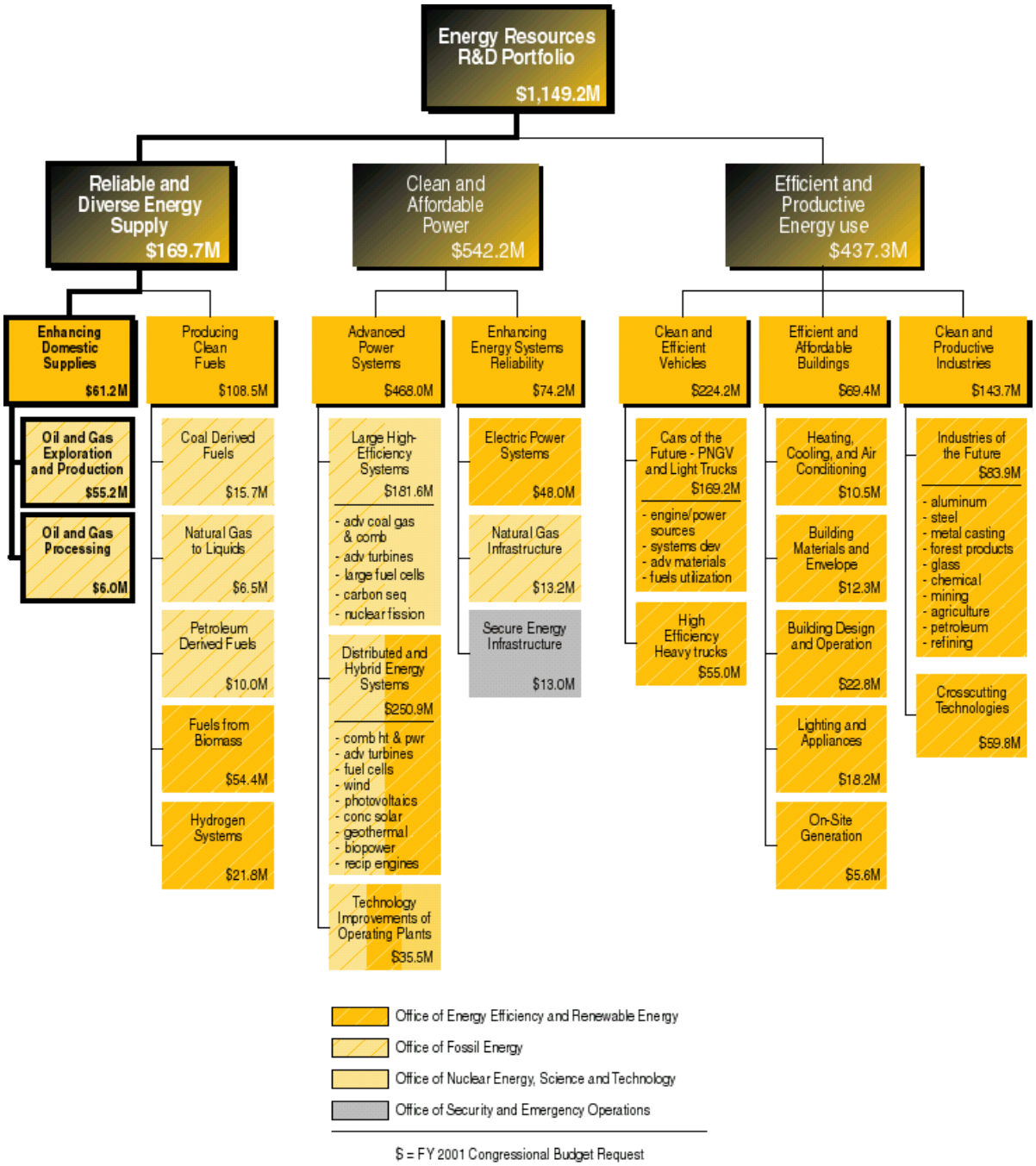
Chapter 3
Enhancing Domestic Supplies



Chapter 3
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Overview

Definition of Focus Area

The "enhancing domestic supplies R&D" portfolio address the Nation's need for stable and secure sources of domestic energy. Specifically, the R&D areas include oil and gas exploration and production (including environmental management), oil and gas processing, gas storage and delivery systems, geothermal energy, and preserving the Nation's critical energy infrastructure.

National Context and Drivers

A secure supply of reasonably priced energy is a prerequisite to U.S. strength in the global marketplace. Oil and gas account for two-thirds of the total U.S. energy consumption, and 97 percent of transportation fuels. Consumption of oil and gas will continue to increase (more than any other source of energy) despite energy efficiency improvements.

Oil security remains a prominent issue despite the relative tranquility in the market in recent years. Our economy is almost totally dependent on oil for its transportation needs. By 2015, it is projected that: (1) demand for petroleum in non-industrialized countries will nearly double; (2) the United States will consume more than 23 million barrels per day of oil and import more than 60 percent of it; and (3) the Middle East will control more than 62 percent of the world petroleum export market. This concentration of export market control will be greater than what existed in the 1970s and early 1980s when disruptions caused severe economic dislocations and fundamentally reordered U.S. and International Energy Agency (IEA) member nations' energy security program priorities.

Domestic natural gas consumption is expected to rise to more than 30 trillion cubic feet by 2015 (a one-third increase) because of its highly competitive cost and its cleanliness and efficiency. Gas can provide a low cost means to slow the growth rate of carbon dioxide emissions and be a bridge to a renewable energy future. Gas will be a significant energy source for moderating carbon emissions well into the middle of the next century. New resources of gas, such as methane hydrates, may prove to be a very large source of production worldwide.

Linkage to CNES Goals and Objectives

The enhancing domestic supplies R&D areas support the following CNES goals and objectives:

- CNES Goal II, Objective 1 - Reduce the vulnerability of the U.S. economy to disruptions in oil supply.

- CNES Goal II, Objective 2 - Ensure energy system reliability, flexibility, and emergency response capability.

- CNES Goal III, Objective 1 - Increase domestic energy production in an environmentally responsible manner.

- CNES Goal IV, Objective 2 - Develop technologies that expand long term energy options.

