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United States Government Accountability Office
Washington, DC 20548

November 6, 2007

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

Subject: *Department of Energy: Oil and Natural Gas Research and Development Activities*

Dear Mr. Chairman:

Domestic oil and natural gas production are important to meeting our nation's energy needs and represented more than 40 percent of the U.S. energy production in 2006. The Department of Energy (DOE) has undertaken research and development (R&D) for oil and natural gas since its inception in the late 1970s. Historically, the federal government has entered into cost-sharing agreements with universities, state agencies, and independent companies to help fund these R&D efforts, which were often long-term, high-risk projects with variable results. In recent appropriations, DOE's funding for oil and natural gas R&D was significantly reduced.

In this context, you asked us to review DOE's R&D activities for oil and natural gas and provide information on (1) how much has been appropriated during the past 10 years, (2) how DOE expended these appropriations and its reported results to date, (3) the potential future results from continuing DOE-sponsored research in oil and natural gas technologies, and (4) the factors that could be considered when determining the federal government's role in oil and natural gas R&D.

We briefed your staff on the results of our work on September 25, 2007. In response to your request, this report summarizes and formally transmits the information provided to your staff during that briefing. The enclosure to this report presents the briefing in its entirety. This report is based on analysis of prior GAO work, budget data for fiscal years 1997 through 2007, and discussions about the results of past oil and natural gas R&D expenditures and the potential future results of oil and natural gas R&D activities. We discussed these issues with officials from DOE and other federal government organizations, industry, states, academia, consulting groups, and the National Academy of Sciences. We performed our work between June 2007 and November 2007 in accordance with generally accepted government auditing standards.

Summary

DOE oil and natural gas R&D appropriations have generally declined from approximately \$162.5 million in fiscal year 1997 to about \$14.3 million in fiscal year 2007.¹ Oil appropriations, which were about \$45.2 million in fiscal year 1997, rose to about \$65.1 million in fiscal year 2001 before declining steadily to approximately \$2.6 million in fiscal year 2007. Natural gas appropriations have also declined from about \$117.3 million in fiscal year 1997 to about \$11.7 million in fiscal year 2007, partially because fuel cell technologies and advanced gas turbines have been removed from the natural gas R&D budget.²

Since 1997, DOE oil and natural gas R&D expenditures include projects for (1) increasing exploration and production; (2) addressing environmental protection; (3) extending reservoir lives; (4) developing gas hydrates; and (5) carrying out other activities, such as the development of fuel cells, gas turbines, and infrastructure improvements, and providing field demonstrations. For example, one project studied the environmental impacts of road building on tundra and found that tundra was more resistant than anticipated. This knowledge provided a basis for companies operating in northern Alaska to extend the exploration season without additional harm to the tundra.

According to DOE officials, if DOE continued to sponsor research in oil and natural gas R&D, it would seek results in three broad areas: (1) increasing domestic oil and natural gas production—especially from independent producers³—to a level higher than otherwise would occur; (2) reducing some environmental impacts by monitoring and conducting assessments of air quality, developing new management options for using water produced during production, and contributing to the overall health of ecosystems; and (3) developing “game changing” technologies, such as methods for finding and producing gas hydrates, and newer enhanced oil recovery technologies and processes that increase production and provide the necessary bridge to commercial carbon dioxide sequestration—the capture and containment of this gas.⁴ Increasing domestic oil and natural gas production could, according to DOE officials, potentially result in increased support for independent producers, less reliance on imported oil, increased government revenues from royalties and taxes, and research projects that help to replenish the talent pool of energy professionals.

¹Dollar amounts for appropriations are unadjusted for inflation.

²These funds were shifted to other areas within DOE and are no longer categorized as natural gas R&D activities.

³Independent producers are oil and natural gas companies that receive nearly all of their revenues from oil and gas production, and that generally lack revenue from refining, transportation, and retail marketing of the products.

⁴Game changing technologies are seen by DOE as technologies or approaches with the potential to dramatically alter thinking about oil and natural gas resources. For example, the methane (natural gas) contained in methane hydrate is estimated to be over 100 times larger than estimated technically recoverable natural gas resources from more conventional reservoirs, which could change thinking regarding the need for natural gas imports from other countries.

On the basis of GAO's prior work, the following questions, among others, could be considered when determining the federal government's role in oil and natural gas R&D: (1) Is the industry motivated to conduct the research on its own? (2) Do cost-sharing opportunities exist for the government? and (3) Do the benefits of the research exceed the cost?⁵ Although competition in oil and natural gas markets should provide incentives for companies to invest in R&D, they may not be adequately motivated to incur the full costs of R&D because they cannot capture all of the benefits. For example, a successful innovator would capture some of the rewards, but those rewards would typically be a fraction—and sometimes a very small fraction—of the overall benefits to society. As such, some industry economists and experts argue that a federal government role is needed because industry may underinvest in oil and natural gas R&D. However, the extent to which industry is underinvesting in this area is unclear because comparable data are not readily available and much of these data are proprietary.

