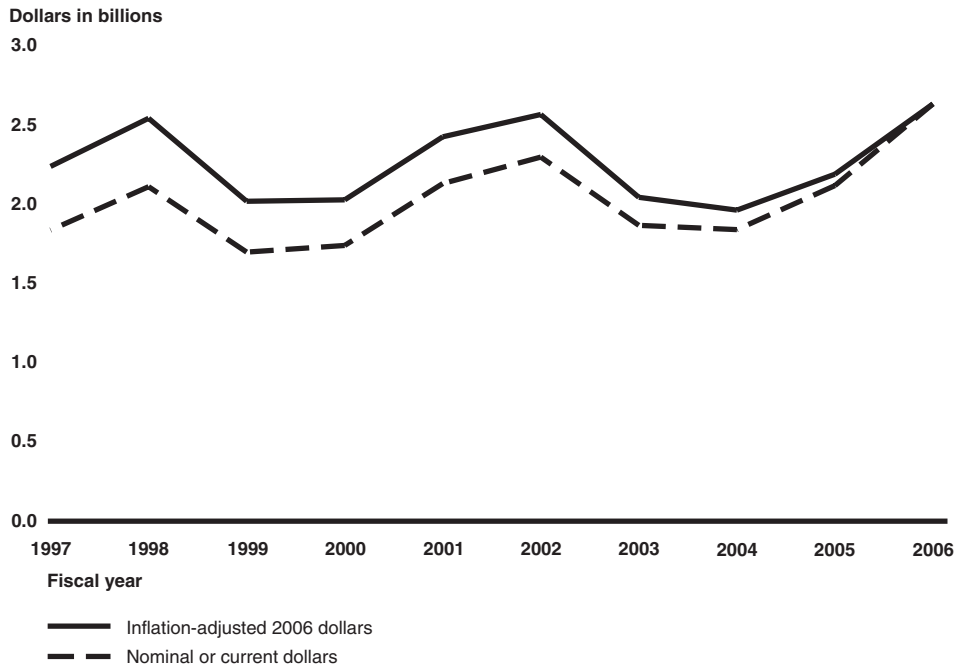
DOE keeps abreast of industry R&D activities and uses a project selection process to ensure that its efforts address industry R&D needs; however, DOE does not formally assess whether industry would undertake this R&D without federal funding. According to DOE officials, DOE participates in numerous consortia, conferences, technical associations, and workshops with the oil and gas industry. Based on its awareness of industry needs gathered from participation at these events, DOE develops research priorities that drive its project solicitations. Applications for individual oil and gas R&D projects are then screened to ensure that the applicant (1) explains the significance of the problem the proposal addresses; (2) demonstrates understanding of the current technology and information gaps; and (3) considers the likelihood that the project will advance the current state of technology. In its review of DOE’s oil and gas R&D budget, OMB has challenged DOE to better justify the need for government research. While DOE’s efforts help to ensure that its efforts address industry R&D needs, we found that DOE neither formally assesses the likelihood that industry would have conducted the R&D without federal funding, nor does it explicitly include such an evaluation in its screening criteria. For instance, we found that several of DOE’s projects addressing challenges in advanced drilling and improved recovery of oil and gas were similar to activities conducted by industry. We are recommending that DOE include in its project selection process a formal assessment of the likelihood that the R&D would not have occurred without federal funding. DOE had no comment on our recommendation, and provided only technical comments which we incorporated as appropriate.

From 1997 through 2006, the U.S. Oil and Gas Industry Invested at Least \$20 Billion in R&D and Currently Focuses Primarily on Near-term Needs

From 1997 through 2006, U.S. industry oil and gas R&D totaled at least \$20.3 billion, and currently focuses mostly on near-term production challenges. Data collected by DOE's Energy Information Administration (EIA)—the statistical agency within DOE that provides independent data, forecasts, and analyses—show that U.S. oil and gas company R&D spending totaled at least \$9.6 billion from 1997 through 2006. Our analysis of service company R&D from SEC 10-K reports, which is not included in EIA's data, indicates that five of the largest service companies spent a comparable amount during this same period—about \$10.7 billion.⁸ This combined R&D spending fluctuated over this period, but generally increased during the last 3 of these years. Specifically, in 1997, industry R&D budgets were about \$1.8 billion; they fell to a low of about \$1.7 billion in 1999, but have since generally increased to about \$2.6 billion in 2006. In 2006, industry R&D spending peaked for this 10-year period, as depicted in figure 1.

⁸Publicly traded companies are required to file 10-K reports annually with the SEC to provide a comprehensive overview of their business and financial condition.

Figure 1: Oil and Gas Industry R&D Spending in Nominal and Real Terms, Fiscal Years 1997–2006



Source: GAO analysis of data provided by the EIA and the SEC.

Note: Nominal dollars reflect actual dollars according to EIA and SEC data. Inflation-adjusted 2006 dollars reflect the same amounts adjusted for inflation according to the fiscal year chain-weighted gross domestic product price index.

Industry officials told us that because of concern for meeting the individual companies' immediate needs, their R&D primarily addresses near-term production problems and challenges, although some also invest in longer-term, high-risk research. The majors, which generally have in-house R&D facilities, typically prioritize near-term research that facilitates their operations and is likely to result in commercially viable products or processes; for example, advanced drilling techniques that will enable them to explore and drill in difficult environments, such as Arctic and very deep waters, and improved oil and gas recovery.⁹ However, the majors we spoke with also told us they devoted some resources toward longer-term, more high-risk research, such as applying nanotechnology, which could allow industry to build and use microscopic devices, to improve oil and gas

⁹Improved oil and gas recovery refers to extraction of oil or gas by any method other than those that rely primarily on natural reservoir pressure, gas lift, or a system of pumps.

recovery and developing oil shale resources—sedimentary rock that can contain oil which may be recovered by heating these rocks—as a commercially viable resource. Majors also participate in research partnerships or consortia, but are more likely to do so when the research is very long term or focused on issues such as compliance with environmental regulations, where companies are less concerned about keeping the resulting technology proprietary.