Uncertainties

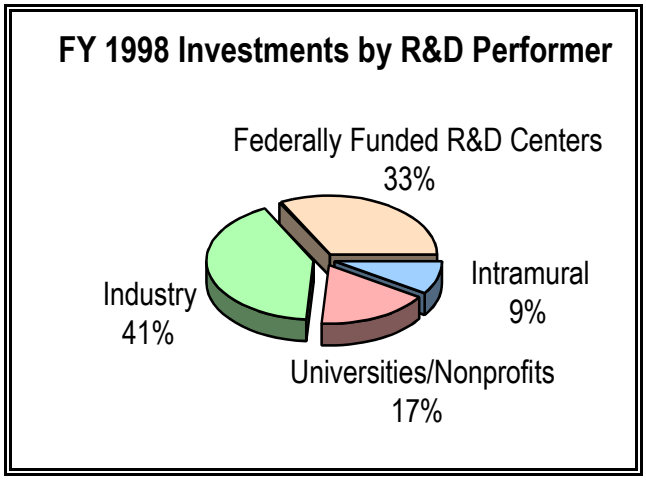
The United States is a mature oil-producing region, although domestic production is more difficult and more costly than overseas production. While an estimated two-thirds of all U.S. oil remains in the ground, much of it is located in deep, complex reservoirs or environmentally sensitive areas. High costs of operations and compliance with U.S. environmental regulations place U.S. producers at a competitive disadvantage with foreign producers.

Development of advanced oil and gas technologies is essential to efficiently maximize the production of domestic resources while preserving our environment. Advanced technologies are required to slow the decrease in domestic production of oil, to enable the processing and use of lower quality domestic crude, and to enhance the production and deliverability of natural gas.

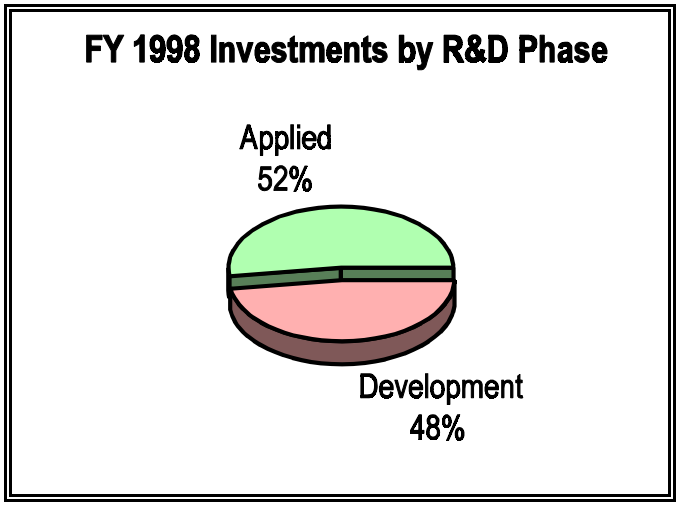
Declining R&D budgets, including the reduction in the Gas Research Institute's budget, have become a reality throughout the domestic energy industry. Electric utilities, in anticipation of increased competition, have already significantly reduced discretionary funding, including reductions of R&D by 30 percent in the past two years. The oil and gas industry has also reduced R&D applicable to domestic prospects by 29 percent, both in response to increased global competition and greater emphasis on overseas opportunities. Deficit-reduction has put increasing pressure on DOE-supported R&D, which has decreased in real terms by about one-third since 1990. Within these spending constraints, important decisions must be made on the priorities and emphasis in DOE's energy R&D programs.

Investment Trends and Rationale

As indicated in the figure below, over 40 percent of the research is performed by industry partners and over 30 percent is performed by the National Laboratories. However, a large



portion of this work is actually done by teams of researchers that frequently includes university participants. In addition, it is anticipated that the role of universities will increase in the future as a result of the closeout of the management and operating contract in the oil program. The type of research performed is evenly divided between applied and development. However, basic research that supports this technology portfolio is conducted in DOE's Office of Science.



Although the two figures above reflect FY 1998 data, the underlying funding trends are expected to be valid for the FY 1999-2001 period.

Issues that may impact the direction of future budgets include:

- The role of natural gas if greenhouse gas reduction becomes a higher National priority.
- The role of the United States in methane hydrate R&D to provide earlier answers on feasibility, production safety, and environmental impacts.
- The need for additional actions to slow or stop the decline in domestic oil production in light of frequent and recurring periods of low prices for oil.

Federal Role

The Federal government role includes:

- Maximize public benefit of oil and gas resources.
- Provide stewardship of Federal lands.
- Promote effective environmental protection.
- Ensure energy security.

- Foster strategic alliances.
- Enhance U.S. global competitiveness.

DOE's role in support of national goals includes efforts to:

- Enhance the efficiency and environmental quality of domestic oil and natural gas exploration, recovery, processing, transport, and storage operations.
- Focus on high risk technology that private companies alone won't undertake.
- Provide scientific and technological information and analysis to assist policymakers in their decision making.
- Contribute to science-based improvements in regulations to reduce uncertainties and costs while achieving optimal environmental protection.

Research needs are identified in combined workshops with Federal, industry, and research personnel. Competitive solicitations are used to identify qualified researchers. The applied research activities, supported by basic and enabling research, are managed by Federal personnel and performed by industry partners, National Laboratories, universities, and commercial research organizations. Centers of excellence and specialized expertise at National Laboratories support various elements of the program. In addition, cost-shared cooperative agreements and consortia are used as vehicles for joint funding of research with industry.

Key Accomplishments

Key accomplishments include:

The Oil Reservoir Class Program includes a total of 32 projects with a total DOE investment of $118 million and industry co-funding of $150 million (56 percent cost sharing). Successful demonstration of waterflooding in a high paraffin oil reservoir added 2.4 million barrels of oil to the region's reserves, resulting in over $12.7 million in taxes and royalties. Because of this demonstration, neighboring companies initiated 11 new waterfloods with more than 300 wells, which are expected to add 31 million barrels of oil and $160 million in Federal revenues. Because these 11 projects cover only 13 percent of the area, widespread application of waterfloods could double or triple the region's reserves and could increase Federal revenues to $500 million.