In short, DOE reports many cost-sharing initiatives that have resulted in technological innovations, which have helped domestic producers—particularly independent producers—maintain production of these important fuels; addressed some environmental issues, such as the need for research on the effects of oil and natural gas activities on surrounding ecosystems; and developed a better understanding of other potential resources, such as gas hydrates. While GAO and others have reported that the overall benefits of these projects have been difficult to quantify and link to DOE's efforts, considering key questions about the need for research, industry commitment to research, and the costs and benefits associated with the research can help define the role of the federal government and assist the Congress in its policy choices.

Agency Comments

We provided DOE with a draft of this report for review and comment. DOE officials had no substantive comments on the report, but they provided technical comments about the potential of gas hydrates, how major oil companies differ from the independents, and our characterization of new carbon sequestration technologies. We incorporated their comments as appropriate.

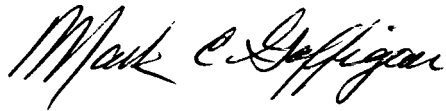
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As agreed with your office, unless you publicly announce its contents earlier, we plan no further distribution of this report until 7 days from its issue date. At that time, we will send copies of this report to appropriate congressional committees; the Secretary of Energy; and other interested parties. In addition, this report will be available at no charge on GAO's Web site at <http://www.gao.gov>.

⁵See, for example, GAO, *Department of Energy: Proposed Budget in Support of the President's Climate Change Technology Initiative*, GAO/RCED-98-147 (Washington, D.C.: Apr. 10, 1998).

If you have any questions or need additional information, 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 at the last page of this report. Major contributors to this report were Chuck Bausell, Ron Belak, Dan Haas (Assistant Director), Stuart Ryba, and Ignacio Yanes. Also contributing to this report were Virginia Chanley, Alison O'Neill, MaryLynn Sergent, Anne Stevens, and Barbara Timmerman.

Sincerely yours,

A handwritten signature in black ink that reads "Mark E. Gaffigan". The signature is written in a cursive, flowing style.

Mark Gaffigan
Acting Director, National Resources and Environment

Enclosure

**Briefing to the Committee on Appropriations,
Subcommittee on Energy and Water Development**



**Department of Energy:
Oil and Natural Gas Research and
Development Activities**

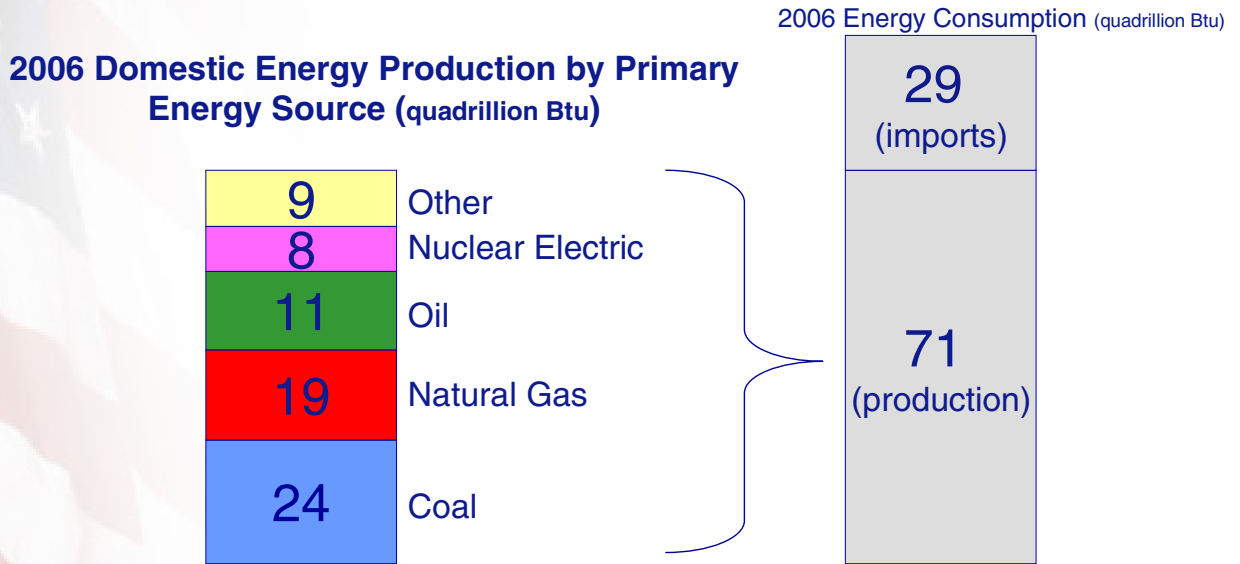
**Briefing to the Committee on Appropriations,
Subcommittee on Energy and
Water Development, U.S. Senate
September 25, 2007**