Service companies, like the majors, dedicate the majority of their research to the immediate needs of their individual clients, although the service companies we contacted also conducted some longer-term R&D in anticipation of clients' future needs. For example, one service company noted that it had begun to research carbon capture and sequestration and gasification of petroleum coke as potential areas that may be important to industry in the future.¹⁰ Service companies may also participate in partnerships or consortia. While most have in-house R&D facilities, they also may outsource some R&D to national laboratories or universities.

The large independents we contacted did not conduct in-house R&D; rather, they typically purchase new technologies and adapt these technologies to meet their unique needs. Additionally, several larger independents develop technology through partnerships with other companies, universities, or DOE. Larger independents' R&D includes efforts to enhance oil recovery, which involves increasing output from maturing wells where the recovery rate of oil is declining, as well as efforts to increase production of unconventional gas and oil.

The small independent producers we interviewed generally do not conduct their own R&D. Small producers reported that they obtain or become aware of new technology through interactions with other companies and “word of mouth,” industry-relevant publications and journals, and professional and state associations like the Society of Petroleum Engineers, the Kansas Independent Oil and Gas Association, and the Petroleum Technology Transfer Council. While they do not conduct their own, in-house R&D, several small producers told us they could benefit from increased R&D in areas such as enhanced oil recovery.

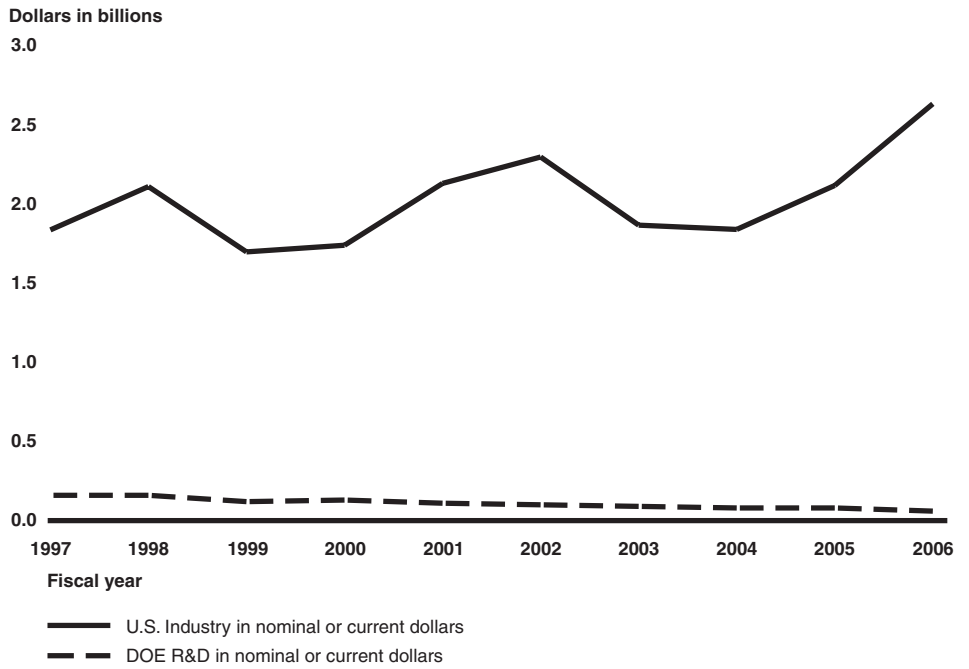
¹⁰Carbon capture and sequestration is a multistage approach for managing produced carbon dioxide by capturing it from stationary point sources such as fossil-fuel-fired power plants, and storing it indefinitely—generally underground in geologic formations or in the ocean. Petroleum coke is a residue with a high carbon content formed during a process that breaks down complex hydrocarbon molecules into simpler forms.

DOE Invested Significantly Less in Oil and Gas R&D Funding Than U.S. Industry and Currently Focuses on Near- and Longer-term Challenges

From 1997 through 2006, DOE invested significantly less in R&D for oil and gas than U.S. industry, and while U.S. industry primarily conducts near-term oil and gas R&D to achieve immediate payoffs, DOE responds to both near- and longer-term challenges. During this period, DOE's oil and gas R&D investment was about \$1.1 billion compared to at least \$20.3 billion invested by U.S. industry. Furthermore, DOE's oil and gas R&D appropriations declined by about 61 percent—falling from \$162.4 million in 1997 to \$62.6 million in fiscal year 2006—while industry's R&D investment has generally increased, as shown in figure 2. More specifically, annual appropriations for oil R&D decreased from \$45.2 million in fiscal year 1997 to \$30.8 million in fiscal year 2006, while appropriations for gas R&D decreased from \$117.3 million in 1997 to \$31.8 million in fiscal year 2006.¹¹

¹¹Part of the decline for gas R&D was due to a transfer of the fuel cell and advanced gas turbines projects out of the gas R&D budget.

Figure 2: DOE and U.S. Industry Oil and Gas R&D Investments, Fiscal Years 1997–2006



Source: GAO analysis of oil and gas investments made by U.S. industry and DOE.

When adjusted for inflation, these declines are even greater. For example, as shown in table 1, DOE’s total oil and gas appropriations declined from about \$198 million in 1997 to about \$62.6 million in 2006—a 68 percent decline in real terms.

Table 1: DOE Oil and Gas Investments, Fiscal Year 1997–2006
Dollars in millions (2006 dollars)

Fiscal year	Oil	Gas	Total
1997	\$55.08	\$142.93	\$198.01
1998	57.46	130.62	188.08
1999	56.28	82.44	138.72
2000	64.96	86.10	151.06
2001	74.10	50.00	124.10
2002	62.82	49.22	112.05
2003	44.87	50.21	95.08
2004	36.39	44.64	81.03

Fiscal year	Oil	Gas	Total
2005	34.10	45.11	79.21
2006	30.81	31.80	62.61
Total	\$516.86	\$713.08	\$1,229.94

Source: GAO analysis of DOE oil and gas appropriations.