In the Natural Gas Program, new imaging technologies, including 3D seismic and vertical seismic profiling, were first utilized in the Texas Gulf Coast Basin and in the Fort Worth Basin. This work resulted in a substantial increase in reserve growth (estimated at 60 TCF) from established gas fields which were thought to be depleted.

A Risk Based Data Management System (RBDMS) originally developed for six States has proven so successful that 25 States have formed a users' group to help each other implement the system. The RBDMS is a PC based program that allows States to manage their underground injection data easily and use it to make risk based regulatory and operational decisions, such as where to assign inspectors for maximum effectiveness. The system enables States to generate reports quickly for the Environmental Protection Agency and the public.

The Department conducted initial design and testing of PDC drill bits now used in about 40 percent of drilling worldwide, an industry with annual sales in excess of $200 million. In addition, the program developed high-temperature drilling muds, high-temperature elastomers for downhole motors, advanced drilling fluid flow instrumentation, high-temperature memory logging tools; and fostered the use of slimhole drilling as an exploration tool for geothermal energy saving 30 to 50 percent of exploration drilling costs.

Industry and the Department of the Interior estimate that new discoveries in the Gulf of Mexico, an area with little exploration activity just a few years ago, may yield as much as 18 billion barrels of oil—more than Prudhoe Bay, Alaska. Technological innovations in subsalt imaging, reservoir characterization, and drilling technologies enhance the ability to discover such potential reserves.

Air motors based on DOE horizontal drilling technology are now being used for most new wells drilled in eastern gas formations. Horizontal drilling techniques, that use air in place of mud to drive and cool the downhole bit motor and remove drilling debris, have vastly improved the efficiency of drilling in Appalachian reservoirs, where mud use causes formation swelling and fracture blockage.

Production improvements at the earliest U.S. wells stimulated by CO_2/sand fracturing were so significant, that DOE received the 1994 Hart's Oil and Gas World Award for introducing the "Best New Technology in the Northeast."

Oil and Gas Exploration and Production

Budget: FY99-$60.8M, FY00-$70.0M, FY01-$55.2M

Background

Even though remaining U.S. oil and gas reserves are substantial, they are becoming more difficult and expensive to discover and produce. Past technology has recovered only an estimated one-third of the oil in place, leaving two-thirds of the U.S. oil resource base—about 350 billion barrels—still in the ground. Yet high operating costs are resulting in the abandonment of more than 16,000 U.S. oil wells each year. With the rising costs of environmental compliance, U.S. oil and gas producers and processors can face competitive disadvantages relative to operators in other areas of the world. These competitive disadvantages contribute to the fact that many major companies are concentrating their new exploration and production investments overseas.

Historical data demonstrate that technology advances are key to keeping energy prices low for consumers and to maintaining the profitability and long-term survival of the domestic industry. Since the 1980s, because of 3-D seismic, advanced drilling systems, and fracturing technologies, our Nation has seen a 14 percent increase in its gas production, despite a 50 percent decline in wellhead prices. Higher gas production in 1994 was achieved with fewer than 9,000 well completions, as compared to 14,250 completions in 1985. Further, success rates of exploratory wells have increased from 29 percent to 38 percent since the 1980s, while costs have substantially decreased. These technology advances, coupled with incentives such as deepwater royalty relief, have made the Gulf of Mexico one of the most active oil and gas exploration areas in the world.

Linkage to CNES Goals and Objectives

The oil and gas exploration and production R&D area supports the following CNES goals and objectives:

- CNES Goal II, Objective 1 - Reduce the vulnerability of the U.S. economy to disruptions in oil supply *(by stabilizing domestic production)*.

- CNES Goal III, Objective 1 - Increase domestic energy production in an environmentally responsible manner *(by increasing domestic gas production and recovering oil with less environmental impact)*.

- CNES Goal IV, Objective 2 - Develop technologies that expand long term energy options *(such as the production of gas from methane hydrates and deep gas formations)*.

The program's efforts focus on enhancing the efficiency and environmental quality of domestic oil and natural gas exploration and production. Improved technology and information are required to boost production of natural gas, a clean and abundant domestic fossil fuel that is an increasingly important component of our Nation's energy portfolio, and to extend the life of domestic oil fields, many of which are marginally economic and operated by independent producers. Specific goals are to find and exploit new resources through resource- and reserve-base expansion, increase recovery through wellbore improvements, extend the life of domestic energy resources and reduce well abandonments, minimize any potential environmental damage from oil and gas operations, and improve understanding/industry cooperation in environmental compliance

Program Description

Technology advances can further the trend toward more cost-effective recovery of domestic oil and gas, particularly from geologically-complex deeper reservoirs. Such advances will enable domestic producers to continue exploring for and recovering oil and gas from reservoirs that would otherwise be economically unviable.

By reducing the costs of domestic oil and gas production, advanced technologies can help to maintain reliable domestic supplies of these vital fuels at competitive prices—a goal of strategic importance to our Nation.

Diagnostics and Imaging

Budget: FY99-$19.3M, FY00-$20.3M, FY01-$15.5M

Description, Objectives, and Performers. Advanced imaging is an increasingly powerful tool for discovery and insight in medicine, engineering, and many other fields. In the oil and gas industry, sophisticated diagnostics and imaging technologies can be used to cost effectively locate and produce domestic reserves. The program supports the development and use of advanced technologies for reservoir characterization and risk based decision making, preserves and provides access to subsurface data, and develops analytical tools to perform the analyses required for accurately quantifying oil and gas resources and reserves.

R&D Challenges. Although the Nation's largest, most easily identified reservoirs have been discovered, potentially substantial reserves still exist, both onshore and offshore, in geologically complex settings or in deeper and smaller compartmentalized reservoirs. The challenge is reducing the costs and risks of exploring for these reservoirs driven by the need to reduce risk and uncertainty in a low product price environment; the need for improved resolution to define smaller, more compartmentalized and deeper reservoirs; and the understanding that reservoir heterogeneity impacts all recovery processes

New imaging and modeling technologies can enable production from tight, inaccessible, and fractured reservoirs, that contain major portions of our Nation's future oil and gas resources. Such reservoirs include fractured shale, fractured tight gas reservoirs in the Rocky Mountain region, deeper parts of producing basins, and reservoirs in deep water or below salt in the Gulf of Mexico.