DOE Research and Development (R&D) for Oil and Natural Gas

Background

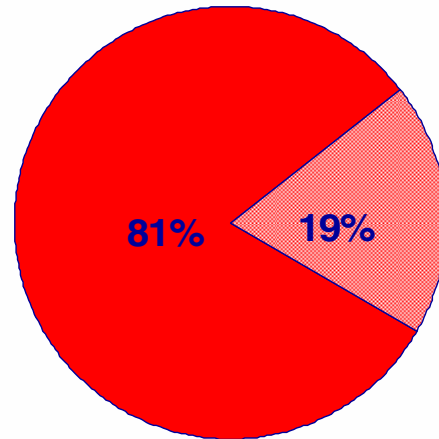
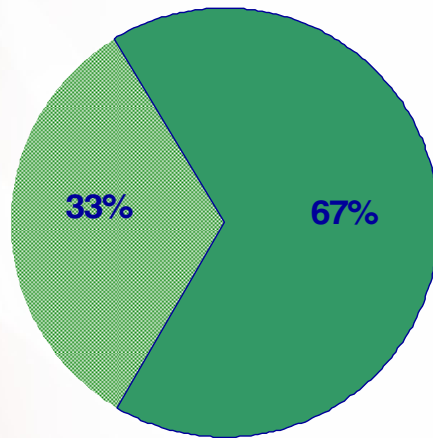
U.S. Consumes More Energy Than it Produces



Source: Energy Information Administration Annual Energy Review 2006 (Preliminary)

Note: Other Includes Renewable Energy Sources and Natural Gas Plant Liquids

U.S. Imports Most of Its Oil and Some of Its Natural Gas



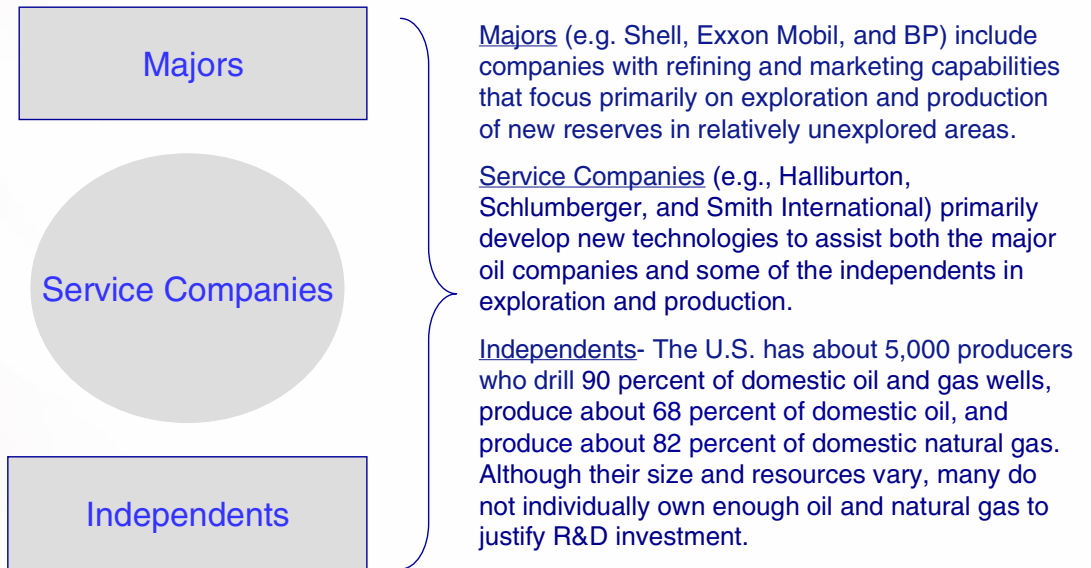
Source: DOE Energy Information Administration 2007



Historical Role of DOE in R&D

- DOE has undertaken research and development (R&D) for oil and natural gas since its inception in the late 1970s.
 - These research activities often fund high-risk, high-cost projects aimed at long-term results.
 - Historically, the federal government has entered into cost-sharing agreements with universities, state agencies, and independent companies to fund these R&D activities.
 - In recent appropriations, DOE has received significantly reduced funding for its oil and natural gas R&D activities.
-

The Key Players in the Oil and Natural Gas Industries Have Varying Interests





Objectives: DOE R&D Activities for Oil and Natural Gas

1. How much has been appropriated during the past ten years?
 2. How have these appropriations been expended and what are DOE's reported results to date?
 3. What are the potential future results from continuing DOE-sponsored research in oil and natural gas technologies?
 4. What factors could be considered when determining the federal government's role in oil and natural gas R&D?
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DOE R&D for Oil and Natural Gas

Scope and Methodology



Scope and Methodology

Scope:

DOE oil and natural gas R&D activities from fiscal year 1997-2007

Methodology:

- Reviewed and analyzed budget data for fiscal years 1997-2007 with officials from DOE and reviewed budget data from the Office of Management and Budget and previous GAO reports.
 - We reviewed studies and discussed the results of oil and natural gas expenditures with officials from DOE, the U.S. Geological Survey, industry, states, academia, think tanks, the National Academy of Sciences, and the International Energy Agency.
 - We discussed the potential future results of continued DOE-sponsored research in oil and natural gas R&D with officials from the same group.
 - We reviewed prior GAO reports as well as reports by the National Academy of Sciences and DOE to determine factors that should be considered when assessing the federal government's role in oil and natural gas R&D.
 - Our assessment of some information is preliminary and has not been fully corroborated. We also did not perform a cost-benefit analysis, nor did we consider additional subsidies to industry through tax breaks.
 - We performed our work between June 2007 and November 2007 in accordance with generally accepted government auditing standards.
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Scope and Methodology: Sources of Information

We discussed DOE's oil and gas R&D activities with:

- Government: DOE Fossil Energy, DOE National Energy Technology Laboratory (NETL), DOE Lawrence Berkeley National Laboratory, United States Geological Survey Energy Resources Program, International Energy Agency
 - Industry: Independent Petroleum Association of America and Research Partnership to Secure Energy for America
 - States and Academia: Colorado Energy Research Institute, University of Texas Bureau of Economic Geology, University of North Dakota Energy and Environmental Research Center, Interstate Oil and Gas Compact Commission, Southern States Energy Board
 - Think Tanks: Cambridge Energy Research Associates and Rocky Mountain Institute
 - National Academy of Sciences: National Research Council
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Results in Brief

Objective 1:

DOE oil and natural gas R&D appropriations have generally declined from approximately \$162 million in fiscal year 1997 to about \$14 million in fiscal year 2007.

Objective 2:

DOE oil and natural gas R&D appropriations resulted in expenditures for projects including:

- increasing exploration and production;
 - addressing environmental protection;
 - extending reservoir lives;
 - developing gas hydrates; and
 - carrying out other activities, such as the development of fuel cells, gas turbines, and infrastructure improvements, and providing field demonstrations.
-

Results in Brief (continued)

Objective 3:

Future DOE oil and natural gas R&D investments could potentially yield results in three broad areas:

- increasing domestic oil and natural gas production—especially from independent producers—to a level higher than otherwise would occur;
- reducing environmental impacts in some cases; and
- developing “game changing” technologies such as (1) gas hydrates and (2) CO₂ sequestration that increases production.

Objective 4:

Among the factors that could be considered when determining the federal government’s role in oil and natural gas R&D are:

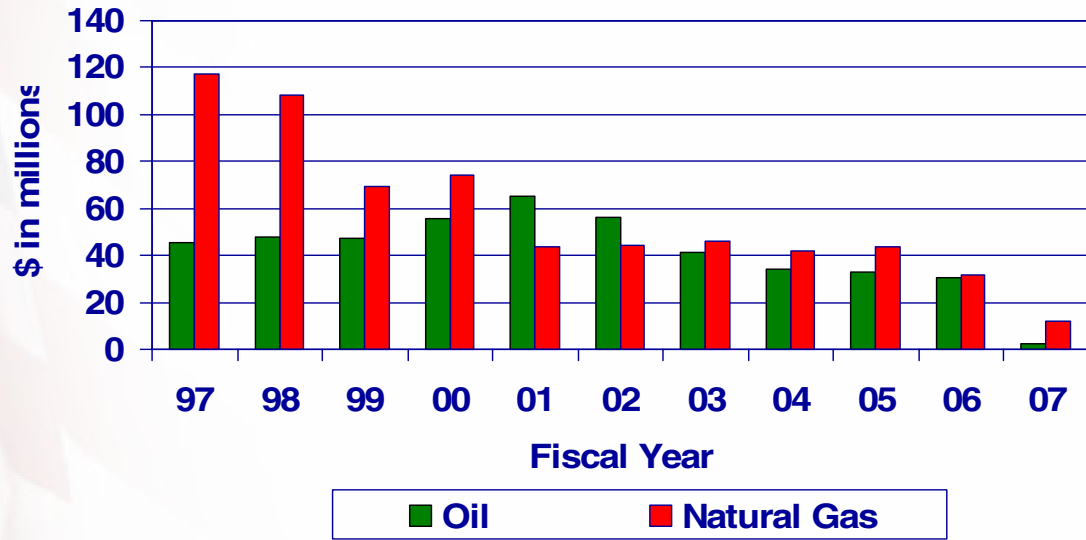
- Is industry motivated to conduct the research on its own?
 - Do cost-sharing opportunities exist for the government?
 - Do benefits of the research exceed the costs?
-



DOE R&D for Oil and Natural Gas

Objective 1: How much has been appropriated during the past ten years?

Appropriations Have Generally Declined From Fiscal Year 1997 to 2007 (in millions of dollars)



Source: GAO analysis of DOE data

Note: Dollar amounts are unadjusted for inflation; when adjusted, the declines are even greater.



Appropriations Have Generally Declined From Fiscal Year 1997 to 2007 (in millions of dollars)

Fiscal Year	Oil Technologies	Gas Technologies	TOTAL
1997	45.184	117.261	162.445
1998	47.708	108.461	156.169
1999	47.344	69.346	116.690
2000	55.747	73.894	129.641
2001	65.095	43.925	109.020
2002	56.244	44.069	100.313
2003	40.983	45.860	86.843
2004	34.107	41.836	75.943
2005	32.985	43.632	76.617
2006	30.805	31.801	62.606
2007	2.625	11.709	14.334
TOTAL	458.827	631.794	1090.621

Source: GAO analysis of DOE data

Note: Dollar amounts are unadjusted for inflation; when adjusted, the declines are even greater.

15



DOE R&D for Oil and Natural Gas

Objective 2: How have these appropriations been expended and what are DOE's reported results to date?