Note: Amounts may not always add due to rounding.

More recently, in fiscal years 2007 and 2008, DOE's oil and gas R&D investments have generally increased from 2006 levels, primarily as a result of funding from EPOA 2005, section 999. During these years, DOE was appropriated a total of about \$161 million for oil and gas R&D activities, which includes \$100 million provided by EPOA 2005, section 999.¹² EPOA 2005, section 999 makes available \$50 million per year for 10 years for oil and gas R&D, to be split between DOE (25 percent) and a nonprofit corporation (75 percent) formed by a consortium. The consortium, known as the Research Partnership to Secure Energy for America (RPSEA), includes U.S. energy research universities, industry, and independent research organizations.¹³ Among other things, DOE is charged with maximizing the value of U.S. gas and other petroleum resources by increasing supply, reducing the cost of exploration and production of such resources, and minimizing environmental impact.

Overall, since 1997, DOE's funds have supported hundreds of near-term projects, as well as research that is longer term and high risk, whereas industry R&D focuses primarily on near-term challenges. DOE uses its non-EPOA 2005 funds for both near- and longer-term R&D projects, including helping industry develop advanced drilling tools, resource imaging devices, enhanced oil recovery technologies, and environmental protection practices that reduce the impacts of oil and gas. Near-term R&D projects include:

- *Advanced drilling tools.* These technologies provide industry with ways to reduce costs, such as developing drill bits that increase the efficiency of

¹²Under EPOA 2005, for fiscal years 2007 through 2017, \$50 million from federal royalty, rent, and bonus money from oil and gas leases is to be deposited into a revolving fund available without fiscal year limitation to DOE for activities involving ultra deepwater, unconventional natural gas, technology challenges of small producers, and complementary research performed by NETL.

¹³EPOA 2005, section 999 also authorized an additional \$100 million for fiscal years 2007 through 2016, but Congress has not appropriated any of these additional funds.

drilling operations. For example, DOE's work in microhole drilling helps develop equipment that is smaller and more transportable, reducing environmental impact.

- *Resource imaging devices.* These technologies assist industry in identifying, locating, and economically recovering oil and gas by providing imaging capabilities that are able to detect and estimate available resources.
- *Enhanced oil recovery.* This technology involves injecting additives, such as gases, chemicals, heat, or microbes, into maturing oil and gas reservoirs to increase production as initial output begins to decrease. Enhanced oil recovery technologies are important because about 400 billion barrels of oil discovered in the United States are unrecoverable by conventional means.
- *Environmental protection.* Among DOE projects that reduce the environmental impacts of oil and gas exploration and production are those aimed at finding beneficial uses for produced water—large volumes of water that may contain salt, chemical compounds, or other contaminants that are trapped in underground formations and are brought to the surface along with oil or gas.

DOE also conducts longer-term, high-risk research. For example, DOE is conducting R&D projects focused on commercially producing gas from methane hydrates.¹⁴ According to DOE, methane hydrates hold more energy than all fossil fuels combined, and the United States has an estimated 25 percent of all worldwide methane hydrate deposits. DOE officials believe that NETL's projects hold tremendous potential to improve the understanding of methane hydrates and increase the ability to develop them. According to DOE officials, this R&D will help U.S. industry overcome two major constraints with the development of methane hydrates: (1) the need to detect and quantify methane hydrate deposits and (2) the demonstration that methane from hydrates can be produced at commercial volumes. Moreover, in our interviews with U.S. industry officials, most reported that they did not conduct R&D on methane hydrates; in fact, most said that R&D for methane hydrates was generally beyond their research time horizon.

¹⁴Methane hydrates are cage-like lattices of ice, inside of which molecules of methane are trapped. Methane is the chief constituent of natural gas.

In addition, DOE manages the EPAct 2005, section 999 program and uses 25 percent of the appropriations to conduct R&D projects in four principal areas: drilling under extreme conditions, environmental impacts of oil and gas development, enhanced and unconventional oil recovery, and resource assessment.¹⁵ RPSEA's share of these appropriations is used to conduct projects related to ultra-deepwater technology, unconventional gas exploration and production technology, and the technology challenges of small producers. Because funding has been distributed only in recent years, DOE and RPSEA projects are in their initial stages.

DOE Works to Ensure That Its R&D Supports Industry, but Does Not Formally Assess the Likelihood That Industry Would Conduct Research Without Federal Funding

DOE relies on its knowledge of industry's R&D and its project selection process to ensure that its R&D supports industry; however, DOE does not formally assess the likelihood that industry would independently conduct this R&D without federal funding. DOE officials obtain information about industry R&D by reviewing technical literature and trade publications; supporting and participating in consortia where industry members share information regarding cost-shared R&D projects; and participating in or conducting conferences, technical association meetings, and workshops. In the last 5 years, DOE has sponsored or cosponsored 43 conferences, and participated in an additional 19. One of the agency's primary means for obtaining first-hand information from industry officials are the workshops DOE conducts with invited stakeholders, including representatives from across the oil and gas industry, as well as representatives from academia and other national labs. These workshops give DOE officials opportunity to gain insight and expertise from industry stakeholders regarding R&D needs, and serve to identify key areas of concern that could potentially benefit from federal R&D support.

In addition to staying abreast of industry's R&D, DOE uses a project selection process that includes an assessment of several factors that help ensure its R&D addresses industry R&D needs. Specifically, DOE uses information it gathers in its workshops to prioritize research areas and guide its Funding Opportunity Announcements (FOA)—requests for proposals in specific research areas such as improving electronic drilling equipment.¹⁶ According to DOE officials, the department conducts more rigorous planning for its section 999 program and its methane hydrates program. Specifically, they noted that for these programs, DOE is required

¹⁵DOE's complementary activities also include program analysis and planning.