R&D Activities. Program activities include:

- Improve seismic and other geophysical acquisition, processing, and interpretation technologies to provide increased resolution and accuracy, with emphasis on single-well, crosswell, and novel surface methods.

- Increase the understanding and measurement of rock and fluid properties, rock-fluid interactions, and fluid flow, and develop techniques to monitor reservoir and production processes that are not currently measurable using, for example, multi-frequency crosshole electromagnetic technology or accelerometer based, multi-level receiver systems for seismic monitoring.

- Increase the accuracy and performance of geologic and reservoir modeling and simulation, especially fast, user friendly, PC-based techniques to mathematically simulate flows, predict the production from a reservoir, and assess the technical and economic viability of development.

- Develop and demonstrate techniques to predict, locate, and exploit reservoir fractures for improved production from low permeability reservoirs. These techniques may include high resolution aeromagnetic surveys to locate structural anomalies, integrated modeling methodology to identify targets, and direction drilling technology to optimize recovery.

- Improve industry knowledge of and access to reservoir characterization technologies.

  – Develop methodologies for the quantitative description and prediction of reservoir characteristics, including fractures and diagenesis, through laboratory analysis of the lithology, in-situ stress, and fracture conductivity.

  – Transfer reservoir characterization data, models, and tools to industry.

- Increase the accuracy of present and future oil and gas resources and reserves estimates, and industry access to them.

  – Work with industry and State and Federal agencies to preserve irreplaceable subsurface geologic data.

  – Provide industry, government, and academic customers with accurate, unbiased, and timely current and predicted future estimates of U.S. resources and reserves.

Accomplishments. The success of a U.S. Department of Energy-sponsored horizontal well drilled three miles deep into a dense sandstone formation in southwestern Wyoming has led to additional commercial drilling that could open up a potentially large new supply of "nonconventional" natural gas in the Rocky Mountain region.

In 1999, Union Pacific Resources Company (UPR) used fracture imaging and advanced drilling technologies developed by the Energy Department and the Gas Research Institute to drill a 17,000-foot deep well with a 1,700-foot horizontal section. Production exceeded expectations with more than 2.1 billion cubic feet of gas produced in the first six months. Now, based on the well's success, UPR is drilling two new horizontal wells into the same formation in the Greater Green River Basin. Additional wells are likely in 2000.

Prior to the Energy Department's Greater Green River Basin Production Improvement Project, which began in 1995, very little work had been done to define the geologic and production characteristics of the tight, fractured Frontier Formation in the Greater Green River Basin. The gas-bearing play covers 900 square miles and has potentially huge reserves. Knowledge from the Energy Department's project convinced Union Pacific Resources that this resource could be economically developed and led to the company's decision to expand its drilling program. The region is checkerboarded with Federal and State acreage. If UPR's current and planned wells achieve comparable production levels, they could generate almost $10 million in Federal and State royalties, almost double the Energy Department's investment.

Drilling Completion and Stimulation

Budget: FY99-$7.7M, FY00-$8.9M, FY01-$7.7M

Description, Objectives, and Performers. Of the entire exploration and production effort, drilling is the moment of truth for oil and gas producers. Drilling tests the validity of geological, geophysical, engineering, and mechanical theories on the existence of new oil and gas reservoirs, and demonstrates whether subsurface analyses have, in fact, succeeded in pinpointing productive pay zones. Sizable investments ride on the results.

DOE's Advanced Drilling, Completion and Stimulation Systems Program focuses on the development of sophisticated technologies and methodologies that can encourage investments in producing new oil and gas plays, and that can increase production from existing plays. Technology advances in this field have already succeeded in reducing costs per foot drilled in the United States by 8 percent over the last 10 years, and the potential for further improvements is significant. Future advances are most likely to result from addressing the full drilling system, not just individual components, with a focus on increasing the net present value of the entire investment. This program will by 2010 contribute the following economic and technological improvements:

- Reduced total drilling costs of 0.5 to 2.0 percent per year.
- Reduced development drilling costs of 10 to 20 percent.
- Reduced stimulation costs of 20 to 30 percent.
- Reduced operating costs of 1 percent per year.
- Reduced dry hole rates of 5 percent.
- Increased reserves per well of 5 to 10 percent.
- Reduced skin factor of 40 to 70 percent.

R&D Challenges. Risks have always been inherent in drilling for oil and gas. Today, the technology challenges are becoming even greater for producers in the United States because much of our remaining oil and gas is locked away in geologically complex formations that necessitate deeper drilling and penetration of harder rock, and the increasing application of such techniques as underbalanced directional drilling, slimhole drilling, and multilateral configurations to address specific geologic environments. Drilling challenges often make investment in domestic exploration and production less attractive than investment in overseas reservoirs often thought to be easier to produce. This uncertainty compounds the known technical risks with perceived to be greater economic risk.

R&D Activities. Technologies under development can increase the value of the exploration and production effort in several ways. First, by increasing the rate of penetration or by lengthening bit life, new methods can enable producers to drill faster, farther, and longer, resulting in reduced

rig time. These technologies include the development of steerable air percussion drilling systems, advanced mud hammers, and high pressure downhole pumps for jet assisted drilling. Improved drilling and completion technologies also reduce formation damage, helping to maintain high well productivity. New stimulation technologies can be more effective than current methods in reviving well productivity after the well production rate declines to below economic levels. New methods also more effectively preserve the integrity of the wellbore over time, including the use of under balanced drilling fluids such as air, nitrogen, or foam. Finally, cost savings and increased environmental protection are also possible by reducing the volume of fluids needed in drilling and stimulation.

Carbon dioxide/sand fracturing technology was introduced into the United States by DOE for low permeability gas bearing formations. This non-damaging technology, which uses a sand-laden liquid CO_2 slurry to extend fractures, has the potential to significantly outperform traditional stimulation approaches. To encourage industry evaluation of the technology, DOE and its partner, Petroleum Consulting Services, have been working with industry to apply CO_2/sand fracturing, along with other stimulation methods, to newly-drilled wells of similar design and geological setting.