Purpose of Oil and Natural Gas R&D Expenditures (Selected Years in millions of dollars)

Budget Categories	FY98	FY02	FY06
Oil Technologies:			
Exploration and Production	30.141	33.207	12.997
Environmental Protection	6.224	10.426	9.242
Reservoir Life Extension	0.000	12.611	5.776
Other	11.343	0.000	2.790
TOTAL Oil	47.708	56.244	30.805
Natural Gas Technologies:			
Exploration and Production	13.566	19.964	17.329
Environmental Protection	3.181	2.537	1,444
Gas Hydrates	0.000	9.568	8.667
Other	91.714	12.000	4.361
TOTAL Natural Gas	108.461	44.069	31.801
TOTAL Oil and Natural Gas	156.169	100.313	62.606

Source: GAO analysis of DOE data



Purpose of Oil and Natural Gas R&D Expenditures

Category	Goals/Details
Exploration and Production	Development of technologies for independents to economically recover the oil remaining in mature fields by expanding the technology options for enhanced oil recovery. Develop technology to find and produce gas from non-conventional and deep gas reservoirs with minimal environmental impact. Also includes resource assessments in new basins and drilling completion and stimulations.
Effective Environmental Protection	Develop technologies and practices that reduce the environmental impact of oil exploration, production, and processing while lowering the cost of effective environmental protection and compliance. Includes examining the specific impact of produced water and the more general problem of water management. Reduce the environmental impacts of natural gas operations and reduce the cost of environmental compliance through a combination of technology development, risk assessment, and regulatory streamlining.
Reservoir Life Extension	Improve recovery from mature fields through (1) prototype development such as microhole technologies for enabling improved access; (2) technology transfer to independents; and (3) policy analysis and planning to increase domestic oil recovery over a wide range of technological and economic conditions.
Gas (Methane) Hydrates	Develop the knowledge and technology to allow methane to be produced from hydrates while protecting the environment. Conduct high risk and long-term research to understand the fundamental characteristics of hydrates and commercially produce the gas.
Other	Includes infrastructure research to enhance the reliability of the nation's oil and gas pipelines and storage; processing technology that evaluates gas to liquid feasibility; recovery field demonstrations that display to independent producers advanced technologies to maximize oil recovery; congressional directed activities; and others. Includes \$39.2 million for fuel cells and \$43.9 million for advanced gas turbines in fiscal year 1998 for natural gas R&D—these projects continued but were transferred out of the natural gas R&D in subsequent years.



Reported Results of Expenditures: Exploration and Production

Results include providing the necessary technologies to identify, locate, and economically recover oil and natural gas remaining in mature fields with minimal environmental impact. Examples include:

- 1 — **Advanced Diagnostic and Imaging** provides deep imaging capabilities, improves resource estimates, develops new methods for detection of reservoir sweet spots, and provides improved CO₂ monitoring.
 - 2 — **Deep Trek** developed more durable equipment in high temperature drilling conditions, and provides real-time communication between the drill bit and surface.
 - 3 — **Stripper Well Revitalization** includes organizing a nationwide consortium to share information and developing low cost techniques for small companies to improve natural gas and oil recovery.
 - 4 — **Enhanced Oil Recovery** efforts unite university knowledge centers with independent producers and develop techniques to use CO₂ injection to increase production.
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Design of a Down-hole Microcomputer Circuit

Objective:

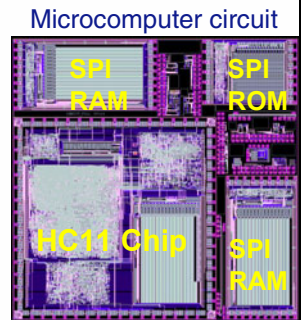
Develop a down-hole microcomputer system that survives 275°C and can be readily incorporated in electronic circuits used by industry.

Accomplishments

Agreed upon design standards (allows broad market application and compatibility with other components under development).

Benefits:

Provides accurate and efficient control of down-hole equipment, communications, data acquisition, and digital signal processing.





Reported Results of Expenditures: Effective Environmental Protection

Results include technologies, practices, and regulations that reduce the environmental impact of oil and natural gas exploration, production, and processing through technology development and risk assessment. Examples include:

- 1 — Waste Disposal of naturally occurring radioactive materials and synthetic mud.
- 2 — Using salt caverns for disposal of non-hazardous oilfield waste.
- 3 — Developing new water treatment technologies to create management options for produced water.
- 4 — Studying the effects of oil and gas activities on the surrounding ecosystem as well as wildlife and their habitat.

Example: Environmental Impacts on Tundra

- DOE/Alaska DNR performed environmental assessment that quantitatively defined the hardness of the ground needed to protect the tundra during road building in different ecosystems;
- According to DOE, the tundra was much more resistant to the impacts of road building than anticipated;
- Assessment determined season could begin earlier without damaging tundra.