¹⁶DOE also refers to these as "solicitations."

to develop annual or multiyear plans. In addition, these programs also obtain input from panels of industry professionals.

As part of its typical selection process, DOE examines the applications submitted in response to its FOAs based on three weighted criteria: scientific and technical merit, technical approach, and technical and management capabilities.¹⁷ Scientific and technical merit, which is weighted most heavily, requires applicants to discuss the significance of the problem the proposal addresses, demonstrate an understanding of the current technology and information gaps that exist, and consider the likelihood that the proposed project will advance the current state of technology, knowledge, or capabilities. The technical approach criterion evaluates the planning and administrative aspects of the proposed plan to ensure that the applicant's planned approach will achieve the project's expected benefits. The technical and management capability criterion evaluates the credentials, capabilities, and experience of the applicant, including whether the applicant can perform the proposed project tasks.

Once applications are received in response to an FOA, they are reviewed by a Merit Review Panel. This panel, which is appointed by DOE, is generally composed of at least three reviewers that are knowledgeable in the subject area. The Merit Review Panel reads, scores, and ranks the proposals based on the criteria stated above, and records their judgments in a Board Report. This report contains the final consensus scores, strengths, and weaknesses determined by the panel for each proposal submitted. This report is then reviewed by a selected senior DOE official who, to maximize the effectiveness of available government funding, also may consider additional factors when selecting among proposals, such as diversity of technological approaches and methods or geographic region. As noted above, DOE officials told us that projects selected under section 999 and the methane hydrates program are subject to additional requirements, including regular peer review.

Over the last several years, OMB has evaluated DOE's R&D programs as part of its goal to identify strengths and weaknesses and make federal programs more effective. OMB has challenged DOE to better justify the need for government research. It has found that DOE's oil R&D program

¹⁷According to DOE officials, weights of criteria depend on objectives of a specific solicitation and specific needs of a program such that development of optimal technical concepts is balanced with diversity of participation and soundly planned R&D.

and part of its gas R&D program fund projects comparable to those funded by private industry, and generally for the direct benefit of private industry. However, OMB specifically acknowledged that the methane hydrates program is an exception that can provide a unique contribution, addressing longer-term research that industry will not likely conduct. DOE officials told us they believe that the process followed prior to OMB's analysis was successful in minimizing DOE duplication of industry oil and gas research, and they have continued to follow these same procedures despite subsequent funding reductions.

Based on our review, DOE's project selection process helps ensure that DOE is informed about industry activities, but the process does not formally assess the likelihood that industry would perform the research without federal funding. Such an assessment is not made because DOE's screening criteria do not explicitly require this type of evaluation. Despite the lack of an assessment, DOE officials continue to believe that DOE's oil and gas R&D activities only minimally duplicate industry's R&D activities because of their extensive interaction with industry. Nonetheless, in our examination of DOE's current projects, we found instances where some—particularly near-term R&D on advanced drilling and improved recovery of oil and gas—are similar to industry's R&D activities. As a result, some of DOE's oil and gas R&D might include activities that industry would conduct without federal funding. On the other hand, we also found examples in which DOE conducts near-term R&D that industry may lack incentive to perform without federal funds. For example, we previously reported that the Bureau of Land Management expressed the need for federal funding to monitor the impact of oil and gas activities on wildlife, groundwater, and surface water in the Powder River Basin in Wyoming and Montana, a major gas producing area.¹⁸ In this regard, we found that DOE partnered with the Bureau of Land Management on several projects related to wildlife and water in the Powder River Basin, primarily because industry has little incentive to conduct research necessary to understand general impacts to wildlife from oil and gas activity.

¹⁸GAO, *Oil and Gas Development: Increased Permitting Activity Has Lessened BLM's Ability to Meet Its Environmental Protection Responsibilities*, [GAO-05-418](#) (Washington, D.C.: June 17, 2005).

Conclusions

DOE plays an important role in conducting oil and gas R&D that U.S. industry may have limited incentive to conduct, such as longer-term, high-risk research. However, in some cases, DOE's near-term R&D may address challenges that industry has an incentive to undertake on its own, without federal funding. While DOE's project selection process includes criteria that help it consider ongoing industry R&D, a more formal and rigorous assessment of its efforts and those of industry would help DOE ensure that it selects projects that industry is unlikely to pursue. Moreover, this formal assessment could help it better justify future funding for its oil and gas R&D.

Recommendation for Executive Action

To better ensure that DOE selects oil and gas R&D projects that industry is unlikely to pursue, we recommend that the Secretary of Energy direct the Assistant Secretary for Fossil Energy to include in DOE's project selection process a formal assessment of the likelihood that the R&D would not have occurred without federal funding.

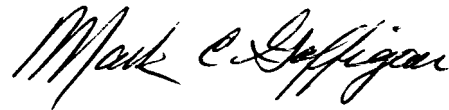
Agency Comments

We provided a copy of our draft report to DOE for its review and comment. DOE had no comment on our recommendation, and provided only technical comments which we incorporated as appropriate.

As agreed with your office, unless you publicly announce the contents of this report earlier, we plan no further distribution until 30 days from the report date. At that time, we will send copies to interested congressional committees and the Secretary of Energy. The report also will be available at no charge on the GAO Web site at <http://www.gao.gov>.

If you or your staff have any questions about this report, 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. GAO staff who made major contributions to this report are listed in appendix III.

Sincerely yours,

A handwritten signature in black ink that reads "Mark E. Gaffigan". The signature is written in a cursive style with a large, stylized "M" and "G".

Mark E. Gaffigan
Director, Natural Resources and Environment

Appendix I: Objectives, Scope, and Methodology

The objectives of this report were to examine (1) how much U.S. industry has invested in oil and gas research and development (R&D) over the last 10 years and the current focus of these activities; (2) how the Department of Energy's (DOE) oil and gas R&D funding and activities compare with industry's, and (3) to what extent DOE ensures that its oil and gas R&D would not occur without federal funding.