Accomplishments. In exploring for oil and gas in the 21st century, smaller may be better. Recent field experiments have enhanced prospects for "microdrilling" technology - a concept that could offer a revolutionary, lower cost approach to oil and gas exploration. This new technology currently allows for drilling holes up to 500 feet deep with all the equipment carried on a tandem-wheel trailer pulled by a standard pickup truck. When developed for deep drilling, the technology will replace traditional methods that use massive amounts of equipment, material and manpower, all of which are extremely expensive.

The concept could be a significant step toward futuristic "rig-less" drilling that could reduce the visual impact that has contributed to public objections to drilling in some areas.

In 1999, four microholes with diameters two to five times smaller than conventional holes were drilled to depths of 300 to 500 feet in alluvium and lake sediments. Microdrilling technology was highlighted as a likely "success story" emerging from the Energy Department's oil and natural gas research program.

Future microdrilling systems could occupy a space roughly 1/20th that of a typical rig and cost about 90 percent less. Companies using microdrilling would also realize additional savings because the technology could ultimately require only about a barrel of fluid per 1,000 feet of drilling to lubricate the bit and motor and remove dirt, whereas conventional drilling requires about 40 barrels of fluid per 1,000 feet. The microdrilling technology is based on the miniaturization of conventional coil tubing techniques that deploy a drill motor and bit on the end of tubing coiled around a spool. The recent test drilled 2 3/8-inch diameter microholes lined with 1 1/4-inch flush joint PVC tubing. Drilling fluids are run through the tubing to turn the motor and drill bit. In place of the usual large mud tanks needed to capture what's dug out of the ground, much smaller tanks suffice.

Reservoir Life Extension
(Includes PUMP – see next section)

Budget: FY99-$24.5M, FY00-$28.2M, FY01-$21.8M

Description, Objectives, and Performers. In partnership with the U.S. oil and gas industry, the Department supports the development of innovative and cost-effective technologies that can extend the productive life of domestic reservoirs. By encouraging advances in oil and gas recovery technologies and facilitating their transfer to producers, DOE can help slow the rate of premature abandonment of U.S. oil and gas wells and reduce our reliance on energy imports.

R&D Challenges. Production at most petroleum reservoirs includes three elements: primary, secondary, and tertiary recovery. Tertiary oil recovery is also known as improved oil recovery (IOR) or enhanced oil recovery (EOR). Primary recovery refers to production when energy stored in the reservoir is sufficient to drive the oil through reservoir rock into a wellbore. As reservoir pressure declines along with oil production rates, much additional oil can still be recovered using secondary recovery techniques. One such technology, waterflooding, displaces the oil and drives it to the wellbores of the producing wells.

Oil displacement in the reservoir is incomplete, however, even with secondary recovery processes. Tertiary oil recovery technologies such as thermal, gas-miscible, chemical, or microbial methods, can provide additional production. Such technologies could potentially recover about half of the 350 billion barrels of "discovered but unrecovered" oil in the United States. These technologies included polymer-augmented waterfloods and polymer-gel profile modification; continuous steam injection and in-situ combustion techniques; continuous gas injection, cyclic, and water-alternating-gas injection; and micellar surfactant and alkaline surfactant polymer flooding. Current U.S. oil production is 6.4 million barrels per day. Of this amount, 63 percent is produced by secondary and tertiary recovery.

In-situ combustion attempts to recover oil by heating it through the burning of a portion of in-place crude. Air or oxygen is injected to facilitate burning. The process is very complex, involving multi-phase flow of flue gases, volatile hydrocarbons, steam, hot water, and oil. Its performance in general has been insufficient to make it economically attractive to producers.

Polymer flooding involves injection into the reservoir of a small slug of surfactant solution, followed by polymer-thickened water, and then brine. Despite its very high displacement efficiency, micellar-polymer flooding is hampered by the high cost of chemicals and excessive chemical losses within the reservoir.

Even though improved oil recovery technologies have significant potential to extend reservoir life, and have been successfully demonstrated in the laboratory and in the field as early as the 1960s, their historically high cost has limited their widespread application. In the last decade, however, dramatic improvements in analytical and assessment tools including integrated reservoir description methods, have led to a greater understanding of the geology of reservoirs and the physical and chemical processes governing flows in porous media. This understanding has led to the development of new technologies that have potential for reservoir life extension.

The problems associated with more complete gas recovery are somewhat different. Research conducted by the Texas Bureau of Economic Geology, on behalf of the Gas Research Institute and DOE, has demonstrated that current production practices fail to recover a large portion of the gas in place. Even after 50 years of commercial production, substantial infield reserve growth exists in bypassed, incompletely drained, and untapped reservoir compartments, not to mention deeper pool potential in many fields.

R&D Activities. To demonstrate that today's reservoir life extension technologies are a highly cost effective alternative to abandonment in many real life situations, DOE launched the Reservoir Class Field Demonstration Program. This area represents the opportunity for in-the-field application of many improved and new reservoir life extension technologies.

The technological premise of the Reservoir Class Program is that reservoirs with a common geologic origin often have common producibility problems. These problems should respond similarly to reservoir life extension technologies. As new or advanced technologies are ready to be demonstrated in the field, a group of producing oil wells often spanning multiple States, are chosen as likely candidates for the demonstration. The wells are chosen because their reservoirs share similar geology, belonging to one of the three reservoir classes selected for demonstrations.

A commitment on the part of all program partners to technology transfer has been a critical factor in the program's success to date. Oil producers (including both small independent companies and major producers), universities, State agencies, service companies, and consultants, in partnership with DOE, team up for development, application, and transfer efforts. Project results are also being fed into a national petroleum technology transfer network. A revised strategy calls for revisiting the three classes and analysis of lessons learned.

In the Natural Gas Recovery Program, the focus is on a more complete characterization of complex heterogeneous reservoirs to afford a more precise placement of new wells and recompletions in existing wells.