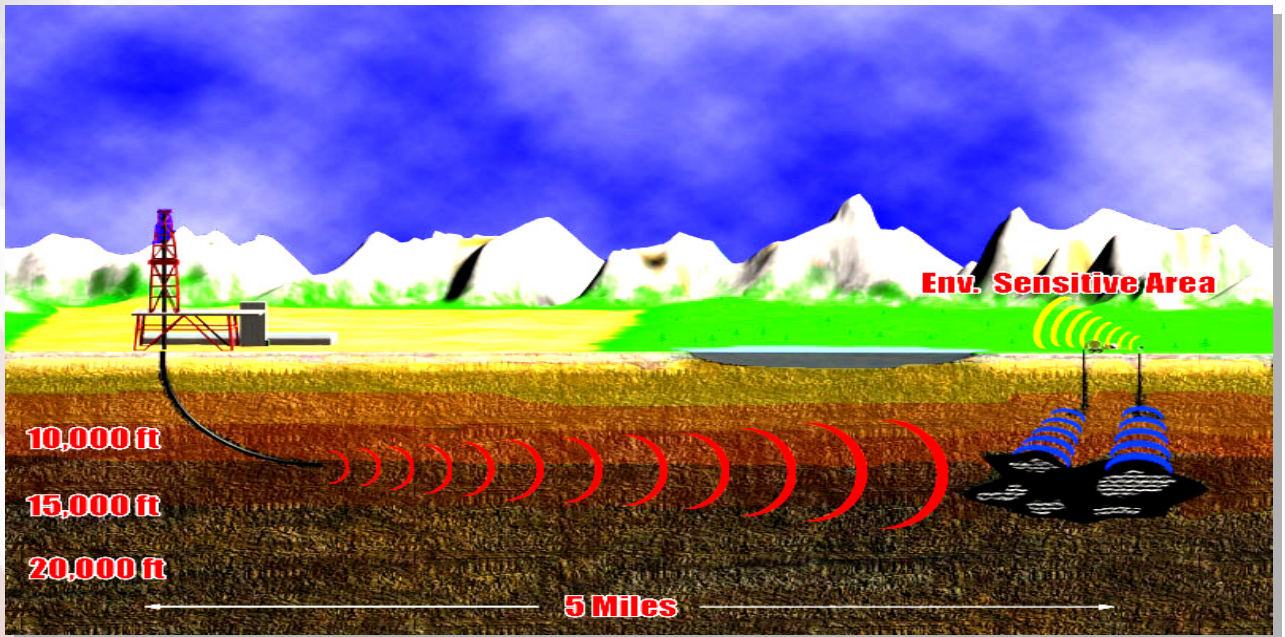


Reported Results of Expenditures: Reservoir Life Extension

Results include developing technologies to more effectively recover domestic oil, extend the life of existing fields, and maximize production through research and technology transfer gained from the field testing of new technologies. Examples include:

- 1 — Using microhole technologies to locate and monitor production in complex reservoirs via new 4-D seismic imaging.
- 2 — Applying new thermal enhanced oil recovery technologies to increase recovery of heavy oil.
- 3 — Transferring technology to independent producers through workshops, presentations, and websites.

Example: Microhole Technologies



Source: DOE's National Energy Technology Laboratory



Reported Results of Expenditures: Gas Hydrates

Results include a better understanding of the fundamental characteristics of hydrates and a basis upon which to develop this source of natural gas as conventional resources decline. DOE is part of a government-industry partnership evaluating:

- 1 — whether gas hydrates are a meaningful resource;
- 2 — how to find them; and
- 3 — how to produce them safely, profitably, and in an environmentally-responsible manner.

Example: Hydrates (Ice that Burns)

2000:

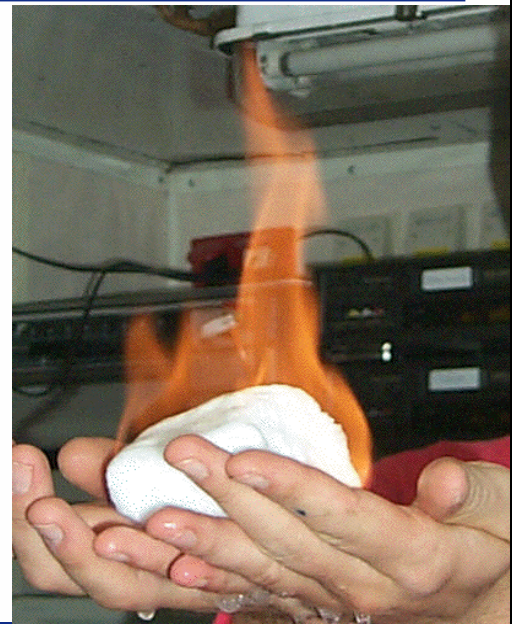
Hydrate science focused on getting a basic understanding
Hydrates were considered a drilling hazard
Hydrates difficult if not impossible to remotely detect

2007:

Proven feasibility of Arctic hydrate production
Understanding that typical hydrate occurrences not a threat
Proven remote detection and some quantification capabilities
for Arctic hydrate

Potential future focus of DOE Research:

Determine the amount of resource available
Determine the capability for reliable remote detection and
quantification of marine hydrates
Demonstrate the ability to produce economic amounts
Understand the environmental implications of hydrates





Reported Results of Expenditures: Other Projects

Reported Results include:

- Fuel Cells and Gas Turbines — the budgets for these projects were subsequently moved out of oil and natural gas R&D.
- Infrastructure improvements that upgrade aging equipment to protect the public from pipeline and equipment leakages.
- Recovery Field Demonstrations that illustrate to independent producers how to implement new technologies developed by DOE and its partners.