To determine how much the U.S. industry has invested in oil and gas R&D over the last 10 years, we used DOE data from the Energy Information Administration (EIA) for 1997 through 2006, the most recent year for which data were available. These data are self-reported by individual companies through a survey administered by DOE, and compiled using DOE's Financial Reporting System (FRS). DOE collects these data from U.S.-based publicly owned companies or U.S.-based subsidiaries that have at least 1 percent of either production or reserves of oil or gas in the United States, or 1 percent of either refining capacity or petroleum product sales in the United States. The sample for 2006 included 27 companies; however, the number of companies included in the survey may vary from year to year. Because these data do not capture spending by service companies or all U.S. or international oil and gas companies that have a presence in the United States but are based abroad, the resulting data underestimate U.S. industry R&D funding. To assess the reliability of these data, we reviewed EIA documentation and interviewed EIA officials to discuss the data contained in the FRS. We found no comprehensive sources of data for oil and gas R&D funding. To gather information about service companies' R&D spending, we obtained data from Security and Exchange Commission (SEC) 10-K Reports for five of the largest service companies (Schlumberger, Halliburton, Baker Hughes, Smith International, and Weatherford International) as identified by various industry sources. These data therefore do not reflect total service company R&D spending. We found the EIA and SEC data to be sufficiently reliable for the purposes of this report.

To determine the current focus of U.S. industry R&D activities, we spoke with officials from oil and gas companies of varying types and sizes, including majors, service companies, and larger and smaller independents. We spoke with 4 majors, 3 service companies, 4 larger independents, and 25 smaller independents. In selecting these companies, we considered a variety of information sources, including: EIA's 2006 FRS, SEC 10-K Reports, and the Oil and Gas Journal's list of top 200 companies in terms of total assets. To select the smaller independents and obtain their contact information, we obtained a database of U.S. oil and gas producers published by Midwest Publishing. Using this database, we selected a

geographically stratified, judgmental sample of 25 oil and gas producers that produce less than 900,000 barrels of oil per year and/or 9.9 billion cubic feet of gas per year. We contacted officials from these companies by phone and conducted a semistructured interview to obtain consistent information from each. Although the results may not be generalized to the industry as a whole, we considered geographic factors that may be associated with differences in R&D efforts in selecting this sample.

To determine how DOE's oil and gas R&D funding compares with U.S. industry, we evaluated DOE's appropriations from 1997 to 2006 and compared them to U.S. industry spending gathered via the EIA's FRS. We obtained data about DOE's appropriations for oil and gas activities and congressionally directed projects from available budget documents. We also obtained information about additional funding included in the Energy Policy Act of 2005 (EPAAct 2005) by reviewing the legislation and through discussions with DOE officials. In addition, we consulted budget information to provide data for DOE's most recent oil and gas appropriations for fiscal years 2007 and 2008. To assess the reliability of DOE's data, we interviewed several key officials from the EIA and from DOE's Office of Fossil Energy, including the National Energy Technology Laboratory. We found the data sufficiently reliable for the purposes of this report.

To determine how DOE's oil and gas R&D activities compare with U.S. industry, we reviewed DOE's detailed project information and related documents and interviewed key officials from EIA and from DOE's Office of Fossil Energy, and the National Energy Technology Laboratory. We compared these responses with those gathered from a judgmental sample of U.S. industry representatives from majors, service companies, and larger and smaller independent oil and gas companies. We also gathered perspectives from organizations such as the Independent Petroleum Association of America, the Research Partnership to Secure Energy for America, the Society of Petroleum Engineers, the American Petroleum Institute, the Petroleum Technology Transfer Council, and the American Association of Petroleum Geologists.

To determine the extent to which DOE ensures that its oil and gas R&D would not occur without federal funding, we discussed industry interaction and the project selection process with DOE officials. We also obtained examples of funding opportunity announcements and workshop summary documents, and reviewed the project selection process with DOE officials.

We also were asked to provide descriptive information about the oil and gas R&D spending and activities other nations' governments are conducting, which is contained in appendix II. To gather information on other nations' government's oil and gas R&D expenditures, we used data from the International Energy Agency (IEA) for 1997 through 2006, the most recent year for which data are available. These data are reported by the individual nations to IEA and compiled annually.¹ Data reported by IEA include total energy R&D expenditures, and oil and gas R&D expenditures broken down into the following subcategories:

- *Enhanced production*, which includes secondary and tertiary recovery of oil and gas;
- *Refining, transportation, and storage*, which includes strategic storage of oil and gas, safety aspects of liquefied natural gas transportation and storage, and pipeline evaluation;
- *Nonconventional production*, which includes advanced drilling technologies for nonconventional oil and gas, heavy oil, deep-water extraction, oil shale, and oil sands;
- *Oil and gas combustion*, which includes turbo engines, several types of turbines, and certain types of flue gas cleanup research;
- *Oil and gas conversion*, which is gas-to-liquid technologies; and
- *Other oil and gas*, which includes development of advanced exploration methods, deep-drilling equipment and techniques, and alleviation of environmental impacts of off-shore oil and gas.

To select the countries highlighted in appendix II, we used 2004 through 2006 oil and gas R&D expenditure data, and ranked the countries with the highest average oil and gas R&D expenditures during those 3 years, with the exception of the United States. According to IEA, the nations with the highest average oil and gas R&D expenditures for 2004 through 2006 were

¹IEA is an organization of 28 industrialized member nations that was established in the wake of the 1973-1974 Arab oil embargo. IEA acts as an energy policy adviser to the member countries in their effort to ensure reliable, affordable, and clean energy for their citizens. Member countries include Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Republic of Korea, Luxembourg, the Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, United Kingdom, and the United States.