Accomplishments. The Oil Reservoir Class Program includes a total of 32 projects with a total DOE investment of $118 million and industry co-funding of $150 million (56 percent cost sharing). Successful demonstration of waterflooding in a high paraffin oil reservoir added 2.4 million barrels of oil to the region's reserves, resulting in over $12.7 million in taxes and royalties. Because of this demonstration, neighboring companies initiated 11 new waterfloods with more than 300 wells, which are expected to add 31 million barrels of oil and $160 million in Federal revenues. Because these 11 projects cover only 13 percent of the area, widespread application of waterfloods could double or triple the region's reserves and could increase Federal revenues to $500 million.

In the Natural Gas Program, new imaging technologies, including 3D seismic and vertical seismic profiling, were first utilized in the Texas Gulf Coast Basin and in the Fort Worth Basin. This work resulted in a substantial increase in reserve growth (estimated at 60 TCF) from established gas fields which were thought to be depleted.

Reservoir Life Extension – Preferred Petroleum Upstream Management Practices (PUMP)*

Budget: FY99-$0.7M, FY00-$3.6M FY01-$2.0M

*PUMP described in detail here to highlight this initiative

Description, Objectives, and Performers. The PUMP program aims to stop the decline in domestic oil production by 2005, an objective of the Comprehensive National Energy Strategy (CNES), by encouraging implementation of the most promising and environmentally protective advanced technologies (Best Practices) for optimizing the recovery of the Nation's valuable oil resources. The program is expected to enable industry to increase domestic production by 200,000 barrels per day in five years.

The PUMP program will employ three strategies for a rapid impact on production:

1. Use known technology transfer mechanisms: DOE will work with States and organizations that are recognized by industry as expert technology providers, for example: The Petroleum Technology Transfer Council with its ten regional centers; State and Regional Industry Trade Associations; and State Geological Surveys.

2. Take a regional approach: The PUMP program will focus on geologic areas that present the highest potential for rapid increased oil production and those regions where the known oil resource is "underproduced." Preliminary analysis indicates that the Smackover Trend (AL, MS, LA, TX), the Delaware Basin (NM and TX), and the Mississippi Salt Basin (Offshore LA, State waters) are candidates for increased oil recovery from underutilized, advanced oil recovery technologies.

3. Support integrated solutions to technology, regulatory and data constraints: The implementation of advanced oil recovery technologies can face multiple hurdles, including incomplete data on geology, reservoir performance and environmental impacts, and outdated or overly burdensome regulations.

R&D Challenges Oil technology program research, by its nature, usually takes more than five years to show significant results in terms of production. Smaller independents do not rapidly implement new technology. In order to meet the five-year goal of the CNES, the PUMP program requires a targeted, aggressive, regional technology transfer program. It will take advantage of current technology transfer efforts and networks, to make direct contact with as many producers as possible, providing them with the most innovative technology, in ways they can most easily use.

In effect, PUMP accelerates the application of technology that could be expected to be implemented by industry over a much longer period of time. However, there is not only a quicker increase in production, but a larger total amount of U.S. oil ultimately recovered due to reductions in operating costs and reduced well abandonments.

R&D Activities. The program will conduct the following activities, in partnership with States, industry, tribes, and academia:

- Increase access to geologic, engineering, production, and environmental technology and information needed by oil producers to make wise investment decisions and improve the efficiency of their oil operations. This effort -- aimed at increasing the availability of data to oil producers in a user-friendly form -- has three components: 1) A best practices program and data base; 2) improved basin-scale analysis and other data management tools; and, 3) enhanced technology transfer, including demonstrations of best practices where needed.

- Environmental problem solving and regulatory streamlining targeted at addressing key regional constraints to the use of PUMP advanced oil recovery technology and avoiding unnecessary increases in compliance costs. The program also includes development of user-friendly, standardized data systems (Risk-Based Data Management System) to improve assessment of environmental risks in oil and gas exploration activities.

Accomplishments: Texas Electronic Compliance and Approval Process Pilot Project, a cooperative effort by the Texas Railroad Commission and the DOE that started August 1999, is streamlining the permit application process and improving access to regulatory data. Electronic drilling permit application will be implemented in 2000.

The Risk-based Data Management project with the Ground Water Protection Council implemented three new features in FY1999: 1) a generic version of the Risk-Based Data Management Systems, which can be inexpensively adapted for use in any State, reducing implementation costs from about $500K to $20K per State, 2) a Geographic Information System (GIS) utility that allows users to view environmental data spatially, and 3) an Internet reporting module for easy development of custom reports.

A competitive solicitation for other elements of the program is expected to be released in early 2000.

Drilling and Production Environmental Management

Budget: FY99-$8.7M, FY00-$9.6M, FY01-$8.9M

Description, Objectives, and Performers. The Department of Energy is working closely with industry to stem the rising costs of environmental protection, and to enable the domestic oil and gas producers to operate more efficiently, contributing fuels, jobs, and economic value to the Nation. DOE and industry are using the best information and science available to find new ways to address our Nation's environmental concerns, and to demonstrate that the needs of a strong economy and a healthy environment can be fully compatible.

Working with industry, DOE's Office of Fossil Energy is helping to ensure that environmental protection approaches make technical, environmental, and economic sense. DOE is well positioned between industry and regulators to champion balanced cost-effective approaches to

environmental protection. DOE's environmental program pursues improvements to the regulatory process, supports development of new technologies, and exercises key responsibilities for energy policies that encourage efficient recovery and ensure adequate secure energy supplies.

R&D Challenges. The rising environmental compliance costs challenge the domestic oil and gas industry to continue its vital contributions to the economy. Compliance with increasing environmental regulation has become costly and increasingly complex. The challenge facing the Nation is to implement environmental and other regulations with greater flexibility and efficiency, while achieving optimal levels of environmental protection at the lowest possible cost.

R&D Activities. To support more informed regulatory decision making, DOE facilitates dialogue among Federal officials, State regulators, industry personnel, and other stakeholders. Through its program activities, DOE can provide assessments of costs or risks, lending an independent voice to the debate. DOE also characterizes problems and possible alternative solutions, catalyzing and contributing to the process of achieving common sense approaches.