Example: Infrastructure

- Provides increased integrity, operational reliability, safety and security of the nation's natural gas infrastructure.
- Reduces greenhouse gas emissions resulting from pipeline and equipment leakage.

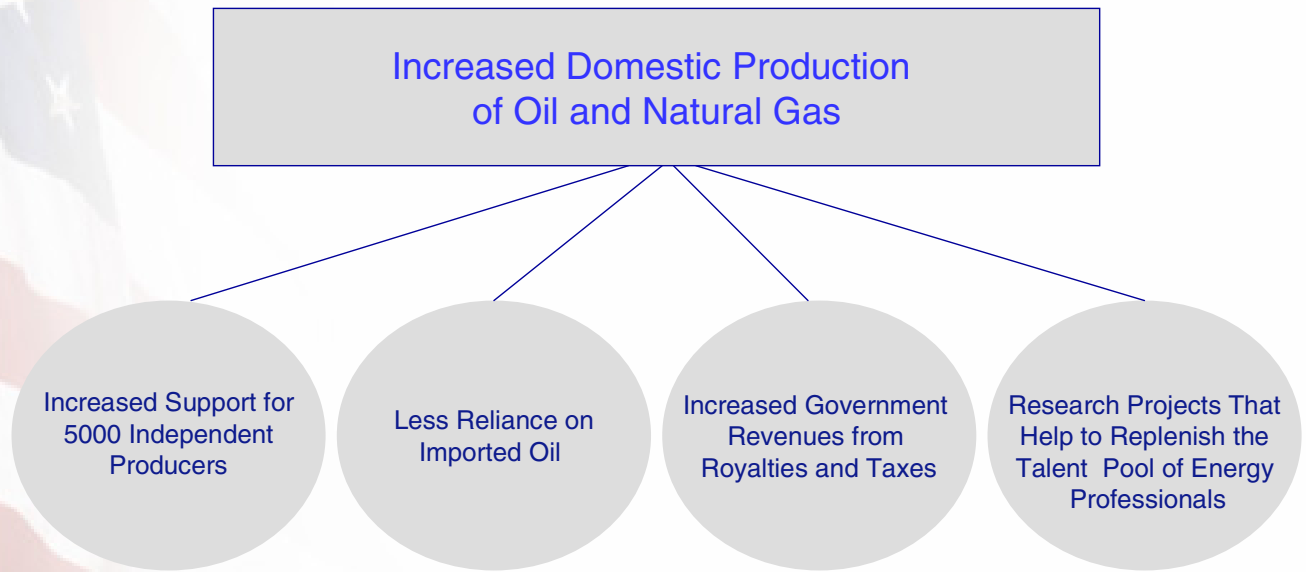




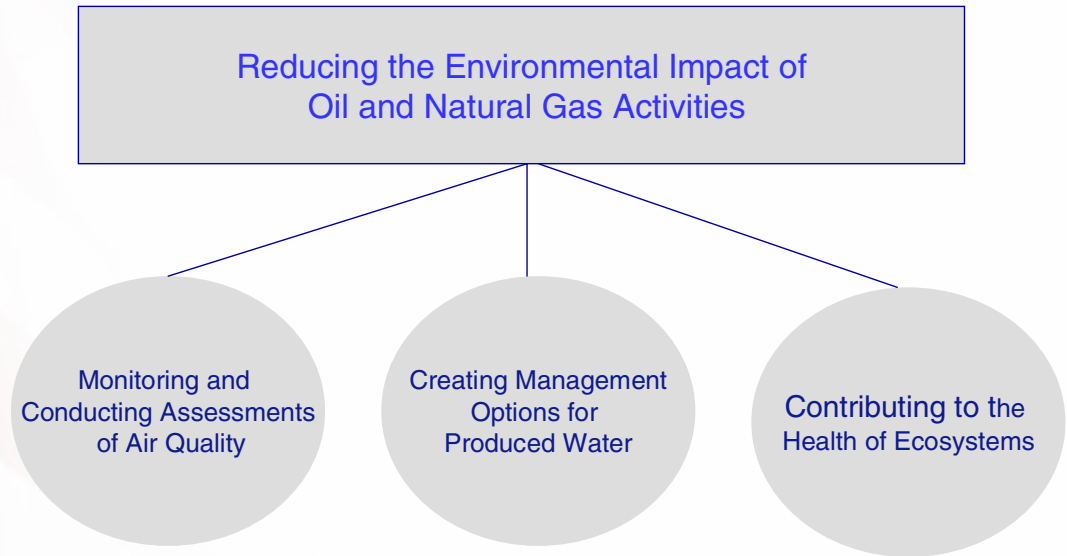
DOE R&D for Oil and Natural Gas

Objective 3: What are the potential future results from continuing DOE-sponsored research in oil and natural gas technologies?