Japan, France, Canada, Norway, Italy, and Switzerland. We attempted to contact officials from these six nations to discuss their oil and gas R&D expenditures, but we did not receive a response from Italy. Therefore, we include data for the remaining five nations in appendix II. We found no comprehensive source of information illustrating the R&D expenditures for all nations, and chose to use IEA data, which we found to be sufficiently reliable for the purposes of this report.

We conducted this performance audit from January 2008 to December 2008 in accordance with generally accepted government auditing standards. Those standards 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.

Appendix II: Oil and Gas R&D Spending and Activities Conducted by Selected Nations' Governments

Canada

Background and Energy R&D

Canada is rich in energy resources, endowed with large reserves of conventional and nonconventional oil and gas, coal, and uranium, and potential for hydroelectric power. It is among the world's largest producers of oil and is a significant energy exporter. According to Canadian officials, the focus of Canada's R&D portfolio is directed in large part by the diversity and abundance of the country's natural energy resources; because these resources are so diverse, the government does not focus its energy R&D efforts heavily in any one area.

Canadian officials stated that one role of government is to fund long-term, high-risk projects that industry is not economically motivated to conduct. Officials also stated that, while the government avoids pursuing research that benefits a specific company, or is duplicative of what the private sector is already doing, government-supported R&D should focus on technology that is relevant and beneficial to industry as a whole. A key component of this objective is the government's increased emphasis on helping move a newly developed product into commercialization in order to accelerate innovation.

From 1997 through 2006, Canada's energy R&D spending totaled approximately \$3 billion, and has generally increased.¹ Spending for the 10-year period reached a low point of about \$241 million in 1999, but increased in subsequent years with the exception of a significant drop in funding in 2004. Energy R&D spending reached its peak for the 10-year period in 2006, totaling nearly \$433 million (see table 2). The research area that received the greatest funding in 2006 was nuclear fission and fusion, followed by spending on fossil fuels.

¹The data in this appendix are adjusted to 2006 U.S. dollars using Purchasing Power Parity, which is a method that reflects foreign data in national currencies converted into U.S. dollars, based on a comparable level of purchasing power these data would have in the United States.

Appendix II: Oil and Gas R&D Spending and Activities Conducted by Selected Nations' Governments

Table 2: Canada's Total Energy R&D Spending

U.S. dollars in millions

	Fiscal Years										Total
	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	
Total Energy R&D	261.0	245.9	240.9	247.9	269.6	292.4	320.7	268.1	413.1	432.8	2,992.3

Source: International Energy Agency.

Note: Totals may not sum due to rounding.

Oil and Gas R&D Spending and Activities

From 1997 through 2006, Canada's national oil and gas R&D spending totaled nearly \$565 million. Over the 10-year period, spending levels fell as low as about \$49 million in 2000, and peaked at about \$71 million in 2005. In 2006, oil and gas R&D totaled over \$62 million and represented more than 14 percent of Canada's total energy R&D spending. The majority of funding goes toward "other oil and gas" and "nonconventional production" (see table 3).

Table 3: Breakdown of Canada's Oil and Gas R&D Spending by Research Area

U.S. dollars in millions

Research Area	Fiscal Years										Total
	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	
Enhanced production	1.9	2.1	12.0	7.7	10.3	9.3	3.5	6.4	10.6	10.4	74.1
Refining transportation and storage	9.6	7.2	10.0	5.9	6.6	8.0	9.5	4.8	6.9	4.6	73.0
Nonconventional production	31.3	33.9	15.7	17.6	21.4	19.1	23.5	17.8	25.2	23.4	228.8
Combustion	a	a	a	a	a	a	a	0.8	0.6	0.6	1.9
Conversion	a	a	a	a	a	a	a	2.7	0.3	0.2	3.1
Other oil and gas	8.7	9.4	15.4	17.5	21.2	17.5	23.7	19.8	27.3	23.4	184.0
Total oil and gas	51.4	52.7	53.1	48.7	59.4	53.9	60.1	52.3	70.8	62.5	565.0

Source: International Energy Agency.

Note: Totals may not sum due to rounding.

^aData were not available for this year.

France

Background and Energy R&D

France has few domestic oil and gas resources, but is a large consumer of energy. According to French officials, the French government has encouraged the use of nuclear power as an alternative energy source where possible, and the proportion of France's total energy consumption derived from oil has decreased from 71 percent in 1973 to 36 percent in 2004.

French officials told us that the main objectives of its energy strategy are to contribute to national energy independence and guarantee security of supply; ensure competitive energy prices; protect human health and the environment, in particular by fighting against climate change; and guarantee access to energy for all. The French government also has worked to redefine what is classified under "research and development." A major study published in 2007 concluded that more activities should be categorized as R&D for reporting purposes, and that the country's previously reported R&D spending data may be artificially low.

From 1997 through 2005, energy R&D spending totaled about \$7.1 billion and has fluctuated: it dipped as low as \$543 million in 2001, and peaked at about \$965 million in 2002. In 2005, the most recent year for which data are available, the French government devoted over \$907 million to energy R&D (see table 4). The research area that received the greatest funding in 2005 was nuclear fission and fusion, followed by spending on fossil fuels.

Table 4: France's Total Energy R&D Spending

U.S. dollars in millions

	Fiscal Years									Total
	1997	1998	1999	2000	2001	2002	2003	2004	2005	
Total Energy R&D	629.8	671.7	786.5	736.5	543.5	965.1	938.9	876.9	907.4	7,056.3

Source: International Energy Agency.

Note: Totals may not sum due to rounding.

Oil and Gas R&D Spending and Activities

From 1997 through 2005, France spent about \$917 million on oil and gas R&D. France's oil and gas R&D spending increased suddenly and dramatically in 2002 from about \$42 million in the previous year to about \$210 million, but spending has declined since 2002. In 2005, oil and gas

Appendix II: Oil and Gas R&D Spending and Activities Conducted by Selected Nations' Governments

R&D totaled over \$151 million and represented more than 16 percent of France's total energy R&D spending (see table 5).