Many times, more cost effective environmental approaches hinge on the development of new technologies. DOE supports such development, focusing on beneficial technology investments that could not be justified by a single company or small group of companies. Some of these technologies have longer term payoffs or high risks; others may have widely diffused benefits that a single company could not capture, but that will accrue to the Nation.

DOE brings unique capabilities to its role, including the scientific capabilities of its National Laboratories, and modeling/analysis tools developed specifically to address energy policy questions. A fundamental commitment to outreach and technology transfer—putting information and new techniques into the hands of those who can use them—enables DOE's efforts to generate maximum benefits for the Nation.

DOE is currently conducting over 60 environmental research and analysis projects. Some projects are national in scope and others are regional in nature, addressing specific technology needs or environmental constraints. Whether a project is initiated at a single site or in a handful of States, technology transfer is an integral part of the program approach. Once a project proves successful, the program focuses on transferring the results nationwide.

Accomplishments. A Risk Based Data Management System (RBDMS) originally developed for six States has proven so successful that 25 States have formed a users' group to help each other implement the system.

The RBDMS is a PC based program that allows States to manage their underground injection data easily and use it to make risk based regulatory and operational decisions, such as where to assign inspectors for maximum effectiveness. The system enables States to generate reports quickly for the Environmental Protection Agency and the public.

Gas Hydrates

Budget: FY99-$0.5M, FY00-$3.0M, FY01-$2.0M

Description, Objectives, and Performers. Methane production from hydrates could contribute low cost natural gas to satisfy domestic demand. As much as 200,000 trillion cubic feet (TCF) of methane may exist in hydrate systems in the U.S. permafrost regions and surrounding waters, which is hundreds of times greater than the estimated conventional U.S. gas resource base of 1,400 TCF. Even if actual reserves prove to be only a small fraction of these estimates, methane hydrate production could alter U.S. and world patterns of energy supply and consumption. Gas production from hydrates will also contribute to energy security and Federal revenues from royalties and lease rentals in the Outer Continental Shelf.

Methane hydrate is a methane bearing, ice-like material that occurs in abundance in marine and arctic sediments and stores immense amounts of methane. A cage of water ice molecules surrounds the gas molecule allowing high methane concentrations–one unit volume of methane hydrate can contain over 160 volumes of gas and less than one unit of water at surface pressures and temperatures. Methane hydrates are found on land in permafrost regions (Alaska) and within ocean floor sediments around the United States.

In the past year, a renewed interest in methane hydrates has been driven by:

- Growing recognition of the need for increased supplies of cleaner domestic fuels in the middle 21st century.
- Expanded industry activities in the Arctic and deep offshore that have increased awareness and interest in hydrate formation, occurrence, and stability.
- Concern about global climate change has emphasized the need to understand the role of hydrates in global carbon cycles.
- Technological progress over the past few years indicates that research will proceed more rapidly than previously expected and with increased expectations of commercial production.
- Increased international activity and significant spending in Japan and India points out the expectation of commercial production in the not-too-distant future.

This program can produce the knowledge and technology necessary for commercial production of methane from hydrates by 2015 and address associated environmental and safety issues.

R&D Challenges. The challenges to turning the potential hydrate resource into gas reserves while developing technologies to assure safe petroleum operations in hydrate areas, and defining the role of methane hydrates in global climate, involve the following:

- Determine the location, sedimentary relationships, and physical characteristics of methane hydrate resources to assess their potential as a domestic and global fuel resource (Resource Characterization).

- Develop the knowledge and technology necessary for commercial production of methane from oceanic and permafrost hydrate systems by 2015 (Production).

- Develop an understanding of the dynamics and distribution of oceanic and permafrost methane hydrate systems sufficient to quantify their role in the global carbon cycle and climate change (Global Carbon Cycle).

- Develop an understanding of the hydrates system in near-seafloor sediments and sedimentary processes, including sediment mass movement and methane release so that safe, standardized procedures for hydrocarbon production and ocean engineering can be assured (Safety and Seafloor Stability).

R&D Activities. Activities include the preparation of a strategy for methane hydrate R&D and an implementation plan.

Accomplishments. A ten-year program, starting in 1982, at the Department of Energy (DOE) Morgantown Energy Technology Center (now the National Energy Technology Laboratory, NETL) supported methane hydrate studies that: established the existence of hydrates in Kuparuk Field, Alaska; completed studies of 15 offshore hydrate basins; developed production models for depressurization and thermal production of gas from hydrates; and built the Gas Hydrate and Sediment Test Lab Instrument. The program was canceled as government policy shifted from long-term, high risk R&D to near-term exploration and production R&D. Although DOE funding stopped, work has continued at the United States Geological Survey (USGS), universities, other laboratories, and overseas.

Oil and Gas Processing

Budget: FY99-$6.3M, FY00-$8.0M, FY01-$6.0M

Background

Throughout many of our western States, there are gas reserves containing high levels of contaminants, which render these reserves economically unmarketable in most instances. Finding ways to utilize such unmarketable gas resources has become essential to sustaining a reliable domestic supply of gas and liquid fuels as our Nation's most accessible and economical supplies are depleted.

In the last decade, environmental regulations have had a far-reaching impact on both the processes and products of the U.S. refining industry. Refineries must comply with increasingly stringent emissions and discharge limits on their processes. At the same time, they must meet demands for lighter, high value finished products, such as gasoline, diesel fuel, jet fuel, and petrochemical feedstocks, whose composition and quality have changed markedly to meet environmental standards. The Clean Air Act Amendments of 1990 have required the production

and use of reformulated gasoline, for example. This and other projected changes in the product slate will result in higher storage and transportation costs, added capital expenditures, and product exchange complications.

According to a recent study by the National Petroleum Council, between 1991 and 2010 environmental compliance costs are projected to exceed $150 billion, including $36 billion for capital equipment. Since 1994 alone, the refining industry has committed over $20 billion to capital equipment for improving environmental performance. Such equipment has absorbed between 75 and 90 percent of total capital expenditures.