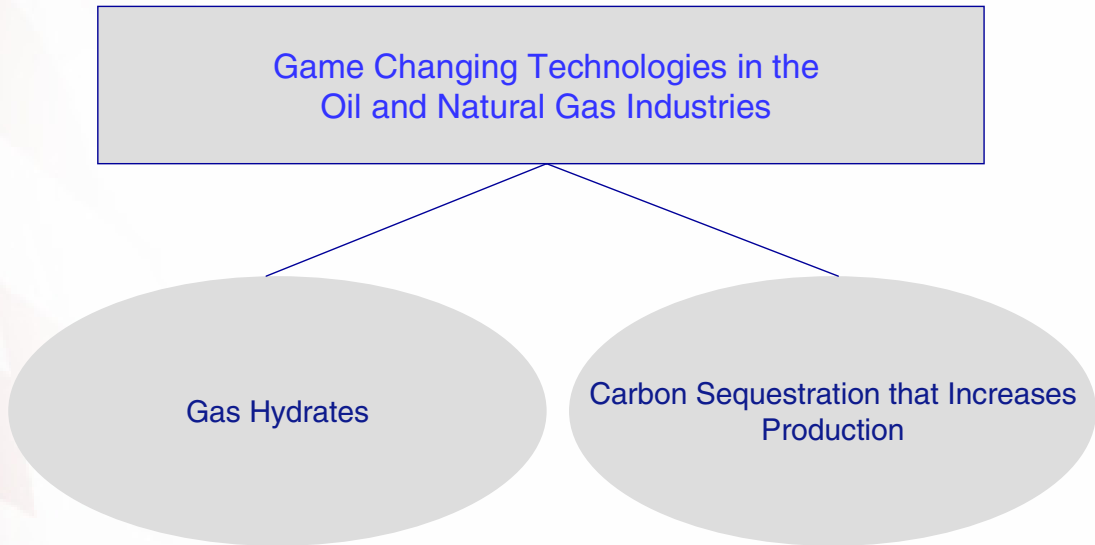
Continuing DOE's Oil and Natural Gas R&D Could Potentially Result in:



Continuing DOE's Oil and Natural Gas R&D Could Potentially Result in:



Continuing DOE's Oil and Natural Gas R&D Could Potentially Result in:





DOE Cites Potential Game Changing Benefits for R&D in Gas Hydrates and Carbon Sequestration

Gas Hydrates:

Refers to gas hydrates as a new source of domestic natural gas with “tantalizing potential”—about 200,000 trillion cubic feet. (Over 100 times more than estimated technically recoverable natural gas resources.)

Acknowledges that the potential benefits would not be understood for several years.

Hydrate R&D is high cost, high risk, and long-term.

Industry is not aggressively pursuing hydrates R&D.

Carbon Sequestration:

Approximately 2/3 (over 400 billion barrels) of domestic oil resource remains after primary recovery.

Identifies over 47 billion barrels of economically recoverable oil that will result from the widespread use of enhanced oil recovery (EOR) technologies.

These technologies may provide the necessary bridge to the development and implementation of next generation CO2 EOR technologies.



DOE R&D for Oil and Natural Gas

Objective 4: What factors could be considered when determining the federal government's role in oil and natural gas R&D?



What factors could be considered when determining the federal government's role in oil and natural gas R&D?

- **Competition in oil and natural gas markets should provide incentives for companies to invest in R&D. Innovations provide competitive advantages by:**
 - (1) reducing costs, and
 - (2) enhancing knowledge

 - **Markets may fail to motivate companies to fully fund R&D. Two examples:**
 - (1) technology — an innovating company may not be able to capture all the benefits while incurring all the costs of R&D (e.g., intellectual property laws inadequate).
 - (2) environmental — cleaner technologies can be at a disadvantage to dirtier ones if environmental costs are not adequately reflected in the market. Thus, no cost advantages are provided to cleaner technologies, thereby reducing incentives to research and develop the cleaner ones.

 - **Based on ongoing and prior work, consideration could be given to questions, such as:**
 - (1) Would the private sector do the research without federal funding? (Would the resulting technology be competitive in the marketplace?)
 - (2) Are there cost-sharing options through a public-private partnership?
 - (3) Do the benefits exceed costs? For example, do independent evaluations indicate that the research program is effective and achieving results?
-



Quantifying the Benefits of DOE R&D Activities Is Inherently Difficult

- As GAO and others have reported, the overall benefits of these projects have been difficult to quantify and link to DOE efforts.
 - In FY2001, the National Academy of Sciences assessed the benefits of federal DOE R&D programs in fossil energy.
 - The Academy found no reliable way to quantify the DOE contribution in most cases, and admitted that doing so remains a methodological challenge. The Academy also judged, in aggregate, benefits of federal energy R&D exceeded costs but observed DOE's overall portfolio included striking successes and expensive failures.
 - DOE quantified the benefits of its fossil energy research in 2004 and judged that the benefits outweighed the cost. However, its report acknowledged that "the future benefits and impacts of R&D programs are inherently uncertain, as are future economic, geopolitical, and regulatory conditions."
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Concluding Observations

Domestic oil and natural gas production remain important to meeting our nation's energy needs and DOE has a long history of R&D in these areas.

DOE-supported R&D has resulted in technological innovations. Some industry economists and experts argue that a federal government role is needed because industry, especially many independent producers, may be under investing in oil and natural gas R&D. The extent to which industry is under-investing is unclear.

Although the benefits of R&D are difficult to quantify, considering key questions about the need for research, industry commitment to research, and the costs and benefits associated with the research can help define the role of the federal government and assist the Congress in its policy choices.

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