According to the oil and gas R&D spending data supplied by IEA for 2005, nearly all of current funding goes toward "enhanced production" and "other oil and gas," which encompasses such research areas as development of advanced exploration methods, deep-drilling equipment and techniques, and alleviation of environmental impact of off-shore oil and gas. French officials with whom we spoke corroborated this, and also highlighted activities related to improvements in refining, combustion, and diversification of energy sources. Their work is done primarily for the benefit of the large French oil and gas industry. The country aims to both improve basic understanding of resources, as well as develop commercially viable products.

Table 5: Breakdown of France's Oil and Gas R&D Spending by Research Area

U.S. dollars in millions

Research Area	Fiscal Years									Total
	1997	1998	1999	2000	2001	2002	2003	2004	2005	
Enhanced production	13.0	12.8	12.8	5.8	0.0	147.7	148.0	119.2	102.2	561.4
Refining transportation and storage	0.0	0.0	0.0	3.8	5.8	0.0	^a	0.5	0.5	10.5
Nonconventional production	0.0	0.0	0.0	0.0	0.5	0.5	^a	^a	^a	1.0
Combustion	^a	^a	^a	^a	^a	^a	0.4	0.4	0.7	1.5
Conversion	^a	^a	^a	^a	^a	^a	0.5	0.4	0.4	1.3
Other oil and gas	24.2	23.9	23.9	28.7	35.3	61.9	50.6	44.7	47.6	340.8
Total oil and gas	37.2	36.7	36.7	38.3	41.6	210.0	199.5	165.2	151.4	916.6

Source: International Energy Agency.

Note: Totals may not sum due to rounding.

^aData were not available for this year.

Japan

Background and Energy R&D

Japan is the third-largest oil consumer in the world, but has virtually no domestic oil or gas reserves and relies heavily on imports to meet its consumption needs. Japan is the second-largest net importer of crude oil and largest net importer of liquefied natural gas in the world. Japan places a high priority on energy research, and has a strong, government-supported, energy R&D program. The Japanese government actively pursues energy resources development as well as efficiency measures in an attempt to improve energy efficiency, reduce dependence on oil, and maintain nuclear power generation.

From 1997 through 2006, energy R&D spending in Japan totaled about \$33.6 billion, and has followed a generally increasing trend. Total energy R&D spending peaked in 2002, reaching a high point of about \$3.9 billion for the 10-year period. A 2-year decline in spending followed this peak in 2002, but spending resumed its upward trend in 2005. In 2006, Japan allocated nearly \$3.4 billion toward energy R&D (see table 6). Nuclear fission and fusion research represented the bulk of R&D spending in 2006, at about \$2.1 billion dollars.

Table 6: Japan's Total Energy R&D Spending

U.S. dollars in millions

	Fiscal Years										Total
	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	
Total Energy R&D	3,147.3	3,177.1	3,157.7	3,234.8	3,256.3	3,941.0	3,600.6	3,357.4	3,372.9	3,384.9	33,629.9

Source: International Energy Agency.

Note: Totals may not sum due to rounding.

Oil and Gas R&D Spending and Activities

Despite representing less than 7 percent of the nation's total energy R&D spending, Japan has spent more on oil and gas R&D than any other IEA nation in recent years. From 1997 through 2006, total oil and gas R&D spending totaled over \$1.3 billion dollars. In 2002, spending increased dramatically to almost \$250 million, more than eight times the amount spent in 2001. In 2006, oil and gas R&D totaled over \$214 million (see table 7).

In 2006, Japan spread its oil and gas R&D among many activities. One example is methane hydrate research. The nation has a large accumulation

Appendix II: Oil and Gas R&D Spending and Activities Conducted by Selected Nations' Governments

of methane hydrates located just off its southeastern coast. Despite methane hydrate research being a relatively new field, Japan has undertaken a significant, multiyear program devoted to researching this potential new energy source. Japan also cooperates and partners with DOE for some of its methane hydrate research.

Table 7: Breakdown of Japan's Oil and Gas R&D Spending by Research Area

U.S. dollars in millions

Research Area	Fiscal Years										Total
	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	
Enhanced production	3.6	22.6	21.0	15.2	22.7	0.0	0.0	0.0	0.0	29.4	114.4
Refining transportation and storage	105.8	58.0	2.5	2.6	2.0	75.5	50.2	138.7	155.2	70.2	660.5
Nonconventional production	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	32.0	32.0
Combustion	a	a	a	a	a	a	a	0.0	0.0	0.0	0.0
Conversion	a	a	a	a	a	a	a	0.0	0.0	23.6	23.6
Other oil and gas	4.9	5.4	5.7	5.3	5.0	173.5	157.3	52.5	31.7	58.9	500.0
Total oil and gas	114.3	86.0	29.1	23.1	29.7	248.9	207.4	191.2	186.9	214.0	1,330.5

Source: International Energy Agency.

Note: Totals may not sum due to rounding.

*Data were not available for this year.

Norway

Background and Energy R&D

Norway has vast proven offshore petroleum reserves, and is the fourth-largest net oil exporting country according to EIA data. Norway's economy is highly dependent on its offshore oil and gas sector, which provides the government with its largest single source of revenue and the largest contribution to gross domestic product. The country also has extensively developed its hydroelectric power industry, and it relies heavily on hydroelectric power as Norway's primary means of domestic electricity generation.

From 1997 through 2006, Norway's energy R&D spending totaled about \$595.6 million, and followed a general upward trend, increasing steadily since 2003. In 2006, the nation spent over \$79 million on energy R&D (see table 8). Within Norway's energy R&D portfolio, the vast majority of spending is dedicated to fossil fuel R&D: the fossil fuel line item represented over 60 percent of total R&D spending in 2006.