Linkage to CNES Goals and Objectives

The program supports the following CNES goal and objective:

- CNES Goal III, Objective 1 - Increase domestic energy production in an environmentally responsible manner. *(by increasing domestic gas production, recovering oil with less environmental impact, and developing cost-effective renewable technologies)*

Program Description

New processing technologies can equip the oil and gas industry to prevent pollution and protect the environment more efficiently than is possible with today's costly retrofit approaches, to handle the challenges posed by lower quality domestic feedstocks, and to produce the more complex, purer, high value product slates that the market now requires. By gathering the scientific information that is essential for sound regulatory decision making as well as developing processing technologies that increase efficiency, decrease costs, and enhance environmental performance, the industry may continue to be profitable in a highly global market place.

Low Quality Gas Upgrading

Budget: FY99-$1.9M, FY00-$1.6M, FY01-$1.6M

Description, Objectives, and Performers. In partnership with the U.S. oil and gas industry, the Department of Energy seeks to advance technologies and processes that will enable gas reserves with high contaminant levels to be upgraded to market specifications using gas purification technologies. Pursuing advanced processes to collect and utilize the methane released during underground coal mining would harness this greenhouse gas and prevent it from being vented into the atmosphere.

R&D Challenges. The Nation's natural gas resource base is vast, however, the primary challenge is to remove the high volumes of naturally occurring contaminants that are produced with the methane. Approximately one-third of our Nation's natural gas resource is low quality gas that does not meet market specifications for pipeline shipment. Typical specifications call for gas with no more than:2 percent carbon dioxide; 4 percent total carbon dioxide, nitrogen, and other inert gases; and 4 parts per million of hydrogen sulfide gas.

Some low quality gas can be blended with higher quality gas to meet market requirements. But much of our low quality gas must be upgraded through gas purification technologies that eliminate or substantially reduce inert and hazardous contaminants. Current technologies can be costly and, in some cases, cost prohibitive. In situations where the cost of upgrading would make producing the gas uneconomical, the gas is simply shut in. Advanced upgrading technologies under development will improve purification techniques while significantly lowering costs.

Another challenge is to capture the methane that is released naturally from coal and surrounding strata in the course of underground coal mining. Most of this methane is currently exhausted to the atmosphere through the mine's ventilation system.

R&D Activities. Low quality gas upgrading program efforts target two technology areas. The first is the development of organic and inorganic membranes that screen and separate gas components. Membranes offer high component selectivity and overall gas throughput. The second area of technology development is gas-contaminant absorption and adsorption systems that have rapid regeneration capability. Both areas of technology development have the potential to significantly reduce gas upgrading costs compared to current technologies.

Coal mine methane R&D efforts focus on the demonstration of available methods to economically collect and utilize this methane for pipeline sales, small-scale electric power generation, and other uses. The goal is to expand the number of mines that utilize emitted gas instead of passing it into the atmosphere.

Accomplishments. A DOE-sponsored project is focused on the development of more efficient and compact physical solvent systems for the upgrading of natural gas with high carbon dioxide and/or hydrogen sulfide content. Researchers at the Institute of Gas Technology are working with representatives from the Gas Research Institute, Shell Oil Company, Michigan Consolidated Gas Company, and others to develop the advanced system designs required to enable the separation processes to proceed using structured packing and/or rotating solvent-gas contactors in place of traditional large absorber towers with many sets of contactor trays. The new designs would allow a five-fold or greater reduction in the size of gas upgrading plants. Such size reduction is particularly valuable for platform-scale upgrading in the Gulf of Mexico.

Oil Processing and Environmental Protection

Budget: FY99-$4.3M, FY00-$4.4M, FY01-$4.4M

Description, Objectives, and Performers. Environmental regulations have resulted in the closing of a number of smaller, less efficient U.S. refineries that have been unable to afford the required capital expenditures. These regulations make the construction of new refineries in the United States unlikely. While larger refining operations are expected to remain viable, recent studies suggest that another 10 percent of U.S. refineries may close. With U.S. refineries already operating at near maximum utilization rates, such a loss in capacity exposes U.S. consumers to gasoline price spikes caused by interruption of operations at any one refinery.

R&D Challenges. Crude oil supplied to refineries is becoming heavier with more sulfur, nitrogen, and heavy metals, while the market requires a product slate that is lighter, with less sulfur and nitrogen, and more oxygenates. Current technology cannot address this. Using present technology, the processing of heavy crude yields unacceptably high levels of low value residual oils, coke by-products, and wastes.

Another challenge is that environmental regulations, particularly the Clean Air Act Amendments of 1990, are forcing refineries to devote substantially more of their budgets to environmental compliance at the expense of their technology development efforts. The impending fine particulate ($PM_{2.5}$) regulations have caused concern within the industry because of the lack of data about origin and formation of this fine particulate matter. Data must be produced that will allow science-based implementation of this proposed regulation.

R&D Activities. This program serves the Nation's environmental objectives by providing sound science for improved regulation and develops fundamental scientific data to facilitate the development of effective refining technologies to prevent pollution formation.

Accomplishments. A recent success story concerns the measurement of emissions from heavy oil storage tanks. In complying with the Clean Air Act Amendments of 1990, which regulate emissions from heavy oil storage tanks, the California Air Resources Board had planned to use existing data on emissions from light oil storage tanks. But these data would probably over-estimate actual emissions by a significant degree because heavy oil has less volatile components than light oil. The project data will enable the State to issue regulations that are based on the more specific and appropriate risks of vapor from heavy oil.

Summary Budget Table (000$)

Enhancing Domestic Supplies Research Areas	FY 1999 Appropriated	FY 2000 Appropriated	FY 2001 Request
Oil and Gas Exploration and Production	**60,757**	**69,967**	**55,219**
Diagnostics and Imaging	19,294	20,269	15,456
Drilling, Completion, and Stimulation	7,720	8,916	7,700
Reservoir Life Extension	24,514	28,164	21,840
Drilling and Production Env. Management	8,737	9,624	8,923
Gas Hydrates	492	2,960	2,000
Oil and Gas Processing	**6,225**	**6,015**	**6,015**
Low Quality Gas Upgrading	1,925	1,615	1,615
Oil Processing and Environmental Protection	4,300	4,400	4,400
Total	**66,982**	**77,948**	**61,234**