Table 8: Norway's Total Energy R&D Spending

U.S. dollars in millions

	Fiscal Years										Total
	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	
Total Energy R&D	50.2	49.8	62.5	53.8	55.2	57.4	54.7	63.9	68.7	79.4	595.6

Source: International Energy Agency.

Note: Totals may not sum due to rounding.

Oil and Gas R&D Spending and Activities

From 1997 through 2006, Norway spent a total of nearly \$300 million on oil and gas R&D, and in this time period, spending in Norway fluctuated widely. Oil and gas R&D spending in 1997 was about \$24 million, it reached a low of about \$22 million in 2002, and in 2006, the most recent year included in our sample, Norway spent nearly \$38 million on oil and gas R&D. According to IEA data, "other oil and gas" makes up the largest portion of oil and gas R&D spending, followed by spending toward enhanced production (see table 9).

Norwegian government officials informed us that the government gives a high priority to oil and gas research, and they spend accordingly. In addition to the high cost of oil and the growing domestic demand, focusing resources in this area serves to bolster the Norwegian government's

Appendix II: Oil and Gas R&D Spending and Activities Conducted by Selected Nations' Governments

efforts to develop an international leadership role in oil and gas R&D. Norway's national oil and gas R&D strategy focuses on sustained profitability in the Norwegian petroleum industry; optimization of domestic resources, primarily those occurring on the Norwegian Continental Shelf; and increased technology and knowledge exports that will bolster international competitive advantages to help Norway achieve a leadership role in oil and gas R&D. These goals are carried out through work in eight technology target areas established by the OG21—the body that helps shape the nation's oil and gas strategy. In addition to the OG21, Norway's attention to oil and gas research is bolstered by another group, DEMO2000, a consortium of public, private, and academic stakeholders conducting oil and gas R&D, which is organized similarly to RPSEA in the United States.

Table 9: Breakdown of Norway's Oil and Gas R&D Spending by Research Area

U.S. dollars in millions

Research Area	Fiscal Years										Total
	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	
Enhanced production	10.3	7.8	9.6	6.3	5.4	4.3	5.5	7.1	5.4	10.3	71.9
Refining transportation and storage	1.8	1.8	3.0	2.5	2.2	1.8	2.2	2.7	3.3	4.3	25.5
Nonconventional production	1.7	1.2	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.5
Combustion	a	a	a	a	a	a	a	0.0	0.0	0.0	0.0
Conversion	a	a	a	a	a	a	a	0.0	0.7	2.0	2.7
Other oil and gas	10.4	12.4	24.4	20.3	19.5	15.7	18.5	22.2	23.7	21.3	188.4
Total oil and gas	24.2	23.2	37.5	29.1	27.1	21.7	26.1	32.0	33.1	37.9	292.0

Source: International Energy Agency.

Note: Totals may not sum due to rounding.

^aData were not available for this year.

Switzerland

Background and Energy R&D

Switzerland imports all of its fossil resources, especially oil, and produces renewable forms of energy domestically. Switzerland's energy policy is guided by its federal constitution, which calls for sufficient, reliable, diversified, cost-effective, and environmentally sound energy supply. It also emphasizes the importance of energy efficiency. To move toward these goals, Switzerland has made efforts to reduce fossil fuel use and related carbon dioxide emissions.

From 1997 through 2006, energy R&D spending totaled nearly \$1.1 billion, and has followed a generally declining trend with some spending fluctuations. In 2006, the Swiss government devoted over \$98 million to energy R&D (see table 10). The research area that received the greatest funding in 2006 was nuclear fission and fusion, followed by spending on renewable energy.

Table 10: Switzerland's Total Energy R&D Spending

U.S. dollars in millions

	Fiscal Years										Total
	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	
Total Energy R&D	124.7	115.8	113.4	104.3	107.4	109.8	111.2	96.9	93.8	98.4	1,075.8

Source: International Energy Agency.

Note: Totals may not sum due to rounding.

Oil and Gas R&D Spending and Activities

From 1997 through 2006, Switzerland spent over \$76 million on oil and gas R&D. Over the 10-year period, Switzerland's oil and gas R&D spending generally followed a pattern of decline, with the exception of a significant rise in funding in 2002 when funding reached a peak of about \$9 million. Despite a relatively steady decline since 2002, spending rose slightly in 2006, the most recent year for which data are available, to total nearly \$7 million (see table 11).

Swiss officials told us that national oil and gas R&D spending is currently focused on research to improve the efficiency and mitigate the environmental impacts of combustion engines that run on fossil fuels. EIA data on Switzerland confirms this: in 2006, over 95 percent of oil and gas R&D funds were dedicated to the combustion line item.

**Appendix II: Oil and Gas R&D Spending and
Activities Conducted by Selected Nations'
Governments**

Table 11: Breakdown of Switzerland's Oil and Gas R&D Spending by Research Area

U.S. dollars in millions

Research Area	Fiscal Years										Total
	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	
Enhanced production	0.0	7.6	7.3	6.7	6.9	9.3	8.8	0.3	0.2	0.3	47.5
Refining transportation and storage	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nonconventional production	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Combustion	a	a	a	a	a	a	a	7.2	6.4	6.6	20.2
Conversion	a	a	a	a	a	a	a	0.0	0.0	0.0	0.0
Other oil and gas	8.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.8
Total oil and gas	8.8	7.6	7.3	6.7	6.9	9.3	8.8	7.5	6.7	6.9	76.5

Source: International Energy Agency.

Note: Totals may not sum due to rounding.

*Data were not available for this year.

Appendix III: GAO Contact and Staff Acknowledgments

GAO Contact

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Staff Acknowledgments

In addition to the individual named above, Daniel Haas (Assistant Director), Chuck Bausell, Ron Belak, Virginia Chanley, Emily Norman, Alison O'Neill, Stuart Ryba, Barbara Timmerman, and Ignacio Yanes made important contributions to this report.

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